XXV INTERNATIONAL CONFERENCE ON GRAPHICS ENGINEERING

"New Horizons in Graphics Engineering"

PROCEEDINGS OF THE XXV INTERNATIONAL CONFERENCE ON GRAPHICS ENGINEERING

June 17th-19th Donostia- San Sebastián 2015

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Prólogo

En este libro se recogen las actas de los trabajos presentados en el XXV Congreso Internacional de Ingeniería Gráfica organizado por Tecnun (universidad de Navarra) en colaboración con Ingegraf y apoyado por las asociaciones ADM y AIP-Primeca.

Este Congreso Internacional ha constituido un foro de reflexión y profundización de los trabajos científicos desarrollados durante estos últimos años. Ha supuesto un intercambio de información acerca de las estrategias investigadoras, innovadoras, así como un debate en torno a los procesos de cambio y mejora de la educación. Cambios que requieren tiempo y que afectan a la práctica de todas las universidades.

"Cuando se está en una encrucijada educativa, resulta decisivo acertar con la dirección. En términos deportivos, se ha comparado la vida social con una carrera de fondo. Pero a mí me gusta más asemejarla a una competición de tiro con arco, en la que lo importante no es llegar antes o alcanzar lejos sino acertar en el blanco. Una buena educación no es aquella que se imparte con más medios y produce jóvenes más competitivos. Es aquella en la que se hace diana: en la que se piensa alto, se siente hondo y se habla claro." (Alejandro Llano, "la era de la educación")

Bajo el lema "Nuevos horizontes de la Ingeniería gráfica" se pretende abordar estos desafíos y difundir sus contenidos, ideas e informaciones entre miles de profesores y expertos que asistieron a este Congreso y con aquellos que no tuvieron la oportunidad de asistir. Se nos presenta un gran reto por delante, hoy en día ya no sirven los modelos de aprendizaje desarrollados hasta ahora, estamos dejando atrás la universidad 2.0 para dar entrada a la futura universidad 3.0 que demanda personas más creativas, mejores emprendedores,

con capacidad más crítica, con una mayor sensibilidad social, con capacidad de adaptación. Se necesita cada vez más saber trabajar uniendo fuerzas, en una universidad más compleja y competitiva, donde resulta imprescindible apoyarse en la inteligencia colectiva, en la suma de saberes.

Finalmente queremos agradecer el apoyo prestado por la Escuela Superior de Ingenieros de la Universidad de Navarra, la asociación Ingegraf, el Gobierno Vasco, Turismo de San Sebastián, y por todas aquellas personas que con su trabajo y dedicación han hecho posible este Congreso.

Dra. María de la Paz Morer Camo

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Irene Sentana (Universidad de Alicante)

Stefano Tornincasa (Politecnico di Torino)

Pedro Ubieto (Universidad de Zaragoza)

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Programme

Miércoles 17 de junio

08:30 - Recepción, acreditación, entrega documentación y acogida de los congresistas.

09:30 - Inauguración del Congreso. Conferencia inaugural. (Aula de Grados)

Tomás Gómez-Acebo	Vicerrector de alumnos de la Universidad de Navarra
Iñigo Puente	Director Tecnun
Guillermo Peris	Presidente Ingegraf
María de la Paz Morer	Presidenta del Congreso

09:45 - Sesión plenaria (Aula de Grados)

Ph.D. Andrew Davol

"The Graphics Revolution in Engineering with Application to Solar Concentrator   Design, Analysis and Testing"

11:00 - Pausa - café

11:30 a 14:00 - Sesión de comunicaciones (ver programa detallado)

14:15 - Almuerzo de trabajo

16:00 - Asamblea plenaria (aula máster) <u>Socios Ingegraf</u>

Jueves 18 de junio

09:00 a 11:30 - Sesión de comunicaciones (ver programa detallado)

11:30 - Pausa-café

12:00 - Sesión plenaria (Aula máster)

Ph.D. Ian Campbell

"Additive manufacturing- research-teaching: opportunities and challenges"

13:00 - Sesión plenaria (aula máster)

Ph.D. Luis Pastor

"Researcher and Professor in Computer Graphics, Virtual Reality and Visual Analytics   at URJC"

14:00 - Almuerzo de trabajo

16:00 - Plan Social

- Visita panorámica por la ciudad con guía.
- Exhibición de partido de cesta punta en Jai-Alai. Fuenterrabía.

21:30 - Cena de gala. Restaurante Tenis Ondarreta (Paseo de Eduardo Chillida 9, 20008 Donostia-San Sebastián)

Viernes 19 de junio

09:00 a 11:15 - Sesión de comunicaciones (ver programa detallado)

11:15 - Pausa-café

11:45 - Sesión plenaria (aula máster)

Ph.D. Margarita Vergara

"Research in Biomechanics and Ergonomics"

13:00 - Acto de clausura

14:00 - Cóctel

Parallel Sessions

PARALLEL SESION 1
Wednesday, June 17th, 2015
11:30 – 14:00

Computer Aided Design & Virtual Prototyping

(AULA MASTER 1   CHAIRMAN: CÉSAR OTERO GONZÁLEZ

11:30 "3D Modeling and functional analysis of a Spanish articulated metal headframe for mineral extraction: comparative analysis with a masonry headframe"
ROJAS SOLA, José Ignacio; PALOMARES MUÑOZ, Isis
University of Jaén

11:45 "3D Digital techniques applied to new design products based on cultural heritage elements"
DE CÓZAR MACÍAS, Óscar David; FLORES RODRÍGUEZ, María Sonia; BLÁZQUEZ PARRA, Elidia Beatriz; LADRÓN DE GUEVARA MUÑOZ, Carmen; MARÍN GRANADOS, Manuel Damián
University of Málaga

12:00 "Quantitative assessment of deforestation in Moulouya River watershed (Morocco) using an innovative remote sensing approach"
AGUILAR TORRES, Fernando José; NEMMAOUI, Abderrahim; AGUILAR, Manuel Ángel; CHOURAK, Mimoun; ZAGHLOUL, Yassine; GARCÍA LORCA, Andrés Miguel
University of Almería, University Mohammed I (Morocco)

12:15 "Geometric design for slate mine workings using keyblock method and photogrammetry"
MENÉNDEZ DÍAZ, Agustín; ORDÓÑEZ GALÁN, Celestino; BOUZA RODRÍGUEZ, José Benito; GARCÍA CORTES, Silverio
University of Oviedo

12:30 "Study space-temporal of São Luis (Upaon-açu) Island: Documentation and analysis of landscape and cultural heritage"
ROCHA DE MORAES REGO, Carlos Augusto; HERRERO-TEJEDOR, Tomás Ramón: PÉREZ MARTÍN, Enrique; BORRALHO DE ANDRADE, Juliane; LÓPEZ HERRERA, Juan Carlos
Technical University of Madrid (UPM)

12:45 "Definition of the use of an Acoustic Methodology for its use in the representation of 2D geometric Objects"
SANTIAGO-PRADERAS, Victor; MANCO, Antonio; DEFEZ, Beatriz; BRUSOLA Fernando, PERIS-FAJARNÉS Guillermo
Polytechnic University of València

13:00 "Analysis of the Integration Process of lightweight ceramic tile in the product line of ceramic companies"
PERIS FAJARNÉS, Guillermo; DEFEZ, Beatriz; LENGUA, Ismael; DUNAI, L.
Polytechnic University of València

13:15 – 14.00h COLOQUIO Y DEBATE

PARALLEL SESION 2
Wednesday, June 17th, 2015
11:30 – 14:00

Product Design
Product Manufacturing

(AULA MASTER 2)   CHAIRMAN: SERGIO RIZZUTI

11:30 *"Design of detachable drum for a front load washer"*
LADRÓN DE GUEVARA MUÑOZ, Mª Carmen; BLÁZQUEZ PARRA, Elidia Beatriz; MARAVER, Ana; CASTILLO RUEDA, Francisca José; LADRÓN DE GUEVARA LÓPEZ, Isidro
University of Málaga

11:45 *"Airvortex: example of multidisciplinary design"*
MIRALBES BUIL, Ramón; RANZ ANGULO, David
University of Zaragoza

12:00 *"Methodology for a sustainable product design"*
VELASCO ORTIZ, Carlos; LACASA FERRER, Enrike; SANTOLAYA SAENZ, José Luis
University of Zaragoza

12:15 *"Direct Digital Manufacturing for sports and medical sciences"*
CAZÓN, Aitor; MATEY, Luis; RODRÍGUEZ,_María Isabel; MORER, Paz; GONZÁLEZ,_Itziar
University of Navarra

12:30 *"The golden ratio in product design"*
MARTÍN AMUNDARÁIN, Iñaki; DOMÍNGUEZ SOMONTE, Manuel; ESPINOSO ESCUDERO, Mª del Mar
University of the Basque Country

12:45 *"Application of plastic parts discretization for analyzing geometric demoldability"*
MARTÍN DOÑATE, Cristina; MERCADO COLMENERO, Jorge Manuel; RUBIO PARAMIO, Miguel Ángel
University of Jaén

13:00 *"Automated system for injection mold design and cost calculation. Objetives and opportunities"*
MARTÍN DOÑATE, Cristina; MERCADO COLMENERO, Jorge Manuel; RUBIO PARAMIO, Miguel Ángel; VIZÁN IDOIPE, Antonio; PÉREZ GARCÍA, Jesús Mª; MÁRQUEZ SEVILLANO, Juan de Juanes; AGUILERA PUERTO, Daniel
University of Jaén

13.15h – 14.00h COLOQUIO Y DEBATE

PARALLEL SESION 3
Thursday, June 18th, 2015
09:00 – 11:15

Computer Aided Design & Virtual Prototyping

(AULA MASTER 1)   CHAIRMAN: BEATRIZ DEFEZ GARCÍA

09:00 *"Multitemporal study of the use and land cover in the municipality of Urbano Santos, MA"*
BORRALHO DE ANDRADE, Juliane; ROCHA DE MORAES REGO, Carlos Augusto; OLIVEIRA DE CARVALHO, Alysson; CABRAL AMORIM, Francielle; LÓPEZ DE HERRERA, Juan
University of Maranhão – Brasil

09:15 *"Management and planning of urban trees by mobile mapping system"*
BOMBÍN BOMBÍN, Eduardo; HERRERO-TEJEDOR, Tomás Ramón; PÉREZ-MARTÍN, Enrique; LÓPEZ HERRERA, Juan Carlos; GARCÍA URIARTE, Óscar; EZQUERRA CANALEJO, Alejandra
Technical University of Madrid (UPM)

09:30 *"Geoinformation as an aid to the response of the emergency services at industrial park"*
MARTÍN ROMERO, Juan Luis; HERRERO-TEJEDOR, Tomás Ramón; PÉREZ MARTÍN, Enrique; LÓPEZ HERRERA, Juan; EZQUERRA CANALEJO, Alejandra
Technical University of Madrid (UPM)

09:45 *"MultiTemporal analysis of the use and land cover in Island of Maranhão"*
BORRALHO DE ANDRADE, Juliane; ROCHA DE MORAES REGO, Carlos Augusto; OLIVEIRA DE CARVALHO, Alysson; CABRAL AMORIM, Francielle; LÓPEZ DE HERRERA, Juan
University of Maranhão - Brasil

10:00 *"Geovisualization of green spaces with augmented reality"*
GALLEGO LARGO, Javier; HERRERO-TEJEDOR, Tomás Ramón; LÓPEZ HERRERA, Juan; PÉREZ MARTÍN, Enrique
Technical University of Madrid (UPM)

10:15 *"Analysis of the recovery of the design intent in redesigning over meshes"*
MINGUEZ, Rikardo; ETXANIZ, Olatz; SOLABERRIETA, Eneko; BARRENETXEA, Lander; ARIAS, Agustín; SIERRA, Egoitz
University of the Basque Country

10:30 *"Digital Image Correlation technique to validate results and hypothesis on the tests for determination of properties of biological soft tissue"*
PEÑA BAQUEDANO, Juan Antonio; RUIZ-ALEJOS, David; MARTÍNEZ, Miguel A.; PEÑA, Estefanía
University of Zaragoza

10:45 *"Exploration of a reference framework for graphic competence"*
CORBELLA RIBES, David; UBIETO ARTUR, Pedro; SENTANA GADEA, Irene; MORER CAMO, Paz
Polytechnic University of Madrid

11:00 – 11:15 COLOQUIO Y DEBATE

PARALLEL SESION 4

Thursday, June 18th, 2015
09:00 – 11:15

Education, Learning & Knowledge
Product Design

(AULA MASTER 2)   CHAIRMAN: JOSÉ IGNACIO ROJAS SOLA

09:00 "A proposal for active learning in groups and roles"
SERRANO, Ana; BIERDERMANN, Anna; ROMERO, Carlos
University of Zaragoza

09:15 "An experiment with Augmented Reality Applied to Education in Graphic Engineering"
GÓMEZ-JAUREGUI, Valentín; MANCHADO, Cristina; OTERO, César
University of Cantabria

09:30 "Review of the contents and methodology of the subject of Graphic Engineering"
ZAMORA, Raúl; RAMOS, Basilio; MELGOSA, Carlos
University of Burgos

09:45 "Graphic engineering in the academic curriculum in the Mechanical Engineering Degree"
MANCHADO, Cristina; GÓMEZ-JÁUREGUI, Valentín; OTERO, César
University of Cantabria

10:00 "Use of lidar technology for detecting energy efficient roofs in urban areas"
SANTAMARÍA PEÑA, Jacinto; SANZ-ADÁN, Félix; MARTÍNEZ RUBIO, Alberto; VALBUENA RABADÁN, Manuel Ángel
University of La Rioja

10:15 "SFM implementation in product design projects with derived specifications"
BIEDERMANN, Anna; SANTOLAYA, José Luis; SERRANO, Ana; LÓPEZ, Ignacio;
FERNÁNDEZ, Arantza; AGUDO, José María; SÁNCHEZ Belén

Univerisity of Zaragoza

10:30 "A new conceptual design of a 180º crate dumper machine"
CAVAS-MARTÍNEZ, Francisco; ANDREU HIDALGO, Alejandro; NIETO MARTÍNEZ, José; FERNÁNDEZ CAÑAVATE, Francisco J.; FERNÁNDEZ PACHECO, Daniel G.
Technical University of Cartagena

10:45 "The use of mathematical functions in product design"
MARTIN AMUNDARAIN, Iñaki; ROMERO CUADRADO, Luis; DOMÍNGUEZ SOMONTE, Manuel
University of the Basque Country

11:00 – 11:15 COLOQUIO Y DEBATE

PARALLEL SESION 5
Friday, June 19th, 2015
09:00 – 11:30

Computer Aided Design & Virtual Prototyping

(AULA MASTER 1)   CHAIRMAN: JORGE GONZÁLEZ PRADA

09:00 "Integration of reverse engineering and dental mandibular dynamics"
SOLABERRIETA, Eneko; BRIZUELA, Aritza; FRAILE, Cristina; MINGUEZ, Rikardo; GARMENDIA, Asier; ETXANIZ, Olatz; PRADIES, Guillermo
University of the Basque Country

09:15 "New tool for assessing changes in bone internal stress after a virtual surgery"
ROCES, Jorge; ÁLVAREZ, Rafael; ALONSO, Jorge; BORJA, Alexandra; CORUJO, Nicolás
University of Oviedo

09:30 "Virtual biomodelling of a biologic structure: the human cornea"
CAVAS-MARTÍNEZ, Francisco; FERNÁNDEZ PACHECO, Daniel G.; de la CRUZ-SÁNCHEZ, Ernesto; NIETO MARTÍNEZ, José, FERNÁNDEZ CAÑAVATE, Francisco J.; ALIO, Jorge
Technical University of Cartagena

09:45 "Review of state of art of Augmented Reality"
ORIOZABALA BRIT, José Antonio; ESPINOSA ESCUDERO, Mª del Mar; DOMÍNGUEZ SOMONTE, Manuel
University of the Basque Country

10:00 "Design and development of a modular recumbent trike for different working scenarios"
CAVAS-MARTÍNEZ, Francisco; SANCHÍS CARAVANTES, Carlos; NIETO MARTÍNEZ, José; FERNÁNDEZ CAÑAVATE, Francisco J.; FERNÁNDEZ-PACHECO, Daniel G.
Technical University of Cartagena

10:15 "Designing for the real workforce: Human factors and ergonomics for the new workforce inclusivity"
GONZÁLEZ, Itziar; MORER, Paz
University of Navarra

10:30 "From Rapid Prototyping to Additive Fabrication"
ORIOZABALA BRIT, José Antonio; ESPINOSA ESCUDERO, Mª del Mar
University of the Basque Country

10:45 "The brainwriting as a method to foster creativity in product design"
RIZZUTI, Sergio
University of Calabria

11:00 "Design and Construction of an Electric Chisel for Underwater Applications"
SPADAFORA, Francesco; GALATI, Daniele; GALLO, Alessandro; BRUNO, Fabio; MUZZUPAPPA, Maurizio
University of Calabria

11:15 – 11:30 COLOQUIO Y DEBATE

PARALLEL SESION 6
Friday, June 19th, 2015
09:00 – 11:30

Education, Learning & Knowledge
Product Design

(AULA MASTER 2)   CHAIRMAN: DAVID CORBELLA RIBES

09:00 "Generation of surface pattern designs and their application to products or environments: an interdisciplinary and creative activity in the engineering degree in industrial design and product development at the university of Zaragoza (Spain)"
SERRANO, Ana; BIEL, Pilar; PÉREZ-SINUSÍA, Ester; RODRIGO, Carmen; GRACIA, Rosario
University of Zaragoza

09:15 "Intrinsic relations between the orthogonal axonometric system and its associated obliques. Analytical proposal and graphic operations"
GONZAGA, Pedro; GIMENA, Lázaro; GIMENA, Faustino Nicolás; GOÑI, Mikel
Public University of Navarra

09:30 "Development of final degree's projects in the field of graphic expression in engineering"
FERNÁNDEZ-VÁZQUEZ, Aránzazu; BIEDERMANN, Anna María
University of Zaragoza

09:45 "Cross-cultural product design: How to sensitize students of Industrial Design Engineering?"
RODRÍGUEZ, María Isabel; MORER, Paz; GONZÁLEZ, Itziar; CAZÓN, Aitor
University of Navarra

10:00 "From Co-working to Multidisciplinary Group Dynamics in an interface design experience"
BIEDERMANN, Anna; LATORRE, Pedro; BALDASSARRI, Sandra; CEREZO, Eva; COMA, Teresa; AGUELO, Antonio; LAGUENS, Miguel
University of Zaragoza

10:15 "Framework to develop ABET outcomes"
MARTÍNEZ MUNETA, Mª Luisa, LÓPEZ DE ÁVILA, Mario; CARRETERO DÍAZ, Antonio; HERNÁNDEZ BAYO, Araceli
Polytechnic University of Madrid

10:30 – 11:30 COLOQUIO Y DEBATE

Plenary Sessions

Miércoles, 17 de junio de 2015

09:45 - 11:00

Sesión Plenaria (Aula de Grados)

Ph.D. Andrew Davol

"The Graphics Revolution in Engineering with Application to Solar Concentrator Design, Analysis and Testing"

Jueves, 18 de junio de 2015

12:00 - 12:45

Sesión Plenaria (Aula Máster)

Ph.D. Ian Campbell

"Additive manufacturing- research-teaching: opportunities and challenges"

Jueves, 18 de junio de 2015

12:45 - 14:00

Sesión Plenaria (Aula Máster)

Ph.D. Luis Pastor

"Researcher and Professor in
Computer Graphics, Virtual Reality
and Visual Analytics at URJC"

Viernes, 19 de junio de 2015

11:45 - 13:00

Sesión Plenaria (Aula Máster)

Ph.D. Margarita Vergara

"Research in Biomechanics and
Ergonomics"

The Graphics Revolution in Engineering with Application to Solar Concentrator Design, Analysis and Testing

Dr. A. Davol*

Special Thanks to: Dr. P. Schwartz**, Simo Alberti***

This presentation will take a brief look at the dramatic influence improved graphics and simulation techniques have had on the career of one engineer and demonstrate the use of Computer Aided Design, Finite Element Analysis and custom Ray Tracing software currently being used to design, analyze and test solar concentrators for cooking applications in the developing world.

As a young BSME graduate in 1987, starting work in the aerospace industry with Boeing Commercial Aircraft on the 747-400, I was producing designs often hand drawn with ink pens on mylar. I left Boeing in 1994 after working as a stress analyst on the 777 initial launch. The 777 not only utilized 3-D CAD but was the first commercial aircraft to not build a physical mock-up and instead relied 100% on the 3-D digital definition for production. I got a front row seat to the streamlined design process this allowed, along with the tools made available for the stress analysts. Witnessing this revolution first hand helped me to understand the power of graphics in engineering.

Much of my career has involved Finite Element Analysis (FEA) in various ways and the change that improved graphics has made in the use of this invaluable tool cannot be overstated. My first experience with FEA was as undergraduate and we had no graphical feedback. Even a simple analysis provided many pages of numerical output that had to be post processed to find critical values. Now the graphical tools available in commercial FEA software offer tremendous opportunities to the analyst and designer to better understand the load paths and overall performance of a design. As computing power becomes more prevalent this revolution has now taken hold in the more computationally demanding Computational Fluid Mechanics fields.

Digital image processing is another area that has had an influence on my more recent career in tissue engineering. Tissues are generally very complex materials to study and taking physical measurements on small samples of living tissues can be extremely challenging. In my work we utilized the image processing

capabilities of Matlab to help us determine the anisotropic (direction dependent) response of bovine cartilage samples to an applied dynamic load. The cost of this technique was substantially less than any other method we studied.

After a six year detour into academic administration I am now involved with a group of faculty and students at Cal Poly, led by Dr. Pete Schwartz, studying solar concentrators for use in developing countries for cooking applications. This has been an ideal project for reconnecting me with the tools that I had used in the past including CAD, FEA, and custom post processing code to help display results in a way easy for the technical and non technical audience to grasp. All of my previous experience with graphics is being utilized in this project

Using solar power for cooking is not a new idea and our group is not the only one pursuing this goal. We are expanding on work done by Wolfgang Sheffler [1] on solar concentrators that utilize a simple single degree of freedom tracking mechanism to follow the sun throughout the day. The advantages of single degree tracking are substantial in cost and maintenance.

This project utilizes CAD software including equation driven surfaces to generate the ideal parabolic dish for use as a solar collector [2]. This process is depicted in Figure 1. This dish is optimized for the Equinox. A solid model is generated to produce a mold which can then be used to produce a repeatable composite dish structure. The unique aspect of the Sheffler design is that instead of tracking the sun as it changes position in the sky throughout the year the shape of the dish is modified to continue to allow the dish to rotate on a single axis parallel to the axis of the earth for daily tracking. FEA along with custom ray-tracing software are being used to predict exactly how the dish and support structure should be designed to optimize the solar collection throughout the year and to ensure that any manual adjustments are simple and easy to implement in a typical developing country environment.

*Professor, Mechanical Engineering, California Polytechnic State University
**Associate Professor, Physics, California Polytechnic State University
***MS, Mechanical Engineering, California Polytechnic State University 2014
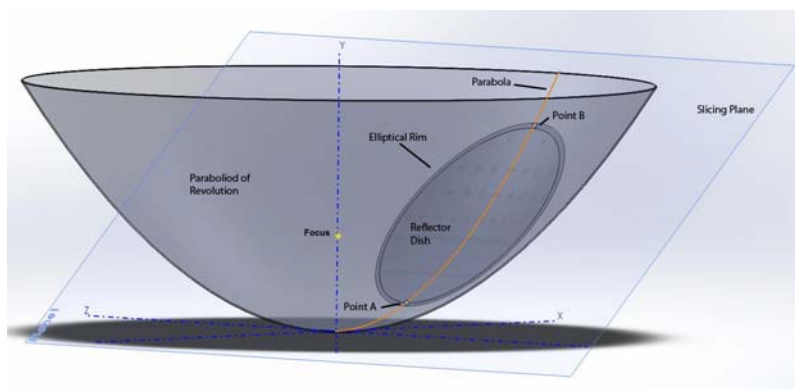
Figure 1, Solidworks used to model parabolic surface generated with equation driven curve. The dish is then defined by intersecting the parabolic surface with a cutting plane. (S. Alberti [2])

Graphical output from the ray-tracing code is being used in several ways to quantify the effectiveness of the concentrators. Figure 2 shows graphical representations of the light rays coming off of the collector and how they converge onto the focus. Figure 3 is a more quantitative look at exactly how the light is distributed around the focus.
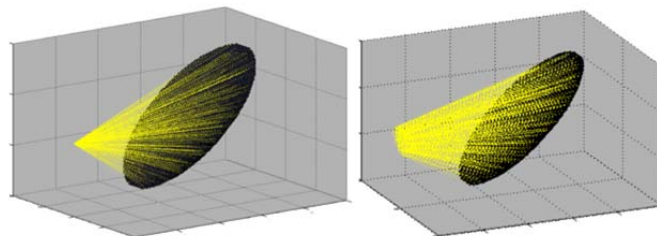
a) Mathematically perfect dish   b) Imperfect dish

Figure 2, Ray tracing results for a perfect dish a) and a dish with imperfections b). As expected the mathematically perfect dish shows the light rays converging to a point whereas the imperfect dish shows the light spreading out at the focus. (S. Alberti [2])
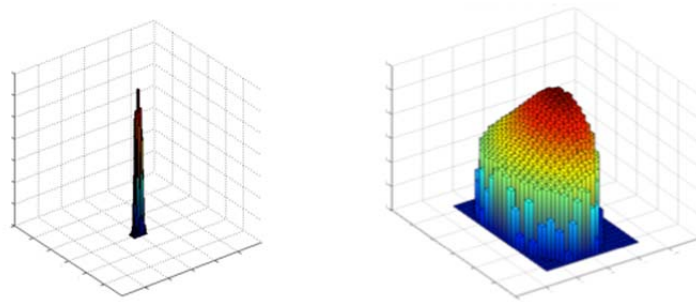
a) Mathematically perfect dish   b) Imperfect dish

Figure 3, Light distribution at focus for perfect dish a) and dish with imperfections b). The distribution in a) is not perfect (a single line at 0,0) in this case because the analysis includes the sun as a disk source instead of a point source of light. (S. Alberti [2])

Currently FEA analysis is being used to predict how the dish will deflect when displacements are imposed at 4 connection points on the rim. Figure 4 shows the results from one analysis on a fiberglass dish. In this phase of the project we are creating code to import the deformed dish geometry into our ray tracing code to analyze how well the deformed dish will perform at various times of the year.

Figure 4, Deformed Collector from ABAQUS Analysis. Note how the edges on the more horizontal axis are deforming in the positive x direction opposite to the edges on the more vertical axis. This is the desired deformation pattern to adjust from the equinox to summer solstice. (A. Davol)
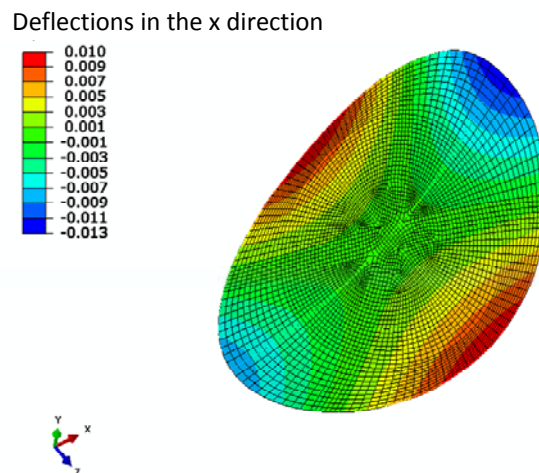
Verification of the actual collectors as constructed is also an important part of this project. While it is possible to do physical testing of the collectors throughout the year in actual application this would be time consuming and expensive. Instead we are experimenting with using a 3-D scanner to scan the surface of the dish into our ray-tracing code. The code can then be used to analyze the effectiveness of the dish throughout the year. Our efforts in this

area have just begun and we are currently using an X-Box Kinect scanner with SKANECT software to capture the actual surface. Figure 5 shows a point cloud captured from a dish prototype. This will be converted into a surface and then analyzed in the ray-tracing code.
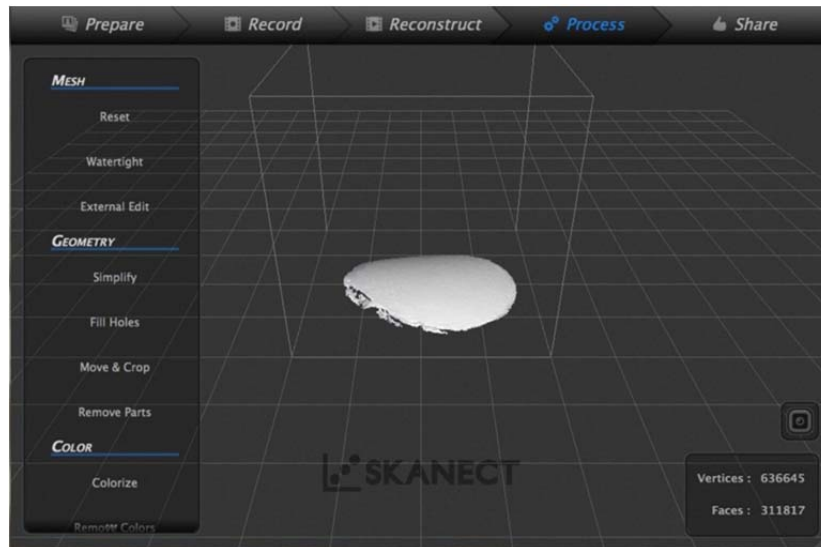
Figure 5, Scanner output of ~2m^2 dish. This output will be converted into a surface and imported into Matlab where a ray-tracing analysis can be run to quantify the effectiveness of the solar concentrator as built.

(A. Davol)

[1] Scheffler, Wolfgang, O Hensel and A Munir. "Design principle and calculations of a Scheffler fixed focus concentrator for medium temperature applications." Solar Energy (2010): 1490- 1502.

[2] Alberti, Simo, "Analysis and Optimization of the Scheffler Solar Concentrator", MS Thesis, California Polytechnic University, San Luis Obispo, CA (2014)

OVERVIEW OF THE DIFFERENT POSSIBILITIES THAT ADDITIVE MANUFACTURING HAS FOR RESEARCH AND TEACHING

Ph.D. Ian Campbell

1   Introduction

Additive manufacturing (AM) is defined by ASTM International to be "the process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies" [1]. This definition covers a range of technologies that vary greatly in the way they join materials together. Each category of technology is described briefly below: [1]

- Vat Photo-polymerisation – liquid resin held in a vat is solidified one layer at a time via the application of an energy source, e.g. a laser beam or ultra-violet light. The layer is lowered into the vat and the next layer solidified on top of it. The process is then repeated until the part is finished.
- Material Jetting – material is "printed" through numerous print-heads to create each layer of the part being built. A secondary material is normally used to support the part as it is being built.
- Binder Jetting – a binder material is printed onto a substrate (normally powder) to fuse particles together, again one layer at a time. The un-fused material normally acts as support for the part being built. The parts very often have to be post-processed to achieve working strength.
- Material Extrusion – material is extruded through an extrusion head that is typically heated to a temperature that will fully or partly melt the material. Usually undertaken layer by layer but full 3-axis control of the extrusion head is also possible.
- Powder Bed Fusion – powdered material is fused together through the application of an energy source, typically a laser beam or an electron beam, again on layer at a time.
- Sheet Lamination – thin sheets of material are stacked and cut, one at a time, to build up the finished part. The sheets are normally bonded together using adhesive.
- Directed Energy Deposition – Typically, a laser beam is directed onto a substrate where it melts powdered material to form a solid. The powdered material is "injected" into the melt-pool and these type of systems can use up to 5-axis control.

The technologies described above use quite a wide range of materials that come in powdered, sheet, filament or liquid form. Materials include polymers,

metals, ceramics, paper and a few composites. The relationship between the different technologies and the types of materials most commonly used with them is shown in table 1. The combinations shown are for commercially available systems; research systems have explored and are continuing to explore other combinations, e.g. ceramic sheet lamination.

	Polymers	Metals	Ceramics	Paper	Composites
Vat Photo-polymerisation	√				√
Material Jetting	√				
Binder Jetting		√	√		
Material Extrusion	√	√	√		
Powder Bed Fusion	√	√			√
Sheet Lamination	√			√	
Directed Energy Deposition		√			

Tab. 1 Types of materials commonly used with different AM technologies.

An important development in the world of AM is the introduction of relatively low-cost machines (typically less than 5000 Euros). Primarily, this has been made possible through the expiry of critical commercial patents and the availability of open source designs and software, most notably through the RepRap project [2]. Such low-cost AM machines are often referred to as 3D Printers (3DPs) and have revolutionised the AM market place in recent years. There has been a bifurcation of the AM market into two different sectors, 3DPs and what can be referred to as industrial AM systems (IAMSs). The capabilities and utilisation of the machines in the two categories are markedly different and this will be referred to in later sections of the paper.

2   Key Drivers

The development of AM over the past three decades has been driven by a number of key factors. Great advances have been made in each of these but there are still many issues to be resolved.

2.1 Process improvements

The first commercial AM system was Stereolithography from 3D Systems, first released in the late 1980s. This was marketed as a "rapid prototyping" system since accuracy was not great. It was suitable for producing one-off models that could be used for "form and fit" analysis, i.e. to appreciate the 3D shape of a part and to check that it assembled correctly with other components. Even this latter analysis was problematic since parts could sometimes warp after building. Several other systems entered the market in the early 1990s including Selective Laser Sintering and Fused Deposition Modeling. The most common

application for these systems was also prototyping. However, as accuracy, repeatability and speed improved, the range of prototyping activities increased to include functional analysis (e.g. aerodynamic testing) and customer appreciation. Processes also became faster and build chambers larger, allowing more models to be produced. However, wider application of AM was severely limited by the material properties that were available.

2.2 Materials development

The first AM materials were photo-curable polymers with limited strength characteristics. However, the range of polymers grew and the inter-layer bonding of parts improved. Engineering plastics including polyamide and ABS were able to closely replicate the material properties seen in injection moulding. This meant that full operational testing could be performed, where engineers and customers could use the prototype in place of the final part. Some allowances still had to be made for anisotropic material properties. The most important development in materials was the introduction of metals. This was first achieved indirectly through the laser fusion of a polymer/metal mix combined with a post-processing step that burned out the polymer binder and replaced it with a metal infiltrate. However, direct metal laser sintering (DMLS) soon followed and the way was now open for metal prototypes and tooling to be produced using AM. Materials development has continued through the addition of numerous metals including stainless steel, tool steel, titanium, cobalt chrome, copper and aluminium. When used with powder bed fusion and directed energy deposition, it is possible to achieve material properties very close to wrought or forged parts. This has been of particular benefit to the aerospace and medical industries were IAMSs are regularly used to produce end-use components and not just prototypes.

2.3 Cost reduction

Ignoring the introduction of 3DPs, AM has always been an expensive technology. This is due to high machine costs, high material costs and slow processing speeds. IAMSs are still very expensive to use, particularly for metals and thus their use is currently limited to high-value adding industries. However, the introduction of polymer-based 3DPs has increased the competition in some parts of the AM market and operating costs are falling. The same may become true for metal AM in the future, although the development of such systems is inherently more problematic because of the high temperatures involved.

2.4 Designing for AM

In general, AM allows much more freedom of geometry, i.e. more complex shapes can be created at very little extra cost. This has presented a unique opportunity (or challenge) to designers. Most designers are familiar with the

standard design for manufacturing and assembly (DFMA) criteria which basically state, keep designs simple so that they are easy to make and assemble. As a result, product design concepts are often simplified to enable easier manufacturing. With AM, many of these compromises are no longer necessary and so more innovative and optimised designs are possible. Several leading design for AM practitioners have grasped this opportunity, creating some spectacular designs that are really only feasible when built using AM. Amongst them are Janne Kyttanen [3] and Lionel Dean [4]. More designers need to become aware of the unique possibilities afforded by AM in order for its use to accelerate.

3 Research Directions

All of the key drivers discussed above have "unfinished business", i.e. much still needs to be achieved. Therefore, future research directions can be largely defined in reference to these drivers. In addition, it is important to make a distinction between fundamental research where ground-breaking new knowledge will be generated and applied research which, to a large extent, involves the innovative application of existing knowledge. Not all organisations are equipped for the former but most can find their own niche in the latter.

3.1 Fundamental research

The critical issues that need to be addressed here are process improvement and materials development. If AM is to take its place alongside established manufacturing processes such as machining, casting and injection moulding, then it needs to meet expected capability levels. Pressing issues are as follows:

- lack of in-process monitoring
- limited accuracy
- process variability
- limited throughput volume
- material properties variability
- limited materials range
- surface finishing requirements
- optimising data handling

Typically, pursuing any one of these issues will require the acquisition of an IAMS and gaining the vendor's permission to access all the process parameters in the controlling software and/or permission to use non-standard materials. Not all vendors will allow this but some are prepared to enter into research partnerships with academic institutions. Addressing these fundamental issues can also be a fruitful use of PhD students who can concentrate on a narrow aspect of process or materials development. There is some scope for fundamental research using open access 3DPs, e.g. investigating different materials and surface finishing treatments. The similarity of materials used

means that some of the results will also carry over to IAMSs. However, these machines are rarely at the "cutting edge" of technology and so results from studying issues such as limited accuracy and process variability are rarely transferable to high-end systems.

3.2 Applied research

A key aim for AM applied research is greater industrialisation of the technologies, i.e. achieving greater acceptance and a wider range of applications within industry and the wider community. Essentially, this research can treat AM machines as manufacturing tools with fixed capabilities (although recognising that these are likely to improve in the future) and then investigate the means by which they can be better integrated into current and future manufacturing systems. Therefore, any organisation with an IAMS can get involved in applied research with some topics also suitable for 3DPs. Indeed, some issues can be addressed even without access to an in-house machine. Typical issues will include:

- Integrating AM with other manufacturing technologies
- Developing new application areas
- Generating data towards AM standards
- Characterisation of AM materials
- New design tools for AM
- Decision support systems

Often, the outputs from applied research can be of more immediate use to industry and so obtaining industrial input to the research may actually be easier. The search for research partners should reach out beyond manufacturing industry since other sectors are also finding important uses for AM, e.g. medicine, architecture, archaeology and the creative industries.

4 Teaching Needs and Enhancements

The impact of AM within teaching can span a very wide spectrum from primary (elementary) to tertiary (higher) education and through to industrial training. Two aspects must be considered, teaching for AM and teaching with AM.

4.1 Teaching for AM (needs)

Assuming that AM (both IAMSs and 3DPs) is going to play a large role within manufacturing and the wider community, the next generation of engineers, designers, artists and medics need to be fully aware of its capabilities and limitations. There is a need to introduce students to the existence of AM at primary level, explain how it works at secondary (high school) level and then provide details of capabilities and limitations at tertiary level. At each level the education will become more focused and in-depth. In theory, organisations wishing to offer this education could do so without actually having access to

AM machines. However, in practice, the use of 3DPs in schools and IAMSs at colleges/universities will offer greater opportunity to demonstrate what is being taught. In tandem with full-time education, AM technology update training should be offered to those already embarked on their careers. An excellent example of this is the America Makes initiative in the United States [5]. It offers a wide range of continuing education courses aimed at engineers, technicians, designers, educators and the layperson.

4.2 Teaching with AM (enhancements)

In schools, AM should be taught as an integrated part of a cross-disciplinary STEM (science, technology, engineering and mathematics) curriculum. When this happens, it opens up a range of possibilities for teachers to enhance the learning experience. For example, 3DPs can be used to support "design and make" projects. Whilst preparing their designs for the 3DP, students will learn about material properties, mechanisms and electronic control, build-time and cost estimation, design optimisation, and many other STEM topics. As students get older and move into college/university, design for AM can be used to promote creative thinking and even entrepreneurial activities. They should be encouraged to "get their hands dirty" by actually making their designs and testing them out. This has always been possible but the time and cost involved with the use of conventional equipment is becoming increasingly prohibitive. 3DPs offer a fast and easy-to-use route to prototype manufacture. It could even be speculated that 3D Printing will enable the current generation of students to recapture the art of "tinkering" that was prevalent amongst their parents and grand-parents.

Amongst the general public there is a desire for "Makers" to design and manufacture their own products. This has given rise to a host of "maker spaces" where anyone can come along with an idea and attempt to make it a reality. In a maker space, 3D Printing will be used alongside other technologies to provide many of the tools necessary to build functional prototypes. There is an opportunity here for educational establishments to provide these facilities with the aim of encouraging laypeople to get interested in design and engineering, perhaps even leading to enrolment on a formal course. This has been the aim behind the Idea to Product (I2P) Labs that started at Vaal University of Technology in South Africa [6] and have now been established in several other countries. Alternatively, an institution's maker space might only be aimed at internal students, such as the DReAm Lab at Loughborough Design School.

5 Conclusions and Future Outlook

AM has developed strongly over the past three decades and its capabilities and applications have both increased accordingly. However, there is much development still needed, both in terms of technology and also people. This presents a wide range of research and teaching opportunities.

In the past, AM was often seen as a competitor to conventional manufacturing. This is now changing as more "hybrid systems" are coming into the market. These combine additive and subtractive materials processing. This will go hand-in-hand with the development of additional metals for use in AM to provide a step-change in IAMS utilization. At the other extreme, 3DPs are becoming cheaper and more accessible, possibly leading to wider usage amongst the general public. The future of AM has never been brighter and the prospects for those involved in it are more exciting than ever. The expectation is for research and teaching opportunities to increase even further.

References

[1] ASTM International. *ASTM F2792: Standard Terminology for Additive Manufacturing Technologies*. Available from http://www.astm.org/Standards/F2792.htm accessed 1 June 2015.

[2] RepRap Project website. reprap.org accessed 1 June 2015.

[3] Janne Kyttanen's website. http://www.jannekyttanen.com/ accessed 1 June 2015.

[4] Lionel Dean's website. http://www.futurefactories.com/ accessed 1 June 2015.

[5] America Makes website. americamakes.us accessed 1 June 2015.

[6] I2P Lab website. http://www.vut.ac.za/index.php/service/units/tti/ts/idea-to-product-i2p accessed 1 June 2015.

Researcher and Professor in Computer Graphics, Virtual Reality and Visual Analytics at URJC

Ph.D. Luis Pastor

The human brain is one of the most complex systems Science is nowadays still trying to understand. Even though the task is overwhelmingly difficult, a number of long-term, multidisciplinary research programs have been launched in different areas of the world, which are little by little bringing progress to this fascinating goal. In additional to traditional Neuroscience laboratory procedures (potentiated by the appearance of powerful laboratory techniques and equipment), new light is being shed by the so-called Computational Neuroscience methods, where simulations –sometimes massive- test different hypothesis or analyze the effect of certain stimuli or surgical procedures within the brain's behaviour. Nevertheless, the analysis of large-scale simulations (just as the analysis of large sets of biological samples) is not an easy task, given the fact that the amount of data on a full scale test can potentially surpass the exascale frontier.

Designing tools for the visual analysis of Neuroscience data (either from Computational or Experimental methods) is also a challenging task, taking into consideration both computational and perceptual aspects. This talk will give a brief overview of the work that is being performed at the URJC's GMRV research group on the design of visual analysis tools for Neuroscience, digging a little bit on the main problems and the solutions posed so far. Previously, a brief introduction to the URJC's GMRV research group will be given in this talk, covering both teaching and research activities within the School of Computer Science & Engineering of the URJC.

Investigación en Biomecánica y Ergonomía

Ph.D. Margarita Vergara

En esta charla se presenta una descripción de diferentes trabajos realizados por la ponente dentro del **grupo de investigación de Biomecánica y Ergonomía** de la Universitat Jaume I (UJI) del cual forma parte en colaboración con profesores de dos áreas de conocimiento (Expresión Gráfica en la Ingeniería e Ingeniería Mecánica). La charla se centra en tres de las seis líneas de investigación desarrolladas en el grupo, aquellas en las que la ponente tiene un papel más relevante: Biomecánica de la mano, Ergonomía de herramientas manuales y Diseño afectivo. En cada una de ellas se presenta una descripción de sus objetivos y de los trabajos y logros más significativos en los últimos años. Se describen también las técnicas de investigación utilizadas, desde las más subjetivas (como la recogida de opiniones directas y su tratamiento estadístico) a las más objetivas (como la medida de diferentes parámetros biomecánicos y fisiológicos), pasando por la modelización biomecánica de las estructuras corporales.

La investigación en **Biomecánica de la mano** tiene como objetivo principal el conocimiento del comportamiento mecánico de la mano humana, con diferentes fines como la planificación de intervenciones quirúrgicas, la mejora del diseño de herramientas, la evaluación de procesos de rehabilitación médica o el desarrollo de manipuladores artificiales o manos biónicas más eficientes. Esta línea es la más prolífica del grupo, con 6 proyectos finalizados y otros 4 en marcha. Las técnicas utilizadas son tanto experimentales como analíticas (modelos biomecánicos). Las técnicas experimentales consisten en el registro de parámetros mecánicos, fundamentalmente posturas y esfuerzos (esfuerzos máximos en determinadas tareas o posturas, presión en la interface mano-objeto agarrado, esfuerzos musculares, etc.). Uno de los objetivos de este tipo de registros es el de caracterizar los mecanismos de agarre utilizados en la prensión y manipulación de diferentes objetos, pero también son fundamentales en la definición y validación de modelos biomecánicos que permitan hacer simulaciones más realistas. El grupo ha desarrollado un modelo tridimensional escalable de la mano humana que contempla sus 25 grados de libertad. El modelo inicial se desarrolló para aplicarlo al diseño ergonómico de herramientas, aunque también se ha empleado en la simulación de patologías de la mano. Incluye la modelización mecánica de músculos, tendones, huesos y

ligamentos, permitiendo el cálculo de esfuerzos ante las diferentes solicitaciones externas. Recientemente, el modelo se ha mejorado incluyendo un modelo de piel más realista, un módulo para predecir la postura de agarre con redes neuronales y la definición de indicadores de calidad del agarre que permiten mejorar las predicciones de esfuerzos. En los proyectos que se están llevando a cabo actualmente, se está caracterizando experimentalmente la cinemática de diferentes articulaciones para mejorar la definición de los ejes de rotación del modelo y se están estudiando las sinergias cinemáticas en la manipulación de objetos al desarrollar actividades de la vida diaria. Además, se ha iniciado un proyecto, junto con el grupo de Robótica de la UJI, para el diseño y evaluación de manos artificiales antropomorfas mediante la simulación del agarre y su aplicación al diseño y control de prótesis de manos.

La línea de **Ergonomía de Herramientas manuales** es la que dio origen al grupo, y está estrechamente relacionada con la Biomecánica de la mano. Su objetivo es conocer en profundidad la ergonomía del agarre de herramientas manejadas con la mano, tanto herramientas manuales como motorizadas, con el fin de mejorar su diseño para que las herramientas sean más seguras, cómodas y fáciles de manejar. Aquí se utilizan todas o casi todas las técnicas de la línea anterior, complementadas con otras más propias del análisis ergonómico de entornos laborales, como son la medida de vibraciones o de ruido provocado por las herramientas motorizadas, y las técnicas subjetivas a través de encuestas para recoger parámetros relativos a la comodidad, molestias y otro tipo de percepciones y opiniones sobre las herramientas o puestos analizados. Estos parámetros subjetivos son por sí mismos de gran valor para el análisis ergonómico, pero además se pueden relacionar con los parámetros objetivos. Por ejemplo, en un estudio sobre herramientas a motor se midió la vibración y ruido generados por herramientas en su lugar de trabajo para comprobar el riesgo que suponen según la normativa, y a su vez se midió también la percepción que los trabajadores tenían de si eran excesivos o no. Los resultados indicaban que los trabajadores eran conscientes del ruido nocivo pero que no lo eran de las vibraciones.

La línea de **Diseño afectivo** es la más reciente, aunque no por ello menos desarrollada. Dentro del grupo se han leído ya dos tesis doctorales, hay otras dos en marcha, y se han desarrollado dos proyectos de investigación financiados en los últimos años. Tiene por objetivo poner a punto, mejorar y aplicar metodologías de diseño emocional o afectivo de productos para ser integradas en una metodología global de diseño centrado en el usuario. En el mercado actual, el consumidor no valora únicamente el precio, la funcionalidad, usabilidad y seguridad de los productos (valores estos últimos

relacionados con la ergonomía) sino que también valora las emociones y los sentimientos que le proporcionan. Las metodologías de diseño emocional como la Ingeniería Kansei, permiten captar las necesidades emocionales de los usuarios y establecer relaciones entre éstas y las características del producto, permitiendo así incorporar en el diseño aquellas características que mejor reflejen las emociones pretendidas. Aquí las técnicas utilizadas fundamentalmente son las subjetivas, en las que con ayuda del diferencial semántico o escalas de Likert, se recoge el perfil emocional de los productos evaluados. Más recientemente, en colaboración con el LabHuman de la Universidad Politécnica de Valencia se han utilizado otras técnicas como el eye-tracking para evaluar productos emocionalmente. Estas metodologías se pueden aplicar no solo a productos de consumo sino también a productos profesionales, como se demostró en un trabajo del grupo en que se aplicó el diferencial semántico a máquinas herramientas. Ente otros logros del grupo cabe destacar el desarrollo de una metodología para clasificar y seleccionar de forma más objetiva los semánticos (palabras o frases utilizadas para medir la percepción de los productos), el estudio del efecto de diferentes formas de presentación de los estímulos en la recogida de datos, y la relación existente entre la percepción del producto y las emociones generadas, así como la relación de todo ello con las preferencias de producto.

Aunque en un principio estas tres líneas pueden parecer disjuntas, comparten métodos y técnicas y se engloban dentro de un objetivo común: mejorar la salud y bienestar de las personas a través de un análisis del funcionamiento del cuerpo humano y la percepción subjetiva para diseñar productos más adaptados a los usuarios y a sus necesidades.

Abstracts of Communications

3D MODELING AND FUNCTIONAL ANALYSIS OF A SPANISH ARTICULATED METAL HEADFRAME FOR MINERAL EXTRACTION: COMPARATIVE ANALYSIS WITH A MASONRY HEADFRAME

Rojas-Sola, José Ignacio; Palomares-Muñoz, Isis

In this paper, we analyze in detail an articulated metal headframe used for mineral extraction. In particular, three-dimensional modeling is performed using software parametric (Autodesk Inventor Professional 2014) of each of the elements of the set. Also, after obtaining the 3D model, a static functional analysis using techniques of Computer-Aided Engineering has been performed, based on the analysis of the von Mises stress and displacement, ensuring that the highest stress concentrations occur in the shaft and in the pulleys, and that the highest concentration of displacements on the pulleys and the cable. Finally, we have established a comparative analysis with a masonry headframe.

3D DIGITAL TECHNIQUES APPLIED TO NEW DESIGN PRODUCTS BASED ON CULTURAL HERITAGE ELEMENTS

De Cózar Macías, Óscar David; Flores Rodíguez, María Sonia; Blázquez Parra, Elidia Beatriz; Ladrón de Guevara Muñoz, Carmen; Marín Granados, Manuel Damián

The aim of this paper is to present the 3D digitalization and posterior treatment of complex heritage elements existing in the Alhambra Palace, so that they can be used as the starting point for the development of new products.

Not only are the direct results of 3D digitalization exploitable and essential for the documentation, recording and research of heritage elements, but also these 3D files compiling the original elements are to be used as the blueprints for the future development of new products and designs, such as constructive elements regarding their application at interior design and architecture projects. The enrichment provided in new products is undeniable as they will depart from the same provenance as the heritage element, which allows the product to increase its market value, and the opening of new Market niches.

It is very important to highlight that any new product creation process will be grounded in full respect and protection of cultural heritage. For this reason, under no circumstances will the original elements be completely reproduced,

not even partial developments of them since this action could undergo the risk of a non-responsible reproduction of the heritage elements.

DEVELOPMENT OF A CONTENT MANAGEMENT SYSTEM (CMS) ON INDUSTRIAL ARCHAEOLOGY: VALORIZATION AND DISSEMINATION OF CONTENTS ON MINIG INDUSTRIAL HERITAGE

Rojas-Sola, José Ignacio, Aguilera-García, Ángel Inocencio

In this communication a Content Management System (CMS) based on Joomla for content broadcasting on industrial archaeology, particularly on the mining industrial heritage is presented. Joomla is an Open source software, developed in PHP and released under GPL license remains the most widely used today. The results of the research project included in the CMS are structured from various perspectives: historical, technological, graphic (virtual) of inventory (through a Geographical Information System (GIS)) and tourism. These resources include an introduction to the subject, websites of interest, relevant literature, inventory records movable and immovable property, photographs, videos, examples of virtual and augmented reality, mining touristic routes or a list of scientific societies, parks, museums and interpretation centers on the subject. Also, the interface (template) is very intuitive and easy to navigate facilitating to the users the assimilation of content and therefore its valorization and dissemination.

QUANTITATIVE ASSESSMENT OF DEFORESTATION IN MOULOUYA RIVER WATERSHED (MOROCCO) USING AN INNOVATIVE REMOTE SENSING APPROACH

Aguilar, Fernando José; Nemmaoui, Abderrahim; Aguilar, Manuel Ángel; Chourak, Mimoun; Zarhloule, Yassine; García Lorca, Andrés Miguel

A regional scale quantitative assessment of deforestation in Moulouya River watershed (Morocco) has been carried out by means of an innovative approach from atmospherically corrected reflectance Landsat images corresponding to 1984 (Landsat 5 TM) and 2013 (Landsat 8 OLI). An Objects Based Image Analysis (OBIA) was undertaken to classify previously segmented objects as forested or non-forested within the 2013 Landsat orthomosaic. Random Forest classifier was applied to a set of training data based on a features vector composed of

different types of objects features, such as vegetation indices, mean spectral values (RGB, near-IR and Shortwave-IR bands) and probabilistic spectral mixture analysis (object endmembers components) of photosynthetic vegetation, non-photosynthetic vegetation and bare soil. Google Earth 2013 image data were employed to train/validate the Random Forest classifier (ground truth), ranking the NDVI vegetation index and the corresponding percentages of photosynthetic vegetation and bare soil (spectral mixture model) as the most statistically significant object features to extract forested and non-forested areas. Regarding classification accuracy, the results were very promising, achieving an overall accuracy of 92.34%. The previously developed classification scheme was applied to 1984 Landsat image data to quantitatively and spatially extract the land cover changes between 1984 and 2013, showing a slight net increase of 5.3% (ca. 8800 ha) in forested areas for the whole regionn.

GEOMETRIC DESIGN FOR SLATE MINE WORKINGS USING KEYBLOCK METHOD AND PHOTOGRAMMETRY

Menéndez-Díaz, Agustín; Ordóñez-Galán, Celestino; Bouza-Rodríguez, José Benito; García-Cortés, Silverio

In recent years, the intensive slate open-pit mining activities have slackened notably, but this is not the case with underground workings, that commonly result in better quality materials and with better yields. It is necessary to study new underground excavation designs (room and pillar method) that take into account potentially unstable blocks and supply optimal support. The goal of these new designs will be to ensure the safety of mining operations and to reduce environmental impact by minimizing waste. We describe a methodology to determine safety factors and the most suitable support for various excavation stages in underground slate workings. Data characterizing the rock mass were collected using a terrestrial laser scanner. Semi-automatic discontinuity detection techniques and safety factors were assessed using these data and the limit equilibrium method. The aforementioned techniques were applied to the pre-design of underground slate mine in northwestern Spain.

STUDY SPACE-TEMPORAL OF SÃO LUIS (UPAON-AÇU) ISLAND: DOCUMENTATION AND ANALYSIS OF LANDSCAPE AND CULTURAL HERITAGE

Rocha de Moraes Rego, Carlos Augusto; Herrero Tejedor, Tomás Ramón; Pérez-Martín, Enrique; Borralho de Andrade, Juliane; López Herrera, Juan

This work has as its main objective conduct a graphic and visual study on the evolution of the landscape in São Luis Island, located in the Department of Maranhão (Brazil). The methodology used is based on a holistic approach to the conception of landscape and subsequent planning of the territory. In a first phase, we proceeded to the identification and mapping of cartography and images over time. To do this is we have pre-selected four sites in the studied area. They are the municipalities that form the island of Sao Luis: Raposa, São José de Ribamar, Paço do Lumiar and São Luis. These places have been documented and analyses from two perspectives: geological-geomorphological perspective in its natural conception of space and the prospect of the occupation of the soil in the model of development followed by that territory. The main result is the creation of an information system that can serve as geo-visual support for the defense of the cultural heritage, and thus help in the decisions of future planning for the study area.

DEFINITION OF THE USE OF AN ACOUSTIC METHODOLOGY FOR ITS USE IN THE REPRESENTATION OF 2D GEOMETRIC OBJECTS

Santiago-Praderas Víctor; Manco, Antonio; Defez, Beatriz; Brusola, Fernando; Peris-Fajarnés, Guillermo

The use of sound to represent geometric shapes or real environments by sounds has been used by different procedures. Basically the natural capacity of detecting the origin of a sound is used every day with this purpose. Nevertheless the chance to use the audio channel for representing 3D spaces is different to the visual channel, the number of sounds per second or the order of how this sounds arrives to the ear have a relevant effect about the capacity for understanding, processing and recognizing objects and shapes. On this paper, a serial of experiments done for representing how the 2D and 3D information can be represented by sounds are described with its initial results. The design of the initial experiments and results is presented on this paper.

ANALYSIS OF THE INTEGRATION PROCESS OF LIGHTWEIGHT CERAMIC TILE IN THE PRODUCT LINE OF CERAMIC COMPANIES

Peris-Fajarnés, Guillermo; Defez, Beatriz; Lengua, Ismael; Dunai, L.

Today there is technology that enables the use of molds which can reduce the amount of clay required for the manufacture of ceramic floor tiles. This implies an impact on the production process at all stages, from raw material consumption, cooking until transport and placement. This may involve, in theory a considerable saving in production cost. This paper sets, analyzes and explains the technical realities of this type of lightweight tile and proposes measures to make for proper full integration into the production process.

DESIGN OF DETACHABLE DRUM FOR A FRONT LOAD WASHER

Ladrón de Guevara, Mª Carmen; Blázquez Parra, Elidia Beatriz; Maraver, Ana; Castillo Rueda, Francisca José, Ladrón de Guevara López, Isidro

Currently, two main types of washing machines exist in the market. Depending on how cloths are placed in and out the washer, they are classified into front-load washers and top-load washers.
Both of them present the same inconvenient and uncomfortable practice when collecting the laundry: clothes that remain at the surface of the spinning basket are difficult to reach, therefore imposing great strain into the user's back and neck area, especially in the case of front-load washers.

The aim of this work is to present the design of a detachable opening system for front-load washing machines. This design is unique since it allows the inner drum to be horizontally drawn from the whole machine in order to remove the cloths after the washing process.

This system introduces a higher efficient and comfortable procedure than current systems use. It allows the use of washers effortlessly, being especially useful for people with any kind of physical disabilities. Loading and unloading the laundry will not require the user's bending over the machine anymore.

AIRVORTEX: EXAMPLE OF MULTIDISCIPLINARY DESIGN

Miralbés Buil, Ramón; Ranz Angulo, David

The aim of this article is to present the design process for a simple product using a multidisciplinary point of view that includes diverse knowledge areas such as aerodynamic design, structural design, ergonomic analysis, material selection, manufacturing process analysis, packing, ecological design, and recycling, as well as to present the prototype manufacturing and the experimental test of the end product. Technologies of reverse engineering have been used to obtain the design solutions of other companies. In addition, it is indispensable to analyze the sequence of use and the product's interaction with both the user and the environment, so the main design specifications must be defined. This methodology has been applied to a simple product installed habitually in the wings of the light aircrafts, named vorticity generators (VG).

METHODOLOGY FOR A SUSTAINABLE PRODUCT DESIGN

Velasco Ortiz, Carlos; Lacasa Ferrer, Enrike; Santolaya Saenz, José Luis

Sustainability applied to industrial processes allows the companies to obtain both lower environmental impact andhigher quality products, as well as to improve the company image and to reduce the manufacturing costs. In order to obtain a more sustainable product development, a methodology that preserves the initial specifications of the product and applies design criteria to reduce its environmental impact, is implemented in this paper.

Two main strategic lines based on the optimization of materials and processes are applied. The eco-indicators of global energy, greenhouse gases emissions and water consumption are used to assess the methodology proposed in the case of a solar tracker mechanism. Because the mass and energy needed to manufacture the components are optimized, a significant reduction on eco-indicator levels is achieved in the new product design.

DIRECT DIGITAL MANUFACTURING FOR SPORTS AND MEDICAL SCIENCES

Cazón, Aitor; Matey, Luis; Rodríguez, María Isabel; Morer, María de la Paz; González, Itziar

Purpose:
Additive Manufacturing (AM), commonly called 3D printing, is the process of making objects layer upon layer from 3D model data in order to test design prototypes (called Rapid Prototyping), to obtain production tools (Rapid Tooling) or to build and then use that prototype as a final part in the final

product (Direct Manufacturing). This paper aims to show new applications of the Direct Digital Manufacturing philosophy for sports and medical sciences. Particularly, the aim of the study is to present three case-studies that take advantage of AM so as to enable practitioners and professional players to manufacture customised 1) foot insoles to treat foot problems, 2) shin pads to be worn by football players and shield them from shin injuries and 3) face masks to protect the face during sports or everyday activities.

Method:
In every case study, prior to fabrication, anthropometric features of volunteer patients were captured by a low-cost 3D scanner and a user-friendly semi-automatic modelling procedure was developed with 'Rhinoceros' and 'Grasshopper' in order to model and customise several features of the three products.

Result:
The resulting virtual designs of the three products were manufactured with the help of four different AM devices while design workflow and the suitability of the physical prototypes were evaluated against volunteers and practitioners. Feedback results from practitioners and volunteers were satisfactory enough in order to consider the design tools provided as a good starting point for future developments.

Discussion & Conclusion:
Further work is still necessary in terms of improvement to the design algorithm, inclusion of new materials and test procedures to verify the physical prototypes to the final user requirements. Nevertheless, this work confirmed that the combination of existing tools of three-dimensional digitisation, user-friendly semi-automatic algorithm within a Computer Aided Design (CAD) and Additive Manufacturing can lead to a technologically feasible and cost-effective solution to improve the traditional design and manufacturing process of customised orthotic and protective devices for sports and medical sciences.

THE GOLDEN RATIO IN PRODUCT DESIGN

Martín Amundarain, Iñaki; Domínguez Somonte, Manuel; Espinosa Escudero, María Del Mar

Nature can not only inspire many solutions in engineering design, but are also efficient, practical and sustainable solutions. This is because over millions of years of evolution, using the technique of trial and error, nature itself has produced effective solutions to the problems of the real world, even discovering new technologies, new materials and new processes when it was necessary.

The difficulty we have to introduce what is observed in nature in the design of a product and how to express it mathematically. The golden ratio can be expressed mathematically aspects in nature, forms that facilitate the design of more efficient products.

In this paper we show how, in addition to aesthetics, the golden ratio gets better technical results; as is the case of the design of a blade of a wind turbine.

APPLICATION OF PLASTIC PARTS DISCRETIZATION FOR ANALYZING GEOMETRIC DEMOLDABILITY

Martín Doñate, Cristina; Mercado Colmenero, Jorge Manuel; Rubio Paramio, Miguel Ángel

Purpose:
El proceso de moldeo por inyección de plásticos, es una de las tecnologías de fabricación con más influencia en la mayoría de los sectores industriales. La primera etapa en el proceso de análisis de la pieza de plastico consiste en determinar las contrasalidas de la pieza, la dirección de desmoldeo y la línea de partición. El análisis geométrico de la desmoldeabilidad tiene como objetivo obtener estos parámetros de manera automatizada para verificar que el diseño de la pieza es adecuado.

Method:
El artículo utiliza un algoritmo de discretización del sólido como paso previo al estudio de la desmoldeabilidad de la pieza de plástico a fabricar. El método de análisis desarrollado determina de manera automatizada el análisis de la desmoldeabilidad geométrica, indicando las áreas de la pieza que serán desmoldeables por ambas cavidades, contrasalidas y áreas no desmoldeables.

Result:
Con el objetivo de validar el algoritmo, se han analizado dos casos de análisis de la desmoldeabilidad en dos piezas diferentes. Se han considerado varias

direcciones de desmoldeo principal para el análisis. Con el propósito de analizar la eficiencia del algoritmo descrito se ha definido un parámetro adimensional Pr o precisión relativa como el ratio entre la precisión de la malla y la longitud de la diagonal del bounding box, expresado en porcentaje. Se ha realizado un análisis para diferentes valores de precisión, teniendo en cuenta como resultado el número total de puntos obtenidos en la discretización así como puntos identificados erróneamente. Para precisiones relativas menores del 2% el número de puntos incorrectamente identificados, no sobrepasó el 1% del número total de puntos en la malla en todos los casos estudiados.

Discussion & Conclusion:
Este trabajo presenta una nueva metodología para el análisis de la desmoldeabilidad automatizada de piezas de inyección de plástico. Este proceso identifica las zonas de la superficie de la pieza, de acuerdo con la configuración del molde. El algoritmo se plantea como un metodo automatizado que no requiere la ayuda de personal especializado para su manejo ni la interacción manual como actualmente ocurre con las soluciones CAD actuales a este problema.

AUTOMATED SYSTEM FOR INJECTION MOLD DESIGN AND COST CALCULATION. OBJECTIVES AND OPPORTUNITIES

Martín Doñate᾽ Cristina; Mercado Colmenero, Jorge Manuel; Rubio Paramio, Miguel Ángel; Vizan Idoipe, Antonio; Pérez García, Jesús María; Márquez Sevillano, Juan de Juanes; Aguilera Puerto, D.

Purpose:
The aim of this paper is the presentation of the objectives and works to perform in the research project CELERMOLD, Research Project of Excellence for Universities and Research Institutions in Andalusia that has been granted in 2014.

Method:
This research project aims to develop a vertical software, consisting of a computing platform that will automate and integrate the process of global mold design, in its geometrical aspect and allow obtaining manufacturing costs in a short period of time.

Result:
The system to be developed will perform in an automated manner a geometric demoldability analysis of the plastic part, pointing onto the workpiece, areas to

demolding by both cavities, side cores and non demoldable areas, calculating at the same time the parting line. Subsequently, a preliminary design of the mold will be performed, defining the mobile devices and other standard elements. Finally, the assembly tooling costs will be estimated.

Discussion & Conclusion:
In order to reduce the delivery time in the plastics industry, the design of the CAD CELERMOLD application, it is seen as a great help for mold designers and users who want to validate the manufacturing of its designs.

MULTITEMPORAL STUDY OF THE USE AND LAND COVER IN THE MUNICIPALITY OF URBANO SANTOS, MA

Borralho de Andrade, Juliane; Rocha de Moraes Rego, Carlos Augusto; Oliveira de Carvalho, Alysson; Cabral Amorim, Francielle; López de Herrera, Juan

The demographic expansion and industrialization that occurred in Brazil, recently, has induced the increase of urban areas and, therefore, the increase of the use of new areas. The multitemporal analysis of a region is a process from which is possible to evaluate how certain information about this region varies with time. Monitoring of land-use and land-cover is important for the study of certain regions, as it contributes for the knowledge of the environmental reality, such as the research regarding solutions for problems that may occur. Therefore, the objective of this paper is to approach the multitemporal study of the land-use and land-cover at the county of Urbano Santos, localized at the territory of the lower Parnaíba, Maranhão State Citizenship to the East of the State of Maranhão in the Northeast region. To fulfill said objective, data obtained by remote sensing technique have been used, such as images from the TM/Landsat 5 satellite from the year of 1984, provided with free charge by INPE - National Institute for Space Research and images from the TM/Landsat 8 from the year of 2014, provided by the website of NASA - National Aeronautics and Space Administration.

MANAGEMENT AND PLANNING OF URBAN TREES BY MOBILE MAPPING SYSTEM

Bombín Bombín, Eduardo; Herrero Tejedor, Tomás Ramón; Pérez Martín, Enrique; López de Herrera, Juan; García Uriarte, Óscar; Ezquerra Canalejo, Alejandra

Countless problems that have arisen in urban woodland, because they don´t complete a planning and proper management, arise currently numerous studies to streamline the implementation of sustainable management of green areas.

Based on the sustainable management model, we create a database and use a set of Geographic Information Technology (GIT), in order to solve the current problems of urban woodland.

The area selected for this study has been the municipality of Alarcón (Madrid), on the basis of the Plan Director of woodland road from Alarcón, and extending it to the green zones, we introduced the "Mobile Mapping System" that is able to capture georeferenced images, and generate a cloud of points, to subsequently make a representation in three dimensions (3D) doing geovisualization of the Park and the sustainable management of this area.

We try to provide municipalities a TIG model, in order to planning the sustainable management of its existing urban trees, avoiding potential problems by anticipating the damage that may occur in the immediate future. We will also use the TIG for the management of the new road and green areas that may be created in the future, in order to prevent anomalies, risks and incidents that are currently being.

GEOINFORMATION AS AN AID TO THE RESPONSE OF THE EMERGENCY SERVICES AT INDUSTRIAL PARK

Martín Romero, Juan Luis; Herrero Tejedor, Tomás Ramón; Pérez-Martín, Enrique; López de Herrera, Juan; Ezquerra Canalejo, Alejandra

The defense against risks that can affect the industrial buildings is one object of study in the field of civil protection at the municipal level.
Increasingly more administrations and users themselves arouse us that the same citizen which must acquire proper training to deal with any problems that arise in the field of security. Today may be timely use of information

systems as an aid to emergency systems that are intended to provide service to society.

The study aims to facilitate the work of those responsible for civil protection through the optimal use of geo-information to shorten response times.

The area used for this study corresponds to an industrial park in the town of Paracuellos del Jarama (Madrid). Maps and images from different sources of information have been used. A database related to inherent risks within the companies that develop their activity within the tested polygon was subsequently designed.

We have created an information system that improves the response of emergency civil protection services by risks in industrial park.

MULTITEMPORAL ANALYSIS OF THE USE AND LAND COVER IN ISLAND OF MARANHÃO

Borralho de Andrade, Juliane; Rocha de Moraes Rego, Carlos Augusto; Oliveira deCarvalho, Alysson; Cabral Amorim, Francielle; López de Herrera, Juan

The process of occupation of the island of Maranhão, has intensified due to the economic, political and social and became worrisome given the fragility of the natural resources to human action. Therefore, the aim of this work was to study the dynamics of landscape and occupation of physical space-territorial Island in the years 1984 and 2010 by means of TM/ Landsat 5. For the image processing was structured a database in GIS, UTM projection, Datum SAD69, using the software SPRING 4.3.3. The images were segmented and subjected to a visual classification. The time series of images showed a trend towards fewer areas of vegetation, particularly in riparian areas (45.5%), secondary forest (17.83%) and mangrove (15.02%). Sandbank areas, depending on the natural dynamics, the changes were less evident (1.5%) It was also observed that the urban area had a high growth rate (143.8%) being distributed over the north central portion of the island. Over the past 26 years, the island had a population growth rate of 112.26%, which represents 84.56% Capital. The results confirm that the analysis of satellite images is an important tool in

mapping the use and occupation of land and assist in planning the physical space-territorial island.

GEOVISUALIZATION OF GREEN SPACES WITH AUGMENTED REALITY

Gallego Largo, Javier; Herrero Tejedor, Tomás Ramón; López de Herrero, Juan; Pérez Martín, Enrique

The management of green spaces in urban areas requires new techniques and instruments that provide all the information available to people.

It is intended to facilitate data-based services to citizens through the use of mobile devices in green spaces, parks and most visited public gardens. The selected area of study has been the Plaza de Oriente (Madrid) and its surroundings. Maps and images from different sources of information have been implemented in this research work. Then we proceeded to develop a database with woodland and existing cultural heritage. Finally, related this information using geolocation and augmented reality system.

We have created a system that allows the user to interact with the single orientation of the camera on your mobile device.

This application allows efficient use through the integration of mobile devices and the knowledge of the cultural heritage associated with the public space.

ANALYSIS OF THE RECOVERY OF THE DESIGN INTENT IN REDESIGNING OVER MESHES

Mínguez, Rikardo; Etxaniz, Olatz; Solaberrieta, Eneko; Barrenetxea, Lander; Arias, Agustín; Sierra, Egoitz

In reverse engineering, an approach to the generation of surfaces in the redesigning of mechanical parts is the reconstruction of the model using a CAD methodology. The geometric information that is used is extracted from the mesh, where the problem is not so much the implementation of the dimensions with the required precision, but the application of some geometric constraints of the original model such as parallelism, perpendicularity, concentricity,

symmetry and tangency. However, the application of these constraints must be often compensated with the minimization of the deviation of the NURBS surface on the point cloud. This paper discusses the implementation of these geometric constraints and quantifies the resulting error. It lays special emphasis on the comparison of results using different levels of digitization quality of the mesh, as well as on the importance of the choice of reference elements.

DIGITAL IMAGE CORRELATION TECHNIQUE TO VALIDATE RESULTS AND HYPOTHESIS ON THE TESTS FOR DETERMINATION OF PROPERTIES OF BIOLOGICAL SOFT TISSUE

Peña, Juan Antonio; Ruiz-Alejos, David; Martínez, Miguel Ángel; Peña, Estefanía

In this work we develop a numerical-experimental methodology to determine the mechanical properties of fascia tissue. To get the mechanical properties of the tissue, we tested fascia tissue by uniaxial tension tests and plane stress along the two preferred directions of anisotropy. Such tests were recorded using a camera system that allows us through digital image techniques obtain a distribution map of the displacements and deformation at every time.

Using the experimental data obtained by uniaxial and plena stress tests, a finite element simulation of real geometry of each test were developed in order to validate the constitutive model proposed. By graphic treatment of the deformable solid images and displacement map, we have compared the experimental and the numerical results. With this data, we are able to validate the experimental hypothesis and constitutive parameters.

Good correlation between numerical and experimental results was found for all compared tests. The displacement map of the samples obtained by numerical results is very similar to the experimental one. The most important error were found on the incompressibility condition for transversal samples.

EXPLORATION OF A REFERENCE FRAMEWORK FOR GRAPHIC COMPETENCE

Corbella Ribes, David; Ubieto Artur, Pedro; Sentana Gadea, Irene; Morer Camo, Paz

Purpose:
This article aims to share valuable knowledge collected by the authors' broad experience as lecturers of Technical Drawing courses in Engineering and Architecture, also called, among other denominations, Graphic Expression in Engineering or in Architecture, Graphic Engineering, or Cartographic Engineering.

Method:
We discuss the kind of relation the courses have with respect to the generic competences delivered to future engineers and therefore with the strategic, methodologies and evaluative implications in the immediate future of engineering.

Result:
There are different levels of proficiency in the graphic language used in engineering and architecture.

Discussion & Conclusion:
The exploration of a reference framework is proposed, which might take the form of a few questionnaires suited to certain levels of communicative competence through Technical Drawing, which, as a universal language, makes it possible to measure the graphic competence of technicians, engineers and other users.

A PROPOSAL FOR ACTIVE LEARNING IN GROUPS AND ROLES

Serrano, Ana; Biedermann, Anna; Romero, Carlos

Motivating students throughout the new learning experiences that involves skills acquisition can improve the teaching/learning process.

This paper describes the results of collaborative work in groups and roles performed by students of the Engineering Degree in Industrial Design and Product Development at the University of Zaragoza in Artistc Expresion of 1st year of the Degree.

With the development of these activities the following aims have been achieved: Detecting the mayor learning difficulties for the students; implementing the link between the contribution of contents of the subject, under study, and the further professional development of the students;

developing students' creativity; encouraging the awareness towards quality and continuous improvement within work; developing skills in interpersonal relations and increasing motivation at work.

Students have developed an active role in the lectures, providing the necessary feedback, such as ideas to improve the teachers' lectures. This dynamics even though it has required an important degree of involvement, both by students and teachers, has been a positive and enriching experience.

AN EXPERIMENT WITH AUGMENTED REALITY APPLIED TO EDUCATION IN GRAPHIC ENGINEERING

Gómez-Jauregui, Valentín; Manchado, Cristina; Otero, César

Purpose:
This work presents an experiment of Augmented Reality (AR) for improving the performance and motivation of engineering students. It was applied to a Graphic Engineering course of the Mechanical Engineering Degree at the University of Cantabria (Spain).

Method:
Conventional teaching notes were enriched with visual markers to virtually deliver 3D CAD models in mobile devices (smartphones, tablets, etc.), laptops or PCs. These tools were intended to help students in visualization tasks, spatial ability and clarification of complex concepts. A validation study was conducted to measure any positive impact on their graphical skills. Furthermore, the experiment was completed with a satisfaction questionnaire to find out if AR can be taken into consideration to enhance the subject into a more exciting and interesting course.

Result:
In general terms, the opinion about the use of AR technology was positive. The experimental group gave medium-high marks to questions related to easiness, clearness of information, quality of models and robustness of the AR tool. The highest marks were given to the attracting and stimulating benefits of the AR method.

Discussion & Conclusion:
Results show that students participating in the pilot study had a relatively high degree of satisfaction with the AR technology. Furthermore, all the students, participants or not, highlighted the interest and attraction aspects of this

technology. Future works will involve more complex models and AR environments as well as a further analysis to find out if the use of AR could have any positive effect in the learning outcomes of mechanical engineering students.

REVIEW OF THE CONTENTS AND METHODOLOGY OF THE SUBJECT OF GRAPHIC ENGINEERING.

Zamora, Raúl; Ramos, Basilio; Melgosa, Carlos

The CIN/351/2009 Order of the Ministry of Science and Innovation establishes the new specific competence "Knowledge and ability to apply the techniques of graphic engineering" in the Degree of Mechanical Engineering, which enables its graduates to exercise the profession of technical engineer. This degree is progressively implemented at the University of Burgos from the year 2010/2011, including in the fifth semester of its Curriculum a subject called Graphic Engineering. The contents and methodology of learning this subject are two aspects that should be investigated.

After three years teaching that subject, in the last class of the course 2014/15 are raised in writing to students answer two open questions to reflect what they would maintain of the classes and what they would change, to identify the strengths and weaknesses of the contents and the methodology employed in this subject.
Are studied and grouped responses qualitatively, developing a new questionnaire, which measured as the Likert scale their level of agreement with maintaining various aspects of the subject and introduce several proposals for change. This questionnaire is filled out anonymously through a survey enabled on the teaching platform "ubuvirtual".

The results of the statistical analysis of the 18 proposed items are the focus of this publication, confirming that students remain mostly the methodology, structure and contents of the course, but also express important aspects that need improvement.

GRAPHIC ENGINEERING SUBJECTS IN THE ACADEMIC CURRICULUM IN THE MECHANICAL ENGINEERING DEGREE

Manchado, Cristina; Gómez-Jauregui, Valentín; Otero, César

This paper is a summary about several Graphic Engineering subjects in the Mechanical Engineering degree in Spanish Universities. The study has been carried out taking into consideration those with the highest position in different international rankings as the Jiao Tong University in Shanghai, Webometrics ranking by the Cybermetrics lab (belonging to CSIC), U-Ranking by BBVA institution, and Scimago by University of Granada. The different subjects are analysed to compare and contrast the aims, course objectives, expected student outcomes, computer tools used and current trends along the selected engineering courses.

The work is based on the syllabi and course guides on the universities official websites.

USE OF LIDAR TECHNOLOGY FOR DETECTING ENERGY EFFICIENT ROOFS IN URBAN AREAS

Santamaria Peña, Jacinto; Sanz-Adan, Félix; Martínez Rubio, Alberto; Valbuena Rabadán, Manuel Ángel

There are many roofs in urban areas that are so different in terms of sunlight incidence. Slope and orientation are decisive factors in solar energy technologies, and they can be optimized by installing solar modules fixed to those roofs that are well oriented.

In Spain, locating the most efficient roofs can be automatically carried out with LIDAR techniques using data provided by the Project PNOA 2008-2012. The flight covers almost all the national territory and has an average density of 0.5 points/m2.

This article aims to describe a quick and accurate methodology to indentify which roofs in urban areas have suitable orientation and tilt values. A density of 0.5 points/m2 could be firstly considered small, but applying very simple post-processing it is enough for the aim of this work. It is used a Digital Elevation Modelling software representing a good solution for discriminating the roof sheets of an urban area that have greater irradiance incidence.

The detection of these roofs can be a good tool for promoting implementation of solar panels with minimal investment and maximum efficiency.

SFM IMPLEMENTATION IN PRODUCT DESIGN PROJECTS WITH DERIVED SPECIFICATIONS

Biedermann, Anna; Santolaya, José Luis; Serrano Tierz, Ana; López Forniés, Ignacio; Fernández Vázquez, Arantza; Agudo, José María; Sánchez-Valverde, Belén

In order to adequately address the difficulty often associated with the design activity and conveniently structure the broad related information, it is necessary to apply different design strategies and support tools. This paper analyzes the initial tasks involved in a product design process in which the product specifications are derived from the factors implicated and a concepts generated analysis.

The use of a matrix-type tool is proposed to support the design process. This tool, denominated 'specifications and factors matrix' or SFM, allows to synthesize and to structure the resulting information of the design activity and previous research. It was implemented within the Engineering Degree in Industrial Design and Product Development at the University of Zaragoza for the development of module projects. The students had evaluated the experience as positive.

A NEW CONCEPTUAL DESIGN OF A 180º CRATE DUMPER MACHINE

Cavas-Martínez, Francisco; Andreu Hidalgo, Alejandro; Nieto Martínez, José; Fernández Cañavate, Francisco J.; Fernández-Pacheco, Daniel G.

The installation of crate tipper machines into the production chains utilized in the horticultural industry has become imperative in this sector. However, the crate tippers existing on the market are designed to be installed in modern production chains, and its installation in older production chains results very difficult to be executed. Furthermore, most of crate tippers that exist on the market provide a rotation angle under 180º, so fruit ends up being hit during the dumping process, which is the main problem of the majority of crate tipper machines. This fact means that a custom design that perfectly fits the needs of the company must be developed. This communication presents a new conceptual design of a 180º crate tipper machine to be utilized in the horticultural industry that provides a great versatility when using crates of different sizes and that permits the fruit to be tipped without being hit.

THE USE OF MATHEMATICAL FUNCTIONS IN PRODUCT DESIGN

Martín Amundarain, Iñaki; Romero Cuadrado, Luis; Domínguez Somonte, Manuel

Most conventional computer aided design (CAD) systems have problems when it comes to graph a 3D surface based on a mathematical function, as an approach to these splines, NURBS and Bézier curves are used. The industry increasingly demand models based on surfaces and shapes defined by mathematical functions.

This article aims to make the study of the art of methodologies used to represent CAD surfaces and evaluate the possibilities to insert a mathematical function for use as a basis for the design of products and the exchange of files between different software.

INTEGRATION OF REVERSE ENGINEERING AND DENTAL MANDIBULAR DYNAMICS

Solaberrieta, Eneko; Brizuela, Aritza; Fraile, Cristina; Mínguez, Rikardo; Garmendia, Asier; Etxaniz, Olatz; Pradies, Guillermo

Purpose:
This study proposes a methodology that integrates reverse engineering and mandibular dynamics in dental CAD/CAM systems. Thus, it aims to provide more objective information to the dental technician for diagnosis, planning and treatment.

Method:
In the proposed methodology, the occlusal contacts are detected by the T-Scan system and occlusal surfaces are obtained using an intraoral scanner. These contacts are projected onto the patient's occlusal surfaces and also, occlusal forces are obtained over time.

Result:
Using this methodology, 4 cases (in vitro and in vivo) have been carried out and the viability of this integration has been analyzed. On the one hand, reliability was determined by analyzing the existence of contacts and an average value of 78% was obtained.

Discussion & Conclusion:
The study is a step forward in digital dentistry, because it determines the exact location of contacts and occlusal forces individual patient over time. This information is more meaningful for the dental professional and in a future study; it should determine the accuracy of the methodology.

NEW TOOL FOR ASSESSING CHANGES IN BONE INTERNAL STRESS AFTER A VIRTUAL SURGERY

Roces, Jorge; Álvarez, Rafael; Alonso, Jorge; Borja, Alexandra; Corujo, Nicolás

There are many biomechanical researches to assess or predict the behaviour of a bone when certain efforts are applied or when a prosthetic element is implanted. The present study proposes a new tool with a low computational cost. This tool accelerates the virtual assessment of the biomechanical behaviour of a bone after adding the insertion of an implant. This paper presents a case of a femur insertion after a THR surgery.

To start, we use specific software developed by the authors, which generates voxel models of bones and prosthesis in AutoCAD®. Based on these models, we can obtain two other FEM models to calculate the internal bone stress and make a comparison between the stress before and after the surgery.

To improve the assessment and to evaluate the stress changes visually, a new voxel model has been created representing the decreases and increases in each node considered. This methodology allows the specialists and designers to quickly verify future damage in bone remodelling after an implantation of prosthesis.

Keywords: Biomechanics, voxel, FEM, stress changes, hip prosthesis, virtual surgery.

VIRTUAL BIOMODELLING OF A BIOLOGIC STRUCTURE: THE HUMAN CORNEA

Cavas-Martínez, Francisco; Fernández-Pacheco, Daniel G.; de la Cruz-Sánchez, Ernesto; Nieto Martínez, José; Fernández Cañavate, Francisco J.; Alio, Jorge L.

Virtual models have revolutionized all fields of engineering over the last 30 years, proving the engineer with a valid tool for analyzing the objects and understanding their physical properties. Specifically in the field of Biomedical Engineering, the use of virtual models of biologic structures has been proved very useful in clinical practice for the diagnosis and surgical reconstruction. The cornea is the most important part of the anterior segment of the human eye. In a natural scenario, the tissue that forms part of the corneal architecture presents a stable geometrical morphology, while in a pathologic scenario a morphological alteration that affects to the geometry of its architecture is detected. This communication presents the virtual modelling of the human cornea as a technique for the diagnosis of the corneal pathology named keratoconus. The obtained results have been clinically validated and demonstrate the functionality of the methodology applied.

REVIEW OF STATE OF ART OF AUGMENTED REALITY

Oriozabala Brit, José Antonio; Espinosa Escudero, María del Mar; Domínguez Somonte, Manuel

Augmented Reality (AR) creates an environment in where the real original information is enriched with virtual information. The first developments used markers but the advancement of technology has generated applications that need no markers. The popularization of mobile devices with high performance has enabled to AR to migrate the applications to the mobile environment to facilitate its dissemination. The AR is changing the way users interact with applications. They have developed many applications in the most varied fields such as games, advertising, travel assistants, education, medical applications, simulation, design, etc.

The aim of this paper is to highlight the current development fields of application of the AR, its advantages and limitations and the improvements to be undertaken by the current technology to be implemented in other areas.

DESIGN AND DEVELOPMENT OF A MODULAR RECUMBENT TRIKE FOR DIFFERENT WORKING SCENARIOS

Cavas-Martínez, Francisco; Sanchís Caravantes, Carlos; Nieto Martínez, José; Fernández Cañavate, Francisco J.; Fernández-Pacheco, Daniel G.

Today recumbent trikes manufacturers are producing high quality products with several models to choose from. However most of them are developed to run in particular scenarios, causing the disuse of the trike for different conditions. This communication presents the design of a modular recumbent trike that enables multiple configurations by switching between the developed modules. This manner, the proposed design permits to obtain different characteristics and overcome situations that would not have been possible before. The product design consists on a main trike structure and 7 modules classified in three blocks: Front, suspension and traction. Furthermore, 3 assemblies are proposed to cover all the possible scenarios. The obtained results demonstrate that modularization can be applied to recumbent trikes with only some small changes and that the adaptability of the proposed design benefits both the companies (they can reach the necessities of more users) and the riders (they can use it on much more situations).

DESIGNING FOR THE REAL WORKFORCE: HUMAN FACTORS AND ERGONOMICS FOR THE NEW WORKFORCE INCLUSIVITY

Gonzalez, Itziar; Morer, Paz

Purpose:
The population is ageing and so is the workforce. Where intellectual and/or creative work (a.k.a. Knowledge work) is demanded, we can benefit from the best of the knowledge and experience acquired though a lifetime, while physical demands are lower. However, current trends present a real challenge for ergonomics and human factors at all levels (physical, cognitive and emotional) which the users are forced to deal with in practice. The current study presents a theoretical framework in order to face the challenge of inclusivity by implementing design changes based on an ergonomics and humans factors perspective.

Method:
The relevant related literature review has been reviewed in order to acquire a vision of the state- of-the-art, covering ergonomics and human factors,

inclusive and universal design related works and field studies that cover the issue of the workstations adjustment.

Result:
For this purpose the benefits for the whole workforce and in ergonomics implementation, the current recommendations review, how ABW makes this issue more relevant and how universal design and inclusive design can contribute for this purpose are exposed. A smart system theoretical framework is proposed.

Discussion & Conclusion:
In the discussion the proposed smart system framework and examples are discussed from the Universal Design perspective. Thus a framework for further development of a smart and inclusive workstation system has been exposed. This can serve as a base for the future development and improvement of the proposed system.

FROM RAPID PROTOTYPING TO ADDITIVE MANUFACTURING

Oriozabala Brit, José Antonio; Espinosa Escudero, María del Mar

In this paper the development of additive manufacturing technology, its advantages, limitations and application areas facing the manufacture of functional products is studied.

BRAINWRITING AS A METHOD TO FOSTER CREATIVITY IN PRODUCT DESIGN

Rizzuti, Sergio

A group of people is generally involved in the design of a new product. Their ability must be oriented and focused on the form and the functionality that the product should have. The nature of the product characteristics must be constantly present during all the design phases, and specifically during the conceptual phase, when the innovative aspects are enhanced. From this point of view the creativity of the design team should be guided or oriented.

The concept design phase must involve all team members and each should consider him/herself part of the creative process. In order to pursue this aspect it is important to create the best conditions concerning the composition of the design team and the relation among its components.

Brainwriting is a method by which everyone can freely explain his/her own ideas and interact with and integrate the ideas proposed by others. It creates a "democratic" environment that is a necessary condition by which thoughts can be expressed.

The paper deals with a revised form of the brainwriting method in which a different sequence and timing of the steps has been verified in a master level class, in a Product Design and Development Course. The main motivation and the new schedule of the method will be reported and discussed.

DESIGN AND CONSTRUCTION OF AN ELECTRIC CHISEL FOR UNDERWATER APPLICATIONS

Spadafora, Francesco; Galati, Daniele; Gallo, Alessandro; Bruno, Fabio; Muzzupappa, Maurizio

This paper presents the design and the prototyping process of an electric chisel to be used in underwater applications. The device has been specifically designed to support the archaeologists involved in the restoration of archaeological submerged structures. This tool stands as a faster and more efficient instrument, if compared with the traditional equipment used to remove marine encrustations. The prototype was designed with conventional CAD systems and was developed using a Rapid Prototyping process. The chisel is equipped with an electric motor, supplied by an external lithium battery pack outfitted with an electronic unit to control the pulse intensity. The entire device is watertight, thanks to a unique design of the static and dynamic seals that are particularly stressed by the blowback impact. The paper includes a detailed description of the design and manufacturing workflow.

GENERATION OF SURFACE PATTERN DESIGNS AND THEIR APPLICATION TO PRODUCTS OR ENVIRONMENTS: AN INTERDISCIPLINARY AND CREATIVE ACTIVITY IN THE ENGINEERING DEGREE IN INDUSTRIAL DESIGN AND PRODUCT DEVELOPMENT AT THE UNIVERSITY OF ZARAGOZA (SPAIN)

Serrano, Ana; Biel, Pilar; Pérez, Ester; Rodrigo, Carmen; Gracia, Rosario

In this paper, we present a learning experience based on the generation of surface pattern designs and their application to various products or environments. This activity is aimed at students of the Engineering Degree in Industrial Design and Product Development at the University of Zaragoza and is integrated into the work by modules in the first semester; composed of the following subjects: Artistic Expression, Aesthetics and History of Design, Mathematics and Computer Science. The task aims at the integration of the students in the different learning results achieved in the works by modules in a creative and interdisciplinary fashion, applying them to the production of surface pattern designs for a product or environment. Thus, this activity allows students to work both, specific and transversal grade skills and connect the contributions of different subjects to the discipline of product design, facilitating the application of knowledge to practice and apply the creative component to their design proposals.

INTRINSIC RELATIONS BETWEEN THE ORTHOGONAL AXONOMETRIC SYSTEM AND ITS ASSOCIATED OBLIQUES. ANALYTICAL PROPOSAL AND GRAPHIC OPERATIONS

Gonzaga, Pedro; Gimena, Lázaro; Gimena, Faustino Nicolás; Goñi, Mikel

The knowledge related to the axonometric perspective is considered bounded and standardised, from the point of view of its well-known and studied analytical approach as well as from its practical applicability as a system of representation. However, if we reflect critically on the traditional way of transmitting the geometrical knowledge already established, we may delve into some constructive aspects. The aim is to open a new approach, an analytical rewriting of the system, capable of supporting and verifying the validity of the new proposed graphic operations. In line with previous studies, this paper shows some graphic constructions that allow a single joint description of invariant relations between an orthogonal axonometric system, its related orthogonal views, and the axonometric oblique systems associated with it. We have started from a unit trirectangular trihedral and have chosen a mobile picture plane containing the vertex of the previous trihedral. Logically, we start from the perpendicular direction to the picture plane, characteristic of the orthogonal axonometric, and from any other direction from which to obtain the oblique axonometric related to the former. This criterion is the unusual starting point that allowed rethinking the described problem and obtaining the intrinsic axonometric relations that are presented.

DEVELOPMENT OF FINAL DEGREE'S PROJECTS IN THE FIELD OF

GRAPHIC EXPRESSION IN ENGINEERING

Fernández-Vázquez, Aránzazu; Biedermann, Anna

Final degree projects could become a useful tool for developing complementary research and lines of investigationwithin any field, but graphic engineering is often forgotten by students when they have to choose the topic of their ownproject. Some reasons can explain this situation, as for example the fact that graphic engineering teachers often
investigate in other fields of engineering. The facts that most of the subjects belonging to graphic engineering area aretaught during the first years of the degrees, and many times are considered as merely "instrumental", only worsen thesituation. In this context, this paper shows a comparison of the final projects carried out in graphic engineering and otherrelated fields. It is pretend to be useful for teachers for proposing topics that could contribute to encourage students fordeveloping more and better final degree projects in the field of graphic engineering.

CROSS-CULTURAL PRODUCT DESIGN: HOW TO SENSITIZE STUDENTS OF INDUSTRIAL DESIGN ENGINEERING?

Rodríguez Ferradas, María Isabel; Morer, Paz; González, Itziar; Cazón, Aitor

Purpose:
It is indisputable that companies competing in a global marketplace have an emerging interest in design professionals that are able to understand the impact of cultural dimensions on the experiences and interaction between people and products. This means that in order for students of industrial design engineering to succeed in their chosen career, in addition to their technical skills must also develop cross-cultural competence to interact effectively in today's global world. To sensitize students to the importance of the cultural dimension of design, in summer 2014 the Degree in Industrial Design at Tecnun, in partnership with Zhejiang University from China, organised its first cross-cultural experiential learning event through an intensive two-week design workshop. These two universities exchanged a group of 10 design students that were challenged, both from a technical and cultural perspective, to work in an immersive experiential learning approach built around a collaborative design project.

Method:

From the methodological point of view, the key to successfully organising and carrying out this experience was the close collaboration between the teaching staff of both universities, as well as the participation of local companies with interest or experience in the internationalisation of their services and/or products in the host country. Professors from both universities co-taught the programme, which allowed closer partnerships and increased trust and exploration of further collaboration for future. In parallel, each group of 10 exchange students attended the workshop in the other university's facilities, where they collaborated with a similar number of local students. Students attended interactive classroom sessions, visited local companies at both locations to learn about product development, participated in cultural visits to local museums, which helped them to deepen their understanding of the local culture, and worked in collaborative cross-cultural teams to tackle a design challenge, which included a final presentation and a proof-of-concept prototype.

Result:
The students' feedback and the companies' evaluation of the results of the design challenges indicate the programme's in providing a positive learning experience in cross-cultural design. Moreover, both universities agreed to continue with the organisation of this workshop in the following years, and other opportunities arose from this experience. As an example, two students from Tecnun went to Zhejiang University to carry out their final degree project in the autumn semester of 2014, one student from Zhejiang applied in 2015 to do a PhD at Tecnun and two mixed groups of students from Tecnun and Zhejiang, who met at this workshop, participated in an international design competition sponsored by a Basque company in the automotive sector. Moreover, from this experience, the Industrial Design team at Tecnun designed an Honours Programme that is focused on cross-cultural design, in order to complement the regular bachelor's degree programme. The Honours Programme will be implemented in 2015-2016.

Discussion & Conclusion:
A workshop of two weeks may seem a priori too short to sensitize a group of industrial design students to the importance of cultural variables in product design. However, our experience with this workshop shows that a short but really immersive experience provides benefits for all the agents involved: students, universities and local companies. In addition to these direct results, the collaborative dynamics leads to the generation of new forms of collaboration between universities and even among students.

FROM CO-WORKING TO MULTIDISCIPLINARY GROUP DYNAMICS IN AN INTERFACE DESIGN EXPERIENCE

Biedermann, Anna; Latorre, Pedro; Baldassarri, Sandra; Cerezo, Eva; Coma, Teresa; Aguelo, Antonio; Laguens, Miguel

This paper introduces a three-year collaboration experience between the Engineering Degree of Industrial Design andProduct Development and the Engineering Degree of Informatics of the University of Zaragoza. The experience reflectsthe methodology evolution from the several project sections development by students of each specialization to themultidisciplinary work-group dynamics.

In order to progress at the multidisciplinary development of interfaces for smart phone applications (which is a complextask involving different disciplines and knowledge areas such as ergonomics, graphic design, perception theory orcomputer sciences, etc.), it was required to count with external experts coaching, observation and reviews of theworking dynamics with enough perspective to be able to propose corrections in the working process.

With the teaching methodology adaptation presented in this paper we want to verify if much better products'development can be achieved. Moreover, it must be highlighted the importance of transversal competence teaching method and the creation of multidisciplinary collaboration networks.

FRAMEWORK TO DEVELOP ABET OUTCOMES

Martínez Muneta, María Luisa; López de Avila, Mario; Carretero Díaz, Antonio; Hernández Bayo, Araceli

This paper presents the steps followed at the Escuela Técnica Superior de Ingenieros Industriales (ETSII) in the Universidad Politécnica de Madrid (UPM) to progressively implement an outcomes assessment framework. The implantation of this framework provides a big set of key performance indicators (KPi) where faculty can develop methodologies or strategies to assess the ABET outcomes. This assessment is understood as the complete process to guide and guarantee that graduates, when they finish their studies, have acquired the knowledge, abilities and skills established in the educational program. This is a process linked to the whole program (and not to a single course or activity). The previous steps to develop the framework will be

presented in this work. Not all the outcomes have been developed with the same deep because the work still hasn't finished but it is unique in our university. The process has took more than two years and provide for all outcome a definition, Kpis, year to assess, methodologies, etc. The framework is in a continuous development stage and suggestions and improvements from teachers are included.

Full Papers

DEVELOPMENT OF A CONTENT MANAGEMENT SYSTEM (CMS) ON INDUSTRIAL ARCHAEOLOGY: VALORIZATION AND DISSEMINATION OF CONTENTS ON MINIG INDUSTRIAL HERITAGE

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Abstract

In this communication a Content Management System (CMS) based on Joomla for content broadcasting on industrial archaeology, particularly on the mining industrial heritage is presented. Joomla is an Open source software, developed in PHP and released under GPL license remains the most widely used today. The results of the research project included in the CMS are structured from various perspectives: historical, technological, graphic (virtual) of inventory (through a Geographical Information System (GIS)) and tourism. These resources include an introduction to the subject, websites of interest, relevant literature, inventory records movable and immovable property, photographs, videos, examples of virtual and augmented reality, mining touristic routes or a list of scientific societies, parks, museums and interpretation centers on the subject. Also, the interface (template) is very intuitive and easy to navigate facilitating to the users the assimilation of content and therefore its valorization and dissemination.

1 Introduction

Perform a set of websites can be a complex and expensive task if you try to do it using a language for creating web pages HTML (*HyperText Markup Language*) directly, and you do not have the right tools. Thus, the first tools were text editors that generated a web page and subsequently they incorporated control structure itself as well as other features, but generally focused on creation rather than the maintenance [1].

To overcome these limitations Content Management Systems (CMS) were created. They maintained web pages easily, providing an interface that controls one or several databases that include the content, and managing independently the content and the design. They also allow the maintenance and updating of website simultaneously by several users.

The CMS is accessed with user access and use the browser using forms. It has two interfaces: Frontend, where all users access to view content, and Backend where managers/editors access to create or modify the contents.

The CMS can be classified depending on the functionality in four types of categories [1]:

The creation of content, incorporating tools for users that create the contents do not need any prior technical knowledge, and thus focus only on creating them.

The management of content, so that, all documents are stored in a centralized database. The management of content can be assigned to different users or groups of users.

The publication of the web pages can be programmed and cancelled automatically programming in advance this time.

The presentation, that is, adapting automatically the contents to the presentation in different browsers (Internet Exploret, FireFox, Chrome, etc.) as well as different platforms (Windows, Linux, Mac, ...).

The most popular CMS that can be found today in the market are [2]:

- Wordpress: The most used CMS today for the development of blogs, one of the best rated. It is developed with PHP (*PHP Hypertext Pre-processor*) and it is free [3].
- Mambo: It is free and created with PHP [4].
- Joomla!: It is created as an improvement of Mambo. It is free and created with PHP [5]
- Drupal: One of the most popular, free and open source. Provides the ability to work with different database systems, and it is created with PHP [6].
- Vignette: The first commercial CMS that appeared on the market [7].

- OsCommerce: Is the CMS most used and known for creating a web shop [8].

Finally, it should be taken in mind that when a web page is designed we have to follow a set of principles in order to be easy to use (usability), to be accessible to people with disabilities (accessibility) and having a structure in which the user c an move easily (navigability). A realization of these principles can be c learly shown [9].

To know more about this tool there are numerous references [10-14].

1.1 Election of the CMS

Of all CMS list ed above, three are the m ost used and known today for creating web pages: Drupal, WordPress and Joomla!. The characteristics of each one are [9]:

Drupal:

- Easy to create web pages with multimedia content.
- It incorporates a kit to create different types of content.
- There are many extensions that increase the chances of publication.
- It allows working with different types of users each one with different permissi ons, enabling collaborative editing of content.
- There are a great variety of templates or themes online.
- It allows the creation of menus and submenus.
- It has the option to add forums for debate and discussion to the website.
- Easy to create polls.
- Publishers can upload and attach files to content.
- It provides the ability to collect statistical information.
- It allows users subscribe to RSS to send news the website.
- It has a book format to display pages.
- It includes a search engine to locate content within the web pages created.

WordPress:

- Ability to display the web pages in a chronological order considering first display the latest.
- The articles are categorized and custom tags.
- Collaborative editing of multiple users with different roles.
- These procedures are performed easily and quickly using online assistants.
- It is possible e nable/disable and moderate comments from readers to all or some of the entrie s posted.
- Provides a set of RSS subscription for users can follow the published news.
- Every new has a separate link that ensures the direct access to it without having to go through the main page.
- Thanks to the installation of plugins it is possible to integrate in the articles and web pages all kinds of multimedia elements: pictures, galleries, audios and videos.
- On the Internet one can find multiple templates or themes that one can download and install.
- The repertoire of favorite links can be sorted by categories or themes.
- The system can also create an entry and set its publication on a specific date and time.
- When an entry is too long it can be fractionated using a mark "read more" or divide it into several pages.
- In the bar or blog sidebars multiple widgets that provide additional and interesting information about the website can be set.
- It supports automatically to publish an entry via sending an email with a specific format.
- A tool th at facilitates the s earch of entri es from a term or t erms that are introduced as data is provided.

Joomla!:

- Articles are organized by content within a website. Contents are assigned to a category that is like folders. It is possible to nest categories in other categories by creating subcategories.
- An unlimited number of web pages can be created and edit them using a simple online editor.
- It allows installing and managing components and modules that increase the fu nctionality and website services.
- The creation of users with different roles and permission levels on content management enables collaborative management of the website.
- It incorporates a template system that lets you change the visual appearance of the website easily.
- The navigation structure and menus and sub-menus can be configured through the backend.
- One can upload images to the server, organize them into folders and use them on any item of content.
- It allows creating lists of links to sites of interest and sort them by categories or themes.

- The position of the different modules can be configured as desired in each and every web page.
- One can manage advertising banner that appear on the homepage to promote products, ideas, projects.
- The publication of content items can be scheduled automatically on the specified date.
- It keeps a history with all the items that are no longer current.
- Readers can send an email to other users.
- Readers can rate the quality of each article.
- Readers can post comments to the articles.
- It monitors and displays the number of visits to each of the items.
- Label can be assigned to articles. This allows consulting articles with the same label.
- It incorporates a powerful search engine so that given one or more words, it locates all articles of the website that contain then.

Finally, after assessing every of the features detailed above for each of the three shortlisted CMS, it has been decided to use Joomla!. In order to download the latest version there is a website in Spanish [15] and different related literature [16-19]. An example previously developed by the author incorporated to a virtual museum can be seen in [20].

1.2   Hosting to install the CMS

To create the website it is necessary to have a hosting where publish the CMS. But before provide the public access to the CMS, web servers, database and PHP can be installed locally in order to see its configuration and final appearance. An alternative to this option is to use an AMP server which integrates Apache, MySQL (relational database management system, multithreading and multi-user) and PHP, for example, XAMPP. It is an independent server of the platform (hence, the X), free software, based mainly on the MySQL database, the Apache web server and the interpreters for scripting languages, PHP and Perl.

Once created and tested successfully, the website can be put public hosting it on a server, and for this we have to choose between a payment server or a public one.

If the choice is to use a free hosting it should be taken into account the following characteristics [21]:

- To know the limit of disk space to accommodate the web pages.
- To know the bandwidth, i.e, how much information can be downloaded per second.
- To know if it provides support via FTP.
- To know if it has restrictions when upload and host files.
- To know if we have to include ads (banner) on the website.
- To read reviews from other users.

A list of the most used hosting with their most relevant characteristics is shown in Tab. 1 [21].

Free Hostings Services	Limit Disk Space	Monthly Bandwidth	MySQL Database	FTP Support	File Upload Restrictions	Banners
Xtreemhost	2500 MB	100 GB	10	Sí	4 MB	No
Frihost	1500 MB	35 GB	ilimitado	Sí	ilimitado	No
000webhost	1536 MB	100 GB	2	Sí	5 MB	No
Byethost	ilimitado	ilimitado	ilimitado	Sí	4 MB	No
Podserver	300 MB	10 GB	7	Sí	5 MB	Sí
Freehostia	250 MB	6 GB	1	Sí	500 KB	No
Zymic	6000 MB	50 GB	3	Sí	15 MB	No
UHostFulll	ilimitado	ilimitado	ilimitado	Sí	ilimitado	No
BeeSimple	1024 MB	10 GB	10	Sí	2 MB	No

Tab. 1 Free hostings most used.

2   Architecture

The first aspect to consider in the design of the website, even before considering aesthetics aspect that it will have, is to consid er the content to include and the access to them. This requires taking into account the following considerations:

- To define the sections and web pages to include.
- To choose the sections or web pages that can be accessed from the home page.
- To decide if any section or web page has to stand out more than others.
- To distribute the content to present between sections and web pages.
- To specify the different access to each of the web pages of the website.
- Specify the number of languages that have the website.

Given these recommendations a diagram (fig. 1) with the structure of the website of the research project on mining industrial heritage was designed.
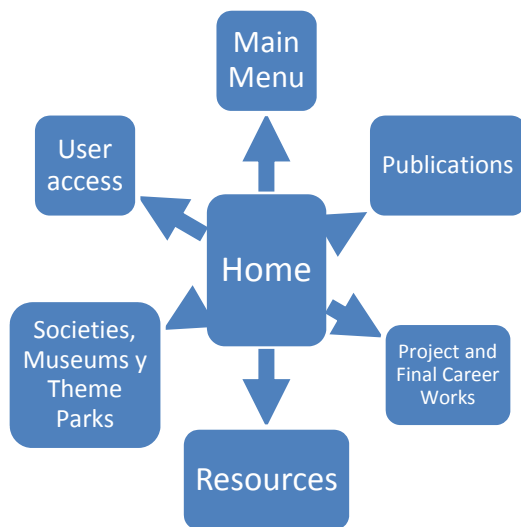
Fig. 1 Website architecture.

3   Structure

Once chosen the website architecture the distribution of the conte nts inside the scre en should be designed, choosing from a series of standard structures differentiated by the location of the navigation block: left (fig. 2a), above (fig. 2b), right (fig. 2c) and combination of the previous them (fig. 2d).
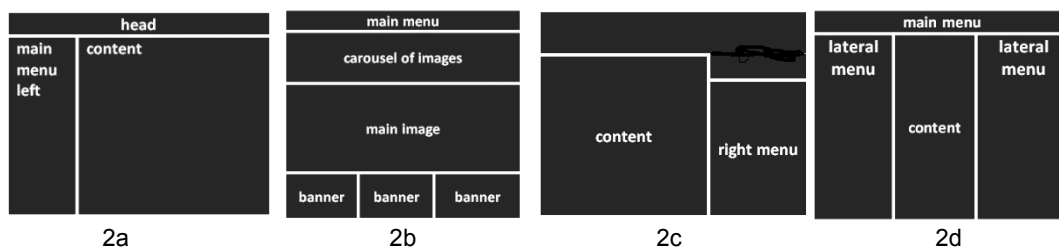
Fig. 2 Standard structures of the web pages.

Finally, the disposition of the navigation block on the right to the website for the web page of the research project on mining industrial heritage (fig. 3) was adopted.

Fig. 3 Website interface.

4   Categories and contents

The normal operating logic of the CMS to display and sort the contents is its assignment to a category or subcategory. In the case of theresearch project under study, the structure of categories in which the contents of the website are categorized is shown in tab. 2.

Start	Publications	Projects and Final Career Works	Resources	Societies, Museums and Theme Parks	Access user
• Preamble • Links of Interest • Relevant Bibliography	• Articles in Scientific Journals • Communications in International Conferences • Book Chapter	• Projects Final Career • Final Works Career	• Photographs and videos of headframes • Inventory of headframes • Photographs of Cornish houses • Inventory of Cornish houses • GIS Inventory and Mining Routes • Augmented Reality • Virtual Reality • Computer Animation	• Institutions, Foundations and Associations • Museums • Mining Parks and Interpretation Centers	• Register • Forgot your username? • Forgot your password?

Tab 2. Categories and contents of the website.

5   Manager of multimedia resources

In order to manage the large amount of multimedia information displayed on the website, we used the administrator of multimedia resources provided by the CMS. To do this, we have created four folders: one for storing the records of the mine shafts, one for the publications, one for the images and the last one for the videos (fig. 4).
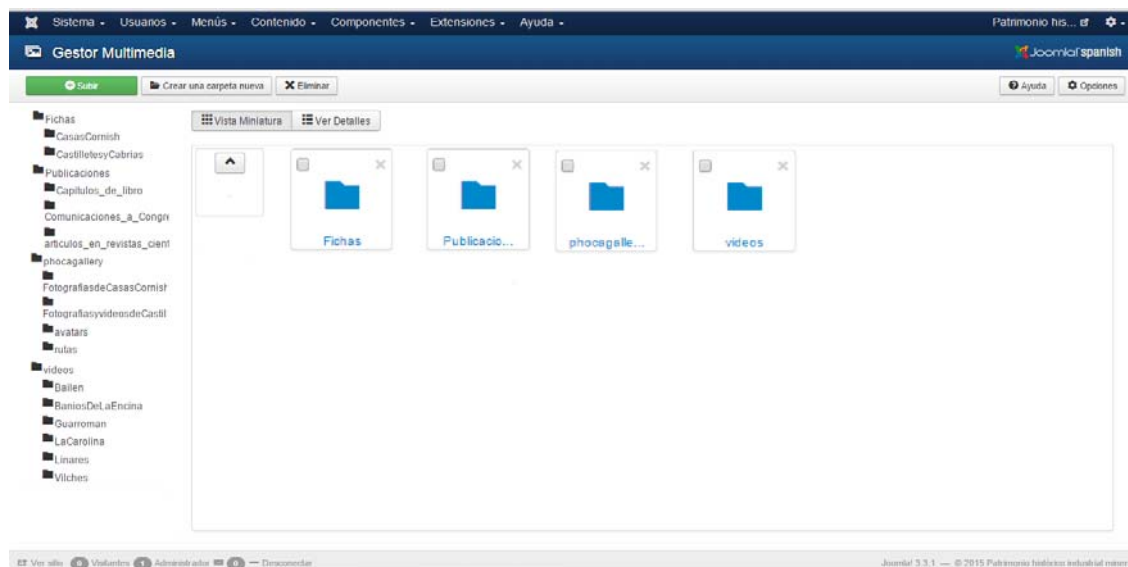
Fig. 4   Appearance and distribution of multimedia information manager of the website.

6   Menus

In order to access and move around the content of the website directly and quickly, we have used menus and submenus. Menus provide access to the different contents of the website as the categories of articles, the specific articles, categories of links, and components and external sites, among others. Also, the menu structure, use the same distribution of the categories seen in section 4 (tab.2) to create the different menus.

7   Extensions

The default installation of Joomla! allows to create normal web pages, because it includes a lot of features. If these are not included can be easily added by installing extensions. There are five types of extensions for Joomla!:

- Components: They are the largest and most complex extensions of all, and they can be seen as 'mini applications'. Most have two parts: one for the public part and one for the Administrative part.
- Modules: They are like 'boxes' that are arranged around a component. For example, the login module, assigning the modules by menu item.
- Plugins: These are the more advanced extensions, and they are in essence event handlers.
- Templates: They allow to change easily the look of the website.
- Languages: They allow to display the website in several languages.

The additional extensions that have been installed in the CMS of mining industrial heritage were:

- Phoca PDF: It allows viewing embedded documents within the website.
- Phoca Gallery: It allows including image thumbnails in the article. When one of them is selected, it expands and allows making an animation showing all images in a folder (fig. 5).
- JWPlayer: It is used to insert several videos in an article. This extension can play videos in the article or full screen, being able to display more than one at a time (fig. 6).
- Google Maps Plugin: It attaches interactive maps where the locations of the mine shafts with related information and tourist mining routes for the visit are displayed (fig. 7).
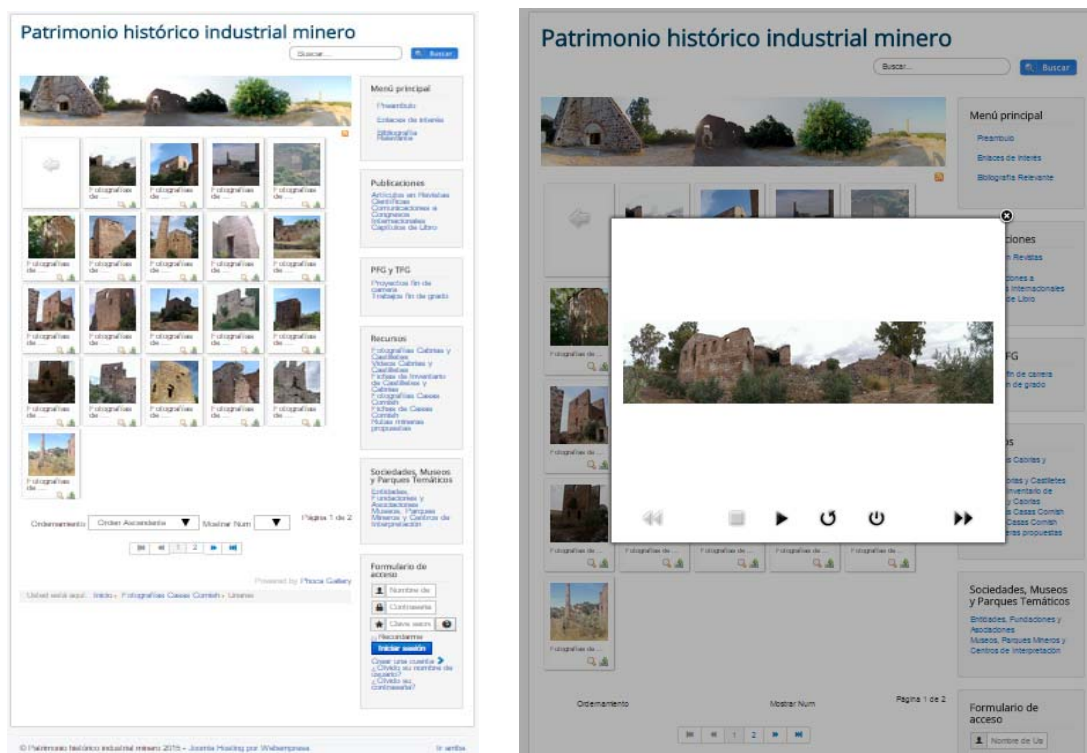
Fig. 5. *Visualization of pictures by Phoca Gallery.*
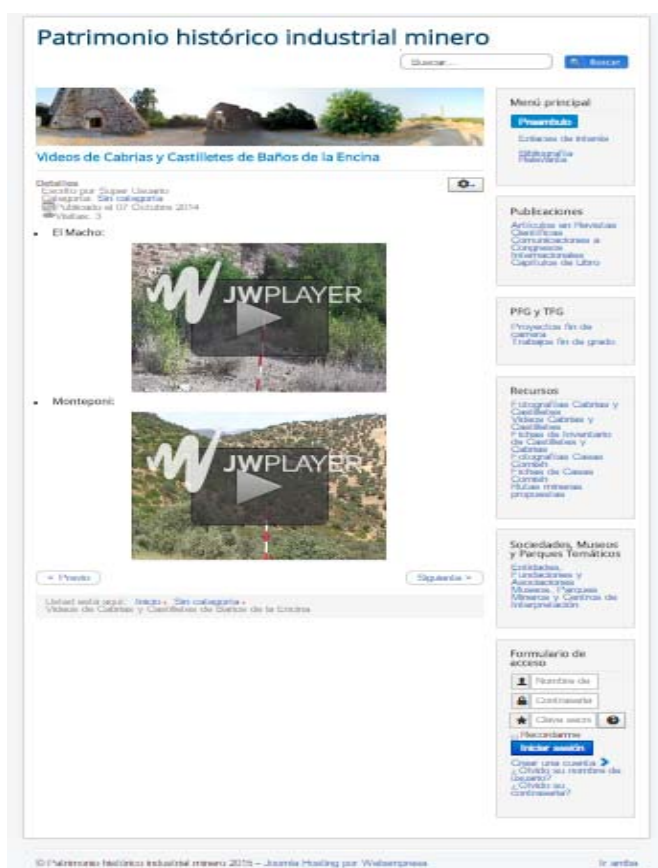
Fig. 6 *Visualization of videos by JWPlayer.*
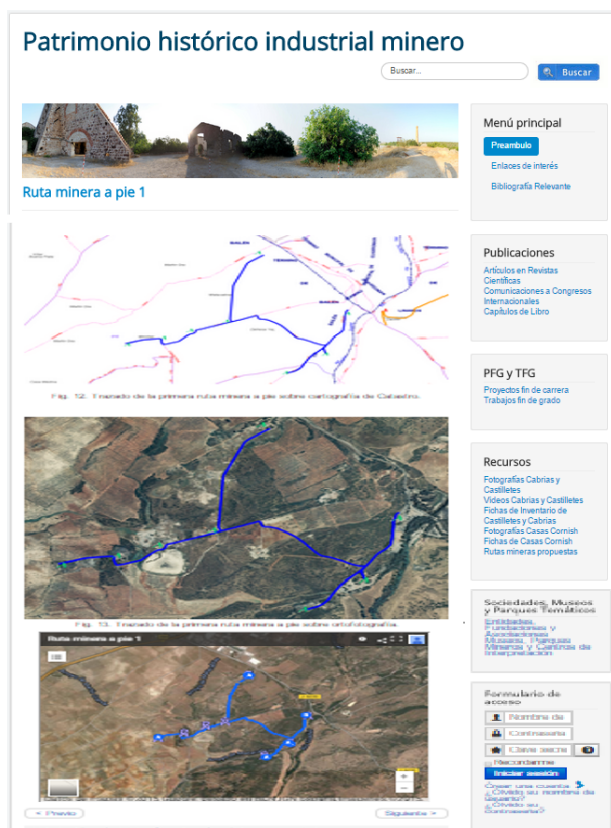
Fig. 7 Visualization of a mining walk route using Google Maps plugin.

Conclusion

In this communication a Content Management System on industrial archeology, specifically about the results of a research project on Mining Industrial Heritage for enhancement and dissemination. It has been designed and developed under Joomla! which is an open source under GPL and developed in PHP.

The contents are structured into 6 categories and subcategories: Start menu (preamble, links of interest, and relevant bibliography), Publications (articles in scientific journals, communications to international conferences, and book chapter), Projects and Final Degree Works, Resources (photographs and videos of headframes, inventory records, photographs of Cornish houses, inventory records of Cornish houses, GIS inventory and mining routes, augmented reality, virtual reality and computer animation), Societies, Museums and Theme Parks (institutions, foundations and associations, museums, mining parks and interpretation centers) and Access Form (register, forgot your username?, forgot your password?).

Finally, the interface (template) is very intuitive and with easy navigation (navigation block on the right), which facilitate to users the assimilation of content and therefore its valorization and dissemination. Also tests self-assessment made reflect a high degree of satisfaction of final user.

Acknowledgement

References

[1]   Mosaic (Universitat Oberta de Catalunya) website
       http://mosaic.uoc.edu/2004/11/29/introduccion-a-los-sistemas-de-gestion-de-contenidos-cms-de-codigo-abierto/ accessed 24 Apr 2015.
[2]   DesarrolloWeb.com website
       http://www.desarrolloweb.com/articulos/que-es-un-cms.html accessed 24 Apr 2015.
[3]   Wordpress website.
       http://wordpress.org/ accessed 24 Apr 2015.
[4]   Mambo website.

http://www.mamboserver.com/ accessed 24 Apr 2015.

[5]   Joomla! website.
        http://www.joomla.org/ accessed 24 Apr 2015.

[6]   Drupal website.
        http://drupal.org/ accessed 24 Apr 2015.

[7]   Vignette website.
        http://www.vignette.com/es accessed 24 Apr 2015.

[8]   OsCommerce website.
        http://www.oscommerce.com/ accessed 24 Apr 2015.

[9]   Uso educativo de las TIC
        http://canaltic.com/blog/?p=1351 accessed 24 Apr 2015

[10]   D. Addey. Content management systems. Glasshaus. 2002.

[11]   A. Mauthe and P.J. Thomas. Professional content management systems: handling digital media assets. John Wiley & Sons. 2004.

[12]   K. Roebuck. Web content management systems (WCMS): high-impact strategies – What do you need to know: definitions, adoptions, impact, benefits, maturity, vendors. Tebbo. 2011.

[13]   W. Maass and T. Kowatsch (Eds.). Semantic technologies in content management systems trends, applications and evaluations. Springer. 2012.

[14]   N.O. Ndubisi. Content management s ystems. B.L. Eden (Ed.). Emerald Group Publishing. 2006.

[15]   Joomla Spanish website.
        http://www.joomlaspanish.org/ accessed 24 Apr 2015.

[16]   S. Burge. Joomla! 3 explained: your step-by-step guide. Addison-Wesley. 2015.

[17]   M. Dexter and L. Landry. Joomla! programación: libro oficial. Anaya Multimedia. 2012.

[18]   T.G. Canavan. Wordpress, J oomla, Drupal: seguridad en los sistem as de gestión de contenidos. Anaya Multimedia. 2011.

[19]   P. Frankowski. Joomla! 3 template essentials: create modern, professional templates using the template framework for Joomla! 3.x . Packt Publishing. 2013.

[20]   J.I. Rojas-Sola, M. Castro -García and M.P. Carranza-Cañadas. *Content management system incorporated in a virtual museum hosting.* Journal of Cultural Heritage 12, 1 (2011) pp 74-81.

[21]   The Joomla! community magazine
        http://magazine.joomla.org/es/ediciones-anteriores/enero-2013/item/1041-servicios-alojamiento-web-gratuito-para-joomla accessed 24 Apr 2015

XXV Congreso
INGEGRAF

GEOMETRIC DESIGN FOR SLATE MINE WORKINGS USING KEYBLOCK METHOD AND PHOTOGRAMMETRY

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Article Information

Abstract

In recent years, the intensive slate open-pit mining activities have slackened notably, but this is not the case with underground workings, that commonly result in better quality materials and with better yields. It is necessary to study new underground excavation designs (room and pillar method) that take into account potentially unstable blocks and supply optimal support. The goal of these new designs will be to ensure the safety of mining operations and to reduce environmental impact by minimizing waste. We describe a methodology to determine safety factors and the most suitable support for various excavation stages in underground slate workings. Data characterizing the rock mass were collected using a terrestrial laser scanner. Semi-automatic discontinuity detection techniques and safety factors were assessed using these data and the limit equilibrium method. The aforementioned techniques were applied to the pre-design of underground slate mine in northwestern Spain.

1 Introduction

In industrial or architectural design, the engineer decides the materials with which to implement works. These are well known materials that are manufactured and assembled beforehand according to detailed construction protocols. Terrain, in this case, is just one element further that affects foundation design in the early stages of construction [1] [2]. In mining operations, however, the terrain where a mine is to be excavated is a crucial element that influences operations throughout the life of the mine from initial design, development and operation to closure and environmental restoration [3].

Most excavations are made in rock masses with very variable geological and geotechnical conditions due to the action of water, seismic effects, earth pressures or the dynamics of the mine itself. The rock in which the mine is excavated is the primary element of resistance, and structural support elements such as metal frames, bolts and shotcrete are all designed to bolster its bearing capacity [4-7].

The characteristics of a rock mass are never truly understood until after excavation, as the information yielded by trial pits, boreholes and geophysical instruments is very limited [8] [9]. However, in mine design it is essential to develop a methodology and excavation criteria that avoids accidents [10] [11] and ensures rock mass stability.

Mining activities disturb the natural balance of the terrain; excavations, in fact, can be considered as accidents induced in a previously geologically stable setting. Geologists and mining engineers act as forensics who analyse the health of the terrain and evaluate the impact of mining operations in order to consider how to minimize possible damage. Faults may occur in the terrain after excavation, but usually not immediately; rather, warnings in the form of signs of instability become progressively more insistent until collapse is finally triggered. Information on the status of a mine or excavation is obtained by correctly interpreting phenomena such as water-table changes and rock falls and controlling for convergence [12] [13].

Our research focused on minimizing rock fall risk in an underground slate mine. The construction crisis of recent years in Spain has significantly reduced intensive open-pit mining operations, with only deposits with better quality slate, better use ratios and lower operating costs continuing to survive. Underground slate workings have tended to survive, even though they require a higher initial investment, because richer seams can be mined without costly overburden stripping and because of the much smaller volume of waste generated, which can, moreover, be used to fill excavated areas.

Excavating a mining cavity generates risk to workers and equipment from possible rock falls due to the effects of gravity or seismic activity. Underground mining is the source of additional hazards that need to be assessed, mainly identifying blocks that could form and the conditions in which they could come loose. A forensic study of the rock mass is therefore necessary to avoid the formation of such blocks.

We studied possible block detachment in a slate mine in Quiroga (province of Lugo, northwestern Spain). The continuity of this open-pit mine could be ensured by taking operations underground, as richer zones of the deposit could be mined without incurring the costs of terrain clearing and preparation. Moreover, underground workings would mitigate the significant visual impact of this open-pit mine and would reduce the cost of landscape restoration.

1.1   Specific objectives

The study aimed to:
• Determine the optimal advance direction δ_{opt} for the excavation.
• Develop crown support measures that would ensure stability against rock falls.
• Calculate the maximum height h for the rooms while maintaining the drift walls stable.

Below we describe the geological and environmental setting in which the mining operations are undertaken. We then describe the analyses performed to characterize the rock mass and the results obtained from simulations of different design options for underground excavation works.

2   Geological and mining setting

Spain is currently a world leading roofing slate producer, with an output of around 500,000 tonnes of processed slate per annum; this represents approximately 50% of the world market for this building material, whose selling price is around USD 750 per tonne.

Virtually all of Spain's slate mines are located in the Truchas syncline (between Ourense and León) and in the Caurel domain (Lugo). Truchas syncline slates are Middle Ordovician (Luarca formation) and Upper Ordovician (the Casaio, Agüeira and Rozadais formations). Luarca slate is mined in the Caurel domain, with the main lithotects mined in Valdeorras (Ourense), La Cabrera (León) and El Caurel (Lugo). The topography in this area is very sharp. Drainage, through inserted valleys, is mainly of surface rainfall runoff, given the impermeable nature of the rocky substratum and scarcity of vegetation. Mining activity dates mainly from the 1960s, with considerable development and greater output in recent decades as a consequence of the introduction of mechanization.

Most of the existing workings are open-cast, with the slate layer accessed by 5-m high descending benches and large-scale removal of overburden. Stripping ratios are around 8-18 m^3 of waste per tonne of marketable slate, leading to annual waste production of approximately 1 million m^3. This huge volume of waste represents a major environmental problem, especially as the region, given its orographic features, lacks adequate dumps. Thus, measures are needed to reduce the volume of waste produced, but also to deal with existing unstable slag heaps affecting the drainage system.

The mining area, covering some 4 km^2 just north of Quiroga (Fig 1), is located in the natural setting of the Sierra del Caurel (Lugo), of undoubted natural and environmental value. Some 2 km away from the mining area is the recumbent syncline of El Caurel, of national geological interest given that it is the largest inclined fold of slate and Armonican quartzite in the Iberian Peninsula.

The crisis in the construction sector has led to the closure of many open-pit slate mines, although companies with underground workings have generally survived better. We studied the possibility of taking slate mining underground in the Quiroga area by extending current operations westward.
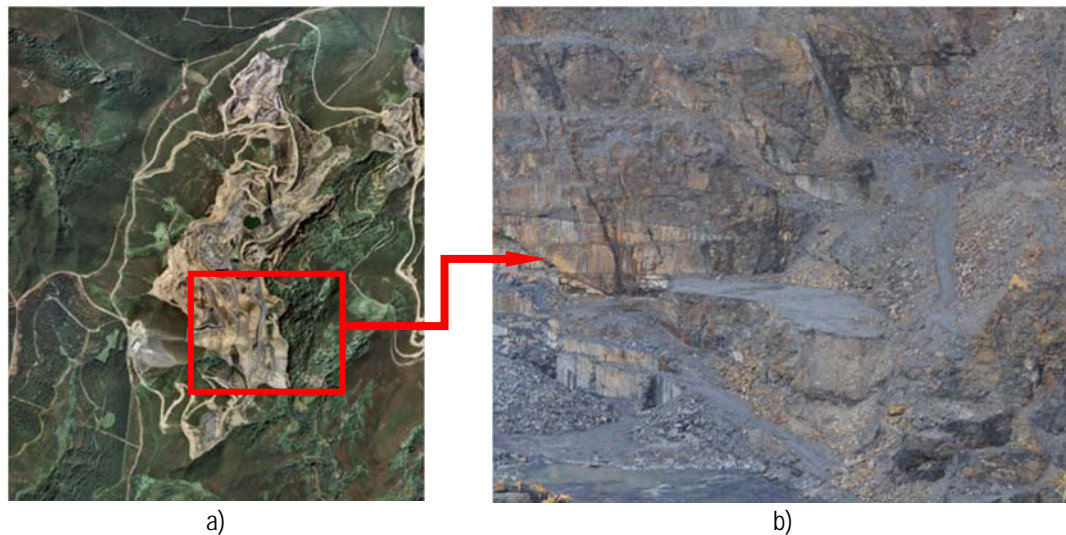
a)   b)

Fig. 1 a) Mining area north of Quiroga in the Sierra del Caurel. b) Detail of the quarry.

3   Geological and discontinuity characterization

The study area has outcrops corresponding to metasedimentary Palaeozoic formations, namely, Armorican quartzite, transition layers, Luarca slate and Aquiana and Silurian limestone, all covered by natural deposits and more recent anthropogenic deposits (waste). Structurally the area belongs to the reverse side of the macrostructure known as the Caurel syncline, so geological formations are inverted, with the oldest layers on top of more recent layers. Fig 2 shows the lithological distribution of materials in the study area and depicts the stratigraphic column for the area. The area bounded by the square in Fig 2 indicates where much of the open-pit mining operations are currently undertaken and where this detailed rock mass study was conducted [14].

Q Quaternary
Q_e Anthropic sediment
Q_c Colluvial and debris slopes
S Undifferentiated Silurian
O_{32} Quartzites and slates.
O_{31} Aquitania limestones.
O_2 Luarca slate
O_{23} Luarca slate (top member) SI
O_{22} Luarca slate (medium member) SI
O_{21} Luarca slate (tottom member)
O_{2mp} Luarca slate (porphyric facies)
O_{12t} Transition layer. Quartzites and slates
O_{12q} Armorican quartzite
SI Exploitable slate levels
Db Intrusive dykes

Fig. 2 Lithological and stratigraphic distribution of materials in the mining area north of Quiroga.

The traditional method for characterizing a rock mass is to measure position, orientation, dip, size and spacing of the discontinuities using a compass, an inclinometer and a ruler. This method is limited by the difficulty of accessing discontinuities, especially when dealing with large vertical slopes (professional climbers need to be used). In addition, data collection is limited to a number of specific points on the solid rock mass, and acquiring the necessary information for the characterization of the rock mass is time consuming. An alternative is to use methods that do not require direct contact with the rock mass, notably terrestrial photogrammetry and terrestrial laser scanning [15-17].

To geometrically characterize rock mass discontinuities we used a RIEGL® LMS-Z390i time-of-flight scanner (see Fig 3a), with a range above 400 m for objects with reflectance greater than 80%, 6-mm accuracy for a single point and a data capture rate of 8000 data points/second. Coupled to the top was a Nikon D90 digital single-lens reflex camera calibrated to apply false colour to the 3D model and so facilitate the identification of areas with discontinuities. For our purposes we considered a scan density of 1 point/cm^2. This scan density was determined by the characteristics of the rock mass, and the minimum scan time necessary to detect discontinuity planes.

a)

b)

Fig. 3 Measurements in the slate quarry using the RIEGL® LMS-Z390i scanner a) and points cloud obtained by laser scanning with the joint sets b).

Discontinuities in a rock mass can be detected from 3D point clouds manually, semi-automatically or automatically. Manual detection is usually done by an expert drawing the discontinuity planes with the help of images superimposed on the points cloud. In semi-automatic detection the expert also decides where the planes of discontinuity are, but rather than draw them, extracts them using adjustment algorithms. Automatic detection, which can be viewed as a segmentation problem, uses either growing algorithms or aggregation algorithms. Growing algorithms are more easily and more rapidly implemented but have drawbacks regarding seed selection and discontinuities [15]. Aggregation algorithms are slower but are more appropriate for densely featured spaces, such as those obtained when determining rock discontinuities. In our research we tested both semi-automatic and automatic approaches to detecting discontinuity planes.

Tab 1 shows the discontinuities clustered in four sets, denominated N1, N2, N3 and N4. Joint set clustering was used to automatically group measured structures into joint sets (see Fig 3 b). The clustering, using a fuzzy K-means algorithm [18] [19], aimed to minimize the distances between mean values of the joint sets and individual measurements (the objective function). The implementation, which minimized the angles between mean orientation and individual orientations within a joint set, used a random set of initial values. The fuzzy K-means algorithm, which required the number of clusters for the data set to be predefined, iteratively recalculated the mean orientations and regrouped the data set based on the distance measures. The solution was the minimum value of the objective function obtained from a variation of initial values. The optimal number of clusters was not known a priori. Hence the fuzzy K-means algorithm was executed several times with a different number K of predefined clusters.

Tab 1 shows the geometric parameters for each of the four joint sets and the corresponding properties of the discontinuities (friction angle, cohesion and tensile strength). These values correspond to values obtained at the laboratory using shear test and tilt test [20].

Joint set	Dip Direction (º)	Dip angle (º)	Spherical Aperture (º)	Confidence Cone (º)	Friction angle	Cohesion kPa	Tensile strength kPa
N1	220	52	27	12	28	50	5.0
N2	148	84	20	8	28	50	5.0
N3	12	43	28	11	22	45	4.5
N4	102	89	20	13	22	45	4.5

Tab. 1 Joint sets and properties of the discontinuities.

As to mean mining front orientation, the rock face value is 81°/77° in the area where the terrestrial laser scanner measurements were made. The mean density of the slate is 2800 kg/m^3 and the whole area is so fractured that the groundwater level is below the area to be excavated, indicating the need for measures to prevent the formation of water pockets and facilitate natural drainage. Table 1 shows friction angle values of 22° to 28° and cohesion values of 50 to 45 kPa (obtained in laboratory tests). Tensile strength was considered to be a tenth part of cohesion. Since the persistence of joints and discontinuities varies between 3 m and 30 m and spacing is between 0.5 m and 10 m, the formation of large keyblocks was considered feasible. The fact that such large blocks would only remain stable through friction of the faces was a key element in excavation design.

4   Underground mine design

Room-and-pillar method (with barrier pillars) was used for mining operations, with systematic rockbolting and shotcrete reinforcement in the roof.

The first task was to excavate and support an advance heading by drilling and blasting. With dimensions of approximately 6 m wide by 5 m high, this heading was gradually widened and deepened — thus forming the extraction banks — until it connected with the tailgate entry under the filling. Fig 4 depicts the construction phases and room dimensions: advance heading excavation (phase I), trench digging (phase II), and room deepening and slate mining (phase III). Operating costs were similar to those applying to the open-pit operation and waste was 15 m^3 per tonne of slate.

For the underground slate mining operations, a working bench at least 25 m wide was necessary to accommodate machinery and equipment. Room height was conditioned by the thickness of the slate seam, and stability of the lateral keyblocks. The mining sequence was downwards and the room crown was stabilized by means of shotcrete. The result was rooms 25 m wide and 100 m long, with a height h that varied depending on rock mass quality.

Fig 4 shows the underground mining design, consisting of two 30 m^2 drifts and two 25x100 m rooms with variable heights that would enable infrastructure work in preparation for slate mining operations. Also evident is the great volume of overburden that would have to be removed for an open-pit operation, with the resulting environmental impact.

An important aspect was to determine the most suitable direction for the advance so as to excavate rooms that would ensure stability. Fig 4 shows the layout of the two rooms and indicates the advance angle δ for the drifts and rooms. The arrangement of the slate layers and the current mine front is such that the rooms can be mined with an advance angle δ of between 270° and 370° (the origin of the angles refers to the geographic north).
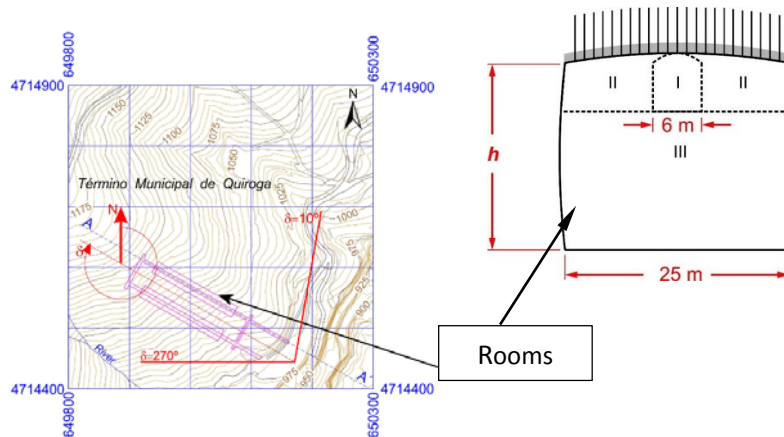
Fig. 4 Plan of the rooms and section with the construction phases I, II and III.

The study aimed to determine the optimal advance direction δ$_{opt}$ for the excavation and develop crown support measures that would ensure stability against rock falls.

This design considered just two rooms. In the excavation sequence, the first room would be mined, then the second room, with the waste extracted from the second room used to fill the first room. This would greatly reduce the need for intermediate piles of waste outside the mine. New rooms could feasibly be dug in parallel, provided rock mass joint distribution is maintained; otherwise, it would be necessary to redefine the geometry and support for excavations in successive enlargements.

For each excavation advance phase, support for the underground mine was designed according to the following criteria:

Phase I. In this advance tunnelling phase, volume and safety factor values for all the keyblocks were calculated. This determined the optimal advance direction δ$_{opt}$ for excavation that would ensure that crown and drift wall keyblocks remained stable and small, as the size of keyblocks should be such as to ensure stability using just a layer of shotcrete.

Phase II. Trenches were excavated on both sides of the initial tunnel. The maximum keyblock that could occur in the crown was identified and then stabilized using shotcrete and rockbolts to ensure a safety factor of at least 1.5. In this case it was not necessary to make calculations for the left and right drift wall blocks since room height was still 5 m.

Phase III. The drift was deepened by downward benching. Because of the great persistence of the joints and because large blocks were possible, the relative position of the keyblock and the friction of its faces had to ensure stability. These factors determined the maximum height h that ensured the stability of the large keyblocks. Room height h was thus increased until blocks with a safety factor of 0.75 were obtained for the drift walls. The final height of the excavated room was determined on the basis of a safety factor of 1.5 in the drift walls.

A program called BLOFOR [21] [22], developed by the authors, was used in all the steps described above to analyse the stability of pentahedral and tetrahedral keyblocks against slipping using limit equilibrium methods and considering a limit safety factor (SFL) of 1.5.

5   Results

5.1   Optimal phase I design

The advance direction of the drift was studied in the 270º and 370º interval. The aim of the analysis was to determine, within this interval, the optimal advance orientation that would reduce the number of keyblocks and so make support less costly. Increments of 5° were considered during optimization, using BLOFOR to calculate the largest volume blocks for the two drift walls and the crown. The maximum tetrahedral keyblock volumes for different excavation directions are depicted in Fig 5. For an advance angle δ of between 280º and 305º large volume blocks appear in the tunnel crown, with the keyblock occurring at δ = 290º.
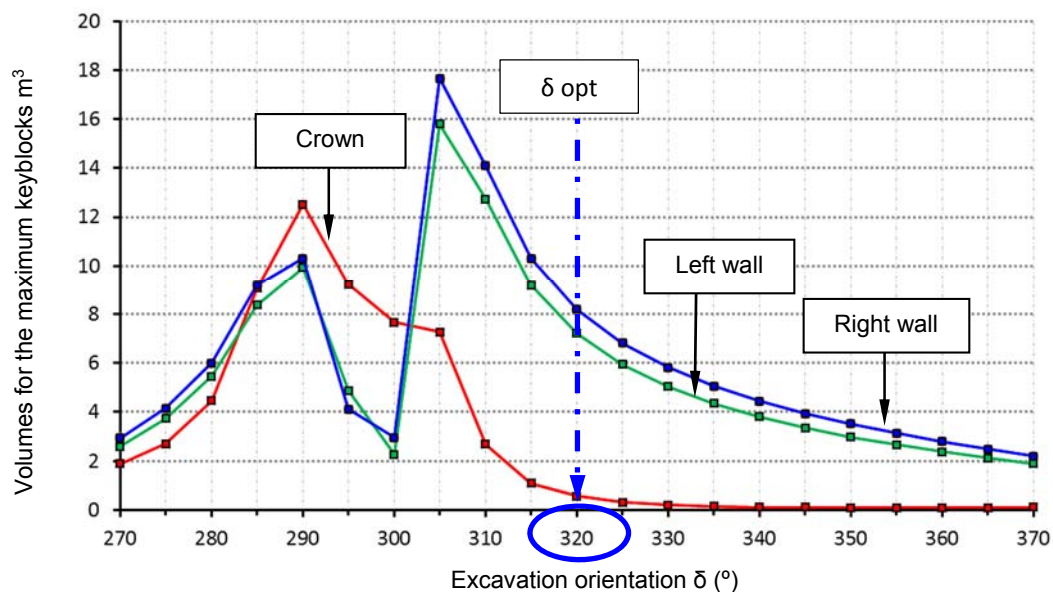
Fig. 5 Volume of tetrahedral keyblocks in the advance heading (phase I).

Blocks of a similar size to those in the crown for angles between 270° and 285° appeared in the left and right drift walls. For an angle of 300° the largest block was produced in the right drift wall, with size decreasing progressively as the tunnel orientation angle increased. The right drift wall blocks were slightly larger than those of the left drift wall for orientation values greater than 305°.

Fig 6 shows the safety factor values for the tetrahedral blocks in the crown and drift walls. Considered was SFL = 1.5, above which the drift wall blocks were stable and the crown blocks unstable.

Simultaneous analyses of Fig 5 and Fig 6 revealed that the best advance orientation was above 310°, as this value resulted in small blocks in the crown and blocks with high safety factors in the drift walls. An optimum advance angle of 320º was finally proposed. The angular interval (310º-330º) has a similar behaviour where blocks were not likely to change in terms of size or safety factor. This direction was also close to the maximum slope line for the slate layer, enabling faster access to higher quality slate zones.
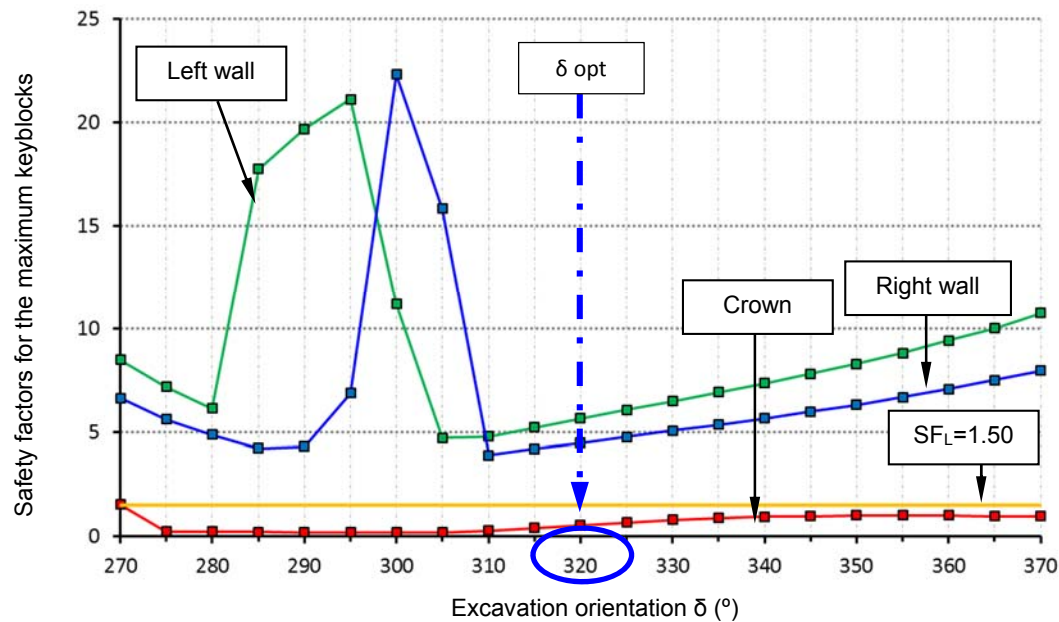
Fig. 6 Safety factor (SF) of tetrahedral keyblocks in the advance heading (phase I).

Fig 7 shows a tetrahedral keyblock from the crown corresponding to δ = 320º, with a safety factor of 0.55 without support. Simulating the effect of supporting these blocks, the BLOFOR program indicated that a 3 cm layer of shotcrete (500 kPa shear strength) increased the safety factor to 13. The stability of the tunnel in the first excavation phase was thus ensured.
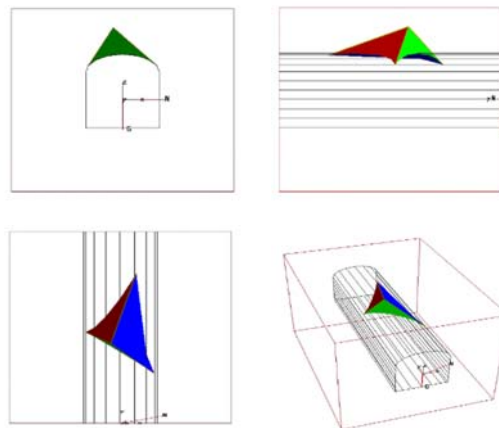
Fig. 7 Tetrahedral keyblock for the crown corresponding to δopt = 320º (phase I).

5.2   Optimal phase II design

Once trenches were excavated roof reinforcement calculations were made, increasing the width of the excavation meant that the unsupported keyblocks presented a very low safety factor of 0.06 for a tetrahedral block volume of 376 m^3 and a weight of 1054 tonnes. For these values, the BLOFOR program calculated the rockbolt and shotcrete values shown in Fig 8. According to the estimates, the safety factor for the supported roof was 1.62.

Shotcrete	
Thickness	18 cm
Shear strength	500 kPa
Anchorage	
Type	Strut with plate
Diameter	26 mm
Fixed length	10 m
Radial spacing	3 m
Lengthways spacing	4 m
Steel resistance	$5 \cdot 10^5$ kPa
Anchorage resistance	1100 kN
Plate resistance	1200 kN
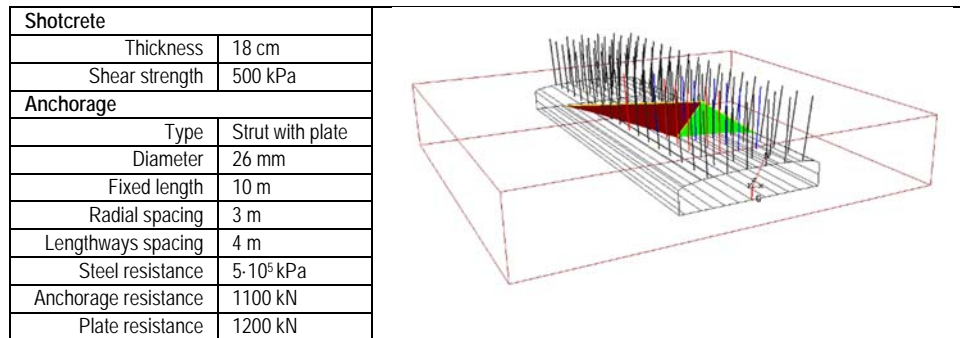
Fig. 8 Support properties (phase II).

5.3   Optimal phase III design

In this phase the blocks in the drift walls were calculated as a function of the height h and the safety factor in order to determine their stability. The results are shown in Fig 9, it illustrates the differences in behaviour between the two drift walls, with the left blocks proving to be more stable. Excavation heights for SFL = 1.5 were hl = 24 m for the left drift wall and hr = 17 m for the right drift wall.

Since the left drift wall was stable, a deeper room was possible on this side, in contrast a stope it is needed at the bottom of the room in the right drift wall. This design was perfectly compatible with excavation using descending benches. The last two 5-m high benches in the right drift wall should remain in order to stabilize any keyblocks that might form.
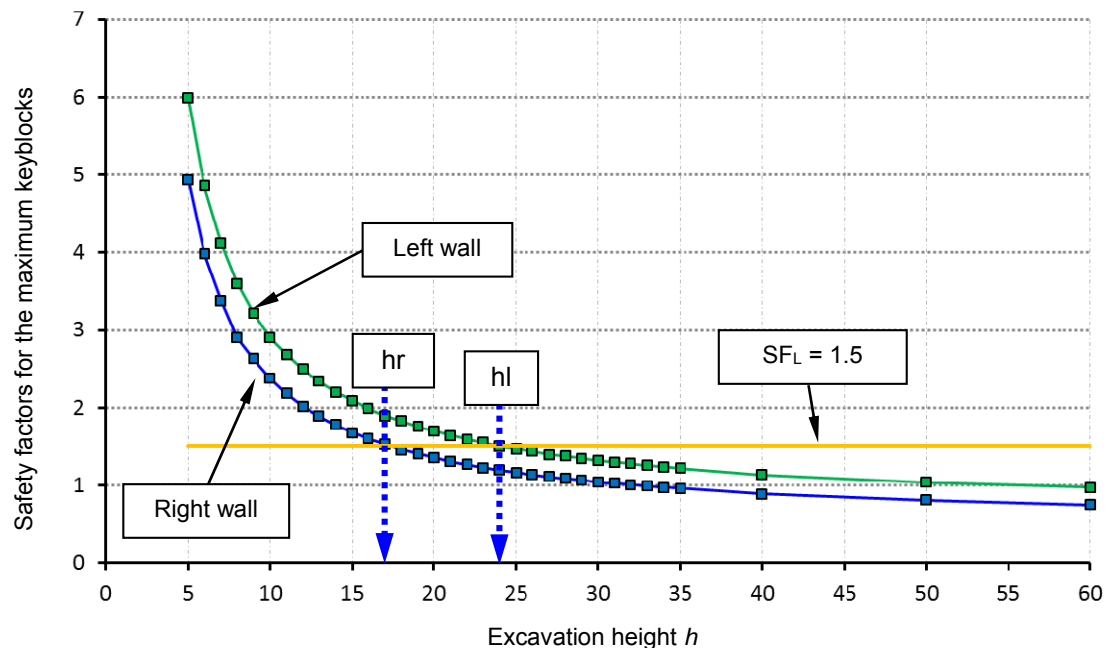
Fig. 9 Variations in the safety factor value for drift wall blocks according to height (phase III).

6   Conclusions

In this study the slate rock mass was characterized by means of a terrestrial laser scanner. With this equipment the geometric parameters of the slate rock mass were inferred. This approach eliminate the risk of accidents during the labours to manually identify discontinuities. After the rock mass characterization, the possible formation of unstable blocks was evaluated in order to determine the most appropriate orientation for the mining operation. This study allows to increase safety work conditions and minimize support costs. The stability of the crown of the rooms excavated in the studied slate rock mass was guaranteed for a limit safety factor of 1.5. Following the numerical results it is possible to open a deeper room in the left wall (24 meters of height). The right wall allows only a more conservative value of 17 meters of height. This approach minimizes the risks associated with underground mine workings and also reduces the environmental impact of the mine, given that the rooms themselves can be used as dumps.

Acknowledgement

References

[1]   T. Ramamurthy T, A. Ghazvinian. *A How to select rock mass parameters for analysis and design*. 12th International Congress on Rock Mechanics of the International Society for Rock Mechanics, ISRM, (2012). pp 115-125.

[2]   JL. Porathur, S. Karekal, P. Palroy. *Web pillar design approach for Highwall Mining extraction.* International Journal of Rock Mechanics and Mining Sciences 64:73-83. (2013) doi: 10.1016/j.ijrmms.2013.08.029.

[3]   LR. Alejano, F. García-Bastante, J. Taboada, R. Migliazza. *Design of room & pillar exploitations of non-expensive minerals and ornamental rocks in Spain.* In, Beijing, 12th International Congress on Rock Mechanics of the International Society for Rock Mechanics, (2012) pp 1453-1456.

[4]   M. Sawada, K. Shin, Y. Inohara, T. Shidahara, T. Hatano, T. Miwa. *A rock mass classification to estimate excavation rate, support and rock properties in a borehole survey*. 12th International Congress on Rock Mechanics of the International Society for Rock Mechanics, ISRM. (2012). pp 2143-2146.

[5]   K. Kaewkongkaew, N. Phien-Wej, D. Kham-Ai. *Prediction of rock mass along tunnels by geostatistical method.* In, Beijing, 2012. 12th International Congress on Rock Mechanics of the International Society for Rock Mechanics, ISRM (2012), pp 1013-1016.

[6]   WR. Prasad, RD. Dwivedi, A. Swarup. *Determination of support pressure for tunnels and caverns using block theory.* Tunnelling and Underground Space Technology 37:55-61. (2013). doi: 10.1016/j.tust.2013.03.006.

[7]   J. Ching, ZY. Yang, JQ. Shiau, CJ. Chen. *Estimation of rock pressure during an excavation/cut in sedimentary rocks with inclined bedding planes.* Structural Safety 41 (0):11-19. (2013), doi:http://dx.doi.org/10.1016/j.strusafe.2012.10.006.

[8]   B. Singh B, RK. Goel RK. Rock Mass Classification. A Practical Approach in Civil Engineering. Elsevier Science Ltd (1999).

[9]   CA. Ozturk, E. Nasuf. *Strength classification of rock material based on textural properties.* Tunnelling and Underground Space Technology 37 (0):45-54. (2013). doi: http://dx.doi.org/10.1016/j.tust.2013.03.005.

[10]   S. Alija, FJ. Torrijo, M. Quinta-Ferreira. *Study of the unexpected collapse of the Ampurdán tunnel (Spain) using a finite elements model.* Bulletin of Engineering Geology and the Environment: 1-13. (2013), doi: 10.1007/s10064-013-0534-z.

[11]   S. Wen, X. Yang. *Risk identification for collapse of tunnel during construction and the countermeasures.* 4th International Conference on Digital Manufacturing and Automation, ICDMA. (2013). pp 1171-1174.

[12]   ST. Liu. *Deformation monitoring during construction of subway tunnels in soft ground.* 6th International symposium on Geotechnical Aspect of Underground Construction in Soft Ground, (2008), pp 312-317.

[13]   SH. Wang, YB. Zhang, N. Zhang, S. Wang. *3-D stability analysis of tunnel structures based on geometric stochastic blocks theory.* International Young Scholars' Symposium on Rock Mechanics - Boundaries of Rock Mechanics Recent Advances and Challenges for the 21st Century. (2008). pp 695-699.

[14]   JC. Barros Lorenzo. *Investigación de Pizarras de la Sierra del Caurel.* Instituto Geológico y Minero de España, Spain (1992).

[15]   S. Fekete, M. Diederichs, M. Lato. *Geotechnical and operational applications for 3-dimensional laser scanning in drill and blast tunnels.* Tunnelling and Underground Space Technology 25 (5):614-628 (2010).

[16]   G. Giglim, N. Casagli. *Semi-automatic extraction of rock mass structural data from high resolution LIDAR point clouds.* International Journal of Rock Mechanics and Mining Sciences 48 (2):187-198. (2011) doi:http://dx.doi.org/10.1016/j.ijrmms.2010.11.009

[17]   Wang, SH. Wang, MD. Guo, ZH. Dong. *Fast digital identification of joint information of tunnel work face and its stability analysis.* Yantu Gongcheng Xuebao/Chinese Journal of Geotechnical Engineering 33 (11):1734-1739. (2011).

[18]   RE. Hammah, JH. Curran. *Fuzzy cluster algorithm for the automatic identification of joint sets.* International Journal of Rock Mechanics and Mining Sciences, 35 (7):889-905, (1998)

[19]   P. Wang, X. Zhao, L. Wan, M. Cai. Hybrid cluster analysis method based on GA and FCM for automatically identifying joint sets. Beijing Keji Daxue Xuebao/Journal of University of Science and Technology Beijing 26 (3):227-232, (2004).

[20]   DC. Wyllie DC, CW. Mah. *Rock slope engineering civil and Mining*, 4 th edition, London: Spon Press, Taylor and Francis Group (2004).

[21]   A. Menéndez-Díaz, C. González-Palacio, AE. Álvarez-Vigil, C. González-Nicieza, P. Ramírez-Oyanguren. *Analysis of tetrahedral and pentahedral key blocks in underground excavations*. Computers and Geotechnics, 36 (6):1009-1023. (2009) doi: 10.1016/j.compgeo.2009.03.013.

[22]   C. González-Palacio, A. Menéndez-Díaz, AE. Álvarez-Vigil, C. González-Nicieza. *Identification of non-pyramidal key blocks in jointed rock masses for tunnel excavation.* Computers and Geotechnics, 32 (3):179-200. (2005). doi:10.1016/j.compgeo.2005.01.004.

XXV Congreso INGEGRAF

STUDY SPACE-TEMPORAL OF SÃO LUIS (UPAON-AÇU) ISLAND: DOCUMENTATION AND ANALYSIS OF LANDSCAPE AND CULTURAL HERITAGE

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Abstract

This work has as its main objective conduct a graphic and visual study on the evolution of the landscape in São Luis Island, located in the Department of Maranhão (Brazil). The methodology used is based on a holistic approach to the conception of landscape and subsequent planning of the territory. In a first phase, we proceeded to the identification and mapping of cartography and images over time. To do this is we have pre-selected four sites in the studied area. They are the municipalities that form the island of Sao Luis: Raposa, São José de Ribamar, Paço do Lumiar and São Luis. These places have been documented and analyses from two perspectives: geological-geomorphological perspective in its natural conception of space and the prospect of the occupation of the soil in the model of development followed by that territory. The main result is the creation of an information system that can serve as geo-visual support for the defense of the cultural heritage, and thus help in the decisions of future planning for the study area.

1. Introduction

The city of Sao Luis on the island of the same name is the capital of the State of Maranhão (Brazil), which has experienced a continuous expansion, as well as a diversification of the forms of occupation of its physical space. This is due, among other factors, to its disorderly population growth. That is why there were disorders in the region, for example has changed its configuration in terms of the ratio of the original vegetation and/or green areas. Also the forms of occupation and exploitation of the resources of land, water and forest, resulting in greater social inequality, environmental crimes, the destruction of homes, finally, the denial of human rights [1].

The complex development of urbanization in recent years, in addition to the consumption of resources of the island, have aggravated already if deteriorated situation of society that lives there. Factors such as inadequate distribution of space contributed to the development of the sources of environmental pollution, both of insalubrity in the maintenance of the natural system, in addition to expose to various risks to the poor [2]. The perpetuating of these impacts introduce new issues in a setting of distortions of what would be the well-being and quality of life; for this reason, an appropriate organization of space determined by consistent public policies, as well as the modes of production and the development of the territory [3].

In this sense, there is a need to obtain more specific data to study the dynamics of the landscape and the occupation of the island, using geo-processing tools that contribute to the follow-up of this expansion, the cartography of the disturbed areas and vegetation as well as its remaining environmental impacts in seeking to maximize the results obtained with the use of this technology [4].

In this context, this paper tries to be a geo-visual update of the local landscape features to enrich the existing knowledge on urban sprawl in this study area. On the other hand, contains some warnings or alerts about gravity in the consumption of resources and expansion of urban areas. In this sense, changes in the perception of the landscape are obvious, so the vegetation of the island has been transforming or disappearing.

1.1 Objective

The main objective is the creation of an information system that can serve as geo-visual support to better understand the evolution of the landscape. In this context is it can collaborate in the defense of the cultural heritage and in the decisions of future planning for the study area. In a first phase we try to analyze a landscape territory for your better understanding, in order to have data prior to possible future interventions covering the strengths of the landscape study.

Understand, draw and represent the main elements of the landscape of the area referred to by the accessible digital resources and new development.

1.2 Study area

The island of Maranhão or Upaon Acu is located to the North of the State of Maranhão, Northeast Brazil, marked by the geographical coordinates 2º 24´ 10" and 2º 46´ 37" South latitude and 44º 22´ 39" and 44º 22´ 39" W, with a total area of 1410,015 km^2 [5] (Fig 1).

The territory of the island is divided into four municipalities that make up the metropolitan region of Sao Luis: Raposa, São Luis, São José de Ribamar and Paço do Lumiar [6]. Today the area is very changed; its natural vegetation along these decades has been replaced by various building elements and buildings. The root cause has been the significant increase in the population of the island and consequential changes to the land use.

Still, they are today visible areas of mangroves, babaçu (secondary vegetation) and some riparian vegetation (Fig 4). This type of ecosystems is based on four main kinds of soils: Latosols red, Neosols Quartzarenics, Argisols, and Gleysols [7].

According to the Brazilian Institute of Geography and Statistics [5], the municipality of São Luis in 2010 had a population of 1.309.330 habitants. The city is the biggest of the island. The climate according to the Koppen classification is Aw´, tropical rainforest, with a predominance of precipitation in the months of January to April and this is due to that the city is close to the area of Inter-tropical Convergence (ZCIT) and the average annual temperature is around 28ºC. The island contains some relevant hydrography rivers, the main are Anil, Bacanga, Tibiri, Paciencia, Maracanã, Calhau, Pimenta, Coqueiro and Cachorros. They are small rivers which flow into the areas of dunes, beaches and mangroves. The two largest are the Anil River having 12,63 km in length and the Bacanga of 22 km to its mouth at the Bay of San Marcos, which is characterized by its area of influence covered mangrove estuaries [8].
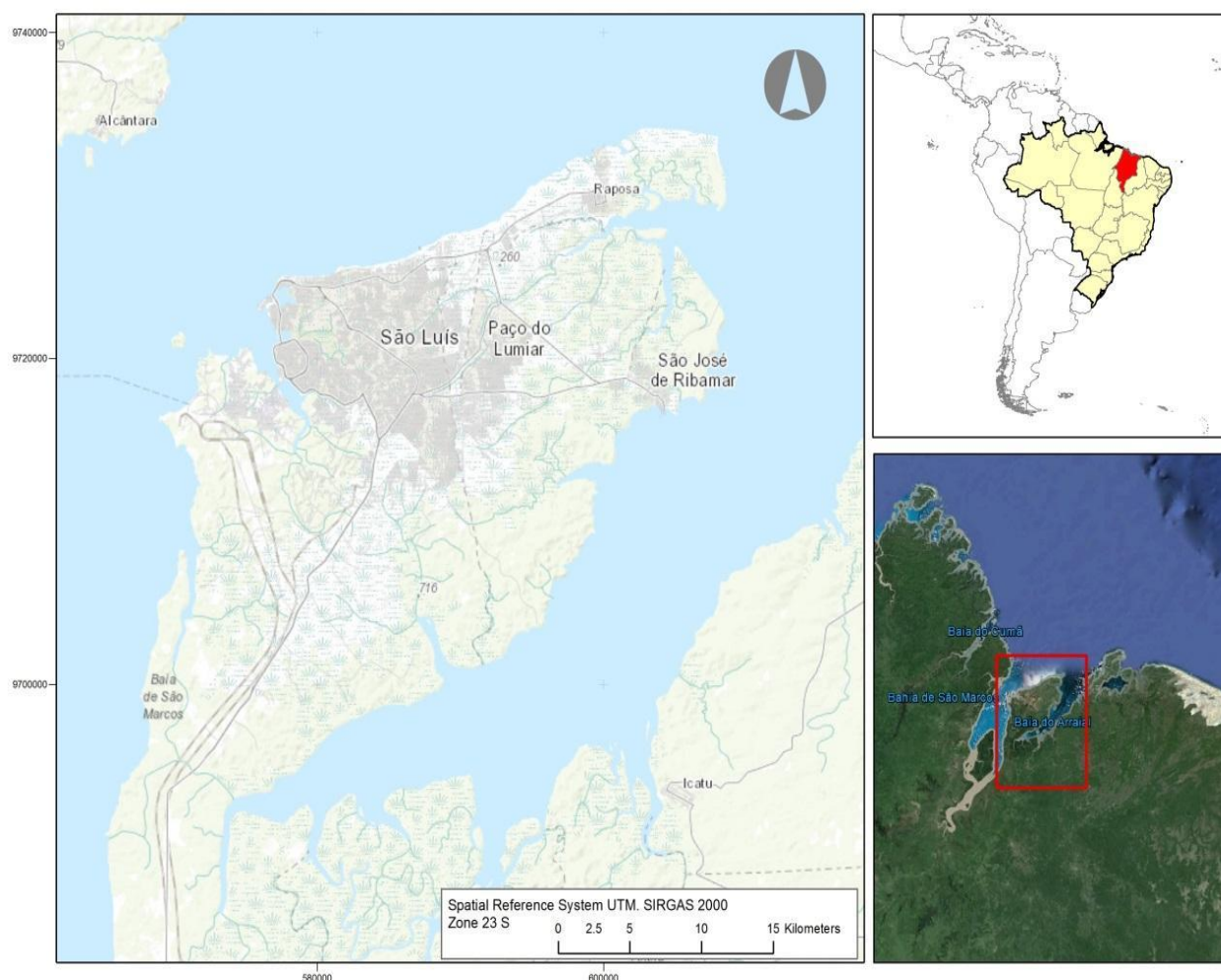
Fig.1 Location of study area. Maranhão Island or Upaon Açu north of Maranhão (northeast Brazil). Spatial Reference System SIRGAS 2000 UTM zone 23S

2   Methodology

This study relies partially on the methodology of Geo-design proposed by Carl Steinitz (2012) [9], work that addresses methods of comprehensive planning of the territory. This approach identifies the points in common that exist between the Sciences of the territory and methods for projecting, is actually an operational framework to build a better future.

On the other hand, this work is also based on criteria described in the book of Drawing the landscape that is lost (a spatial model of agricultural heritage) by Esther Isabel Prada Llorente (2014) [10], as well as in the specific experience in this field of Geovisualization Unique Spaces and Heritage (GESyP) research group.

The successive transformations and the human factor. Different levels of integration scales linking both the life experience of the community itself through the images and the text set out to understand the landscape. A landscape "source" that teaches us how a particular social group built the place (Fig. 2).

Steinitz proposes and organizes the case studies into three different groups geodiseño. Proactive, participatory and sequential. Geodiseño equipment assumed to be able to develop a proposal for the future of the study area. Constraints and combinatorial methods where the team geodiseño not certain about the fundamental initial decision. Model based, agent-based and optimized. Mixed model that includes the sequential method and based on agents. In these models geodiseño team you understand the rules that guide the process of change. For this work the model of participatory change is proposed, potentially more democratic than the other models. (Fig. 3).

The created information system contains different displays and photo-interpretations of the study on the island including abiotic analysis: geological and geomorphological issues relating to topography, hydrography and soil science; biotic analysis: natural vegetation (forest, mangle, scrubland and riparian vegetation). Plant species with photographs and diagrams or drawings of its structure, botanical data and environmental characteristics; rural anthropic analysis representing networks of roads and/or trails as well as a mosaic of subdivisions; anthropic urban analysis representing each town and scattered buildings; study on the toponymy of local, reflecting those place names that describe the main abiotic, biotic, anthropic and cultural heritage elements.

They are set at least three areas scalar for this type of photo-interpretation, territorial scale ranging Department of Maranhão to the delimitation of the island of Sao Luis. The scale of the municipality which includes the four municipalities surveyed in the island itself: Sao Luis, Paso de Lumiar and São José de Ribamar and Raposa. Finally, the analysis focuses on which we call urban scale, which includes the settlements of people raised and built to date in each of the four municipalities we studied. Designed information system contains each of the three areas scalar submitted to the workflow may be seen in (Fig. 4). Following the guidelines of the participatory model applied to the region of Osa, Costa Rica [9], the proposal is representation to the process and evaluation, through change in the landscape, valuing the social and economic impacts to arrive at decisions that have to do with future patterns in the use of the soil and of the cultural heritage.

For the development of the work, has been mainly used the software ArcMap desktop backgrounds and images in digital format, with different characteristics. The development of this project, at this stage has been developed in Spain, it has forced us to use sources of information of the infrastructure of spatial data of Brazil, accessible via the web, at a later stage will be completed with photo-interpretation and specific cartography generated on the own land.
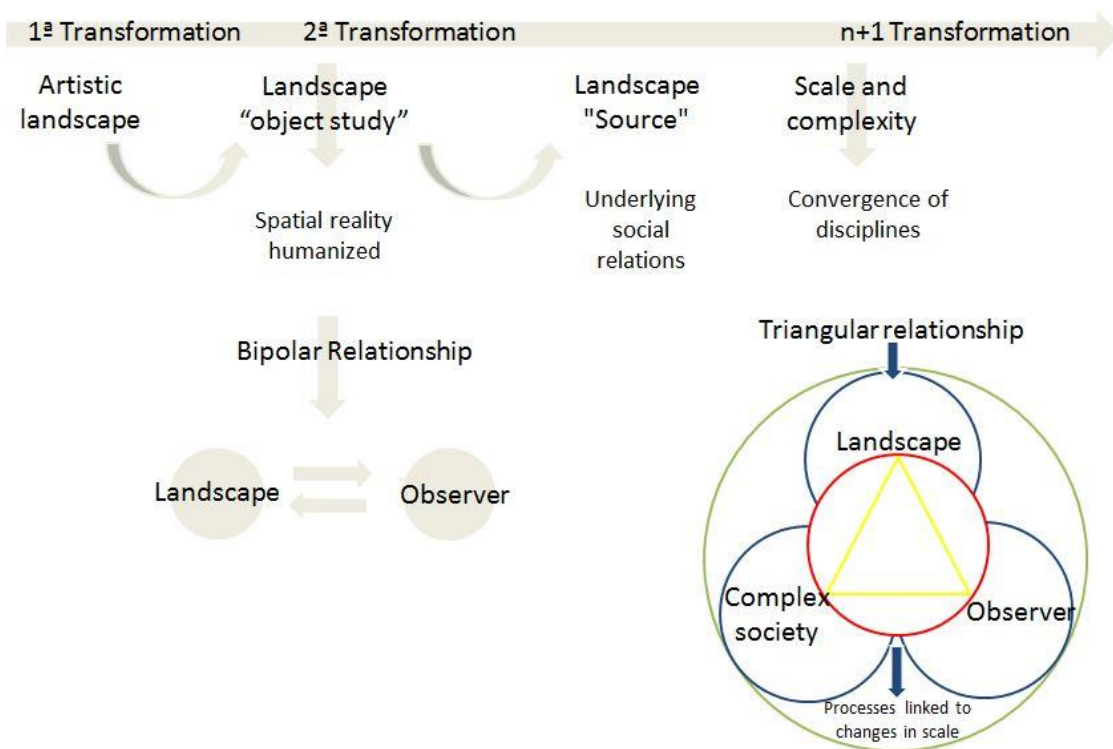
Fig. 2 Landscape as an objective and external perception, the landscape as a source and insight. Map of the transformations in the formation of the modern concept of scenery. In Atlas of agricultural landscapes of Spain. Esther L. Prada
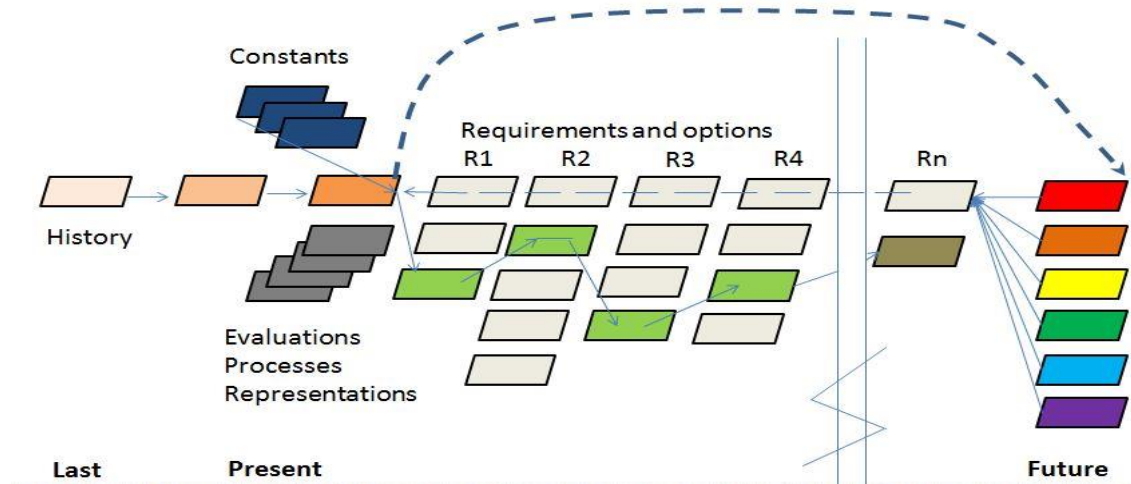
Fig. 3 The participatory model change considers the ideas of each collaborator. Any disagreement between the initial project team members are indicated by "future" of different color. Bibliographic source: C. Steinitz
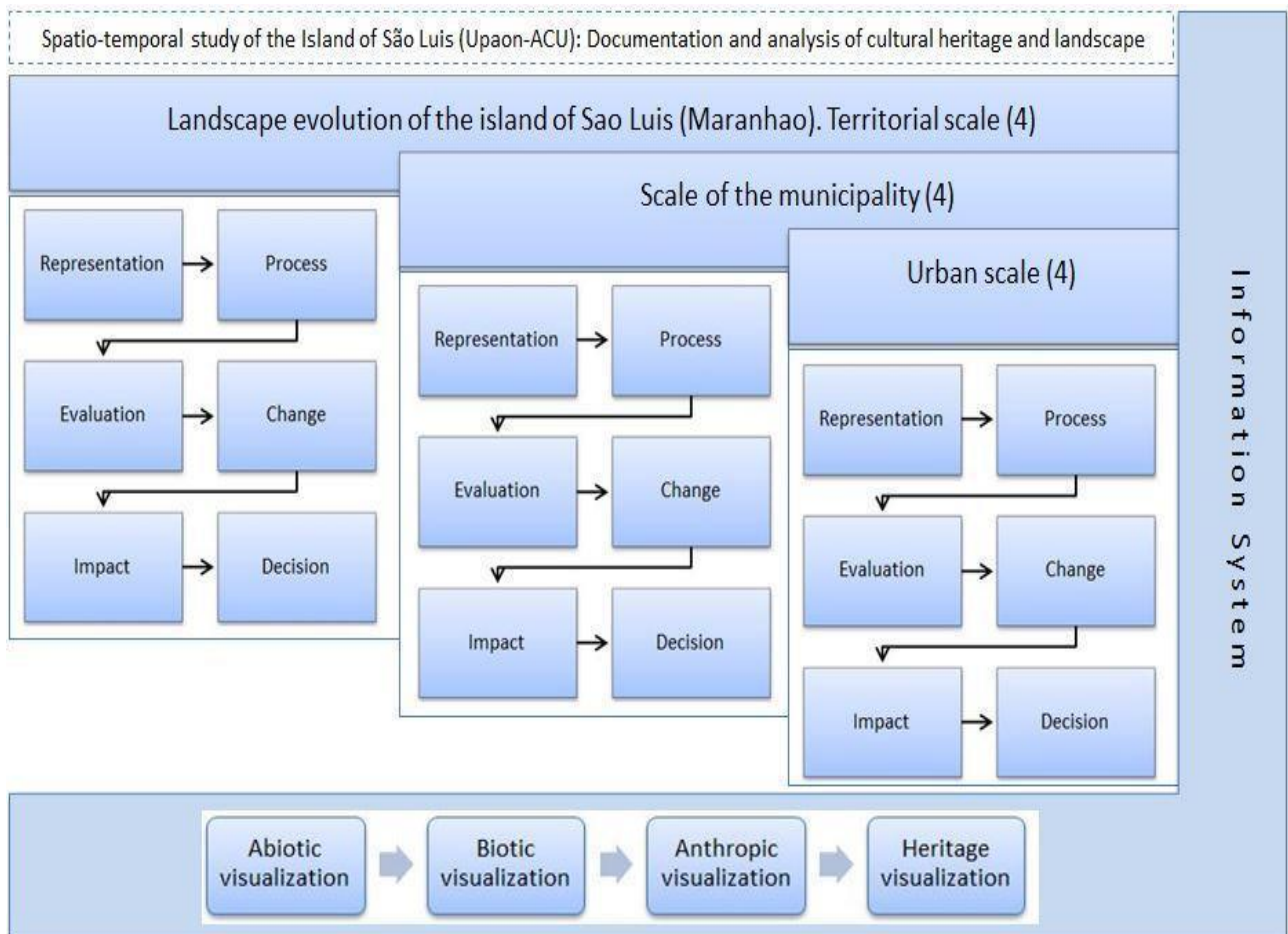
Fig.4 Methodology used in this study (from Steinitz and Prada)

3   Result and Discussion

The island of São Luis (Fig. 3, section a) has suffered a great increase in population during the last decades, this has affected the structure and characterization of the local landscape. According to the Brazilian Geography and Statistics Institute Studies (IBGE) [9], the estimate for the population in 2014 on the island is 1,3 million, an increase of 59,4% in relation to the census in the year of 1991, which had a population of 820 thousand habitants and 138,1% in relation to population of 1690 which was about 10 thousand habitants. This great population growth according to Gomes [11] (2008), can provide a series of environmental problems, such as intensive land use in the central areas, replacement of green areas by built-up areas, proliferation of settlements that do not consider the physical restrictions of the areas, destruction of areas of preservation and loss of biodiversity, both in the flora as fauna, pollution of water resources, among others. All these problems are increasingly visible in the reality of the island. In this sense has been represented in the (Fig. 5, section b) with the four municipality's division: 1. 1. Sao Luis, 2. Sao Jose de Ribamar, 3. Paço de Lumiar y 4. Raposa. Variation of land use for residence in the last 35 years, (1980-2015) of is reflected in Brown's less than higher intensity. In addition this graphic representation contains a straight line that reflects the profile altitude in the visible representation in b´ (SW/NE), he notes the slight unevenness which exists on the island.

The rapid population growth has been fueled by several factors, such as the rural exodus, the high number of children by couples (3-5), persons from other Brazilian States which are situated in this area. On the other hand, there are factors that have influenced directly the process of consumption of natural resources, also contributed to the deformation of the landscape. These disruptive elements have proliferated in this context due to the lack of both urban and rural planning. The study made by Amorim [1] where he made a temporary analysis of the years from 1984 until 2010 on the use and coverage of the ground on the island, have shown that growth and occupation of the disordered population has led to environmental degradation and expansion of the risks of habitability of the citizens. In this regard, it was found that in the period under study there was an increase of 143 of the population, causing a reduction of the Green surface of the island. Amorim [1] relates that will yield a decrease in the areas of scrub banks (45,50%), scrub secondary (17,83%) and mangrove (15,02%). And on the coast, in the areas of dominance of banks of sand, because the natural dynamics, interactions were inconspicuous (1,5%).

a: Gulf of Maranhao
b-b´: Altitude profile and municipality (4)
c: geomorphology types (1-2)
d: vegetation types (1-4)
e: soil types (1-5)
f: geology types (1-3)
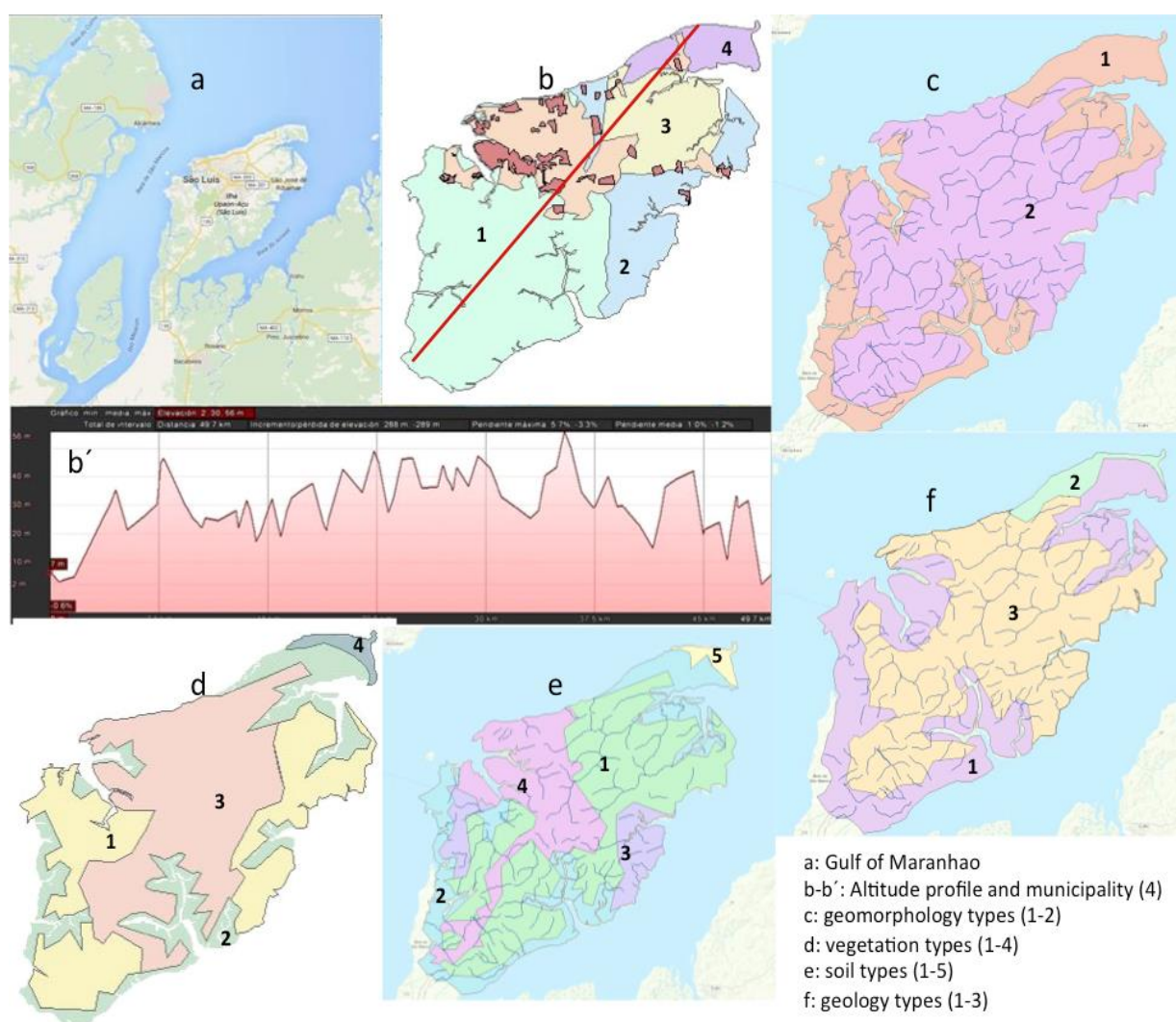
Fig. 5 Gulf of Maranhao/Sao Luis: plot types and visualization major geophysical factors.

In relation to geomorphological studies in this region, various authors have made contributions over time, highlighting [12-13-14-15-16-17-18-19-20-21-22-23-24].

However, many of these works contain data on small areas or specific parts of the island, as the works contained in the Radambrasil project, which was published in 1973. This study included a work of topographic data of geology, geomorphology, soils, vegetation and potential use of the land, finally, in the year of 1998 was published a documentary related to geomorphological characterization of São Luis Island, but did not include the taxonomic analysis of the relief.

São Luis Island is located in the central position in the Maranhense Gulf. According to contributions as [12], the Maranhense Gulf suffered physiognomics changes since its genesis, related to changes in relative sea level and tectonic processes. In short, was not the lifting of the coastal strip, in the Pliocene, which results in the overprint of the sewer system and barriers against erosion, followed by a new uprising with the resumption of erosion and deepening of valleys at a lower level.

In the Pleistocene, came a marine regression, resulting in a new configuration of the bays of San Marcos and San Jose, insulation Maranhão Island and leaving as a witness in the continent in the marine plain Perizes.

At the end of the Pleistocene, there was a new uprising of less intensity and a marine transgression moderate, responsible for the redefinition of the morphology of Golfão Maranhão. Later there were small changes in mean sea level. From the geomorphologic point of view as shown in (Fig. 5, section c) distinguishes two structural domains: (1) tabuleiros costeiros (coastal plains with predominance of sedimentary basins) and (2) coastal mangroves with Quaternary sedimentary deposits. From the geological point of view shown in (Fig. 5, section f) three types of domains: (1) deposits of swamps and mangroves holocénicos, (2) marine deposits of the coast and (3) typical maranhense region Itapecuru formation, typical formation of the region maranhense.

In Fig. 5, section e, they have represented the five main types of soils: (1) Argisol yellow Dystrophic, (2) Glysol tiomorfico orthic, (3) Latosol yellow Dystrophic, (4) urbanized Area, and (5) Neosol Quartzarenico ortico.

The arrival of the Pindaré-Mirim and Mearim rivers make up the large estuary that already surrounds the so-called crab island in the Bay of San Marcos. On the other side of the island of Maranhão, in the eastern part, the Bay of Arraial is located. The slope of the lower Mearim is insignificant and the influence of the sea in these conditions is constant and incisive in such estuaries that also facilitates the intrusion of the tides.

On the other hand the river bed degradation is evident with deforestation, with discharges of the domestic and industrial wastewater, the lack of regulation of landfill sites and mineral extractions have influenced the removal of silt and clay. In the (Fig. 5, section d) are four predominant vegetation types on the island: (1) Open forest of the Highlands with secondary vegetation. (2) Pioneer formations with fluvial and maritime influences (mangrove) (3) Forest open upland agricultural guidance and training (4) Pioneer with maritime influences on shrub-like domain.

That perception of the landscape in the top soils are sandy or loamy, textured depth calcareous intrusions and quartzite are already. In these regions of Amazonian domain are known the incessant fire linked to different agro-forestry and mining practices. This coupled with the rains, which are constant in the region; end up intensely damaging increasingly unprotected soil by indiscriminate logging. The result is the decrease of nutrients, loss of humus, important for the fertility of the vegetation [25].

It seems obvious that human influence and/or geographical determinism are decisive factors in an analysis of these characteristics. In a territory as the studied the physical evolution of the space is consistent with these aspects and contributes to the development and configuration of the landscape.

The trend is a feature that is quantified and is represented in the corresponding map. It affects two or more periods of time and is used for each area scale. At the end the trends for each case study will provide complexity, stability, regressive, progressive and will be positive or negative [26]. Relate the abiotic evolution or Geophysics of the island with trends of biotic and anthropic character through maps, graphs and images seem to confirm elements and information that are already known [27].

Is included (Fig. 6) with four representative images of four domains corresponding to the four studied municipal districts. They reflect processes geophysical, biogeographic and urban changes and trends assessed and inventoried.
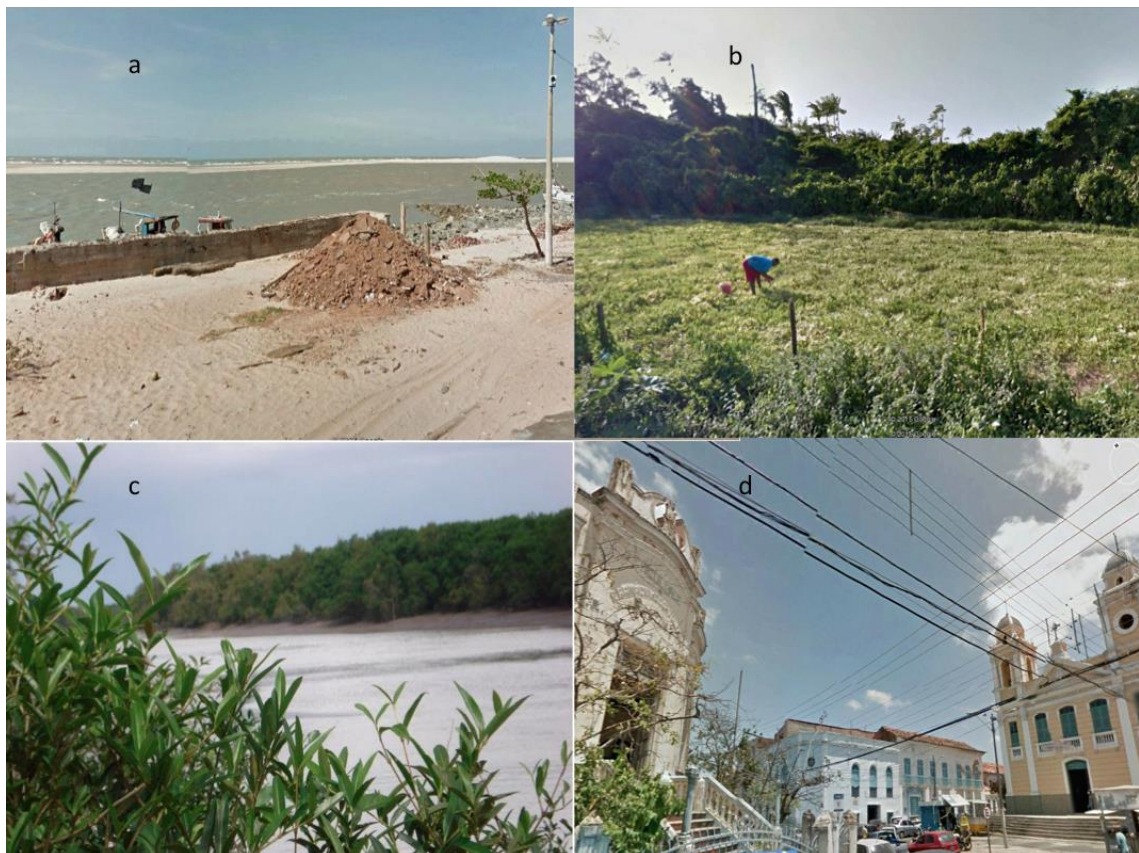
Fig. 6 Images corresponding to the four municipalities studied: a) Raposa coastal dunes. b) Agricultural practices in the field of Paço de Lumiar. c) Tibiri TajaÇuaba river bank vegetation (São José de Ribamar). d) Historical heritage of downtown São Luís.

Finally, (Fig. 7) shows structural changes in a natural landscape of coastal dunes in the north of the municipality of Raposa, As can be seen, it is a fragile landscape. The steady increase in tourism is a major factor of deterioration.

Fig. 7 Changes in the structure of the natural landscape through pollution of resources, degradation, disorderly process of occupation, predatory use of resources and tourism. Municipality of Raposa.

4   Conclusion

This work has focused on organizing and documenting a set of data and graphic information necessary to assess the evolution of the landscape in the studied field. Therefore, we have an information system that enables effective responses for proper planning.

Obtaining graphics, drawings, maps and images through the use of certain spatial infrastructures (SDI), mainly located in Brazil; seem to presenting some of the problems that may be related to accessibility to today. Problems related with permissions of network, digitization or simply availability permits have been so decisive and limiting factors for the implementation of a system such as that proposed. There are countless data, information or studies that can be found in the network or in bibliographic consultation on the studied space funds dispersed way. It is an island and a city with a heritage and unique cultural landscapes. The heritage built over the past four centuries, mainly in São Luis, first with then French and Iberian influences, gives the whole a singular value. Since colonial times the Tupinambás or old settlers began a modeling process of the landscape through fishing and farming, practices such as cultivation of cassava and sweet potato.

This work at this stage provides an organized information system based on a methodology so proven and innovative as proposed by Professor Steinitz [9]. For comprehensive planning should converge on the proposed scales data from four municipalities. Therefore, from representation to the decision-making, observing processes, evaluating changes and trends, quantifying impacts.

Integrate all this information and at the same time arrange it so that it is useful is a challenge. With this work we tried to lay the foundations so that the generated system can be called as an expert in heritage and cultural landscape of the island of Maranhão.

One of the main determinants of the current landscape is high human concentration in certain areas and the strong growth of the population in the past 50 years. Another decisive factor for the whole State of Maranhão is the opening to the sea, navigation over time, an Amazon geography.

Acknowledgement

References

[1] AMORIM, F.C.; ANDRADE, J.B.; CARVALHO,A.O.; PINHEIRO,D.C.; REGO, C.A.R.M. Análise Multitemporal Do Uso E Cobertura Do Solo Na Ilha Do Maranhão. Territórios, Paisagens e suas dinâmicas. / CASTRO, Claudio Eduardo de; BERNAT, Issac Giribet; SILVA, Quésia Duarte da; SODRÉ, Ronaldo Barros. São Luís: EDUEMA. ISBN: 978-85-8227-039-4. p 403 – 414. 2014.

[2] CORVALAN, C.; BRIGGS, D.; KJELLTROM, T. Development of Environmental Health Indicators. In: Linkage methods for environmental and health analysis. UNEP, USEPA, WHO. Genebra.1996.

[3] COSTA, S. M.; SANCHES, R. Crescimento Urbano e Meio Ambiente: Uma Abordagem Metodológica Utilizando Geotecnologias. In: Simpósio Brasileiro de Sensoriamento Remoto, 11., 2001, Foz do Iguaçu. Anais... São José dos Campos: INPE. p. 1081-1088. 2001.

[4] MENESES, P. R. Fundamentos de Sensoriamento Remoto. Brasília: 2006.

[5] INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. Perfil dos municípios brasileiros. IBGE: Rio de Janeiro, 2011.

[6] CORDEIRO, E. C, DINIZ, J. S., Região metropolitana da grande São Luís: além da retórica municipalista, o que serve como entrave para sua "efetivação"? In: III Jornada Internacional de Políticas Públicas, São Luis, 2007.

[7] UEMA – Universidade Estadual do Maranhão, NUGEO. Mapa de solos. São Luis: 2009.

[8] ARAUJO, E.P, TELES, M. G. L, LAGO, W. S., Delimitação das bacias hidrográficas da Ilha do Maranhão a partir de dados SRTM In: Anais XIV Simpósio Brasileiro de Sensoriamento Remoto, Natal, Brasil, 25-30 abril 2009, INPE, p. 4631-4638.

[9] STEINITZ, C. Geodiseño, Esri Press, 380 New York Street, Redlands, California 92373-8100- 2012.

[10] PRADA, E. Dibujando el paisaje que se va. Un modelo espacial del patrimonio agrario. Ministerio de Agricultura, Alimentación y Medio Ambiente. ISBN: 97884-491-1383-3. 2014.

[11] GOMES, P. S. Ocupação do Solo e Microclimas Urbanos: o caso de Montes Claros, MG. 2008. 212 f. Dissertação (Mestrado em Arquitetura) – Departamento de Arquitetura e Urbanismo, Universidade Federal de Santa Catarina, Florianópolis, 2008.

[12] AB'SABER, A. N. Contribuição à geomorfologia do estado do Maranhão. Notícia Geomorfológica. Ano 3, n. 5, 1960, p. 35-40.

[13] BRASIL. Ministério das Minas e Energia. Departamento Nacional de Produção Mineral. Projeto Radam. Folha SA.23 São Luís e parte da folha SA.24 Fortaleza: geologia, geomorfologia, solos, vegetação, uso potencial da terra (Levantamento de Recursos Naturais, 3). Rio de Janeiro, 1973

[14] DIAS, L. J. B. S.; NOGUEIRA JÚNIOR, J. D. M. Contribuição às análises ambientais da ilha do Maranhão. Ciências Humanas em Revista. São Luís:UFMA, v. 3, n.2, dez. 2005, p. 127- 144.

[15] MARANHÃO. Estudo de geomorfologia litorânea. Macrozoneamento do Golfão Maranhense. Diagnóstico Ambiental da Microregião da Aglomeração Urbana de São Luís e dos Municípios de Alcântara, Bacabeira e Rosário. São Luís: Sema/MMA/PNMA, 1998.

[16] PEREIRA, E. D. Avaliação da vulnerabilidade natural à contaminação do solo e do aqüífero do reservatório Batatã – São Luís (MA). Tese (Doutorado) Rio Claro: UNESP. 2006.

[17] PEREIRA, E. D; ZAINE, J. E. Mapa geológico-geotécnico da bacia do rio Bacanga – São Luís (MA). Geociências. v. 26, n. 1, São Paulo: Unesp, 2007, p. 45-54.

[18] SATHLER, R. et al. Erosive processes in urban areas in the island of Maranhão – Brazil. Sociedade & Natureza, Uberlândia, Special Issue, , May, 2005, p. 161-173.

[19] SILVA, Q. D.; PEREIRA, K. D. Matriz de dissecação do relevo: um estudo de caso da subbacia hidrográfica do rio Santa Bárbara. Relatório Final de Projeto de Pesquisa. São Luís: Uema, 2008.

[20]   SILVA, S. C. O.; SALES, V. C. C. Processos morfodinâmicos na praia da Ponta d'Areia: uso de espaços litorâneos e impactos ambientais. 2009. SIMPÓSIO BRASILEIRO DE GEOGRAFIA FÍSICA APLICADA, 13, 2009, Viçosa. Anais...Viçosa: Universidade Federal de Viçosa.

[21]   SOUZA, U. D. V. et al. Caracterização geomorfológica e paisagística da área costeira de Panaquatira, município de São José de Ribamar-MA. SIMPÓSIO NACIONAL DE GEOMORFOLOGIA/ CONFERENCE ON GEOMORPHOLOGY, 6, 2006, Goiânia. Anais...Goiânia: UGB.

[22]   TEIXEIRA, S. G.; SOUZA FILHO, P. W. M. Mapeamento de ambientes costeiros tropicais (Golfão Maranhense, Brasil) utilizando imagens de sensores remotos orbitais. Revista Brasileira de Geofísica. Suplemento 1, n. 27, 2009, p. 69-82.

[23]   UFMA. Estudo de Impacto Ambiental e Relatório de Impacto Ambiental da Refinaria Premium I. V. 2. São Luís: UFMA, 2009.

[24]   SILVA, Q.D. MAPEAMENTO GEOMORFOLÓGICO DA ILHA DO MARANHÃO. Tese (doutorado) - Universidade Estadual Paulista, Faculdade de Ciências e Tecnologia. 2012.

[25]   MONJE, X. Estudio mediante Sistemas de Información Geográfica (GIS) de la evolución de la vegetación natural en Cataluña. Aproximación al caso del Valle del Freser durante el periodo 1956-2000, Barcelona, 2003.

[26]   RAFAEL, S.; HELENA, P.; ANTONIO, J. T. G.; EMÍLIO, V. B. Caracterização de voçorocas na ilha do Maranhão. Anuário do Instituto de Geociênciasversão impressa ISSN 0101-9759. Anu. Inst. Geocienc. v.32 n.1 Rio de Janeiro jun. 2009.

[27]   The National Geographic Society has been inspiring people to care about the planet since 1888.http://maps.google.com/gallery/publisher?pub=National+Geographic+Society

Definition of the use of an Acoustic Methodology for its use in the representation of 2D geometric Objects.

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Abstract

The use of sound to represent geometric shapes or real environments by sounds has been used by different procedures. Basically the natural capacity of detecting the origin of a sound is used every day with this purpose. Nevertheless the chance to use the audio channel for representing 3D spaces is different to the visual channel, the number of sounds per second or the order of how this sounds arrives to the ear have a relevant effect about the capacity for understanding, processing and recognizing objects and shapes. On this paper, a serial of experiments done for representing how the 2D and 3D information can be represented by sounds are described with its initial results. The design of the initial experiments and results is presented on this paper.

1   Introduction

There are relevant examples of Blind people to echolocate by hearing the eco of the clicks with his tongue or snaps his fingers. By this way, Blind people are able to percibe sahpes. This capacity can be artificially used by a substitution of a real eco by a "virtual eco" with a better audio "characteristics" which basically are done to increase the potential number of users. There are some examples of Electronic Travel Aid Systems as the one of Leslie Kay (1980) KASPA, or the Peter Meijer(1992) with PHILIPS based on audio codification were training is needed or the developed by Gonzalez Mora (1999) which uses HRTF continuous tones to reconstruct the audio map of environments scanned with a camera system. On this one the uses of HRTF functions makes the device able to be used without training. In any case, this last device was a tool just for indoors prepared scenarios.

On this work a group of shapes was created. A group of figures inscribed in a circles of 15cm of diameter were given to the blind, and a representation of the shape with sound was done. A design of the figure was created in the computer in 2 Dimension. The representation of each dot of the computer design by sounds was presented to the user who has to peak the correct shape by teaching and associating the shape with the sound map.

1.1   Audio database and bidimensional geometric shapes

The area for representing the shapes covered initially from -32° to 32° of azimuth, with steps of 8° and 6 elevation from -20° to 40° with steps of 10°. After we improve the resolution to 17 points (from -64° to 64°

with steps of 8°) for each azimuth and for 11 elevations (from -40° to 60°, steps of 10°). For each position a sound corresponding for 1 0 depth levels was created by a volume r eduction with a l ogarithmic scale (distance from 90 cm to 10 meters). By using this "audio ·d matrix" a selection of the sounds corresponding with the X,Y,Z was created in 2D, were X,Y is the coordinate of the position and Z the level of distance to the observer. The shapes prepared were the square, triangle, empty square, star, empty triangle, cross, hexagon and empty hexagon. An example of the triangle is shown in fig. 1.

A program in Mat lab combined with C++ and Visual Studio was created for the representation of the sounds. By this program a cal ibration of the Int erclick (audio separation between sounds), Overlap (Audio overlapping between sounds) and sequence of the sounds were configurable (part 1.2.)
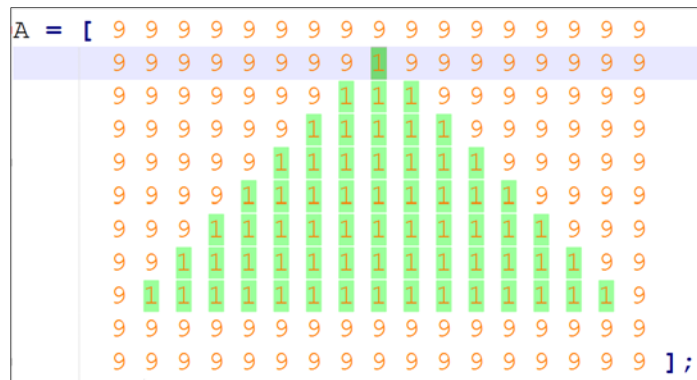
Fig. 1

1.2 Interclick and overlap timing, strategies of playing

The *interclick* and the *overlap* are two values which affect to the comprehension of the space as well as the playing strategy of sounds (order o sequence). The *interclick* is the time occurre d between two following sounds played. The *overlap* time is a time th at we have to decide to start following sequences of sounds. We chose diffe rent times of in terclick and overlap according to huma n limit of sound se nsitivity, to bette r understand the role played by these values in perception and understanding of geometric shapes. The times were initially fixed because of the impossibility to change it in the Matlab software and they were about 100 milliseconds. After, with the next programs we set interclicks of 80, 50, 20, 11 and 5 milliseconds. At the end of the preparation of this virtual environment we made different strategies to know if the brain cognition can have different approaches in perceiving geometric shapes, moving away from left-to-right and top-to-bottom ordered idea. These are the strategies :

- Linear
- Circular
- Random

For linear strategy :

1. *From Top To the Bottom* – In this way we start from the first left corner to the end of line and for the next line we start from left, until the last line.
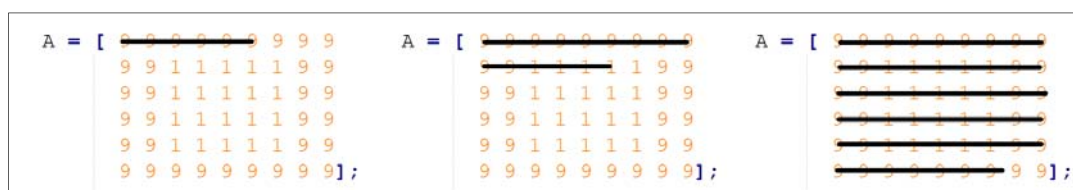
Fig. 2

2. *From Top To the Bottom Snake* – In this way we start from the first left corner, proceeding to the end of the next line, like a snake, until the end of last line.
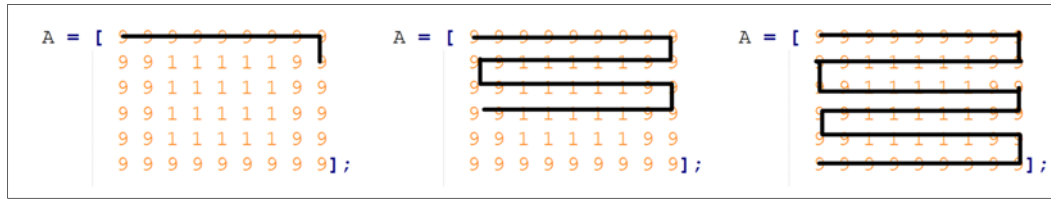
Fig. 3

3. *From Bottom To the Top* – In this way we start from the last right corner to the start of each line and for the previous line we start from right, until the first line.
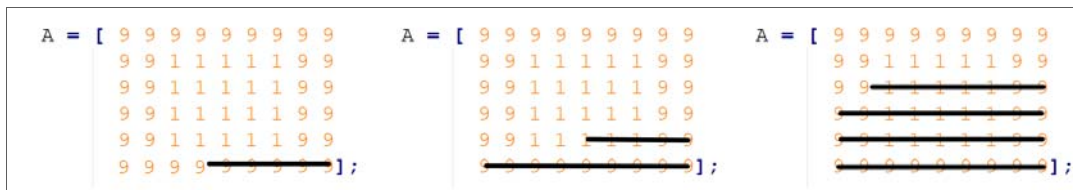
Fig. 4

4. *From Bottom To the Top Snake* – In this way we start from the last right corner, proceeding to the end of the previous line, like a snake, until the start of first line.
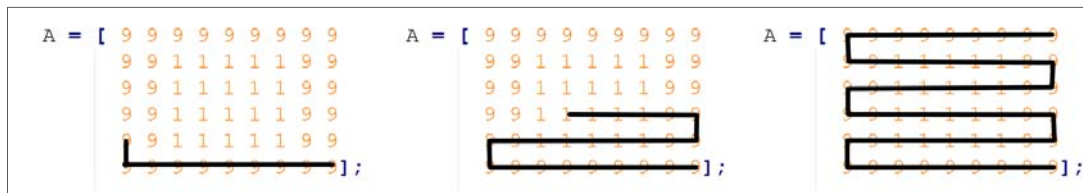
Fig. 5

Each of these can be rendered in sounds normally or interlaced vertical, starting from top to bottom and ending from bottom to the top, or interlaced horizontal, starting from right to left or left to the right, ending from left to the right or right to the left.

To better understand, the fig.6 can help.
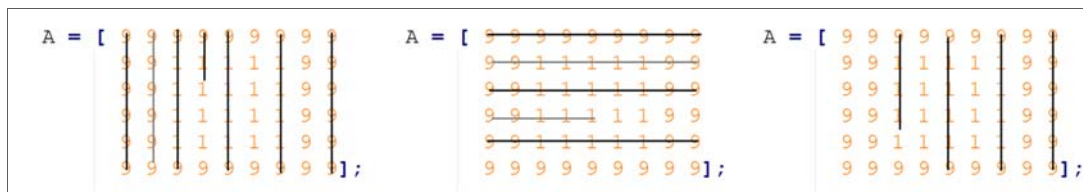
Fig. 6

For spiral strategy :

1. *From Focus To the Corners Spiral Clockwise* – In this way we start from center, then we do a clockwise spiral until the completion of figure/image.
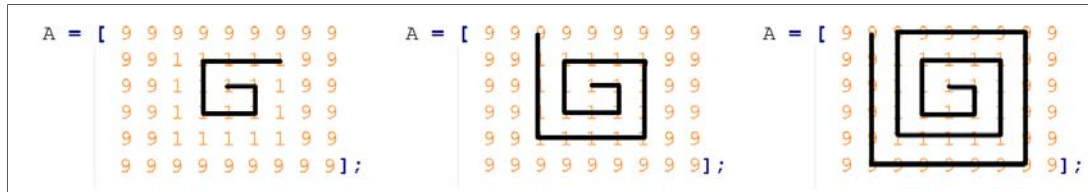
Fig. 7

2. *From Corners To the Focus Spiral Clockwise* – Here we start from one of corners and then doing a clockwise spiral we complete the entire image.
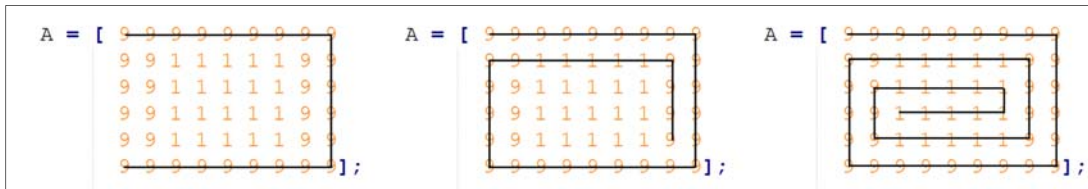
Fig. 8

3. *From Focus To the Corners Spiral Counter-Clockwise* – In this way we start from center, then we do a counter-clockwise spiral until the completion of figure/image.
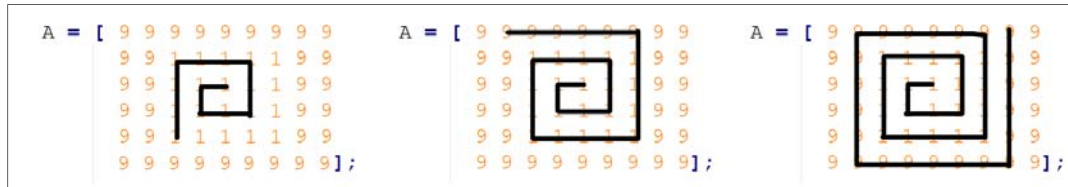
Fig. 9

4. *From Corners To the Focus Spiral Counter-Clockwise* – Here we start from one of corners and then doing a counter-clockwise spiral we complete the entire image.

For random strategy :

1. *Completely Random* – In this case we write an algorithm that picks randomly points of the matrix until the completion of the frame.
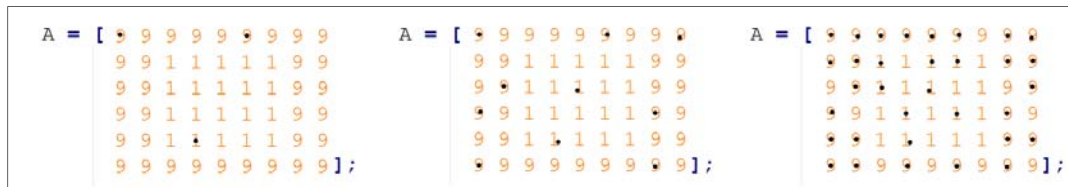
Fig. 10

2. *Random with probability* – In this way each zone is represented by a casual random, but the target is to pick elements of the center zone with a probability of 80%, the next zone, going outside, with 60% and the corner zones with 20%.
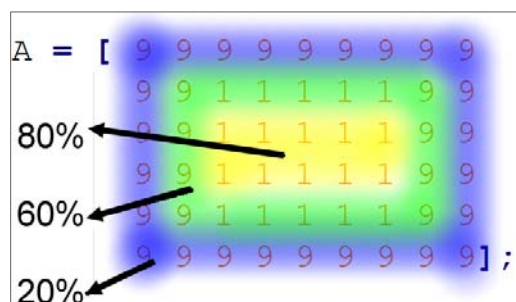
Fig. 11

2   Experiments and results

The experimental trails were done by people with vision. Good results were observed, but the appare ntly evidence, reduce number of shapes and seeing capacity make the users able to perceive and associate the shapes with the sound relatively easily.

A first attempt with a blind user has been done, particularly with a child, 7 years old, to know how a real user can perceive these sounds, without having any idea of spatial location.

2.1   Experiments with people

The process has shown initially its utility with people with visual capacity, and first trials has been done with blind user.

The trials were validated by a 7 years old Blind Child who did feel comfortable with the sounds. In the first 10 trials we didn't explain to the child the program logic of playing sounds to better understand how naturally was the approach in listening to this ne w 3D audio database and we didn't put an y geometric shape but simply the left-to-right and top-to-bottom ordered audio sequence, asking her to trace with finger what she was listening. Effectively she was able immediately to recognize the audio proceeding. After this little training we launch on the program the geometric shapes. The child had to touch and pick the corresponding plastic shape printed with a 3D printer. In addition we collected also responses from a total of 6 people completely sighted. After a training the capacity of recognizing all the shapes by no limit of audio repetition times was achieved in 100% of the cases..

2.2   Results collected

The volunteers who participated at the pr oject following the technica l steps and is sue were able to understand the shapes, particularly empty ones. They had also the possibility to try different strategies, in which the linear resulted the most clear, with the minimum percentage of errors.

The 7 people who accessed to the tests were able to perceive the provenience of the 3D stereo sounds from the space. It can be confirmed that it is possible to perceive and recognize by this methodology a number of defined shapes.

The test was prepared increasing the interclick over 40 milliseconds by an adjustment repeating the same known shape until a comfortable comprehensive shape by the user. It was observed a difference in the capacity of comprehension when it was under 40 milliseconds, especially with shapes more complex.

It seems that the tool created for the measurement of the parameters of Interlock, Overlap and Strategy can be considered initially as a valid system.

3   Conclusion and future developments

The protocol design on this work seems to be a valid tool for obtaining the best adjustment for defining the Interclick, Overlap and strategy for the different types of sounds, for the different models of headphones and for the maximum and minimum level of area and distance.

When the interclick is long, it has been seen that it is difficult for the perception to associate to the same shape consecutive sounds and requires a bigger effort, but by other hand, when the interclick is too short the brain doesn't have the capacity to fix the sound position in the map, so if shoul d exist and optimum probably depending on the user, but it has to be measured.

Regarding to the strateg y, the initial results show for now that linear an d left-to-right a nd top-to-bottom ordered strategy seems to be the best choi ce. This is because human are used to read ing with the same method (at least in the majorit y of the world) and the brain more befits to ordered way to understand and remember things. In the coming steps we will use all of these informati on to construct a device for bl ind people that can help them during their daily life.

Further progress will be make tests with people on all the strategies, inter-click times and overlap times to find the best combination that can better make able them to perceive environment and/or figures and shapes.

Bibliographic references

[1] B. Gardner, K. Martin. HRT F Measurements of a KEMAR Dummy-Head Microphone. MIT Media Lab. (1994).

[2] L. Dunai, G. Peris Fajarnes, B. Defez Garcia, V. Santiago Praderas, and I. Dunai, *The Influence of the Interclick Interval on Moving Sound Source Localization for Navigation Systems.* Acoustical Phy sics 56 (2010) 370–375

[3] T. Evreinova, G.Evreinov, R. Raisamo *An Exploration of Volumetric Data in Auditory Space.* Journal of Audio English Society 62 (2014) 172-187

[4] J.L. González-Mora, A. Rodríguez- Hernández, L.F Rodríguez-Ramos, L. Díaz-Saco, N.Sosa , *Development of a new space perception system for blind people, based on the creation of a virtual acoustic space*

[5]   M. Iyer, M. Joshi, N. Gupta and L. Hmurcik. Vertical A Study of the Relationship between Head Related Transfer Functions and Elevations International Conference on Ima ge Processing, Computer Vision and Pattern Recognition. 2010.

[6] B. G. Shinn-C unningham. Distance cues for virtual auditory space. Proceedings of the F irst IEEE Pacific-Rim Conference on Multimedia. December, 2000.

[7] T. Rodemann. A stud y on distance estimation in binaural sound localization. The 2010 IEEE/RSJ International Conference on Intelligent Robots and Systems of Taipei, October 2010.

[8] C. Drioli, N. Orio. Elementi di Acustica e Psicoacustica. 2004.

[9] J. Lewald. *Exceptional ability of blind humans to hear sound motion: Implications for the emergence of auditory space.* Neuropsychologia 51(2013)181–186

[10] J.A. Fodor, Z. W. Pylyshyn. Connectionism and cognitive architecture: A critical analysis. 1988.

[11] E. Giordani. Elementi di spazializzazione del suono. October 2012.

[12] F. Avanzini, G. De Poli. *Sound in space.* October 2012.

[13] S. Getzmann, *The effect of eye position and background noise on vertical sound localization.* Hearing Research 169 (2002) 130-139

[14] L. Picinali, La simulazione della distanza in un algoritmo per la spazializzazione binaurale. Associazione Italiana di Acustica 34° Convegno Nazionale June 2007

XXV Congreso
INGEGRAF

ANALYSIS OF THE INTEGRATION PROCESS OF LIGHTWEIGHT CERAMIC TILE IN THE PRODUCT LINE OF CERAMIC COMPANIES

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Abstract

Today there is technology that enables the use of molds which can reduce the amount of clay required for the manufacture of ceramic floor tiles. This implies an impact on the production process at all stages, from raw material consumption, cooking until transport and placement. This may involve, in theory a considerable saving in production cost. This paper sets, analyzes and explains the technical realities of this type of lightweight tile and proposes measures to make for proper full integration into the production process.

1   Introduction

The ceramic tile industry is a key sector in Spain. Spain is the third largest export volume of tile and the second in Europe. The ceramic sector produced in 2013 420 million m2 of ceramic in Spain. The ceramic industry is the third industry that gives Spain biggest trade surplus (€ 2,240 million in 2013). It generates about 14,300 direct jobs. (Source: Spanish Association of Manufacturers of Ceramic Tile ASCER.).

95% of Spanish tile production is concentrated in the province of Castellón (Valencia). It is one of the sectors with the highest energy consumption in the Valencia region, second only to the transport sector. The final consumption of energy in this region, according to sources of the Valencian Energy Agency (AVEN), amounted to 9,499 ktoe, 3,087 ktoe of which were consumed by the industrial sector. This sector thus represents 33% of energy consumption in Valencia.

Published by the Valencian Energy Agency, studies emphasize that the Valencian ceramic sector annually consumes 30% of the total energy consumed by the entire industry of Valencia. The Spanish manufacturing sector of ceramic tiles and atomized powder consists of over 200 companies. Enterprises engaged in the manufacture of ceramic tiles are in total 215, of which 13 are dedicated exclusively to the production of atomized powder (ASCER).

CERAMIC PRODUCERS IN SPAIN

■ Ceramic tiles   ■ Atomized powder
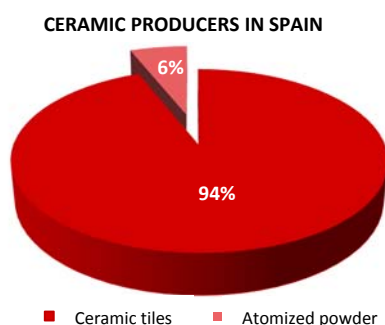
Figure 1. Distribution of ceramic producers in Spain. Source: ASCER

The number of ceramic companies decreased during the period of economic crisis. However, today is increasing by the good performance of exports to emerging countries. In fact, in 2014 there has been a 6% increase in the production of ceramic tiles. Source: ASCER.

Ceramic tile is a product that requires a large amount of heat energy for manufacturing. A structural design specially oriented to reduce these energy requirements, would save a lot of natural gas in production. Also it would save fuel in transport the final product to the point of sale.

The objective of this research is to make a ceramic tile design specially designed to reduce the mass of the product, with the same or better mechanical and thermal properties.

1.1   The characteristics of energy consumption in ceramic tiles

The distribution of carbon dioxide has been plotted in Figure 2.
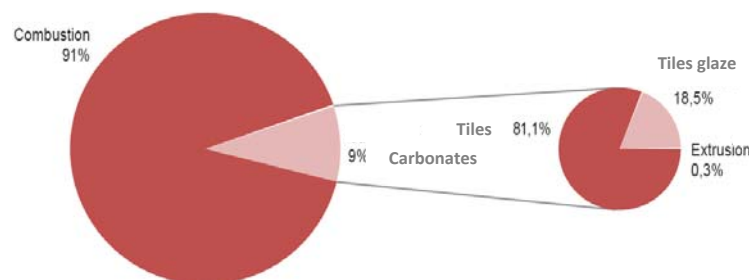
Figure 2. Distribution of carbon dioxide emissions in the manufacture of ceramic tiles AVAP.

As shown in the previous figure, 91% of carbon dioxide generated in the manufacturing process of tiles are due to the combustion of natural gas; the remaining 9% are emissions from the decomposition of carbonates during the baking step. Of these emissions, most are due to manufacturing tiles, being the type of composition with higher content of carbonates. Emissions of carbon dioxide in the manufacture of extruded tiles represent only 0.3% due to low carbonate content of the compositions used and the low share of production of this type of product on the total production.

Carbon dioxide emissions associated with the manufacture of ceramic tiles in Spain have increased in recent years.

They have also taken steps to try to reduce CO2 emissions through technological changes that have occurred in the sector in the last two decades, aimed at making more efficient use of energy. The major changes include:

- The spread of natural gas as fuel.
- The generalization of the single firing process short cycle (50 - 60 min approximately.) versus the double cooking cycle long (about 50 hours), with replacement of tunnel kilns furnaces by roller trolleys (2007 production 96.3% was produced by single firing).
- The improved insulation in furnaces and energy efficiency of the burners.
- The use of waste heat from the ovens at the very stage of cooking or drying stages, mainly in trucks dryers located at the entrance of the furnaces.
- Increasing the solids content of the aqueous suspensions of clay, to reduce the amount of water to be evaporated in the spray drying.
- The use of cogeneration systems, whereby a more efficient use of primary energy is done by leveraging the manufacturing process exhaust gas turbine and cogeneration engines, while electricity is generated.

However it has not been done, so far, no action to try to reduce the mass of the tiles maintain their physical strength properties.

The main objective of this research is to achieve energy savings in industry production of ceramic tiles of up to 15% of costs and up to 20% in energy savings.

1.2   Needs of the ceramic industry

One of the main objectives of companies in the ceramics sector is to reduce production costs through energy savings. Much of ceramic production cost is because the ceramic tile needs a lot of heat energy for manufacturing. A ceramic tile, depending on its composition, may have a manufacturing temperature range between 1,100 ° C and 1,200 ° C in a cycle of about 60 minutes.

The following figures is shown the distribution of energy consumption and energy costs in these businesses.
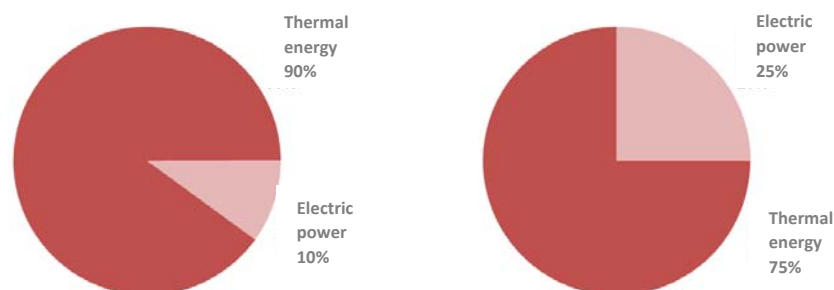
Figure 3. Distribution of energy consumption and cost in manufacturing ceramic tiles.

Therefore a reduction of 15% in energy consumption means big savings for companies in the ceramic sector.

2 Purpose

Today ceramic tiles are embossed on the back. This is necessary because it would be dangerously slippery during manufacture and not having unfavorable during placement [1].

But it does not take into acco unt the design of the relief on the back, the most common current cerami c reliefs: fine rib, parallel stripes, checkerboard, honeycomb and irregular [2]. Some of the reliefs used can be seen in Figure 4.
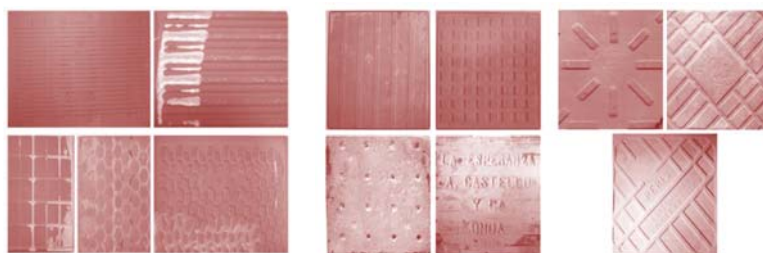
Figure 4. Sample design embossed on the back of ceramic tiles. [3]

The main novelty of the project hosts mode consists of the grid at the back of the ceramic tile, it should be granted so that the socket is loaded directly onto the rib profile. The manufacture and raised offers four key benefits, which affect the design of ceramic mold pressing [4].

- The drastic reduction in raw material forming the filling socket made directly on the punch having mechanized grid. In the trad itional system, where the relief is the upper punch, filling is uniform and the relief is generated according to the different degree of compaction between the inner and outer faces of the grid.
- The considerable saving in kinetic energy, since mass transport and store during the production process and later in the logistic distribution is lower. Mass reductions reaching 30%.
- The considerable saving of heat ener gy, because the mass is less dr ying and firing. Re ductions of up to 15%.
- Maintenance and even improvement of the mecha nical properties of the final product. Also, the design avoids the blossoming of recessed ribs on the face side (honeycomb type model with dome finish).

The tile has indisputable benefits under his rib reaching 20% to reduce production costs.

3   Method

To achieve the proposed objective there have been various numerical models of ceramic product with the aim of reducing its mass with the same physical properties by changing the rib ceramic tile back reliefs deep can save up to 30% by mass [5].

To achieve th e objective different ge ometries are studied, taking into account the per centage of mass reduction as well as the study of mechanical properties by using finite element analysis. The final product must meet or exceed the characteristics of a tile of the same size characteristics. The influence parameters are changed in the fina l solution on saving material and the mecha nical response is also d etermined. Specifically for the final assessment, three parameters are taken into account:

- The angle of inclin ation of the inner wall of the basic p yramid with respect to the horizontal , conditioned by the diameter of the circle in which the base is limited.
- The interior of the basic pyramid.
- The thickness of the rib.
- The depth of the rib.

To do this, they are modeled on the basic geometry chosen, variants, in order to perform a second parametric study. These latter geometries have been called parametric geometries.

The material considered for all models, including the base model has the following characteristics:

- Material name, "ceramics".
- Composition: 40% clay-caolita, 40% feldspar, 20% quartz.

Basic geometries
Volumetrically, all models have the same dimensions:

- Size: 333 x 333 mm^2.
- Thickness: 9 mm.

Test 1: Application of a uniform pressure

In this test a distributed lo ad of 0.1 N / mm2 on the norm al to this face side and applied. This value was considered appropriate for simulating approximately de100 kg weight evenly distributed on the tile.
The hidden face was considered totally restricted (displacements and rotations as the 3 spatia l axes is prevented), simulating the effect exerted by the bonding material after placement of the piece.

Test 2: Applying a point load (bending test).

In this case, a poi nt load of 1.500 N on the geometric center of the face side an d normal to it was applied. This value was considered appropriate, since the rule requires believes loads between 1.100 and 2.000 N. As constraints, the piece resting on two of its parallel edges was considered.
This test simulates an actual bending strength test, but on a finished pr oduct rather than on a materi al specimen [6-8].
Since, in general, the tile is not designed to work primarily in tension or compression, it was considered that the implementation of these two models would yield sufficient results to determine the optimal geometry.
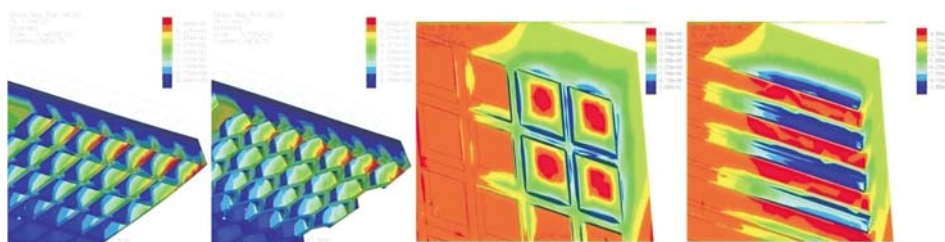
Figure 4. Simulation by finite element technique.
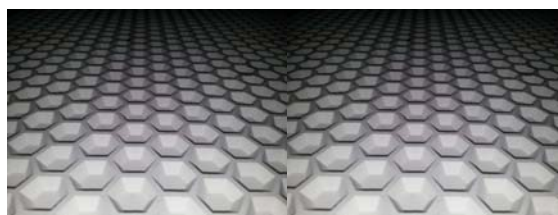
4   Result

Energy saving cooking due to the decline of the mass is to be verified,   but could be estimated to be between 5 and 15% with respect to the consumption of natural gas. Given the high cost of energy, and also the technology for recycling the combustion gases, it can be estimated that the energy savings could reduce production costs by up to 20%.

A 40-ton trailer en route spends half 32 liters of diesel per 100 kilometers, equivalent to 0.8 liters per ton.

A 30% reduction of 40 tonnes a reduction of 12 tons in the same volume with reduced consumption of approximately 9.6 liters per 100 km.

One aspect to consider is the health and safety prevention at work.

More than a quarter of the accidents related to cargo handling. Back injuries affecting a large number of workers and leave them disabled literally have a lot to do with it.

Figure 5. Tests with a reduction of up to 30% mass.

5   Conclusion

Initial studies by the team have shown, theoretically, can be obtained ceramic structures models the back such that its mass is reduced by up to 30% without loss of physical properties.

Energy saving cooking due to the decline of the mass is to be verified, but it could be estimated that would save between 5 and 15% of natural gas consumption. Given the high cost of energy, and also the technology for recycling the combustion gases, it can be estimated that the energy savings could reduce production costs by up to 20%.

Acknowledgement

References

[1]   DEFEZ B., TORTAJADA I., MAGAL T., PERIS-FAJARNÉS G., "Nuevas estrategias de diseño en baldosa cerámica", Congreso internacional conjunto XVI ADM-XIX INGEGRAF, Italia, 2007.

[2]   MORENO A., "Ceramic tiles: Above and beyond traditional applications", Journal of the European Ceramic Society, 27:1607-1613, 2007.

[3]   ESTALL V.J., "Catálogo de la colección de azulejos de serie del siglo XIX", Faenza Editrice Ibérica, Castellón, 2000.

[4]   GALINDO R., "El molde en la fabricación de la baldosa cerámica", MACER, Castellón, 2002

[5]   SANCHEZ E., GARCÍA-T EN J., REGUEIRO M., "Materias para la industria cerámica española. Situación actual y perspectivas", Boletín de la Sociedad Española de Cerámica y Vidrio, 45(1):1-12, 2006.

[6]   CAMACHO H., FUENTES M.E., FUENTES I., GARCÍA A., PÉREZ A., "Evolución de la distribución de tensiones en un cuerpo cerámico durante la cocción. Parte 1: Planteamiento de los problemas", Boletín de la Sociedad Española de Cerámica y Vidrio, 42(5):283-288, 2003.

[7]   CAMACHO H., FUENTES M.E., FUENTES I., GARCÍA A., PÉREZ A., "Evolución de la distribución de tensiones en un cuerpo cerámico durante la cocción. Parte 2: Cálculo de los perfiles", Boletín de la Sociedad Española de Cerámica y Vidrio, 42(6):353-359, 2003.

[8]   MARRERO M., RAMÍREZ A., LUCAS R., " Distribución de tensiones en las fachadas de azulejos sujetas a dilataciones térmicas", Boletín de la Sociedad Española de Cerámica y Vidrio, 45(4):259-264, 2006.

DESIGN OF DETACHABLE DRUM FOR A FRONT LOAD WASHER

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Abstract

Currently, two main types of washing machines exist in the market. Depending on how cloths are placed in and out the washer, they are classified into front-load washers and top-load washers.

Both of them present the same inconvenient and uncomfortable practice when collecting the laundry: clothes that remain at the surface of the spinning basket are difficult to reach, therefore imposing great strain into the user's back and neck area, especially in the case of front-load washers.

The aim of this work is to present the design of a detachable opening system for front-load washing machines. This design is unique since it allows the inner drum to be horizontally drawn from the whole machine in order to remove the cloths after the washing process.

This system introduces a higher efficient and comfortable procedure than current systems use. It allows the use of washers effortlessly, being especially useful for people with any kind of physical disabilities. Loading and unloading the laundry will not require the user's bending over the machine anymore.

1   Introduction

Nowadays, there is an evident need to adapt ergonomically everyday products for everyone and especially for physically disabled people.

Two kinds of washers currently exist in the market, the differentiation among them lies in the way clothes are loaded and unloaded. On the one hand, front-load washers, which account for approximately 90% of the existing models, and on the other hand, top-load washers (10%).

These front and top-load and unload systems present, among others, the inconvenience and discomfort of removing and placing the clothes inside, since reaching the clothing that remains around the drum during the centrifugation implies putting the back and neck under great strain. The system that presents the largest inconvenience or difficulties is the front-load machine.

This paper proposes the design of a detachable drum system that allows removing clothes from the washer with no need to bend over, nor introduce the arm to completely empty it, which makes this product far more efficient, and brings significant health benefits.

1.1   Legal Framework and Recommendations

The law 31/1995 of November 8th, of Occupational Risk Prevention, determines the fundamental body of guarantees and responsibilities required to establish an appropriate health protection level of workers against risks arising from work conditions. The Technical Guide of manual handling of loads (RD. 487/1997, of April, 14th) indicates that manual handling of any load with a weight higher than 3 kg may involve risk of back injury if handled under unfavourable ergonomic conditions.

2   State of the art

1

Making a brief tour through history, at first, clothes were washed by boiling them into hot water and soap. Sometimes, they were hit by wooden shovels and then placed in wooden jars. In 1780, Robinson from Lancashire patented a machine to wash and squeeze clothes but it remains uncertain whether it was finally built or not. In 1782, Henry Sidgier, from England, brings off a wooden jar-shaped washing machine which had to be impelled manually by means of a crank handle. In 1855, a machine to wash and dry clothes is built in Crimea's hospitals. In 1880, the first washing machines that heated the water by means of gas or coal came out. The engineer Nikola Tesla invented an electric engine around 1888. In 1901, the north American Alva Fisher devised the first electric washer, by adding an electric engine to one of the existing machines to propel the drum. An automatic mechanism was used to invert the whirl action so that the clothes do not get entangled.

Then, washing machines with rollers to wring the clothes were developed. After the WWII, in 1945, the off sales of washing machines began throughout the Western world. In 1960, timers were added, and few years later, microprocessors as well. In summary, from the first hand-operated washing machine to the currently existing one, different changes were implemented in a sense that washers have been almost completely transformed.

2.1   From the aesthetical point of view / perspective

The aesthetical and functional evolution of the washing machine has been especially significant along the last years due to the implementation of microelectronics. When comparing an electric washer, for instance, the one from Alva J. Fisher in 1901, to one with a futuristic design and reduced size such as the Electrolux Sfera, a giant aesthetic change can be observed even without paying attention to the also giant technological differences between those two models (Fig. 1).
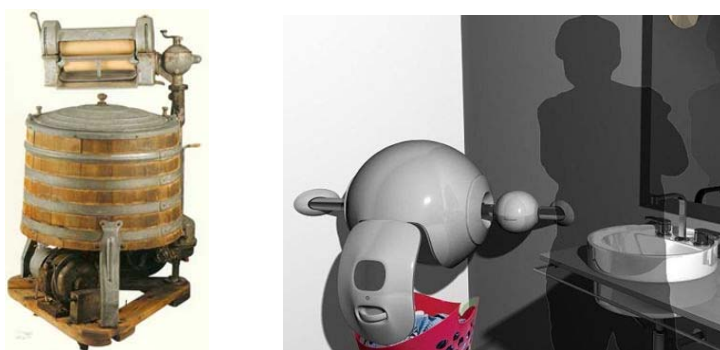
**Fig. 1 : Left. Electric washer created by Alva J.Fisher 1901.
Right. Electrolux Sfera**

Furthermore, in the aesthetic aspect, panelable appliances that were widespread in the 80's have given now way to modern formulae, curved and stylized designs, and with multiple color variations. However, industrial designers all over the world have not yet abandoned the race to find the washer of the future. The washer that will improve the previous version and will not only wash better, but also be more appealing and take up less space.

2.2   From the ecological point of view / perspective

The search for washers that are respectful with the environment is another milestone to achieve. Along these lines, some design projects can be found, such as the Kaionwave by Electrolux that do not require water or have a power consumption lower than a light bulb and the E-wash by Levente Szabo, winner of the Electrolux Design Lab 2007 contest, that use a concept of a washer employing "washing walnuts" (Fig. 2).


Fig. 2. Left. KaionWAVE washer.Right. E-Wash washer

2

3   The proposed design

The aim of this work is not to prese nt an a esthetical design but to give a functional response to the existing problem at removing clothes from a front-load washer.

After several preliminary designs and sketches based on design proposals for a washer with the m ain market advantage of h aving a detach able basket a ccommodated inside the washer drum, the de sign shown Fig. 3 was accomplished and elected for further development.
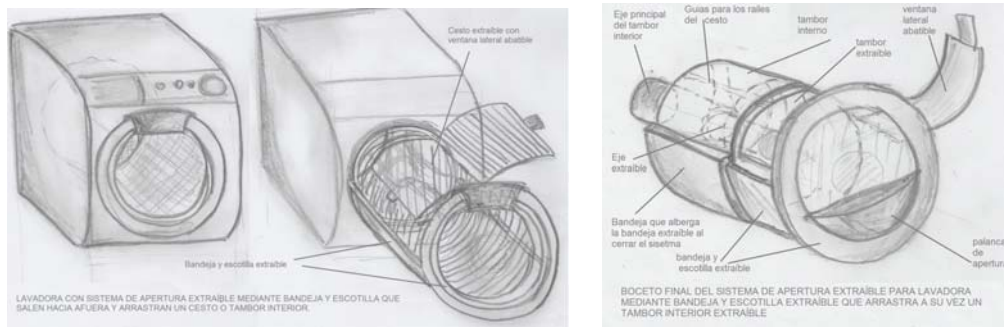

Fig. 3 Initial draft. Washer with detachable basket.

The devised system features a removable tray in charge of dragging the clothes basket. The tray draws in a hollow place intended for it an d becomes part of the interior design of the drum. Meanwhile, the detachable basket has a drop side window that allows putting in and out the clothes comfortably, with no need for awkward postures to reach the bottom of the drum.

3.1   General description / Overview of the final design

The system is composed of 68 elements, of which 33 are different. The most representative elements are shown in figures 4 and 5.

Its general dimensions differ few from the existing systems now, for t his reason, it can be easily adapted to them. Yet, the fact of being a detachable system implies enough space for the detaching action needs to be provided.

Regarding the product er gonomics, the t echnical specifications of the prese nt design are in anthropometric data der ived from the Spanish population. Namely, the opening lever must be bro ad enough to be well held. Consequently, this dimension will be close to 85.29 mm, which is the hand palm size approximately.
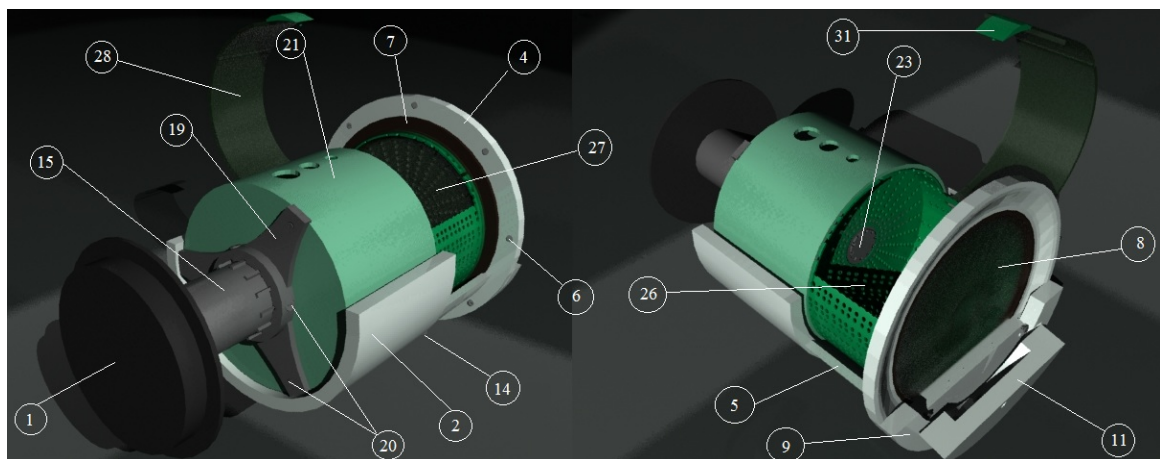
Fig. 4 Opening system for a front-load washer

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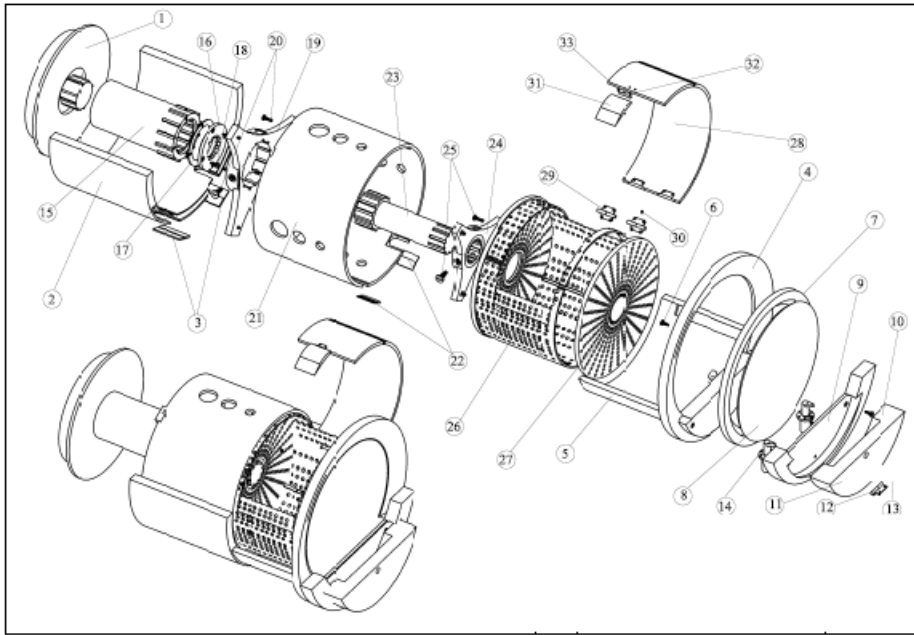
Fig. 5 Exploded-view of the detachable drum assembly.

3.2   Performance/Operation analysis

Once the main parts that compose the whole assembly are known, their function is described.

The whole set is placed on top of the supporting tray (2) (Fig. 6 left) that has a slot at the lower base in order to enable the linear displacement of the detachable tray that is part of the door (5) (Fig. 9). It also has two slots at the base where the detachable system grips fit (14) when the device is closed (Fig. 6 right). On top of this part (2) almost the whole assembly is set. This part is fixed inside the washer.
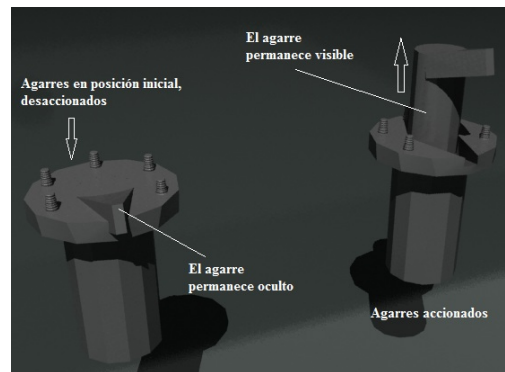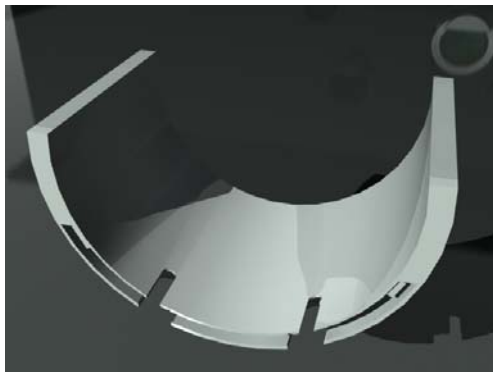
Fig. 6 .Left:. Detachable tray support. Right: Grips

The telescopic shaft (15 and 23) (Fig. 7) enables the whirl so that the washer works properly, and facilitates the extraction of the detachable drum (21) once the washing process has finished. This shaft transmits the drum movement through spreaders (19, 24) (Fig. 4 and 5). The telescopic shaft is fixed to the drum base so that the female shaft (15) becomes fixed to the drum (21) and the detachable male shaft (23) is installed in the detachable drum (26). In order to make these shafts work united, they count with a series of grooves that resemble a ribbed shaft at the base.

4
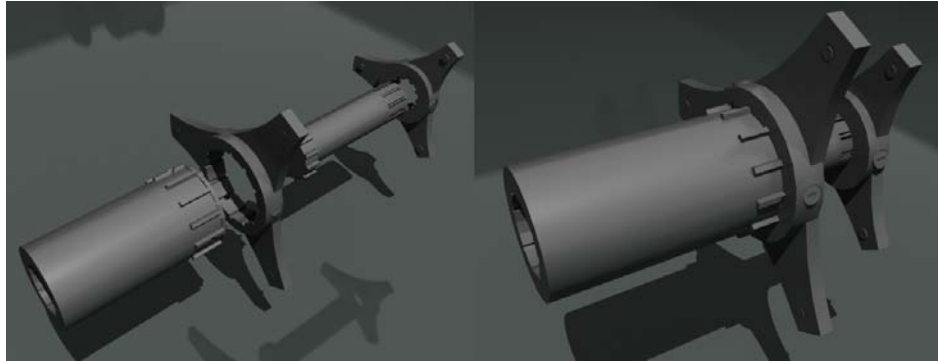
Fig. 7. Telescopic shaft and spreaders

Thereby, once the supporting system is mounted, it will count with the inside drum (21) and the detachable drum (26) (Fig. 8). Both drums must spin together when the washing process starts and stop when it finishes. This set has a bore at the base thro ugh which the telescopic shaft crosses in or der to transmit the turning movement to the whole system. Naturally, this shaft is connected at its far end with a pulleys system and an e ngine so that the w asher can operate. The above mentioned shafts transmit the engine's turning movement to the drum by means of spreaders gripped to the lower part of each drum.
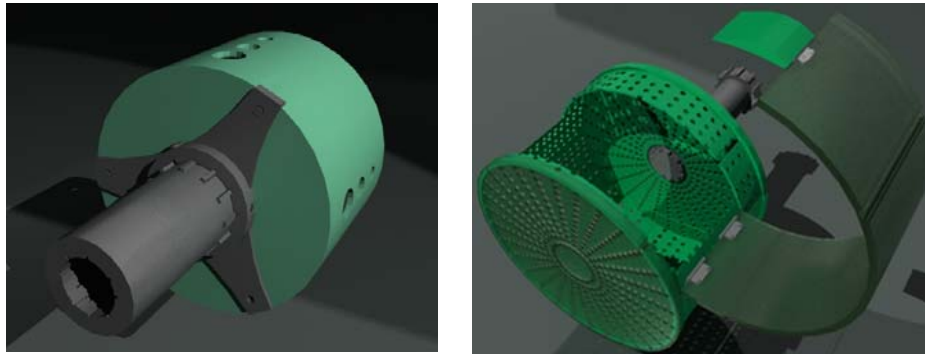
Fig. 8 Left: Inside drum. Right: Detachable drum.

The washer opens just by driving out the door outside lever (11) (Fig. 9); this lever actuates in the grips (14) located under the tra y and fasten the detachable basket (26) so t hat when the door o pens, it al so brings forward the basket and the tray that holds the system. Likewise, at this very moment, the telescopic shaft enlarges to allow this translation.

Once the s ystem is detache d, and the la bour ends, the system is to be close d. For this purp ose, the system is pushed inside by driving in the lever (11) and bringing everything inside the washer. As soon as the lever returns to its position, the grips are released and return to their init ial hidden position to the effect that the washing can begin.
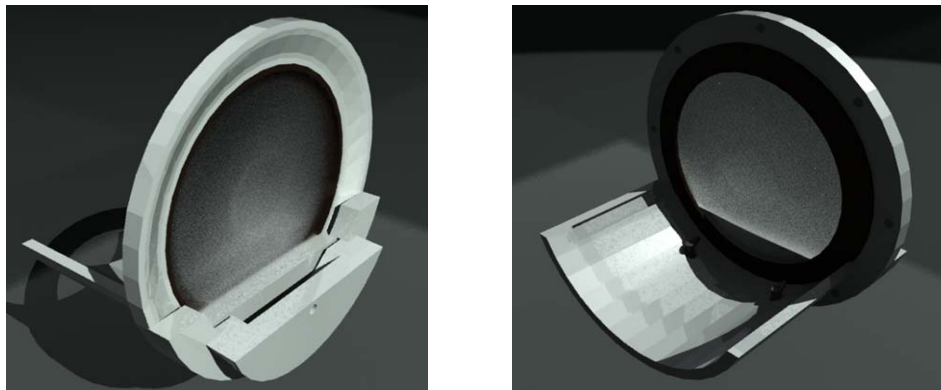

Fig. 9. Door of the washer, with hatch, opening lever, and tray.

5

Grips attached to the assembly to enable the basket detaching, are embedded in the door and opening lever, and are connected to the tray and drums so that when the system is close, it reaches the position shown in Fig. 10. left, where the grips stay hidden and do not interfere with the turning movement of the drums. At the detaching process, the grips are visible for the basket ejection as figure 10 right shows.
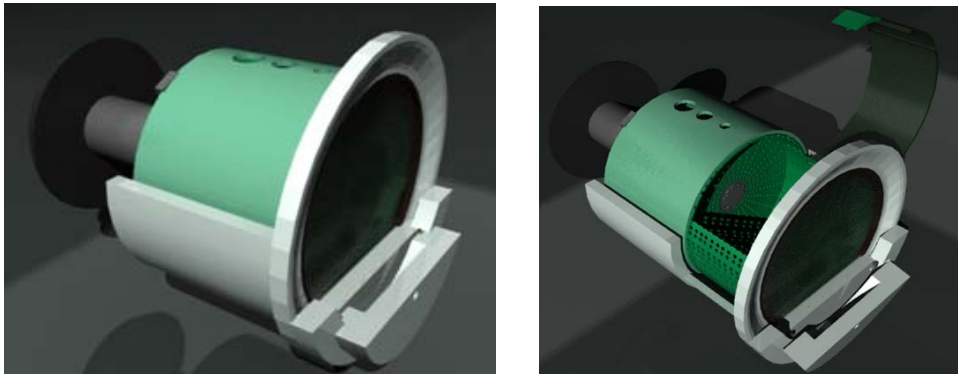
Fig. 10. Hand operated mechanism to extract the drum with grips.

In order for the detachable basket to come out in a progressive and soft manner, the inside drum counts on the consequent slots for the basket sliding movement, therefore drawing an easier extraction. The gaps intended for the grips of the inside drum are executed as slots to ensure the system closure, while in the detachable drum are performed as inside bores where they are fixed (Fig. 11).
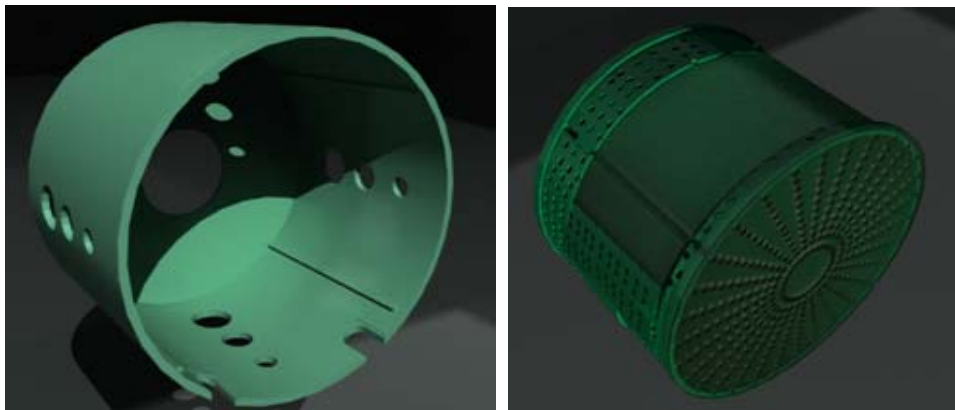
Fig. 11 Inside detachable basket with swing door (close)

The detachable drum has a transparent opening at the top that opens to one side. Through this opening, the clothes are loaded or/and unloaded. Once this action is done, the upper opening is closed again. (Fig. 11)

Fig. 12 The system open.

Just by pushing the door inside and pressing the lever again, the system closes. Then, the microcontact works one more time and locks the door at the same time releasing the detachable basket grips. Once this is done, the basket is also released and spins together with the inside basket when the washing process is selected to initiate. Finally, figure 12 shows how the system remains when it is open.

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4 Conclusion

Although the presented design of an opening system for front-load washers with double detachable drum is aimed to any public in general, it provides a higher impact among people with reduced mobility.

The chosen dimensions differ few from any conventional washing machine. It is also important to highlight that dealing with a detachable system requires a major usage of space for proper operation. It is possible to use any kind of engine to operate the whirling action, however a Direct Drive motor is highly recommended for having greater advantages. This is a completely different design to what can be found in the market, a novel, functional and efficient design. This opening system allows the process of loading and unloading clothes at any moment in a comfortable way, all this thanks to an inside drum that can be easily, softly and progressively detached.

References

[1] Richardson, T y Lokensgard, E. (20 00). Industria del plástico: plástico industrial Ed. Paraninfo 2000.

[2] Shisley, J E. y Mischke, Ch. R. (2002). Diseño en ingeniería mecánica. Ed. MacGraw Hill (6º Ed.).

[3] Askeland, D. R. (2001). Ciencia e ingeniería de los materiales. Ed. Paraninfo. Madrid.

[4] Norton, Robert L. (2009) Di seño de maquinaria. Síntesis y análisis de máq uinas y mecanismos. (4º ed.) Ed. Mc Graw Hill

[5] Shackelford, J. F. (2010). Introducción a la Ciencia de los Materiales para Ingenieros. (7ª ed.). Ed. Pearson educación.

[6] Ramos Carpio, M.A. (1988). Ingeniería de los materiales plásticos.. Ed. Díaz de Santos.

[7] Alcaide Marcial, J; Diego Más, J. y Artacho Ramírez, M. . Diseño de producto. El proceso de diseño. SPUPV. Valencia, 2001

[8] VV.AA Manual de ergonomía (1997) Ed. Mapfre

[9] VV.AA Ergonomía (2003) Ed. Instituto Nacional de Seguridad E.H.

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METHODOLOGY FOR A SUSTAINABLE PRODUCT DESIGN

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Abstract

Sustainability applied to industrial processes allows the companies to obtain both lower environmental impact and higher quality products, as well as to improve the company image and to reduce the manufacturing costs. In order to obtain a more sustainable product development, a methodology that preserves the initial specifications of the product and applies design criteria to reduce its environmental impact, is implemented in this paper.

Two main strategic lines based on the optimization of materials and processes are applied. The eco-indicators of global energy, greenhouse gases emissions and water consumption are used to assess the methodology proposed in the case of a solar tracker mechanism. Because the mass and energy needed to manufacture the components are optimized, a significant reduction on eco-indicator levels is achieved in the new product design.

1 Introduction

The industrial world is increasingly aware of environmental impact of the products it makes [1]. In order to integrate environmental considerations into product development, the combination of eco-design with life cycle assessment is suggested [2-4].

Life cycle assessment (LCA) is an environmental management tool internationally recognised through the standard ISO 14040 [5]. It allows evaluating overall environmental impacts through the analysis of a number of inputs (raw material, energy and water) and outputs (emissions, products) and it helps to identify which are the stages and industrial activities most problematic related to the specific product through its total lifetime (fig. 1).
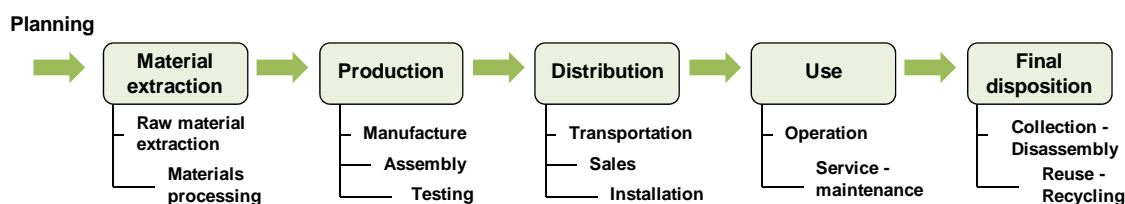

Fig. 1. Stages of the product life cycle.

Van Hemel [6], supported by the United Nations Environment Programme [7], created the Life Cycle Design Strategies Wheel or LiDS wheel (fig. 2), in which different strategies to achieve sustainability are identified around the product life cycle. The following strategies were proposed: new concept development, selection of low-impact materials, reduction of materials, optimization of production techniques, selection of efficient distribution systems, reduction of the environmental impact in the use stage, optimization of initial life-time and optimization of end-of-life system. The LiDS wheel can be used to estimate the environmental profile of an existing product or to qualify the action plan for a new and more sustainable product.
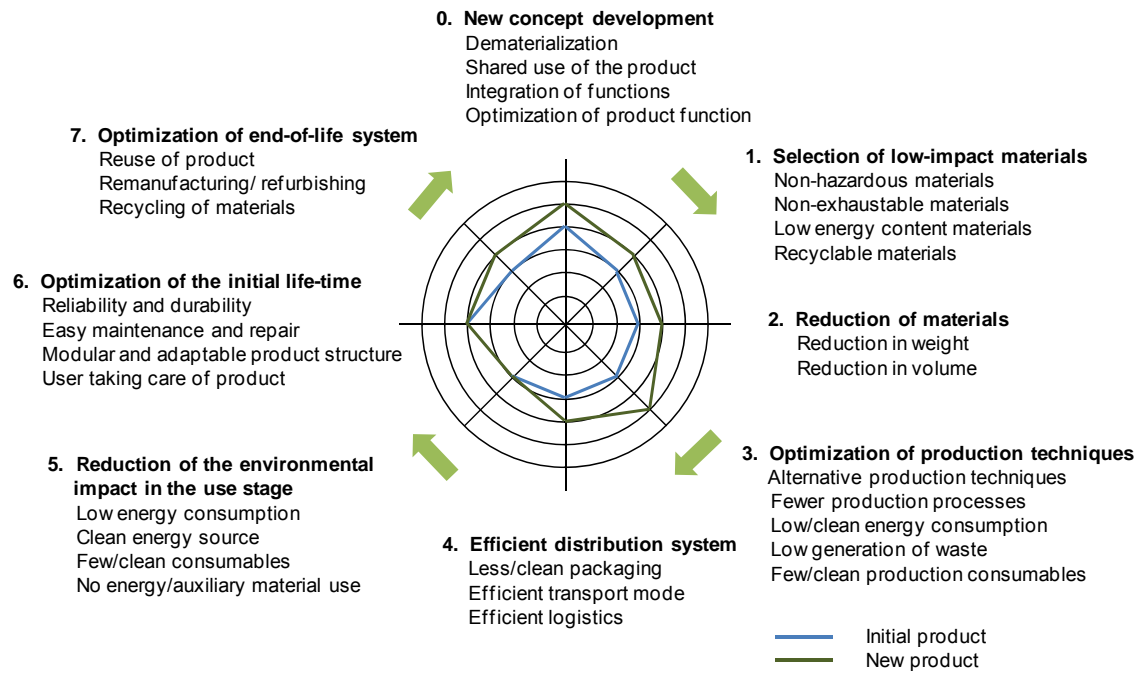
0. New concept development
Dematerialization
Shared use of the product
Integration of functions
Optimization of product function

7. Optimization of end-of-life system
Reuse of product
Remanufacturing/ refurbishing
Recycling of materials

6. Optimization of the initial life-time
Reliability and durability
Easy maintenance and repair
Modular and adaptable product structure
User taking care of product

5. Reduction of the environmental impact in the use stage
Low energy consumption
Clean energy source
Few/clean consumables
No energy/auxiliary material use

4. Efficient distribution system
Less/clean packaging
Efficient transport mode
Efficient logistics

1. Selection of low-impact materials
Non-hazardous materials
Non-exhaustable materials
Low energy content materials
Recyclable materials

2. Reduction of materials
Reduction in weight
Reduction in volume

3. Optimization of production techniques
Alternative production techniques
Fewer production processes
Low/clean energy consumption
Low generation of waste
Few/clean production consumables

Initial product
New product

Fig. 2. The LIDS wheel. Source: Van Hemel (1998).

This work focuses on the early stages of the product life cycle and it aims at the application of product design criteria to make it more sustainable. First, a methodology to adequately select materials and processes is proposed. Next section shows how this methodology is implemented in a case study. Eco-indicators of the initial and new products are compared in the last section.

2 Methodology

In order to achieve a more sustainable product development two main strategic lines are proposed: optimization of materials and optimization of processes. As shown in fig. 3, a number of tasks supported by suitable design criteria should be developed to improve the product sustainability. A set of eco-indicators are finally obtained to evaluate alternatives and to facilitate the selection of materials and processes.
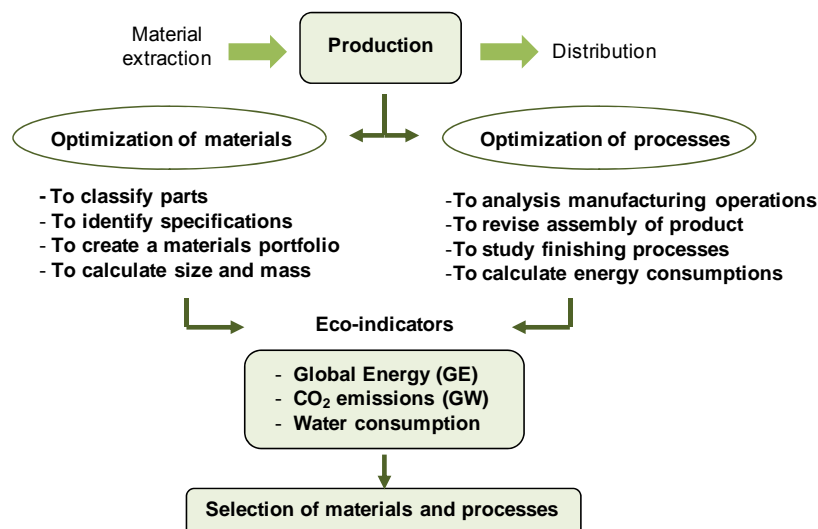
Fig. 3. Methodology for a more sustainable product development.
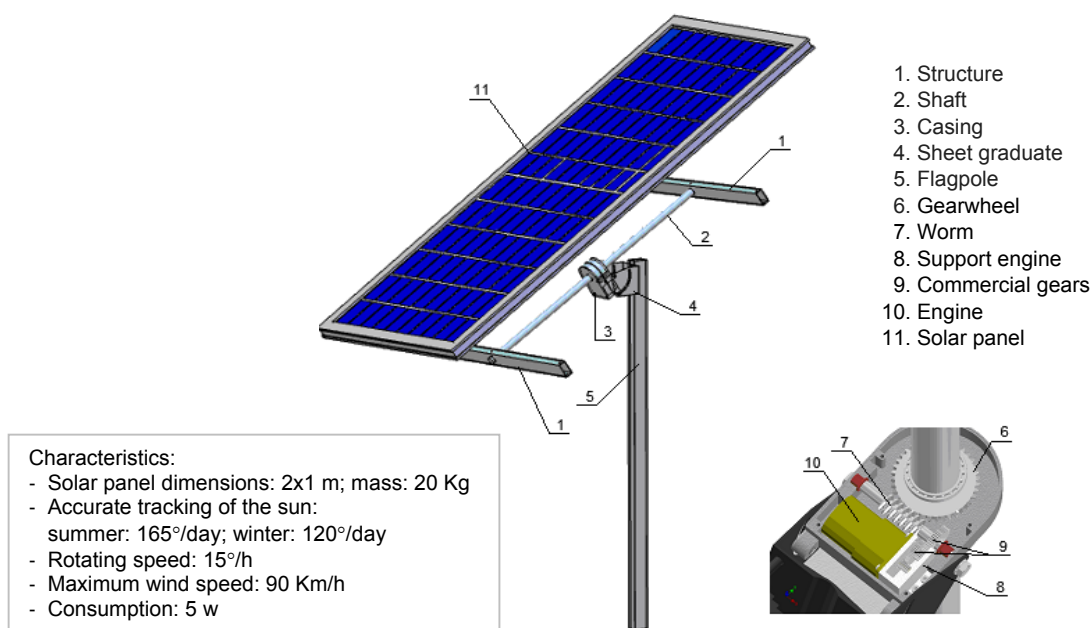
The optimization of materials for each component of a specific product involves both the correct selection of the material to make it and the suitable evaluation of their mass. The analysis of the product structure and the classification of their parts are initially required tasks.

Afterwards, the identification of design specifications, the creation of a possible materials portfolio and the calculation of the size and mass for those materials able to fulfil design specifications, are carried out.

On the other hand, the optimization of processes implies the analysis of manufacturing operations, machines consumptions, joint systems and finishing processes involved in the product development. Materials and processes needed in packaging are also addressed. The following design criteria are proposed: reduction of the materials number, minimization of the raw material and material removed masses, increasing use of commercial components and easy product disassembly.

3   Case study

The product examined in this work is a single-axis solar tracker for household systems or low power installations. The components of this mechanism are shown in fig. 4. The photovoltaic panel is positioned on an aluminum structure and is programmed to daily follow the motion of the sun. Furthermore, it can be seasonally adjusted in order to obtain an increase of the energy production. The solar tracker must resist exposure to the weather and it should have low maintenance.

1. Structure
2. Shaft
3. Casing
4. Sheet graduate
5. Flagpole
6. Gearwheel
7. Worm
8. Support engine
9. Commercial gears
10. Engine
11. Solar panel

Characteristics:
- Solar panel dimensions: 2x1 m; mass: 20 Kg
- Accurate tracking of the sun:
  summer: 165°/day; winter: 120°/day
- Rotating speed: 15°/h
- Maximum wind speed: 90 Km/h
- Consumption: 5 w

Fig. 4. Solar tracker components.

Different materials were used to manufacture this mechanism. The mass of each one and the mass of raw material used along the manufacturing process are shown in tab 1. As can be seen, the packaging mass was included in the raw material list, but no contributes to the final product mass.

Materials	Mass (Kg)	Raw material (Kg)	Machines	Time (s)	Energy (Kw·s)
Galvanized steel	16.95	16.97	Saw	14	2.7
AISI 304	0.93	1	CNC Turning	194	32.4
F-1100	0.02	0.03	CNC Milling	572	506.9
Aluminium	1.98	1.99	Drill	37.4	10.3
Nylon	0.03	0.06	Guillotine	4.5	0.22
Polypropylene	0.30	0.31	Folding mach.	3.5	$0.5 \cdot 10^{-3}$
Packaging	-	2.36	Injection mach.	240	156.5
Total	**20.22**	**22.74**	**Total**	**1065.4**	**709.3**

Tab. 1. Solar tracker materials and manufacturing parameters. Initial product.

The sequence of operations required to manufacture each part of the solar tracker was analyzed in detail. Tab. 1 shows the machines list, the estimated processing times in each machine and the resulting energy consumptions to carry out a complete device.

3.1 Eco-indicators of the initial product

Specific software was used to calculate eco-indicators of the product. The input data was structured in the following blocks:
- Product mass, that takes into account the mass of materials making up the product.
- Processing, where the energy and consumables needed along the manufacturing process are specified.
- Material removed, where the difference between raw material and product masses is considered.
- Packaging, that includes data of materials used at this stage of the product development process.

In this work, global energy (GE), global warming (GW) and water consumption are obtained. These eco-indicators represent respectively, the overall energy consumed along the product development process, from the raw materials extraction phase to the packaging, the mass of CO_2 emitted to the atmosphere and the water volume consumed along this process. Values for each input block ant total values are shown in tab. 2.

	GE (MJ)	GW (KgCO$_2$)	Water (l)
Product mass	1645.8	106.5	341.4
Processing	4.8	0.23	0.6
Material removed	12.4	0.94	6.5
Packaging	82.9	1.49	109.9
Total	**1745.9**	**109.2**	**458.4**

Tab. 2. Solar tracker eco-indicators. Initial product.

We can observe that the product mass with a contribution over 90% is the most influential factor on eco-indicators. Nevertheless, the effect of each material is different. Fig. 5 shows the product mass distribution for four materials: galvanized steel, stainless steel, aluminium and polypropylene. Moreover, it is represented how each material contributes to increase the global energy and global warming eco-indicators in the initial product. It should be noted that the aluminium mass is only 10% of the total product mass but it represents respectively, 37.5% and 30% of the GE and GW eco-indicators.

Solar tracker - Initial product
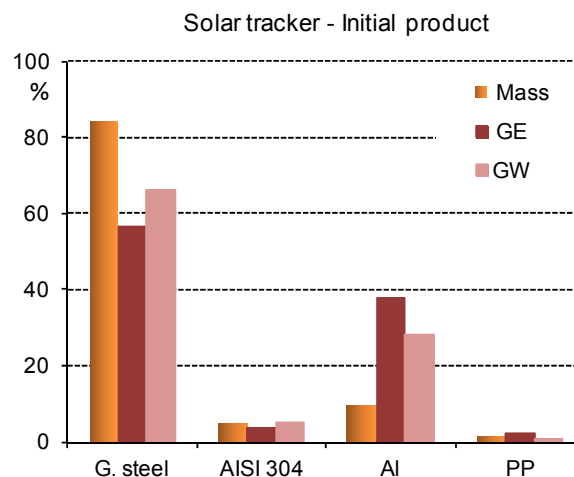
Fig. 5. Distribution of mass, GE and GW eco-indicators for different materials.

3.2 Optimization of materials

The non-commercial components of the solar tracker, which were marked from 1 to 8 in fig. 4 are analyzed in this section. Components are arranged in agreement with their initial volume in tab. 3. The design specifications for each one as well as possible materials able to fulfil them are listed. Each alternative was studied and the resulting sizes and component masses are also shown.

Next, global energy, global warming and water consumption eco-indicators were calculated for each material. Results are shown in tab. 4. Those materials with the lowest eco-indicators, which are galvanized steel and polypropylene, are finally selected. As will be seen in tab. 5 of the next section, a substantial reduction of 33% for the total product mass is consequently obtained.

Solar tracker					
Component	**Specifications**	**Materials portfolio**	**Size and mass**		
Flagpole	- Weatherability - Strength (C_s=3) - Max. turn of panel: 53° front, 82.5° side	- Galvanized steel - AISI 304 - Aluminium - Nylon	- Length: 1200 mm		
			G. steel: 60x30x4 mm; 6.17 Kg	AISI 304: 60x30x4 mm; 6.28 Kg	Aluminium: 60x40x5 mm; 2.24 Kg
Structure	- Weatherability - Strength (C_s=3) - Solar panel: 2x1m	- Galvanized steel - AISI 304 - Aluminium - Nylon	- Length: 1150 mm		
			G. steel: 40x30x1.5mm; 1.82 Kg	AISI 304: 40x30x1.5mm; 1.85 Kg	Aluminium: 50x30x2 mm; 0.93 Kg
Shaft	- Weatherability - Strength (C_s=3) - Solar panel: 2x1 m	- Galvanized steel - AISI 304 - Aluminium - Nylon	- Length: 1000 mm		
			G. steel: ϕ=30;e=4 mm; 2.56 Kg	AISI 304: ϕ=30;e=4 mm; 2.60 Kg	Aluminium: ϕ=30 mm; 0.93 Kg
Casing	- Weatherability - Strength (C_s=3)	- Polypropylene - Polystyrene - Wood	PP: 0.283 Kg	PS: 0.321 Kg	Wood: 0.206 Kg
Sheet graduate	- Weatherability - Strength (C_s=3)	- Galvanized steel - AISI 304	- Thickness: 3 mm;		
			G. steel: 0.845 Kg		AISI 304: 0.861 Kg
Worm	- Strength (C_s=3)	- Polypropylene - Polystyrene - Nylon	- Length: 116 mm		
			PP: 0.011 Kg	PS: 0.012 Kg	Nylon: 0.014 Kg
Gearwheel	- Strength (C_s=3)	- Polypropylene - Polystyrene - Nylon	PP: 0.010 Kg	PS: 0.011 Kg	Nylon: 0.012 Kg
Engine support	- Engine dimensions: 70x70x114 mm	- Polypropylene - Polystyrene - Nylon	PP: 0.005 Kg	PS: 0.006 Kg	Nylon: 0.007 Kg

Tab. 3. Components of the solar tracker. Size and mass for different materials.

Component	Eco-indicators	Materials					
		G. steel	**AISI 304**	**Al**	**Nylon**	**PP**	**PS**
Flagpole	GE (MJ)	209.78	382.8	431.5	-	-	-
	GW (KgCO_2)	17.44	38.29	23.18	-	-	-
	Water (l)	0	467.3	0	-	-	-
Structure	GE (MJ)	61.88	112.92	179.14	-	-	-
	GW (KgCO_2)	5.15	11.29	9.62	-	-	-
	Water (l)	0	137.84	0	-	-	-
Shaft	GE (MJ)	87.04	158.83	389	-	-	-
	GW (KgCO_2)	7.24	15.88	20.9	-	-	-
	Water (l)	0	193.88	0	-	-	-
Casing	GE (MJ)	-	-	-	-	20.57	27.84
	GW (KgCO_2)	-	-	-	-	0.56	0.89
	Water (l)	-	-	-	-	1.36	1.57
Sheet graduate	GE (MJ)	28.73	52.42	-	-	-	-
	GW (KgCO_2)	2.39	5.24	-	-	-	-
	Water (l)	0	64	-	-	-	-
Worm	GE (MJ)	-	-	-	1.67	0.8	1
	GW (KgCO_2)	-	-	-	0.12	0.02	0.03
	Water (l)	-	-	-	0.22	0.05	0.06
Gearwheel	GE (MJ)	-	-	-	1.4	0.7	0.95
	GW (KgCO_2)	-	-	-	0.1	0.02	0.03
	Water (l)	-	-	-	0.2	0.04	0.05
Engine support	GE (MJ)	-	-	-	0.84	0.36	0.52
	GW (KgCO_2)	-	-	-	0.06	0.009	0.02
	Water (l)	-	-	-	0.11	0.024	0.03

Tab. 4. Components of the solar tracker. Eco-indicators for different materials.

3.3   Optimization of processes

If tab. 1 is examined, we observe that the machine more time used and that more energy consumes along the manufacturing process is the milling, but the number of operations is low and the most of them are simple. Hence, the processing block has a small effect on eco-indicators (tab. 2). Energy consumption was mainly improved through the efficient use of injection machine to manufacture the worm, gearwheel and engine support components using polypropylene instead of machining nylon. As consequence, a slight reduction of 6% was obtained in the energy consumption (tab. 5).

Materials	Mass (Kg)	Raw material (Kg)	Machines	Time (s)	Energy (Kw·s)
Galvanized steel	13.21	13.38	Saw	7.9	1.8
AISI 304	-	-	CNC Turning	2.5	0.4
F-1100	-	-	CNC Milling	254.1	488
Aluminium	-	-	Drill	32.1	9.1
Nylon	-	-	Guillotine	4.5	0.22
Polypropylene	0.31	0.34	Folding mach.	3.5	$0.5 \cdot 10^{-3}$
Packaging	-	0.8	Injection mach.	480	167.1
Total	**13.52**	**14.52**	**Total**	**782.7**	**666.6**

Tab. 5. Solar tracker materials and manufacturing parameters. New product.

In order to reduce the material removed along the production process, structural profiles, metallic sheet and plastic pellets were conveniently selected. Thus, if we observe the mass data of the new product in tab. 5, only 0.2 Kg of raw material is removed along the production process. Packaging was also modified, because the overall size of the product is smaller, the initial cardboard box of 0.4x0.4x1.6 m was also reduced to 0.12x0.14x1.3 m. Thus, a notable increase from 9 to 48 was achieved in the number of boxes stored on a pallet and a considerable reduction from 2.36 to 0.8 Kg was obtained in the packaging mass.

Qualitatively, the improvement of the product environmental profile can be shown through the difference between the new and initial product overall ratings in the LiDS wheel (fig. 6). The scales on the wheel range from 0 (dead center) to 6 (outer radius). This improvement is particularly noted for the strategies involved along the initial stages of the product life cycle.
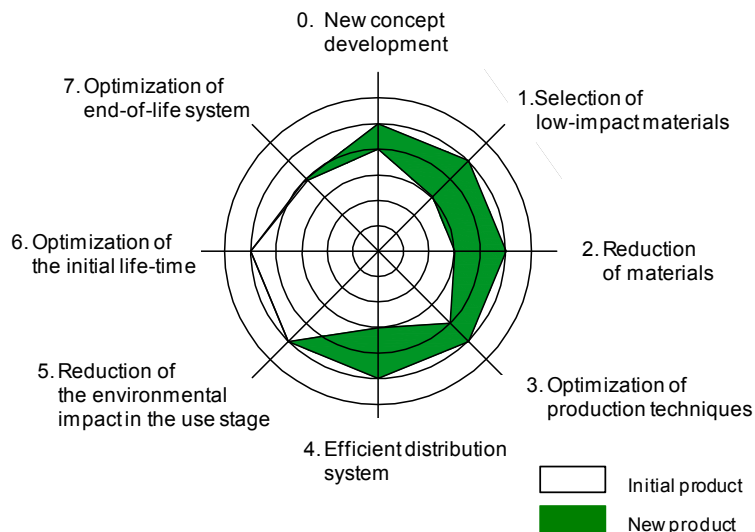
Fig. 5. Overall ratings for the initial and new designs of solar tracker.

3.4   Eco-indicators of the new product

The global energy (GE), global warming (GW) and water consumption eco-indicators were also determined for the new product. Tab. 6 shows a significant decrease of eco-indicator levels for each input block due to the optimization strategies applied. GE and GW experience a reduction around 33% in the product mass and processing blocks, while this reduction go up approximately 60% for the material removed and packaging blocks.

	GE (MJ)	GW (KgCO$_2$)	Water (l)
Product mass	1075.8	69.4	270.7
Processing	3.2	0.15	0.3
Material removed	5.3	0.4	0.09
Packaging	31.4	0.5	47.4
Total	**1115.7**	**70.4**	**318.5**

Tab. 6. Solar tracker eco-indicators. New product.

Total values of eco-indicators obtained for the new product are compared with those obtained for the initial product in fig. 6. A reduction of 35% is achieved for global energy and global warming eco-indicators. The water consumption drops 30 % due mainly to the substitution of aluminium by galvanized steel.
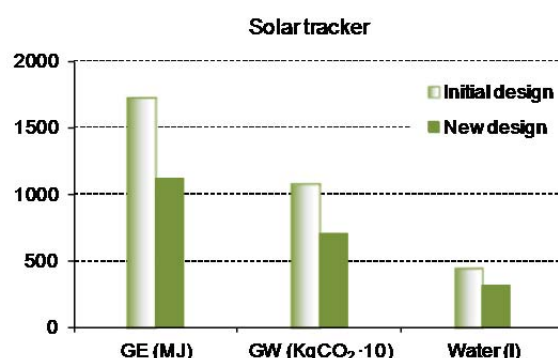
Fig. 6. Variation of product eco-indicators.

4 Conclusion

In this paper, two main strategic lines affecting the early stages of the product life cycle have been proposed to achieve a more sustainable product: optimization of materials and optimization of processes. These strategies have involved the development of a number of tasks supported by the application of suitable design criteria. The approach has been implemented to improve the design of a solar tracker mechanism. Eco-indicators of global energy, global warming and water consumption have been respectively obtained for the initial and new product.

The product mass has been the most influential factor in the sustainability improvement of the product. Applying strategies of materials optimization, a reduction of 33% has been achieved in the product mass and the number of different materials has been reduced. Particularly, aluminium has been substituted by galvanized steel and nylon by polypropylene. The optimization of process has been focused on the reduction of material removed and packaging masses, where a drop around 60% has been achieved. As a result of the methodology implementation, the initial product specifications have been preserved while also a total decrease over 30% has been obtained in the eco-indicators.

References

[1]   C. van Hemel, J. Cramer. *Barriers and stimuli for eco-design in SMEs.* Journal of Cleaner Production 10 (2002) pp 439-453.
[2]   W. Wentzel, M. Hauschild, L. Alting. Environmental assessment of products, vol. 1: Methodology tools and case studies in product development. Kluwer Academic Publisher, Norwel, Mass. USA, 2001.
[3]   IHOBE - Sociedad Pública de Gestión Ambiental. Manual Práctico de Ecodiseño. Operativa de implantación en siete pasos. Ed. IHOBE, S.A. 2000.
[4]   W. Wimmer, R. Zust, K. Lee. Ecodesign implementation. A systematic guidance on integrating environmental considerations into product development. Springer Science Media Dordrecht, 2004.
[5]   ISO 14040: 2006. Environmental management. Life cycle assessment. Principles and framework, 2006.
[6]   C. van Hemel. Eco-design, empirically explored. Thesis, Delf University of Technology, 1998.
[7]   United Nations Environment Programme (UNEP). Design for sustainability. A step-by-step approach. website: http://www.d4s-sbs.org/.

THE GOLDEN RATIO IN PRODUCT DESIGN

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Abstract

Nature can not only inspire many solutions in engineering design, but are also efficient, practical and sustainable solutions. This is because over millions of years of evolution, using the technique of trial and error, nature itself has produced effective solutions to the problems of the real world, even discovering new technologies, new materials and new processes when it was necessary.

The difficulty we have to introduce what is observed in nature in the design of a product and how to express it mathematically. The golden ratio can be expressed mathematically aspects in nature, forms that facilitate the design of more efficient products.

In this paper we show how, in addition to aesthetics, the golden ratio gets better technical results; as is the case of the design of a blade of a wind turbine.

1   Introduction

From the beginning, mankind has always observed nature, has tried to get to know it, understand it, learn from it and imitate since its survival depended on it. Since the discovery of fire for heat and then cook food, to designing and making objects and utensils made from wood, bone, stone, etc.

If thousands of years ago the need to rest it was satisfied with sitting on a rock, on a log or on a mound today, the derivative is a chair. Thus, the need to drink led to the design of a glass, preying on a spear, moving on a bicycle, etc. Clearly, many of the creations and designs developed by man stem from patterns observed in nature.

Nature can not only inspire many solutions in engineering design, but are also efficient, practical and sustainable solutions. This is because over millions of years of evolution, using the technique of trial and error, nature itself has produced effective solutions to the problems of the real world, even discovering new technologies, new materials and new processes when it was necessary. Janine Benyus wrote in her book Biomimicry:

Innovation inspired by nature in 1997 [1]: "After 3.8 billion years of research and development, failures are fossils, and what surrounds us is the secret of survival".

Some representative examples of the efficiency of nature can be: the spider web, five times more tensile strength than steel; elastic resins produced by mussels, with ability to adhere to wet surfaces; honeycombs with hexagonal shapes, able to store more honey with lower consumption in building materials; or the level of sustainability of balanced ecosystems, capable of amazing recoveries to serious disturbances [2].

Thus, using nature itself as field data collection, and with the aim of bringing technology to the different designs and processes that nature has evolved, Julian Vincent, at the Center for Biomimetic and Natural Technologies at the University of Reading in England has developed a database of "biological patents" [3], in which a multitude of designs and processes found while watching nature are collected.

Biomimetics, a term coined by Otto Schmitt in the 1950s, is the application of methods and natural systems to engineering and technology. This means looking at nature and learning how different species have faced their challenges in the struggle to develop a competitive advantage, analyze the keys to its success and using this knowledge as a source of inspiration for the development of innovative solutions.

However, all the adaptations that occur in nature do so by maintaining a balance between different biological functions, often contradictory. Therefore, it is essential to isolate those details or specifics of natural designs involved in improving a property, in demand for the particular design of each case [2].

Thus, if a particular design objective is to improve the resistance property to a particular kind of efforts, it is logical to consider the adjustments that nature has developed to provide or improve that particular property, to understand how this feature works without backing to nature, to try to play them after studying isolation of their biological functions [4].

Each discipline derives from nature its technological solutions in a different way. Biology is focused on:

- Replicating natural manufacturing methods, such as production of chemical compounds by plants and animals.

- Imitating mechanisms found in nature such as Velcro and gecko tape.

- Apply the principles of social organization of organisms like ants, bees, and microorganisms.

Architecture analyzes the structures and more efficient ways of nature. An example of application in the design of structures can be inverted catenary used by Gaudí in the Park Guell, as biomimetic inspiration to maximize performance, optimize routes or ways to minimize tensions, etc.

Medicine has always been based in nature to obtain drugs, both using substances directly obtained from nature and observing the behaviour of the different viruses and bacteria. Sometimes the finished product is even taken even directly from nature as in the case of organ transplants.

Economy, the currency market specifically uses the Fibonacci sequence as trend pattern.

Engineering and industrial design developed forms, structures and mechanisms in the design of technology, based on those used by other beings of nature. A lot of examples are collected in the database of "biological patents" Dr. Vincent.

In this comprehensive set of designs, shapes and processes found in nature, appears and surprises, a proportion that has been used historically: the golden ratio.

2   The golden ratio

Very often, in different aspects of nature, patterns and shapes that repeat appear. An example of this can be seen in the shells of molluscs, the antlers of some animals or the distribution of pipes in a sunflower (Fig. 1). Following an analysis of these forms is relatively simple to find the golden ratio, reason why they are known as golden forms.

Fig. 1 Golden forms in nature

The golden ratio, also called golden, is an irrational number represented by the Greek letter Phi (Φ) and whose value is (1 + √5) / 2 ≈ 1.6180339887. It can be used to split a line or rectangle into two unequal parts, so the keep an identical to that between the majority and the initial element proportion (Fig. 2). This ratio creates another proportionally identical to the original line, a factor to consider in the growth of the elements. It has some interesting properties and was discovered in antiquity, not as "unity" but as a ratio or proportion [5]

Fig. 2 Golden ratio

$$\frac{x}{1} = \frac{1+x}{x} = \; \Phi = 1.618033 \dots$$

Knowing its mathematical expression [6], allows to display certain characteristics of the golden ratio, and also favors its use in generating forms that can serve as a basis for product design [7] . Will help to know the different ways it can acquire as the golden rectangle (Fig. 3), the golden spiral (Fig. 4), the golden triangle (Fig. 5), golden angle (Fig. 6) as well as the Fibonacci sequence, fractals, etc. [8]
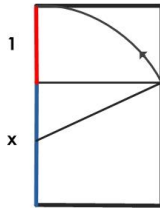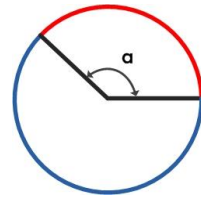

*Fig. 3 Golden rectangle* *Fig. 4 Golden spiral* *Fig. 5 Golden triangle* *Fig. 6 Golden angle*
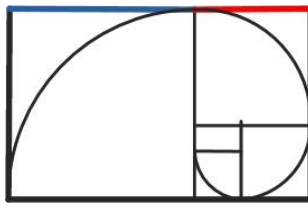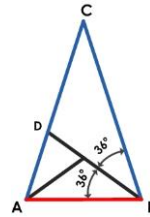
One of the most popular features of the golden ratio is the special aesthetic that provides forms and objects that follow it. That is why, throughout history, has been used in many architectural elements and works of art that convey to those who observe a feeling of beauty and harmony.

There are not few works of art in which we have used the golden ratio. Between them, Las Meninas by Diego Velazquez (Fig. 7), the Mona Lisa (Fig. 8) of Leonardo Da Vinci, Two harlequins (Fig. 9) and The Last Supper (Fig. 10) of Salvador Dalí, and various works of Eduardo Chillida, it gives them universality and timelessness.
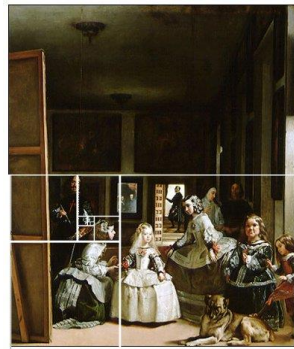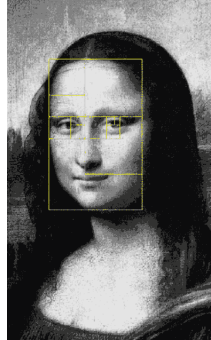
Fig. 7 Las Meninas *Fig. 8 The Mona Lisa*

Fig. 9 two harlequins *Fig. 10 The Last Supper*
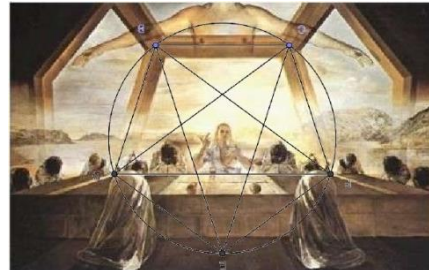
Meanwhile, some of the examples of architectural elements using the golden ratio are: the pyramid of Cheops (Fig. 11), the Parthenon in its symmetry (Fig. 12) and facades, or the proportions of the Eiffel Tower (Fig. 13).
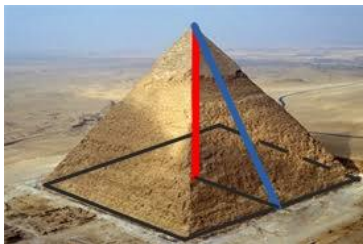
Fig. 11 the Cheops pyramid *Fig. 12 the Parthenon* *Fig. 13 Eiffel tower*
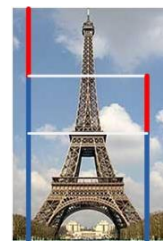
You can also find examples of using the golden ratio apart from art and architecture. Thus, in music, you can see the golden ratio in the formal structures of the sonatas of Wolfgang Amadeus Mozart and the Fifth Symphony by Ludwig van Beethoven. Even the foreign exchange market is affected, as the Fibonacci sequence is used as trend pattern [9].

It is evident that throughout history this proportion has been used by the man with a basically aesthetic purpose, mainly in the field of art and architecture. As regards nature, it is conceivable that the golden ratio is related to the improvement of other properties and characteristics of those elements on which it is located. An example that can support this hypothesis is the egg shape. While in the golden ratio geometry (Fig. 14) clearly appears, it seems quite apparent that this geometry has related skills necessary to protect their content.
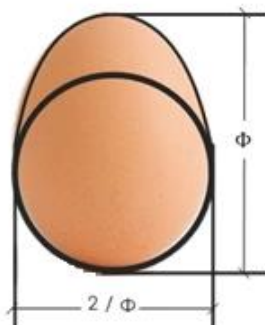
Fig. 14 Golden ratio in the egg

Although the fields of application of this ratio can range from medicine, biology, architecture, art or the currency market, to engineering in general, this article aims to focus on its application in industrial design. More specifically in the natural use of the golden ratio in the design of a product, without using it solely from the perspective of beauty, and taking into account the relationship which gives the shape or feature natural element, in order to bring that certain property to our product.

3   Methodology

Therefore, it is necessary to define a method aimed at transferring naturally occurring forms to industrial design, in order to obtain products more aesthetically attractive and, from the functional point of view, more efficient.

The possibility of expressing mathematically forms of nature has obvious advantages:
- Easy to play at different scales
- High accuracy in reproducing forms, avoiding the use of Bezier curves or spline
- Define a clear methodology for the transfer forms.

These mathematical expressions can be treated by current software representation of mathematical functions which, attached to the three-dimensional aided design systems, may allow direct passage of natural forms to product design.

Some of these natural forms have been made mathematically. One example is the involute [6], a natural curve that can be observed in the peak of the eagles in the dorsal fins of sharks, in the leaves of some palms, etc. This curve, defined as the path described by the end of a rope winding in a cylinder, is used as a basis for designing the tooth profile of a gear. The parable is the curve that takes a cable that has to bear a burden, and that is used for the design of satellite dishes using their particular characteristic in the reflection of a wave.

In the case of the golden ratio, it seems logical that may have associated properties still unknown and that could improve different aspects of design properties of some products. This hypothesis opens the door to developing multiple lines of research.

For example, the particular form of the portion containing flowers nectar, an aromatic aqueous solution produced to attract the insects responsible for pollination, could enhance the aroma thereof, increasing system efficiency. It is conceivable, therefore, that the use of a golden way to design a bottle of cologne, besides providing proper aesthetics to the marketing and sale could in turn enhance the flavor of its contents.

In this sense, different lines of research in different fields of application have already produced the first results. Thus in Suzumoto et al. [10], using a three-dimensional PV module whose configuration is based on the Fibonacci numbers, in order to make more efficient use of sunlight is proposed. Agrawal and Aware

[12] proposed a method of finding the golden section which is used to optimize an algorithm tracking the maximum power point of photovoltaic systems.

In the field of radiation medicine, during a dynamic MRI (RMD), the kinetic motion or contrast variability are often difficult to predict, which hinders the proper choice of update rate of the image or temporal resolution. In Winkelmann et al. [12] demonstrate that a system based on the golden ratio is the optimal value for the reconstruction of images in a dynamic magnetic resonance (RMD).

A.P. Manso et al. [13], investigated the influence of the geometrical parameters of the cross section of the flow channel in the performance of a fuel cell proton exchange membrane. After analyzing different cross sections, it is concluded that the best performance occurs when the relationship between the height and width of the channel is equal to the golden ratio.

To test this, a simulation was performed with a vertical axis wind turbine and the way was changed to obtain 2 models, the first shaped golden and the other one without the ratio for comparing simulation results.

4   Simulation

Then, the experiment in order to get results that support the importance of the golden ratio in the design is exposed, from the aesthetic point not only to provide better technical object designed.

To prepare the experiment arises a model that circumvented the difficulty of giving shape corresponding to the possible variations in the results matter. It seeks to modify the minimum possible between the two variants. So, we start with a design with golden ratio (Fig. 15) and the second without such proportion (Fig. 16).
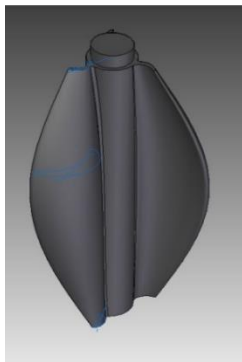
Fig. 15 Golden forms design

Fig. 16 No golden forms design

The differences between the two models are the cross sections defining the wind turbine blade. The area of the section has remained, to maintain the same weight in the 2 cases. (Fig. 17 and 18).
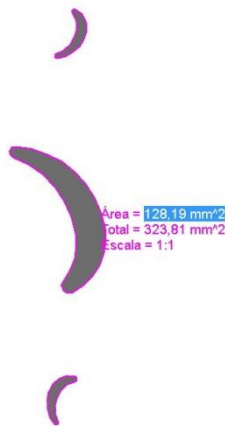
Fig. 17 Golden cross sections

Fig. 18 No golden cross sections

A simulation was performed with ANSYS 14.5 with the following characteristics:
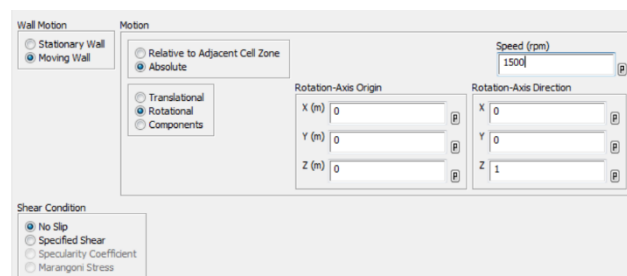
- Constant air density, "Pressurebased solver", (Fig. 19).
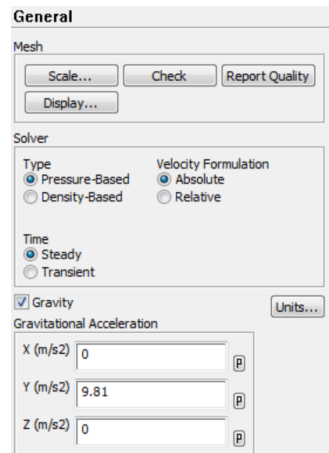
Fig. 19 Air density

- Laminar air flow, (Fig. 20).
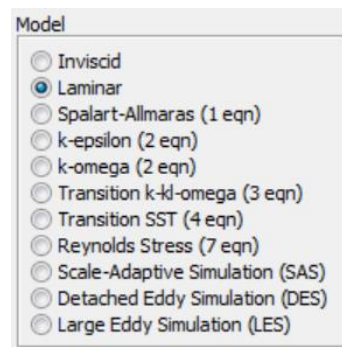
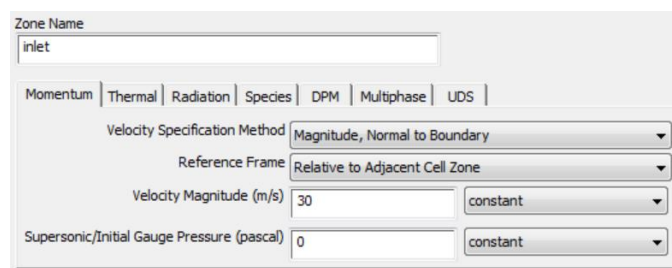*Fig. 20 Air flow*

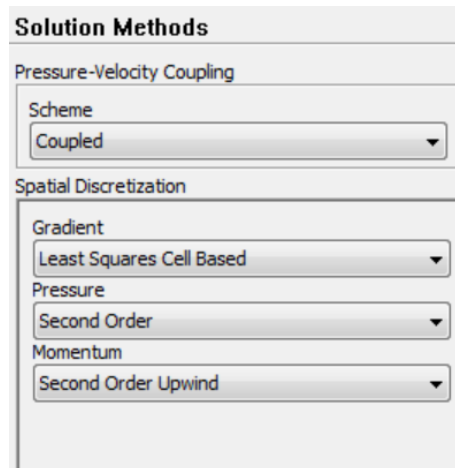- Speed of rotation of the shafts, 1500 rpm (Fig. 21).

Fig. 21 Speed of rotation

- Air speed in the X axis, 30m/s, (Fig. 22).

Fig. 22 Air speed

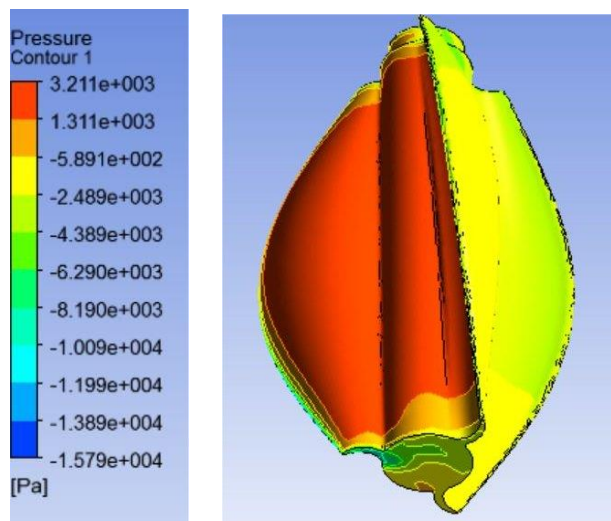-   Method of calculation of second order (Fig. 23).

Fig. 23 Calculation Method

5   Results

After simulation we obtain the following results:

For design aureus, following values (Fig. 24 y Fig. 25):

Fig. 24 Model golden moments

Fig. 25 Pressure contour plot of the golden model

If not golden design, following values (Fig. 26 y Fig. 27):

```
Moments - Moment Center (0 0 0)
                              Moments (n-m)
Zone                          Pressure
body                          (0.10041259 0.16838764 0.010423568)
------------------------      ------------------------------------------
Net                           (0.10041259 0.16838764 0.010423568)

Moments - Moment Center (0 0 0) Moment Axis (0 0 1)
                              Moments (n-m)
Zone                          Pressure        Viscous         Total
body                          0.010423568     3.7907386e-05   0.010461475
------------------------      ---------------  ---------------  -------------
Net                           0.010423568     3.7907386e-05   0.010461475
```

Fig. 26 Model no golden moments
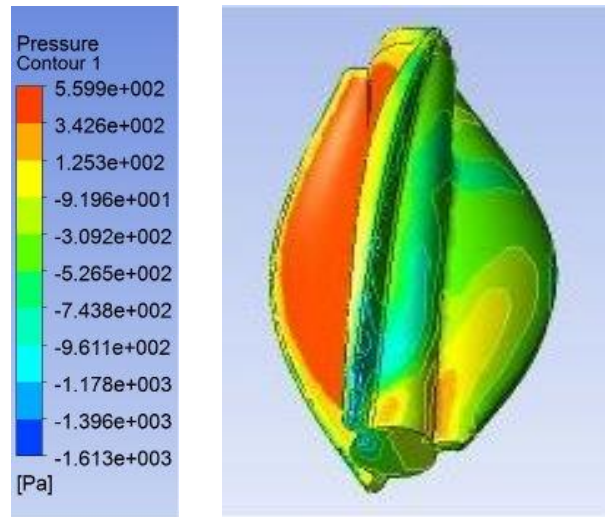
Fig. 27 Pressure contour plot of model not golden

Comparing the graphs obtained in Figure 25 and 27 it is shown that the pressure boundary is greater in the case of the former, that is, in the configuration corresponding to the golden design. In this sense, one can say that compared to the case not aureus more force per unit area is available

From (1) and (2) we have the expression (3), in which you can see the relationship between the mechanical power applied, P, on the drive shaft, the force exerted on turbine blades, F , the radius r and angular velocity ω (Fig. 28):

$$P = T * \omega \quad (1)$$

Where,

P= Power transmitted to the drive shaft W.

T= torque traction on Nw • m.

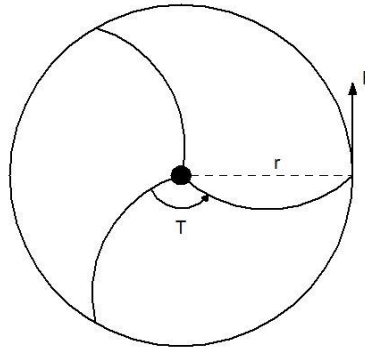*ω*= angular velocity in rad / s.

$$T = F * r \quad (2)$$

Where,

F= surface force NW.

r = turning radius in m

Fig. 28 Forces resulting from rotation

$$P = F * r * \omega \quad (3)$$

Assuming a constant angular velocity to both cases as we have greater pressure contour and therefore a greater strength in case aureus, more mechanical shaft power is transmitted, ie, both capture the same kinetic wind power, they have the same swept area but in the case aureus its use is more efficient to transmit more power to the axle.

Moreover, from the expression linear speed VL (4) and centripetal acceleration a_c (5), and known expression of the centripetal force F_c (6), substituting (4) into (5) and (5) in (6), expression of centripetal force (7) is obtained based on the mass m, the square of the angular velocity ω and the turning radius r, (Fig. 29):
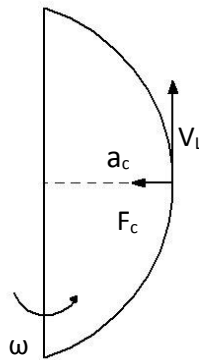
Fig. 29 Forces resulting from rotation

$$V_L = \omega * r \quad (4)$$

$$a_c = \frac{VL^2}{r} \quad (5)$$

$$F_c = m * a_c \quad (6)$$

$$F_c = m * \omega^2 * r \quad (7)$$

For the same power P transmitted to the drive shaft, in the golden model as we have more force F rotational speed ω is reduced compared with the case not aureus. Thus, the centripetal force is reduced quadratically with respect to the case not aureus, which means a reduction in the tensile stresses to which the wind turbine will be subjected to golden configuration.

6   Conclusion

In this article we have presented the results obtained from the comparison of two models of vertical axis wind turbine, the difference being that one of the models has laid golden proportions for the design of the blades.

The results showed that when the configuration of the blade of the wind turbine is based on golden proportions the power transmitted to the drive shaft is greater for the same wind speed incident. Moreover, it has been observed that the tensile stresses taken in the golden model are minor compared with the model not aureus.

With all this, it has been found that, by applying the golden ratio in the design of vertical axis wind turbines, not only the mechanical properties thereof are improved, but the system efficiency is also improved by a higher rate of conversion of wind power into useful mechanical power to the drive shaft.

With the results, we can say that the Golden Ratio can give more functionality to the product while the aesthetic that searches all design. Knowing how to introduce this ratio properly will differentiate and improve the product. Therefore, depending on the feature that is needed in the product will be where we need to study how to introduce the proportion or form.

Knowing how to enter what it is observed in nature in the design can open several lines of investigation after the results obtained.

References

[1] Janine M. Benyus, Biomimicry: Innovation Inspired by Nature, Harper Perennial, 1997

[2] B. K. YVES COINEAU, "Bionics and design: witnesses to the evolution of this approach," 10 NATURE, DESIGN AND INNOVATION, 1994.

[3] http://www.asknature.org/

[4] M. Doblaré Castellano, INGENIERÍA BIOLÓGICA. UNA INGENIERÍA PARA EL SIGLO XXI. Zaragoza, España: Prensas Universitarias de Zaragoza, 2010

[5] Stephen Skinner, Geometría sagrada: Descifrando el código, Gaia, 2007

[6] M. Akhtaruzzaman, A. A. Shafie, T. Ahsan, M. S. Alam, S. M. Raihan, M. K. Hasan and M. B. Haider, "Golden ratio, the phi, and its geometrical substantiation," in Research and Development (SCOReD), 2011 IEEE Student Conference On, 2011, pp. 425-430

[7] Matila C. Ghyka, Estética De Las Proporciones En La Naturaleza Y En Las Artes. Barcelona, Ed. Poseidon, 1977

[8] Fernando Corbalán, La Proporción Áurea. España: EDITEC, 2010

[9] G. Violeta, "How to use Fibonacci retracement to predict forex market", Journal of Knowledge Management, Economics and Information Technology, vol. Vol 1, pp. 24-38, 2011 February. 2011.

[10] S. Suzumoto, L. Tayo and T. Yachi, "Output power characteristics of a three-dimensional photovoltaic module using Fibonacci number composition" in Telecommunications Energy Conference (INTELEC), 2012 IEEE 34th International, 2012, pp. 1-7

[11] J. Agrawal and M. Aware, "Golden section search (GSS) algorithm for maximum power point tracking in photovoltaic system" in Power Electronics (IICPE), 2012 IEEE 5th India International Conference On, 2012, pp. 1-6

[12] S. Winkelmann, T. Schaeffter, T. Koehler, H. Eggers and O. Doessel, "An Optimal Radial Profile Order Based on the Golden Ratio for Time-Resolved MRI", Medical Imaging, IEEE Transactions On, vol. 26, pp. 68-76, 2007.

[13] A.P. Manso, F.F. Marzo, M. Garmendia Mujika, J. Barranco, A. Lorenzo, Numerical analysis of the influence of the channel cross-section aspect ratio on the performance of a PEM fuel cell with serpentine flow field design, International Journal of Hydrogen Energy, 36 (2011), pp. 6795–6808

XXV Congreso
INGEGRAF

APPLICATION OF PLASTIC PARTS DISCRETIZATION FOR ANALYZING GEOMETRIC DEMOLDABILITY

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Abstract

Purpose:
El proceso de moldeo por inyección de plásticos, es una de las tecnologías de fabricación con más influencia en la mayoría de los sectores industriales. La primera etapa en el proceso de análisis de la pieza de plastico consiste en determinar las contrasalidas de la pieza, la dirección de desmoldeo y la línea de partición. El análisis geométrico de la desmoldeabilidad tiene como objetivo obtener estos parámetros de manera automatizada para verificar que el diseño de la pieza es adecuado.

Method:
El artículo utiliza un algoritmo de discretización del sólido como paso previo al estudio de la desmoldeabilidad de la pieza de plástico a fabricar. El método de análisis desarrollado determina de manera automatizada el análisis de la desmoldeabilidad geométrica, indicando las áreas de la pieza que serán desmoldeables por ambas cavidades, contrasalidas y áreas no desmoldeables.

Result:
Con el objetivo de validar el algoritmo, se han analizado dos casos de análisis de la desmoldeabilidad en dos piezas diferentes. Se han considerado varias direcciones de desmoldeo principal para el análisis. Con el propósito de analizar la eficiencia del algoritmo descrito se ha definido un parámetro adimensional Pr o precisión relativa como el ratio entre la precisión de la malla y la longitud de la diagonal del bounding box, expresado en porcentaje. Se ha realizado un análisis para diferentes valores de precisión, teniendo en cuenta como resultado el número total de puntos obtenidos en la discretización así como puntos identificados erróneamente. Para precisiones relativas menores del 2% el número de puntos incorrectamente identificados, no sobrepasó el 1% del número total de puntos en la malla en todos los casos estudiados.

Discussion & Conclusion:
Este trabajo presenta una nueva metodología para el análisis de la desmoldeabilidad automatizada de piezas de inyección de plástico. Este proceso identifica las zonas de la superficie de la pieza, de acuerdo con la configuración del molde. El algoritmo se plantea como un metodo automatizado que no requiere la ayuda de personal especializadopara su manejo ni la interacción manual como actualmente ocurre con las soluciones CAD actuales a este problema.

1 Introduccion

El proceso de moldeo por inyección de plástico, es el proceso industrial más usado en la fabricación de piezas que requieran de altos volúmenes de producción y un buen control dimensional. Este proceso cíclico, se lleva a cabo en tres fases; la fase de llenado, la fase de compactación y la fase de enfriamiento. Durante la primera fase, el polímero fundido llena la cavidad de la pieza, desplazándose a través del bebedero, la mazarota y las entradas. En la fase de compactación, una cantidad de polímero adicional llena la cavidad para compensar la pérdida de volumen por el proceso de contracción. La fase de enfriamiento tiene lugar, de manera concurrente con la fase de llenado y de compactación considerando el tiempo para la plastificación del polímero y el tiempo adicional requerido para obtener un 80% de producto solidificado. Existe actualmente una demanda relacionada con una reducción en los tiempos de diseño y manufactura para moldes de inyección de plástico, siendo por tanto necesaria una automatización del proceso de diseño del molde de plástico. Los sistemas CAED (Computer Aided Engineering Design Systems), son sistemas pensados para ayudar a los ingenieros en tareas tales como el análisis, la simulación, el diseño y la manufactura del producto.

Los sistemas CAED disponibles a n ivel comercial(p.j. M oldflow para inyección de p lástico) pueden, predecir la progresión del flujo de plástico fundido y la localización de las líneas de soldadura, optimizar el espesor de la pieza y las condiciones del proceso como el tiempo de inyección, la temperatura de inyección, la presión de compactación, el tiempo ciclo, determinar la presión de inyección y la fuerza de cierre, diseñar los sistemas de refrigeración, y estimar la deformación de un componente(ref. Moldflow)

Sin embargo la determinación de las contr asalidas de una pieza, así como el cálcu lo de la línea de partición de manera automatizada sigue siendo dependiente de la experiencia del diseñador.

La determinación de l a línea de partici ón, la sup erficie de partición así como las co ntrasalidas y correderas se ha planteado como una interesante área de investigación en el ámbito del diseño de moldes de inyección de plástico. Hasta el momento se han seguido varias líneas de investigación, con el propósito de identificar estas características en la pieza de plástico [1-15].

Fu[16] clasificó las contrasalidas en diferentes categorías de acuerdo a las direcciones normales de las caras de la pi eza y utilizando un sistema de reco nocimiento de featur es. Khardekar[17] describió un algoritmo, que identifica y muestra las contrasalidas de la pieza de plástico de la pieza a moldear basados en el uso de GPU'S. Hui [18] introdujo la definición de superficies visibles e invisibles para determinar los bordes comunes para la generación de la línea de partición.

A la l uz de los problemas señalados, se propone en este artículo u n nuevo método de análisis de la desmoldeabilidad, independiente del sistema CAD e implementado en un software standard. Este algoritmo transforma la pieza sólida en una m alla de puntos recolocando los puntos en l a malla en base a su desmoldeabilidad.

2 Metodologia

A continuación se describe el método de discretización del sólido utilizado como base para la realización del posterior análisis de desmoldeabilidad de la pieza de plástico.

2.1 Proceso de discretización de la pieza de plástico

El algoritmo de discretización propuesto se divide en tres etapas d e acuerdo al estu dio de las tre s direcciones normales de des moldeo principales. En una primera etapa, el pr oceso de discretización se realiza a lo largo de la dirección de desmoldeo d_z o d. Este proceso determina las zonas de desmoldeo iniciales a lo largo de la dirección de desmoldeo y las zonas no desmoldeables a lo largo de d_z. La dirección principal de desmoldeo es definida por el diseñador como dato de partida. Una vez realizado el análisis, el diseñador puede cambiar su elección si este no lo encuentra optimo.

En una se gunda etapa se r ealiza la d iscretización del sólido a lo l argo de las d os direcciones de desmoldeo d_x y d_y normales entre si y a la dirección principal de desmoldeo. En esta fase se localizan puntos pertenecientes a zonas des moldeables de segunda clase, del mismo modo se loc alizan las zon as no desmoldeables a lo largo de estos ejes laterales.

En las siguientes etapas alguno de estos puntos serán reasignados a zonas desmoldeables de primera clase(cavidad superior e inferior) o bien serán considerados como correderas laterales.

2.2 Discretización del solido a lo largo de la dirección de desmoldeo

El proceso de discretización a lo largo de la dirección de desmoldeo d_z, se divide en las siguientes etapas:
1) Calculo del bounding box. Fig 1
2) Sección del cuerpo por un plano paralelo al plano YOZ. Fig 1
3) Cálculo de puntos intersección
4) Localización de los puntos en los nodos de la malla 3D.
5) Clasificación de los puntos de acuerdo a su desmoldeabilidad inicial
6) Almacenamiento de los puntos en diferentes matrices de puntos Tab 1
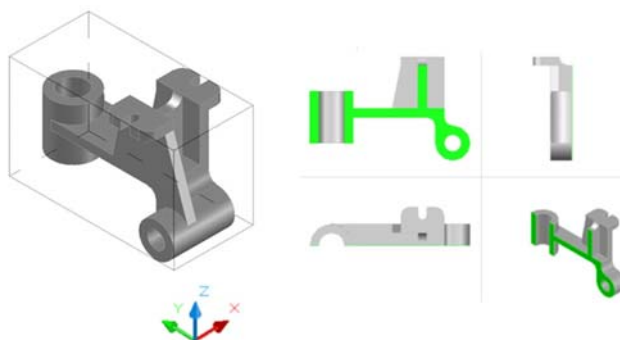7) Renderizado de la malla

Fig. 1 Bounding box y sección a lo largo del plano YOZ.

DIRECCION DE DESMOLDEO PRINCIPAL Z	Π : Conjunto de puntos con máxima coordenada z. Pertenecen a la zona desmoldeable a lo largo de la dirección de desmoldeo d.Se representan mediante color verde.	$\Pi \subseteq \mathcal{B}' \subseteq \mathbb{R}^3$
	Ω : Conjunto de puntos con mínima coordenada z. Pertenecen a la zona desmoldeable a lo largo de la dirección de desmoldeo d.Se representan mediante color azul.	$\Omega \subseteq \mathcal{B}' \subseteq \mathbb{R}^3$
	Φ : Conjunto de puntos con coordenada intermedia z. En un primer momento no desmoldean a lo largo de la dirección +d y –d.Pertenecen a la zona desmoldeable a lo largo de la dirección de desmoldeo d. No se visualizarán en pantalla en esta etapa.	$\Phi \subseteq \mathcal{B}' \subseteq \mathbb{R}^3$

Tab. 1 Matrices de puntos posterior al análisis en la direccion de desmodleo Z.

2.3   Recolocación de puntos en la malla

El proceso de discretización proporciona una información muy útil pero no suficiente para definir el mapa de desmoldeabilidad. Es necesario introducir un segundo análisis consistente en un conjunto de criterios de clasificación para transformar la malla discreta de puntos en el mapa de desmoldeabilidad deseado. Una clasificación jerárquica en términos de desmoldeabilidad se introduce en esta fase.

El algoritmo de reasignación de puntos incluye varios subalgoritmos, que comparan cada punto con el resto de los puntos incl uidos en la zona alta de jera rquización de desm oldeabilidad. De acuerd o a esta comparación, es posible un cambio de la misma en cada punto.
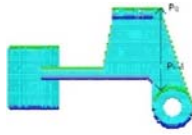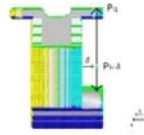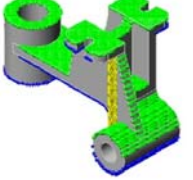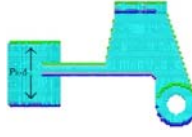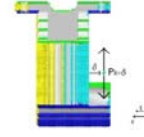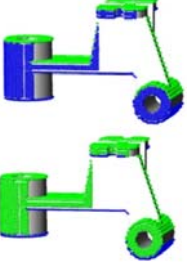
Los algoritmos de reasign ación recolocan puntos que cumplen un as determinadas condiciones geométricas en matrices de puntos clasificados con anterioridad.

Para el proceso de reasignación se van a considerar 4 casos:

1) Puntos co n posibilidad de reasignación a cavi dad inferior, prim er nivel en l a jerarquía de desmoldeabilidad(cavidad inferior)

2) Puntos con posibilidad de reasignación a cavidad superior, primer nivel en la jerarquía de desmoldeo(cavidad superior)

3) Puntos desmoldeables a lo largo de la dirección X, fabricables mediante correderas laterales, segundo nivel en la jerarquía de desmoldeo (Corredera lateral)

4) Puntos c on posibilidad de reasignación a ambas cavidades, primer nivel en la jerarquía de desmoldeo(ambas cavidades).

Cuatro algoritmos han sido desarrollados para resolver los cuatro casos de reasignación. Cada algoritmo resuelve cada uno de los c asos a lo l argo de la d irección de d esmoldeo, - d$_x$ y +d$_x$. Para cad a punto perteneciente a las matrices de desmo ldeo lateral se realiza un desplazamiento virtual hacia el exterior de la pieza de valor igual a la pr ecisión de la malla, si se cumple n las siguientes condiciones geométricas, el punto cambiará su jerarquía en la escala de desmoldeo ascendiendo en la misma y cambiando su función en el mapa, tab 2.

CAVIDAD INF	$If \ \exists \begin{Bmatrix} P_q(x_q, y_q, z_q) \in \Omega \\ \Omega \subseteq \mathcal{B} \subseteq \mathbb{R}^3 \end{Bmatrix} : \begin{Bmatrix} x_{k-\delta} = x_q \\ y_k = y_q \\ z_k < z_q \end{Bmatrix}$ $\Rightarrow P_k(x_k, y_k, z_k) \in \Omega$	
CAVIDAD SUP	$If \ \exists \begin{Bmatrix} P_q(x_q, y_q, z_q) \in \Pi \\ \Pi \subseteq \mathcal{B} \subseteq \mathbb{R}^3 \end{Bmatrix} : \begin{Bmatrix} x_{k-\delta} = x_q \\ y_k = y_q \\ z_k > z_q \end{Bmatrix}$ $\Rightarrow P_k(x_k, y_k, z_k) \in \Pi$	

CORREDERA LAT	$If \; \exists \begin{Bmatrix} P_q(x_q, y_q, z_q) \in \Pi \\ \Pi \subseteq \mathcal{B} \subseteq \mathbb{R}^3 \end{Bmatrix} : \begin{Bmatrix} x_{k-\delta} = x_q \\ y_k = y_q \\ z_k < z_q \end{Bmatrix}$ $\Rightarrow \; P_k(x_k, y_k, z_k) \in \theta$			
AMBAS CAVIDADES	$If \; \exists \begin{Bmatrix} P_q(x_q, y_q, z_q) \in \Omega \\ \Omega \subseteq \mathcal{B} \subseteq \mathbb{R}^3 \\ P_t(x_t, y_t, z_t) \in \Pi \\ \Pi \subseteq \mathcal{B} \subseteq \mathbb{R}^3 \end{Bmatrix}$ $: \{x_t \neq x_{k-\delta} \neq x_q\}$ $\Rightarrow \; P_k(x_k, y_k, z_k) \in \Pi \; or \; \Omega$			

Tab. 2 Tabla con criterios de reasignación.

2.4 Reconocimiento de puntos no desmoldeables a lo largo de las direcciones laterales de desmoldeo X e Y

El proceso de reasignación de puntos no desmoldeables a lo largo de los ejes laterales de desmoldeo X e Y se divide en dos etapas. En un primer lugar se realiza un nuevo desplazamiento virtual de valor igual a la precisión de la malla, hacia el interior y el exterior de la pieza a lo largo de la dirección de desmoldeo lateral X para realizar posteriormente una segunda reasignación por medio de una comparación de puntos vecinos.

En el proceso de reasignación se han considerado varios casos:

1)Puntos reasignados a cavidad superior
2) Puntos reasignados a cavidad inferior
3) Puntos reasignados a correderas laterales, a lo largo del eje Y(no agujeros pasantes)
4) Puntos no desmoldeables
5) Puntos reasignados a ambas cavidades
6) Puntos reasignados a correderas laterales a lo largo del eje Y(agujeros pasantes)

Las condiciones geométricas de reasignación quedan indicadas en la tabla 2

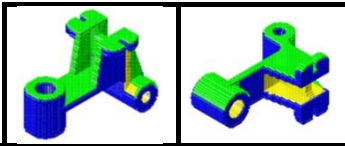|	
Cavidad superior	$If \; \exists \begin{Bmatrix} P_q(x_q, y_q, z_q) \in \Pi \\ \Pi \subseteq \mathcal{B} \subseteq \mathbb{R}^3 \end{Bmatrix} : \begin{Bmatrix} x_{k+\delta} = x_q \\ y_k = y_q \\ z_k > z_q \end{Bmatrix} \Rightarrow \; P_k(x_k, y_k, z_k) \in \Pi$
Cavidad inferior	$If \; \exists \begin{Bmatrix} P_q(x_q, y_q, z_q) \in \Omega \\ \Omega \subseteq \mathcal{B} \subseteq \mathbb{R}^3 \end{Bmatrix} : \begin{Bmatrix} x_{k+\delta} = x_q \\ y_k = y_q \\ z_k < z_q \end{Bmatrix} \Rightarrow \; P_k(x_k, y_k, z_k) \in \Omega$
Correderas laterals para agujeros ciegos a lo largo de Y	$If \; \exists \begin{Bmatrix} P_q(x_q, y_q, z_q) \in \psi \\ \psi \subseteq \mathcal{B} \subseteq \mathbb{R}^3 \end{Bmatrix} : \begin{Bmatrix} x_{k+\delta} = x_q \\ y_k < y_q \\ z_k = z_q \end{Bmatrix} \Rightarrow \; P_k(x_k, y_k, z_k) \in \psi$
P_k no desmoldeables a lo largo de X	$If \; \exists \begin{Bmatrix} P_u(x_u, y_u, z_u) \in \Phi \\ \Phi \subseteq \mathcal{B} \subseteq \mathbb{R}^3 \end{Bmatrix} : \begin{Bmatrix} x_{k+\delta} = x_u \\ z_k > z_u \\ y_k = y_u \end{Bmatrix} \; and \; \exists \begin{Bmatrix} P_q(x_q, y_q, z_q) \in \Delta \\ P_t(x_t, y_t, z_t) \in \Delta \\ \Delta \subseteq \mathcal{B} \subseteq \mathbb{R}^3 \end{Bmatrix} :$ $\begin{Bmatrix} z_t = z_k = z_q \\ x_t = x_{k+\delta} = x_q \\ y_q > y_k > y_t \end{Bmatrix}$ $\Rightarrow \; P_k(x_k, y_k, z_k) \in \Upsilon$
Ambas cavidades	$If \; \nexists \begin{Bmatrix} P_q(x_q, y_q, z_q) \in \Omega \\ \Omega \subseteq \mathcal{B} \subseteq \mathbb{R}^3 \\ P_t(x_t, y_t, z_t) \in \Pi \\ \Pi \subseteq \mathcal{B} \subseteq \mathbb{R}^3 \end{Bmatrix} : \{x_t = x_{k+\delta} = x_q\} \Rightarrow \; P_k(x_k, y_k, z_k) \in \Pi \; or \; \Omega$
Correderas laterales para agujeros a lo largo de Y	$If \; \nexists \begin{Bmatrix} P_q(x_q, y_q, z_q) \in \mathcal{B} \\ \mathcal{B} \subseteq \mathbb{R}^3 \end{Bmatrix} : \begin{Bmatrix} x_{k+\delta} = x_q \\ y_k \leq y_q \\ z_k = z_q \end{Bmatrix} or \; \nexists \begin{Bmatrix} P_q(x_q, y_q, z_q) \in \mathcal{B} \\ \mathcal{B} \subseteq \mathbb{R}^3 \end{Bmatrix} : \begin{Bmatrix} x_{k+\delta} = x_q \\ y_k \geq y_q \\ z_k = z_q \end{Bmatrix}$ $\Rightarrow \; P_k(x_k, y_k, z_k) \in \psi \; or \; \Gamma$

Tab. 2 Tabla con condiciones de reasignación.

3 Resultados

Con el objetivo de validar el algoritmo, se han analizado dos casos de análisis de la desmoldeabilidad en dos piezas diferentes (A y B). Se han considerado varias direcciones de desmoldeo principal para el análisis. En el sólido A, la dirección principal de desmoldeo fue elegida coincidente con los ejes de los agujeros pasantes .Con el objetivo de analizar la eficiencia del método propuesto se ha definido un parámetro adimensional P_r o precisión relativa como el ratio entre la precisión de la malla y la longitud de la diagonal del bounding box, expresado como un porcentaje.

Se ha realizado un análisis para diferentes valores de precisión, teniendo en cuenta como resultado el número total de puntos obtenidos en la discretización así como puntos identificados erróneamente.

Para precisiones relativas menores del 2 % el número de puntos inc orrectamente identificados, no sobrepasó el 1% del número total de puntos en la malla en todos los casos estudiados.

P_R %	% error	t(min)	% error	t(min)
1,15	0,04	8,77	0,00	6,87
1,25	0,06	5,13	0,03	4,72
1,35	0,05	3,28	0,09	2,92
1,45	0,06	2,55	0,02	1,95
1,55	0,12	1,70	0,02	1,60
1,65	0,16	1,30	0,04	1,10
1,75	0,20	0,92	0,00	0,85
1,85	0,15	0,72	0,04	0,53
1,95	0,25	0,52	0,00	0,52
2,05	0,5	0,35	0,4	0,5

4 Conclusiones y lineas de investigacion futuras

Este trabajo presenta una nueva metodología para el análisis de la desmoldeabilidad automatizada de piezas de inyección de plástico. Este proceso identifica las zonas de la superficie de la pieza, de acuerdo con la configuración del molde. El presente algoritmo geométrico permite establecer un link entre el diseño de la pieza y la configuración del molde en un esfuerzo por mejorar el proceso de diseño de la pieza de plástico.

Como trabajo futuro se plantea el recoger la malla de puntos por zonas de desmoldeabilidad y diseñar de manera automatizada las partes del molde que lo conformarán.

5.- Agradecimientos

References

[1] Chen L.L., Chou S.Y, Woo T.C. "*Parting directions for mould and die design*" Computer Aided Design Volume 25 number 12 December 1993.

[2] Weinstein M., Manoochehri S. "Geometric influence of a molded part on the draw direction range and parting line locations" Journal of Mechanical Design Vol 1 18 March 19 96X. Fischer and D. Coutell ier. *Editorial*. International Journal on Interacti ve Design and Manufacturing 1, 1 (2007) pp 1-4.

[3] Ahn, De Berg, Bose, Cheng ,Halperin , Matousek , Swartzkopf, *"Separating an object from its cast"* . Computer aided Design, 34, 547-59,2002

[4] Dhaliwal S, Gupta SK,Huang J, Priyadarshi A. *"Algorithms for computing global accessibility cones".* Journal of Computing and Information Science in Engineering 2003;3(3):200–9

[5] Huang J, Gupta SK, Stoppel K. "Generating sacrificial multi-piece molds using accessibility driven spatial partitioning". Computer Aided Design 2003;35(3):1147–60.

[6]   Priyadarshi, Gupta S.K. "Geometric Algorithms for automated d esign of multipi ece permanent molds" computer Aided Design 36(3): 241-260, 2004.

[7]   Chen Y, Rose n DW. "A reverse glu e approach to autom ated construction of multi-pi ece molds". J Comput Inf Sci Eng 2003;3(3):219–30

[8]   Banerjee A.G., Gupta S.K." Geometrical algorithms for automated design of side actions in injection moulding of complex parts" Computer Aided Design, 39 882-897 (2007)

[9]   Ye X.G. Fuh JYH, Lee K.S.: "A hybrid method for rec ognition of undercut features from molded part". Computer aided design 2001; 33:1023-34.

[10]   Ran J.Q., Fu M.W.: "Design of internal pi ns in injection mold CAD via the automatic recognition of undercut features" Computer Aided Design 2010 42 582-597.

[11]   Ganter M.A., T uss L.L. "C omputer-Assisted Parting Line Development for Cast Patt ern Production" AFS Transactions, pp 795-800 - 1990.

[12]   Wong T., Tan S.T., Sze W.S., *"Parting line formation by slicing a trimmed surface model"* Proceedings of the 1996 ASME Design Engineering Technical Conference and Computers in Engineering Conference August 18-22, 1996 Irvine, California.

[13]   Rubio M.A.,Pérez J.M., Rios J. *" A Procedure for Plastic parts demoldability analisys"* Robotics and Computer Integrated Manufacturing Vol 22 2006

[14]   Lu HY, Lee WB. *"Detection of interference elements and release directions in die-cast and injection-moulded components".* Proceedings of the Instituti on of Mech anical Engineers, Part B Journal of Engineering Manufacture 2000;214(6):431–41

[15]   Shin K.H. Lee K.W." Design of side cores of injection molds from auto matic detection of interference faces". Journal of Design and Manufacturing 1993;3:225-36

[16]   Fu M.W, Fuh J.Y.H., Nee A.Y.C. *"Undercut feature recognition in an injection mould design system"* Computer Aided Design Vol 31 1999 777-790

[17]   Khardekar, Burton and McMains.*"finding feasible mold parting directions using graphics hardware"* Computer Aided Design 38(2006)327-341

[18]   Hui K.C., T an S.T. *"Mould design with sweep operations, a heuristic search approach"* Computer Aided Design Volume 24 number 2 february 1992

AUTOMATED SYSTEM FOR INJECTION MOLD DESIGN AND COST CALCULATION. OBJECTIVES AND OPPORTUNITIES

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Abstract

Purpose:
The aim of this paper is the presentation of the objectives and works to perform in the research project CELERMOLD, Research Project of Excellence for Universities and Research Institutions in Andalusia that has been granted in 2014.

Method:
This research project aims to develop a vertical software, consisting of a computing platform that will automate and integrate the process of global mold design, in its geometrical aspect and allow obtaining manufacturing costs in a short period of time.

Result:
The system to be developed will perform in an automated manner a geometric demoldability analysis of the plastic part, pointing onto the workpiece, areas to demolding by both cavities, side cores and non demoldable areas, calculating at the same time the parting line. Subsequently, a preliminary design of the mold will be performed, defining the mobile devices and other standard elements. Finally, the assembly tooling costs will be estimated.

Discussion & Conclusion:
In order to reduce the delivery time in the plastics industry, the design of the CAD CELERMOLD application, it is seen as a great help for mold designers and users who want to validate the manufacturing of its designs.

1   Introduction

Plastic injection molding is a versatile, fast and efficient process that aims to produce components of complex surface, by injecting the pressurized molten plastic into a mold. The design of the injection mold is essential to the manufacture of plastic parts. It is a complex task that involves a lot of time and requires a deep knowledge of the subject, as well as an extensive experience. Additional information about manufacturing resources, delivery time and cost data is also required.

Plastic injection mold consists of two upper and lower cavities, which are fixed on the mold carrier plates of the injection molding machine. After the filling, cooling and solidification process fig 1, the mold is opened along the parting direction. The part remains attached with the sprue to the movable mold half (ejection side).

By continuing path opening, the ejector assembly of the mold contacts a machine fixed bar that actuates automatically once the mold has reached the end of its opening stroke. At the end of the closing movement (when the mold is fully closed) the ejector assembly is in its final or rest position.
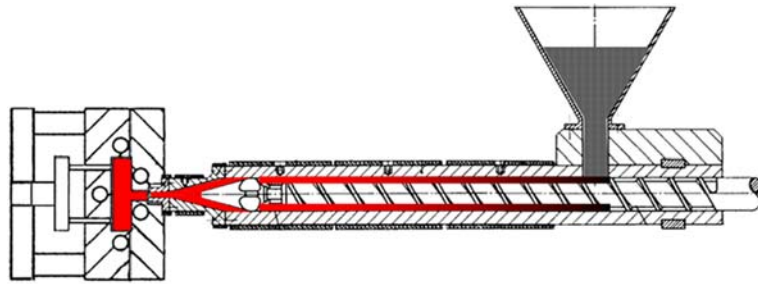
Fig 1.- Injection molding process

The direction in which both cavities are displaced is known as parting direction; an undercut region is the part which is inaccessible from the parting direction in both directions. Side cores are normally used to solve the problem of undercuts fig 2. An injection mold may have a single cavity or multiple cavities.
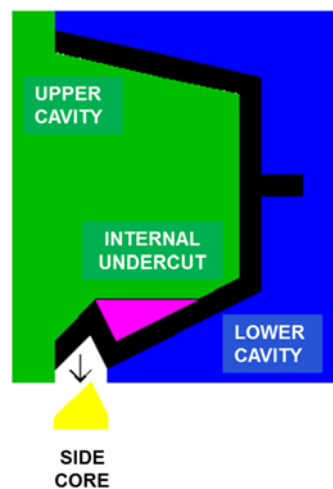
Fig 2. - Disposition of the mold parts

The design of the plastic injection mold comprises several tasks, including, shrinkage of the part, demolding angle, number of cavities, cavities desi gn, mold design, design of the part ing line, upper and lower cavity design, ejection system, cooling system, and standard components.

Many of the c urrently available commercial CAD s ystems (SolidWorks, CATIA, Inventor, NX, etc) h ave modules for mold des ign. These modules are widely used to speed up the process of prod uct design in relation to the design of complex molds to assist the designer in reviews.

A limitation associated with mold design modules is the lack of automation, since knowledge of the designer, interaction and input data are essential. These shortcomings in the automation of the design process causing a high number of iterations and a long lead time for mold design.

In order to reduce the delivery time in the plastics industry, the design of a CAD application for mold design is presented. This software will provide a good level of automation and will be an aid for mold designers and users who want to validate manufacturing plastic parts.

2   Background

The global problem of designing and manufacturing the plastic part can be divided into three different blocks.
- Analysis of geometric demoldability of the plastic part.
- Automated mold design.
- Estimation of mold tooling costs.

Demoldability analysis and calculation of the parting line has been one of the major areas of research over the years because it is a key task in the design of the mold. One of the most widely used research lines for performing the analysis demoldability of the plastic part is the one that establishes a parallelism between visibility and demoldability [1-5]. If a surface is visi ble from one direction it is d emoldable along it. Demoldability map of a surface is the set of directions from which such surface is visible. The complexity of calculating a surface visibility obviously depend on the complexity of the surface itself, which in the extreme

case of free surfaces, would be determined by calculating the visibility of each of its points. Visibility maps for surfaces [1] are used differently depending on the method of analysis that is to be applied. One of the first methods used to analyze parts demoldability applying visibility maps was proposed by Chen L.L. et al. [2], which introduced the concept of pocket for the calculation of non demoldable areas Fig.3.
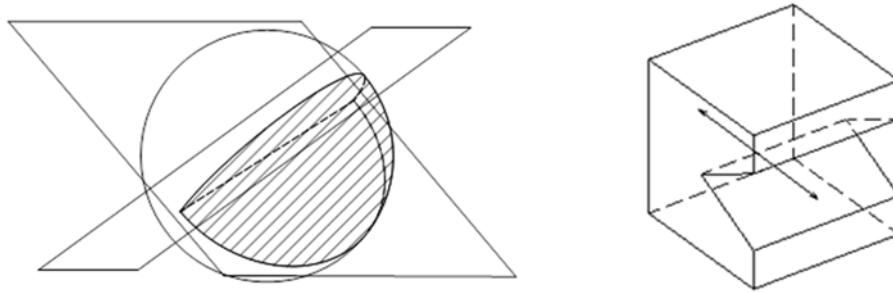

Fig 3. Visibility map for full pocket. Possible parting directions for the part of the example.

Other research groups proposed a method for calculating the parting line based on the classification of the surfaces regarding its orientation relative to the pull direction and connectivity [6, 7]. The classification is based on the sign of the dot product between the normal to each surface and pull direction Fig 4.
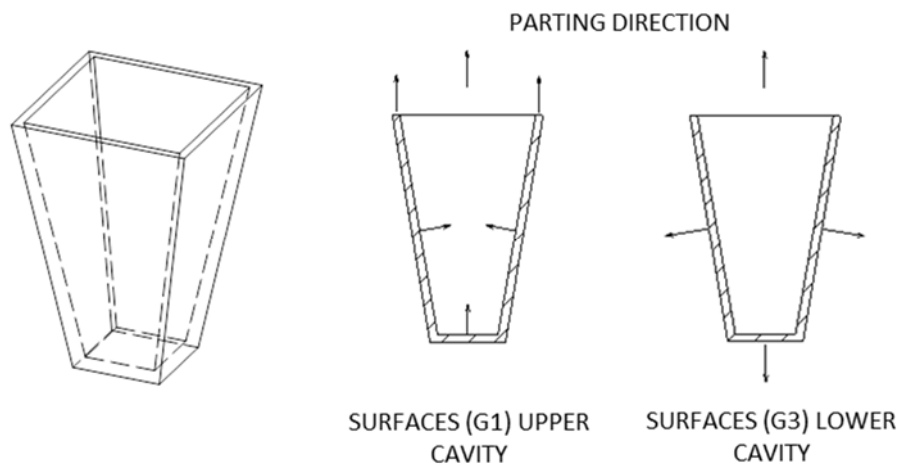
Fig 4. Classification of surfaces in areas

Another research lines, use heuristic search techniques to locate the parting direction and the lateral side cores [8] fig 4.
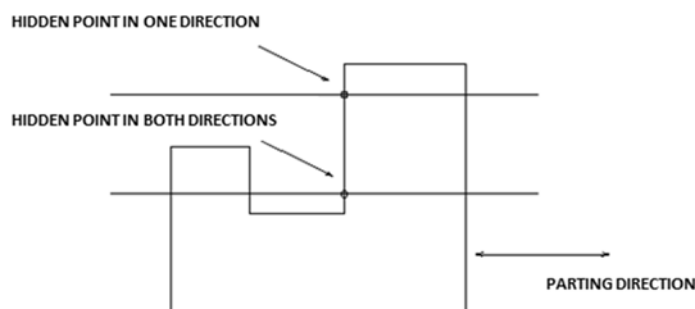
Fig 5. Location of points for determining the blocking factor

Following the work done in the field of ana lysis demoldability, another line of res earch is that uses the technique of recognition of characteristics or features [9-17].All methods described so far require information about the topological relationships of geometric analysis for demoldability of the plastic parts.
To solve this problem methods based on the study of the model sections, cut the body by a set of plans that are parallel to the parting direction and analyze the model externally. [18-22].

In the field of academic research, several researchers have focused on the study of automated mold design. In recognizing features Ye et al. [23] proposes a hierarchical representation based on object-oriented and focused on the study of the features and a geometric simplification with a symbolic approach for automatic modeling functions mold assembly. However the rec ognition of features on com plex surfaces, is ver y complex.

In terms of CAD techn ology, Neo et al. [32] developed an application for designing injection molds plastic IMOLD based on the k ernel of commercial 3D CAD application using a programming language object-oriented.

Ma et al. [25] presented a model libraries for mold components incorporating different geometric and non-geometric information topologies. However, the mold design is very demanding and is not solved completely, also remains dependent on the experience [26]

Many researchers [27-29] have tried to automate the entire process of mold design using KBE approaches such as rule- based reasoning. In his research th ey obtained rules rel ating to desig n and mol d design expertise based on the exper ience provided by mold designers, handbooks and knowledge of traditional type. This heuristic knowledge called empirical rules in engineering was represented in terms of design rules. All research presented are limited to specific areas or simple parts and are too theoretical to be applied to an actual mold [26].

Regarding commercial mechanical design CAD systems[30-42], they are mainly limited to providing tools for geometric modeling and automate some routine tasks of mold design at the stage of detailed design.

Given the growing demand for a quick and a ccurate estimation of mold cost, it has been developed some software packages. Brost Enterpris es has developed the Moldquoter system. This wizard provides an estimated price of the mold based on data such as the dimensions of the piece, the desired characteristics, the number of cavities, the layout etc. Materialise software provides independent software for calculating mold budgets in an automated manner. To some extent the commercial software packages mentioned can automate routine parts of calculation costs and guide inexperienced users to terminate an estimate using a standard support. But it still requires an e xperienced user to design the mold structure and enter th e necessary information into the system.

Magic Tooling Expert assists the user o n displaying molding problems of the part a nd determines the complexity and cost of desig ning the mol d parting lines, analysis of undercuts, demolding analysis and thickness etc. the estimated cost is adjusted on the basis of scale factors such as influence of the electrodes, sliding size and inserts, extra parameters, cost of assembly time, machining time etc. Other similar software are: Power Shape integrated into the CAD system De lcam, Cimatron, or QuickQuote, software developed by Quickparts an online system for estimating costs.

To some extent, mentioned commercial software packages can automate routine parts of calculation costs and guide inexperienced users to finalizing an estimation using a standard support. But it still requires an experienced user to design a mold structure and enter the necessary information in the system [26].

This project has bee n originated by the d evelopment of a ne w methodology for aut omated analysis of demoldability in plastic inj ection parts resul t of a t hesis conducted at the Univ ersity of Jaén [18]. This algorithm will be the basis for the automated design and cost of the injection mold plastic part manufactured.

3   Opportunity, scope and potential of the work to be performed

The objective of this project is the integration and research of new solutions that will be integrated in an intelligent software platform that will automate the process of desi gn and cost estimati on of th e plastic injection mold, incorporating a new demoldability algorithm [19] as the core of the application, such as basis for complete automation of the process..

For geometric demoldability analysis, the algorithm of demoldability will be integrated and programmed into the environment by taking part data as a i nput. The software will be independen of internal information of the part, sinc e the g eometric analysis is performed in an external manner. Subsequently intelligent automated plastic injection mold design module that manufactures the part to be molded will be developed. On the last stage the criteria for estimating mold tooling costs by obtaining data on the geometry of the part will be established.

This project is part of a c ollaboration between two research groups: Research Group Engineering GIS Graphic Jaen (TIC-159) from the University of Jaen and Engineering Research Group in Manufacturing (GI-IF) of the Polytechnic University Madrid, as well as the Technological Plastic Center R&D&I ANDALTEC. As a result of the project we are expected to obtain:

1) Development of new methods of geometrical analysis of the plastic part.
2) Apply the knowledge gained in a computing platform that will enable exploitation of results in the field of science and technology at industrial level.

The platform developed will optimize the pro cesses of design and production in companies of the plastics field situated in Andalusia, reducing design time on repetitive tasks, as well as the estimated costs of tooling. In this type of budget, time and accuracy are vital to get the business.

Acknowledgement

References

[1]   Woo T.C. "Visibility maps and spherical algorithms" Computer Aided Design Volume 26 Number 1 January 1994

[2]   Chen L.L., Chou S.Y, Woo T.C. "Parting directions for mould and die design" Computer Aided Design Volume 25 number 12 December 1993.

[3]   Chen L.L., Chou S.Y, Woo T.C." Partial visibility for selecting a parting direction in mold and die design" Journal of Manufacturing Systems Volume 14 number 5 1995.

[4]   Weinstein M., Manoochehri S. "Geometric influence of a molded part on the draw direction range and parting line locations" Journal of Mechanical Design Vol 118 March 1996.

[5]   Weinstein, M., and Manoochehri, S.. "Optimal parting line design of molded and cast parts for manufacturability". Journal of Manufacturing Systems 16, 1, 1—12,1997

[6]   Nee A.Y.C., Fu, M.W., Fuh J.Y.H., Lee K.S., Zhang Y.F. "Determination of optimal parting direction in plastic injection mould design" Annals of the CIRP, 46/1/1997 429-432.

[7]   Nee A.Y.C., Fu M.W., Fuh J.Y.H, Lee K.S., Zhang Y.F." Automatic determination of 3D parting Lines and Surfaces in Plastic Injection Mould Design" Annals of the CIRP Vol 47/1/1998: 95-99.

[8]   Hui K.C., Tan S.T. "Mould design with sweep operations, a heuristic search approach" Computer Aided Design Volume 24 number 2 february 1992

[9]   Fu M.W, Fuh J.Y.H., Nee A.Y.C. "Undercut feature recognition in an injection mould design system" Computer Aided Design Vol 31 777-790 1999.

[10]   Fu M.W., Fuh J,Y.H., Nee A.Y.C. " Generation of optimal parting direction based on undercut features in injection molded parts" IIE Transactions 1999; 31: 947-55.

[11]   Fu M.W, Nee A.Y.C., Fuh J.Y.H "The application of surface visibility and moldability to parting line generation" Computer Aided Design Vol 34 2002 469-480.

[12]   Fu M.W., Nee A.Y.C., Fuh J.Y.H. "A core and cavity generation method in injection mold design" International Journal of Production Research 2001;39:121-38.

[13]   Fu M.W., "The application of surface demoldability and moldability to side core design in die and mold CAD" Computer Aided Design Vol 40 2008 567-575.

[14]   Yin ZP, Han Ding, You-Lun Xiong: "Virtual prototyping of mold design: geometric mouldability analysis for near-net-shape manufactured parts by feature recognition and geometric reasoning". Computer-Aided Design 33(2):2001 137-154

[15]   Ye X.G. Fuh JYH, Lee K.S.: "A hybrid method for recognition of undercut features from molded part". Computer aided design 2001; 33:1023-34.

[16]   Ye X.G. Fuh JYH, Lee K.S.: "Automotive undercut feature recognition for side core design of injection molds". Journal of Mechanical Design 2004;126:519-26.

[17]   Ran J.Q., Fu M.W.: "Design of internal pins in injection mold CAD via the automatic recognition of undercut features" Computer Aided Design 2010 42 582-597.

[18]   Martin Doñate C. Metodologia para el analisis automatizado de la desmoldeabilidad de piezas de inyección de plastico basado en su geometría .Tesis Doctoral Universidad de Jaen 2010

[19]   Martin Doñate, C.; Rubio Paramio, M. A." New methodology for demoldability analysis based on volume discretization algorithms " Computer-Aided Design 45 (2), 2013 : 229-240 .

[20]   Ganter M.A., Tuss L.L. "Computer-Assisted Parting Line Development for Cast Pattern Production" AFS Transactions, pp 795-800 - 1990.

[21]   Wong T., Tan S.T., Sze W.S., "Parting line formation by slicing a trimmed surface model" Proceedings of the 1996 ASME Design Engineering Technical Conference and Computers in Engineering Conference August 18-22, 1996 Irvine, California.

[22]   Rubio M.A.,Pérez J.M., Rios J. " A Procedure for Plastic parts demoldability analisys" Robotics and Computer Integrated Manufacturing Vol 22 2006

[23]   Ye X.G., Fuh Y.H.,Lee K.S. " Automated assembly modelling for plastic injection molds. International Journal Adv Manufacturing Technol 16:739-747 2000

[24]   Neo TL, Lee KS Three-dimensional kernel development for injection mould design. Int J Adv Manuf Technol 17:453–461 2001

[25]   Ma YS, Tong T An object-oriented design tool for associative cooling channels in plastic injection moulds. Int J Adv Manuf Technol 23:79–86 2004

[26]   Chan W.M. · Pinfold . M.,· Kwong C.K. · Szeto W.H. A review of research, commercial software packages and patents on family mould layout design automation and optimisationInt J Adv Manuf Technol 57:23–47 2011

[27]   Cinquegrana DA Knowledge-based injection mould design automation. D.Eng. thesis, University of Lowell 1990

[28]   Mok CK, Chin KS,Ho JKL An interactive knowledgebased CAD system for mould design in injection moulding processes. Int J Adv Manuf Technol 17:27–38 2001

[29]   Chan WM, Yan L, Xiang W, Cheok BT A 3D CAD knowledge-based assisted injection mould design system. Int J Adv Manuf Technol 22:387–395 2003

[30]   Claudia C (1999) CadKey® 97 quick reference. ISBN 0-7668- 0144-6. Delmar, New York

[31]   George Oa (2008) Mastering AutoCAD® 2009 and AutoCAD® LT 2009. ISBN 978-0-470-28704-0. Wiley,Indiana

[32]   IMSI (2009) TurboCAD® 16 2D and 3D training guides.IMSI

[33]   Siemens®PLM(2010)UG®NXtoolingbrochure.http:// www.plm.automation.siemens.com /en_us/ Images/4672_tcm1023-4494.pdf.

[34]   PTC® (2010) ProEngineer® tool design and expert mould base brochure.
         http://www.ptc.com/WCMS/files/63763/en/4411_Manufacturing_DS_EN.pdf.
[35]   VISI®(2010)VISI®Moulddatasheet. http://www.verosoftware.
         com/cms/files/products/visi/downloads/VISI_Mould.pdf.
[36]   CAXA®(2010)CAXA®2D/3Ddatasheet.http://www.caxa.
         com/cn/zhuanji/caxaenglish/english.html#CAD/CAM.
[37]   IMOLD®(2010)IMOLD®forSolidworks®technicalspecification. http://www.imold.com/view/page/imold.
         Accessed 20 Mar 2010.
[38]   Dassaultsystems(2010)SolidWorks®mechanicalCADcapabilities.
         http://www.solidworks.com/sw/products/mcad-3ddesign-software.htm.
[39]   Dassaultsystems(2010)Catia®formouldanddiebrochure.
         http://www.plm.automation.siemens.com/en_us/products/velocity/solidedge/overview/add_on_apps/m
         old_design.shtml.
[40]   Delcam® (2010) Delcam® toolmaker. http://www.powershape. com/general/toolmaker.asp.
[41]   Siemens®PLM(2010)Solidedge®mouldtooling.http:// www.plm.automation.siemens.com
         /en_us/products/velocity/solidedge/overview/add_on_apps/mold_design.shtml.
[42]   Cimatron®(2009)CimatronE®moulddesign.
         http://www.cimatron.com/SIP_STORAGE/FILES/0/1760.pdf

MULTITEMPORAL STUDY OF THE USE AND LAND COVER IN THE MUNICIPALITY OF URBANO SANTOS, MA

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Abstract

The demographic expansion and industrialization that occurred in Brazil, recently, has induced the increase of urban areas and, therefore, the increase of the use of new areas. The multitemporal analysis of a region is a process from which is possible to evaluate how certain information about this region varies with time. Monitoring of land-use and land-cover is important for the study of certain regions, as it contributes for the knowledge of the environmental reality, such as the research regarding solutions for problems that may occur. Therefore, the objective of this paper is to approach the multitemporal study of the land-use and land-cover at the county of Urbano Santos, localized at the territory of the lower Parnaíba, Maranhão State Citizenship to the East of the State of Maranhão in the Northeast region. To fulfill said objective, data obtained by remote sensing technique have been used, such as images from the TM/Landsat 5 satellite from the year of 1984, provided with free charge by INPE - National Institute for Space Research and images from the TM/Landsat 8 from the year of 2014, provided by the website of NASA - National Aeronautics and Space Administration.

1 Introduction

With the rice of technology, the global dynamism in geographic space and uniform alteration that the man maintains is elementary for the planning and control of space. Whereas some concerns that appear related to the sustainable use of natural resources in recent decades mainly. Depending on how these resources are used and exploited, the effect can cause ecological imbalance, causing degradation and alteration of the environment.

After the Atlantic Forest, the Cerrado is the Brazilian ecosystem with bigger process of change for human occupation. With increasing pressure to open new areas, aiming at increasing the production of meat and grains for export, there has been a progressive depletion of natural resources in the region. In the last three decades, the Cerrado has been degraded by the expansion of the Brazilian agricultural frontier [1]

A data comparison from different eras, for the same region, is known as multi-temporal analysis. Geographic Information System (GIS) point of view consists of an overlay operation, for example, overlapping of different letters in the same location. This type of work allows characterizing the changes in land cover type a specific place [2].

Systems and remote sensing techniques may allow the study of the environmental evolution of a region through multi-temporal analysis, making comparisons of the same landscape between two or more times and could thus assist in environmental monitoring in the region [3].

1.1   Objective

General objective

To analyze the evolution of change in the vegetation cover and its relation to land use in the municipality of Urbano Santos, with the recognition of the local agricultural landscape and its evolution over 30 years (1984 and 2014), creating a database for help define guiding policies of regional development.

Specific objectives
- Develop land use and vegetation cover maps using the satellite images Landsat TM 5 and Landsat TM 8 for Urbano Santos-MA;
- Quantify areas of use and defined coverage in images;
- Evaluate and compare the changes through a time series of 30 years (1984 and 2014).

2   Method

The studied area is the municipality of Urban Santos, located in the territory of Citizenship Low Parnaíba Maranhão, to the east of the State of Maranhão, between the coordinates 03º 44' 23"S and 42° 57' 46" W, distant 280 km of São Luís capital. The municipality has an area of 1.207.634 km². The estimated population in 2013 is 26 833 habitants, according to IBGE [4].

The vegetation that predominates in the region is formed by open savannah with diverse floristic composition; among the most common species are *Attalea speciosa* Mart. (Babaçu), *Copernicia cerífera* (Carnaúba) and *Mauritia vinifera* (Buriti). The Cerrado Courts generally have grasslands with scattered trees or saplings. The climate that predominates in the municipality is Tropical with winter rains, according to Koppen climate classification, with moderate water deficiency in the months from June to September.

For the continuation of this work were employed the following data and applications: a) satellite digital scenes Landsat TM-5 with a spatial resolution of 30 m, the year 1984 acquired the free site <www.inpe.br>; b) satellite digital scenes Landsat TM-8 with spatial resolution of 15 m, the year 2014, acquired the site, *http: earthobservatory.nasa.gov*. c) Letters planialtimetrics Letras-SUDENE in the range of ES 1 : 100,000 and d) software SPRING.

For the processing of digital images as well as for data analysis, it was used Georeferenced Information Processing System (SPRING), version 4.3.3. With the help of software, the areas bounded form, classified and quantified as the land cover changes and land use, through the interpretation of satellite images Landsat TM5 and Landsat corresponding TM8 the study area, the municipality mentioned above, with a space time 30 years. The work was basically split into five stages, namely: Acquisition of images, Georeferencing, Cut the municipalities, regions and rating Segmentation, Interpretation and Visual Ranking.

At the beginning of the process of targeting the region start from a pixel or pixels. According to National Institute for Space Research (2000), for each region of the segmented calculate the spectral attributes, such as: mean, variance, and texture. The aggregation of the regions is performed according to the criteria of similarity and area are provided by the analyst.

The preliminary results generated by Espíndola et al. [5], shows values between 8 and 10 to 20 and 25 of area, can be good indicators of an ideal segmentation. In the case of this work, better targeting has been generated for similarity of 15 and 30 area, in disagreement with the above values.

The results were adjusted guidance for the interpretation of visual, based on elements of photo-interpretation, how: tint, shape, shadow, texture, eliminating elements that were added to classes without following the criteria predefined for segmentation and delimitation of new areas that were ignored by the digital classification.

After correction of segmentation, polygons errors are identified in the visual interpretation all the images. Classifying and quantifying the space occupied in all are identified with colors for each defined class polygons.

3   Results and Discussion

Through visual analysis performed on the images, it was established that with agricultural growth, and especially the appearance of eucalyptus and soybean industries, there has been a disorganized occupation and indiscriminate use of land, especially the Cerrado ecosystem (Table 1).

Classification	1984 (ha)	%	2014 (ha)	%	Variation (ha)
Agriculture	5.639,10	4,7	20.006,46	16,6	14.367,4

Urban use	178,34	0,15	1.258,67	1,04	1.080,33
Savannah tree	78.860,45	65,3	81.542,55	67,4	2.682,1
Savannah park	36.156,68	30	18.023,35	15	18.133,33

Table 1. Area of use land according to the image and their properties compared in the year 1984 and 2014.

Deforestation rampant in urban Saints, mainly to meet the great agricultural demand, not only causes the extinction of animal species and native vegetation and also leads to increase environmental problems. It was noticed that the Savannah Park suffered a very considerable reduction of approximately 18,000 ha, while the Land Use grew rampant, with a range of about 15,000 there (Figure 1 and 2).
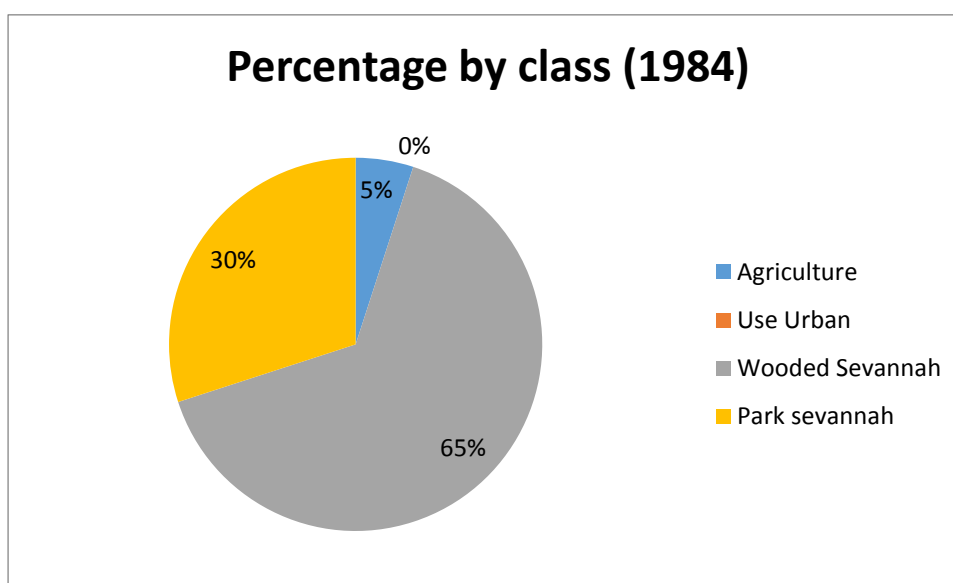
*Fig.1 Percentage by class of Urbanos Santos-MA (1984)*
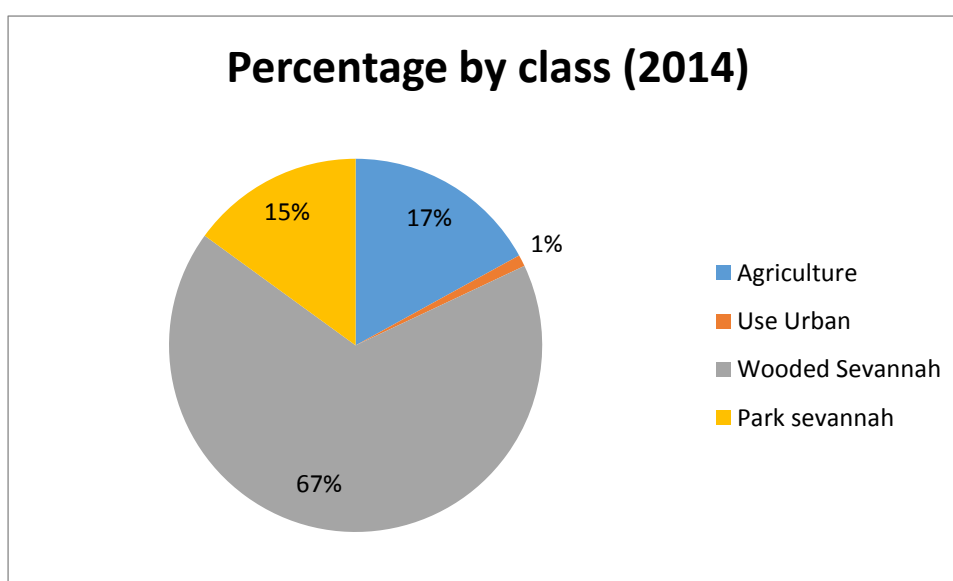
*Fig. 2 Percentage by class of Urbanos Santos-MA (2014).*

The removal of the native vegetation in the region intensifies the process of environment degradation. The increased level of these areas and the short time in which it occurs is worryingly.

This Geographic Information System and remote sensing provides an extensive set of knowledge to characterize dynamic phenomena that occur in agricultural areas. As a result, growth and validation of multi-temporal analysis techniques are important to conduct the necessary knowledge to better use of remote sensing in this field. Through the interpretation of satellite images reached up, an updated and accurate thematic map of the different spatial structures resulting from the process of occupation and land use (Figures 3 and 4).
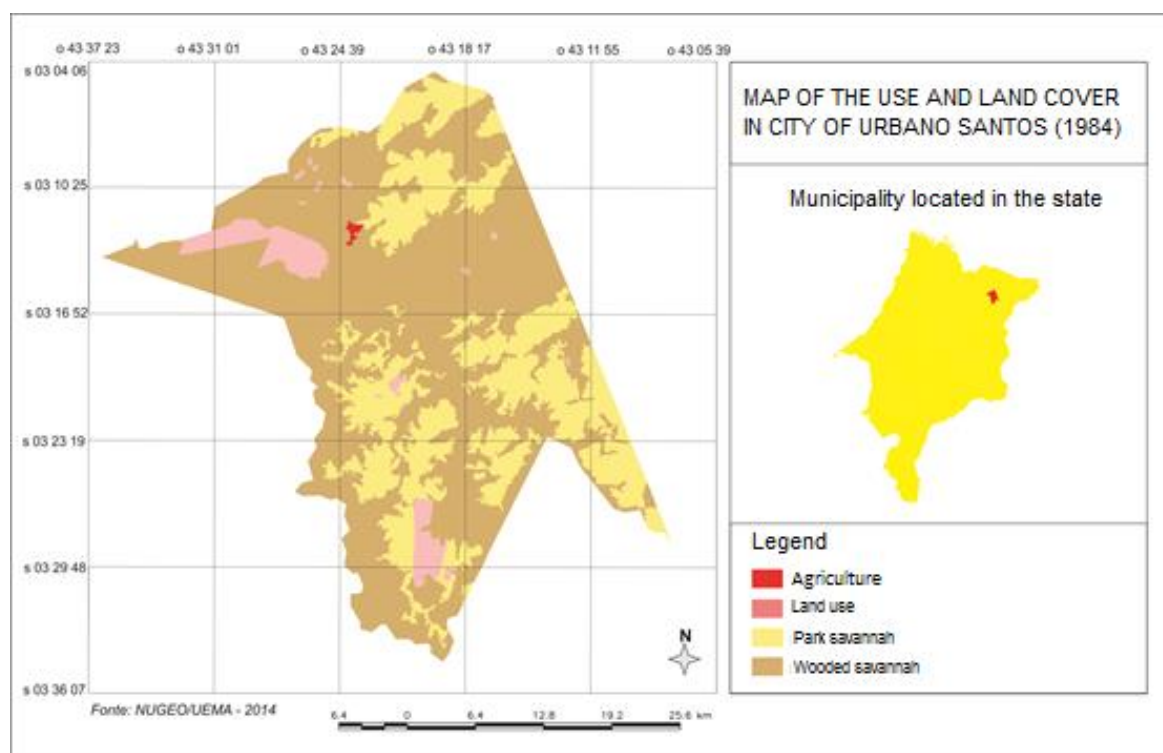
Fig. 3 Map of the use and land cover in city of Urbano Santos - MA (1984)
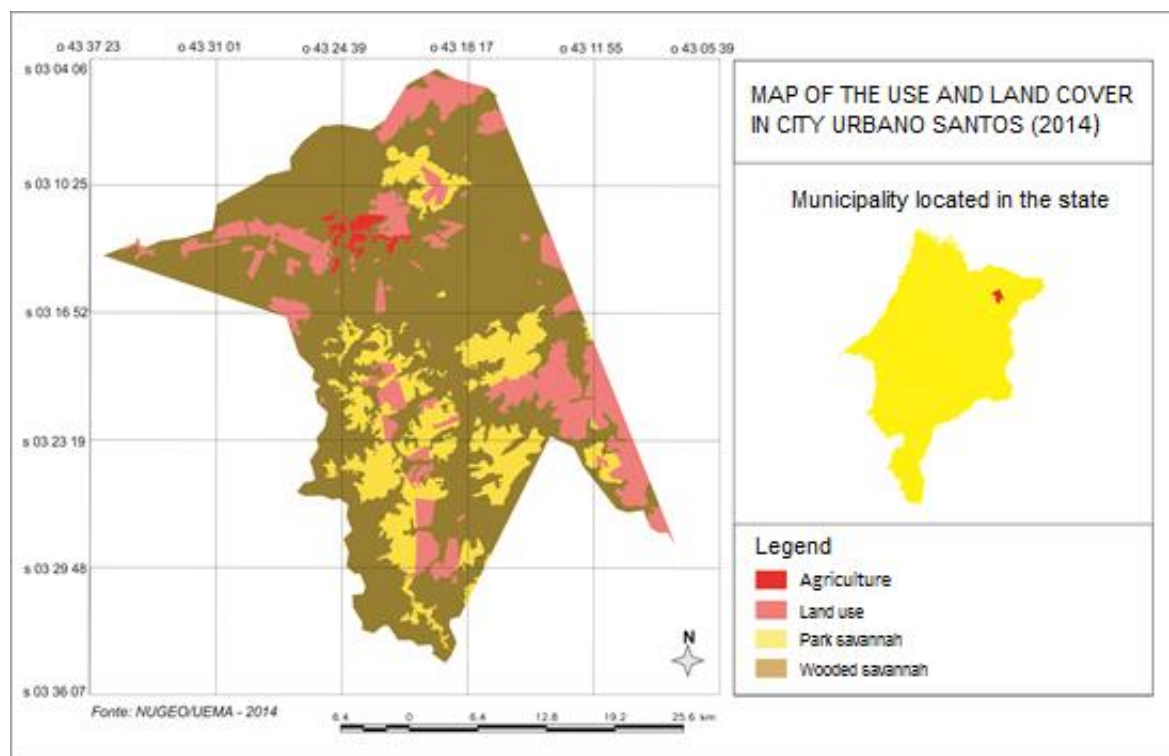
Fig. 4 Map of the use and land cover in city of Urbano Santos - MA (2014)

4 Conclusion

In view of this, the discussion and interpretation of the results obtained by analyzing the images, depending on the applied methodology to the following conclusions:

1. In the areas of Savannah Park in 30 years (1984-2014) there was a reduction of approximately 18,000 ha, while the areas of Land use, had an increase of approximately 15,000 ha, what can we say, according to visualization and interpretation of satellite images, which are considerable variations in what concerns the use and coverage, due to the growth of soybean farming and especially eucalyptus.
2. From the highlights shown in this study, there is just how overblown the process of occupation and land use in the municipality of Urbano Santos-MA, whose environment is fragile, and already has high levels of land use as a result indiscriminate replace the original vegetation cover for large areas of eucalyptus and soybean crops.

References

[1]   SANTOS, P. S.; EPIPHANIO, J. C. N. Avaliação histórica da expansão agrícola sobre o Cerrado no município de Luís Eduardo Magalhães, Bahia. In: XIV SIMPÓSIO BRASILEIRO DE SENSORIAMENTO REMOTO, 2009. Natal. Anais... São José dos Campos: INPE, 2009. p.6181-6188.

[2]   PARANHOS FILHO; A.C.; FIORI, A.P.; DISPERATI, L.; LUCCHESI, C.; CIALI, A. e LASTORIA, G. "Avaliação multitemporal das perdas dos solos na bacia do rio taquarizinho através de SIG". Artigo publicado no Boletim Paranaense de Geociências. N. 52, p.49-59. 2003.

[3]   GRIGIO, A.M. Aplicação de Sensoriamento Remoto e Sistema de Informação Geográfica na determinação da vulnerabilidade natural e ambiental no Município de Guamaré (RN): Simulação de Risco às Atividades da Indústria Petrolífera.Natal. Dissertação de mestrado. Programa de Pós-graduação em Geodinâmica e Geofísica. Universidade Federal do Rio Grande do Norte. 2003.

[4]   INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA - IBGE. Censo Demográfico 2013. Available at: <ibge.gov.br>. Accessed on: March 25, 2015.

[5]   ESPÍNDOLA, G. M. et al. Spatial autocorrelation indicators for evaluation of remote sensing image segmentation algorithms. In: GIS AND SPATIAL ANALYSIS 2005 ANNUAL

CONFERENCE OF THE INTERNATIONAL ASSOCIATION FOR MATHEMATICAL GEOLOGY. Proceedings… Toronto, Canadá. 2005.

INGEGRAF

MANAGEMENT AND PLANNING OF URBAN TREES BY MOBILE MAPPING SYSTEM

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Article Information

Abstract

Countless problems that have arisen in urban woodland, because they don´t complete a planning and proper management, arise currently numerous studies to streamline the implementation of sustainable management of green areas.

Based on the sustainable management model, we create a database and use a set of Geographic Information Technology (GIT), in order to solve the current problems of urban woodland.

The area selected for this study has been the municipality of Alcorcón (Madrid), on the basis of the Plan Director of woodland road from Alcorcón, and extending it to the green zones, we introduced the "Mobile Mapping System" that is able to capture georeferenced images, and generate a cloud of points, to subsequently make a representation in three dimensions (3D) doing a geovisualization of the Park and the sustainable management of this area.

We try to provide municipalities a TIG model, in order to planning the sustainable management of its existing urban trees, avoiding potential problems by anticipating the damage that may occur in the immediate future. We will also use the TIG for the management of the new road and green areas that may be created in the future, in order to prevent anomalies, risks and incidents that are currently being.

1 Introduction

Urban woodland management is a topic of great interest for proper urban planning.

The woodland of the cities is a necessary element to create a climate of well-being for all citizens. Brings benefits to reduce pollution, regulate the temperature and humidity environment and make more pleasant cityscape in an attempt to approach to the natural environment.

The problem is that in cities that have grown very quickly, urban expansion was made without carrying out planning in the implementation of urban woodland.

We looked for tree species of shade and rapid growth, but without taking into account their dimensions and spaces for planting. We looked for very repetitive and species well adapted to the urban environment, like the Platanus (Platanus x acerifolia) and other. They were not taken into account plantation frames nor the future development of the trees. Nor was taken into account, in the aerial part, the distance to the facades, urban furnishings, to parked cars. It is also important to note that in the root zone, the safety distance to the underground facility was not raised. Criteria and recommendations based on experience for this type of interventions [1] have emerged in recent years.

Known as smart cities are characterized by using data from sensor networks. Integrate this information and then analyze it are phases necessary to make good decisions. The vegetation and other natural elements and / or artificial that are on the ground have often been the subject of study of spatial remote sensing [2] [3]. However the detection of those same elements from terrestrial mobile platforms has been

less common. In This study we present an application of Mobile Mapping System (MMS) in the management of urban trees. Gets a 3d vision of the visited area that can be complement to urban inventory of different type [4]. Geometrical data of the cloud of points that allow quick interventions on the green areas may also be removed.

1.1   Area of study

Alcorcón is one of the 179 municipalities in the province of Madrid (Spain) (Fig. 1). Its location near Madrid has been decisive in the evolution of the landscape elements. The municipality of Alcorcón has an area of 33.79 square kilometers and residents 168000. The nearly 15,000 units Alcorcon street trees are distributed in 72 different species, but its distribution is not homogeneous. There are so many units distributed in city parks.
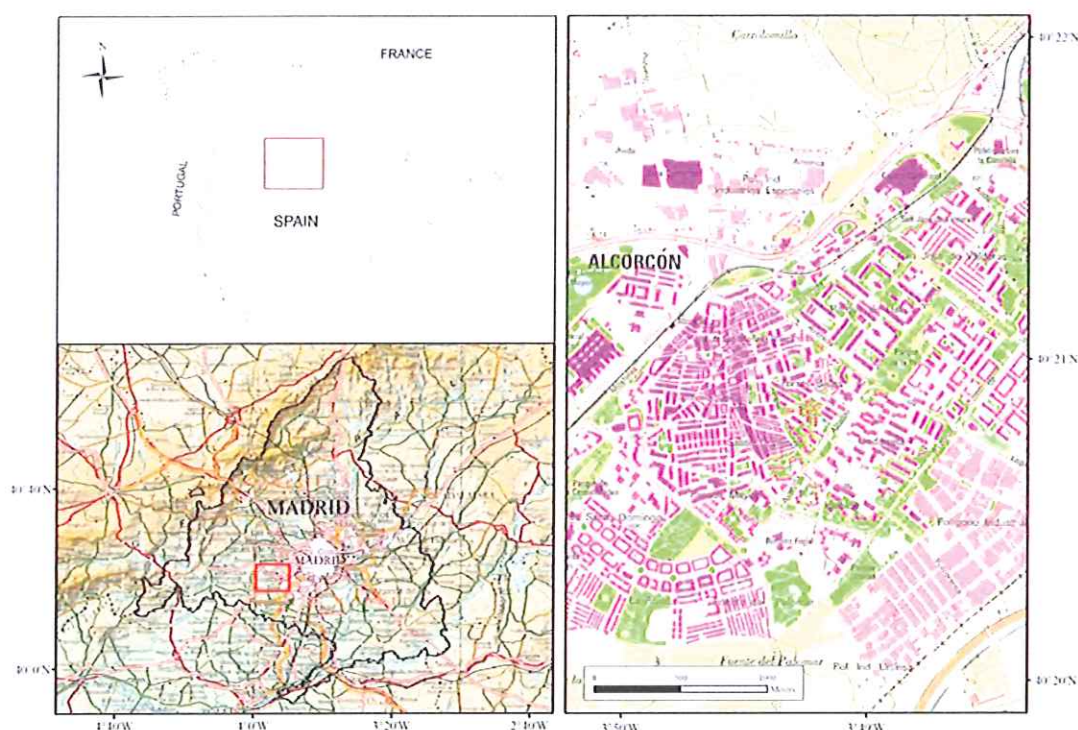

Fig. 1 Location maps of zone the experimental study (Lisboa Park-Alcorcón)

2   Method overview

Furthermore, over the last five years, some very big companies such as Google, Tele Atlas and NAVTEQ have adopted the technology on a large scale, introducing substantial fleets of mobile mapping vehicles for their imaging and mapping operations. Topcon´s IP-S2 Mobile Mapping System is a technology that is being used in studies of information systems because of its speed and accuracy in acquiring massive data [5].

The study and analysis of the historical evolution of the landscape is essential in rural and urban planning [6]. Upgrade of cartographic information has been done using data supplied by fieldwork and implemented by geographic information system Ingrid. Ingrid is the "software" that is part of all applications "Ingra" trade name under which it is distributed. You can view and edit the vector data of 2D Geo Map references on different orthophoto funds. Data for mobile laser scanning system was collected with IPS2 Topcon (Fig. 2). With the mobile mapping system in the test site was driven around twice, in clockwise and counter-clockwise

direction, at speed of about 25-35 km/h. This system can collect also image data (still cameras or video). This methodology has been used by [7] [8] [9].

Fig. 2 Map municipality of Alcorcon (INGRID System) and detail of IPS2 (Mobile Mapping System)

This work has been followed the methodology described in the scheme of the Fif. 3. The use of mobile mapping system (MMS) has been used to obtain a three-dimensional survey (3D) of the area visited. The information and data with other geodata from the current management of urban trees (Web Map Services and GIS green City-Ingrid) will give us the possibility to identify types of trees and greenery. From this inventory information and geodata will have a real and current display 2D and 3D. This current digital image, is the basis on which proposals for improving the management of urban woodland will be formulated.
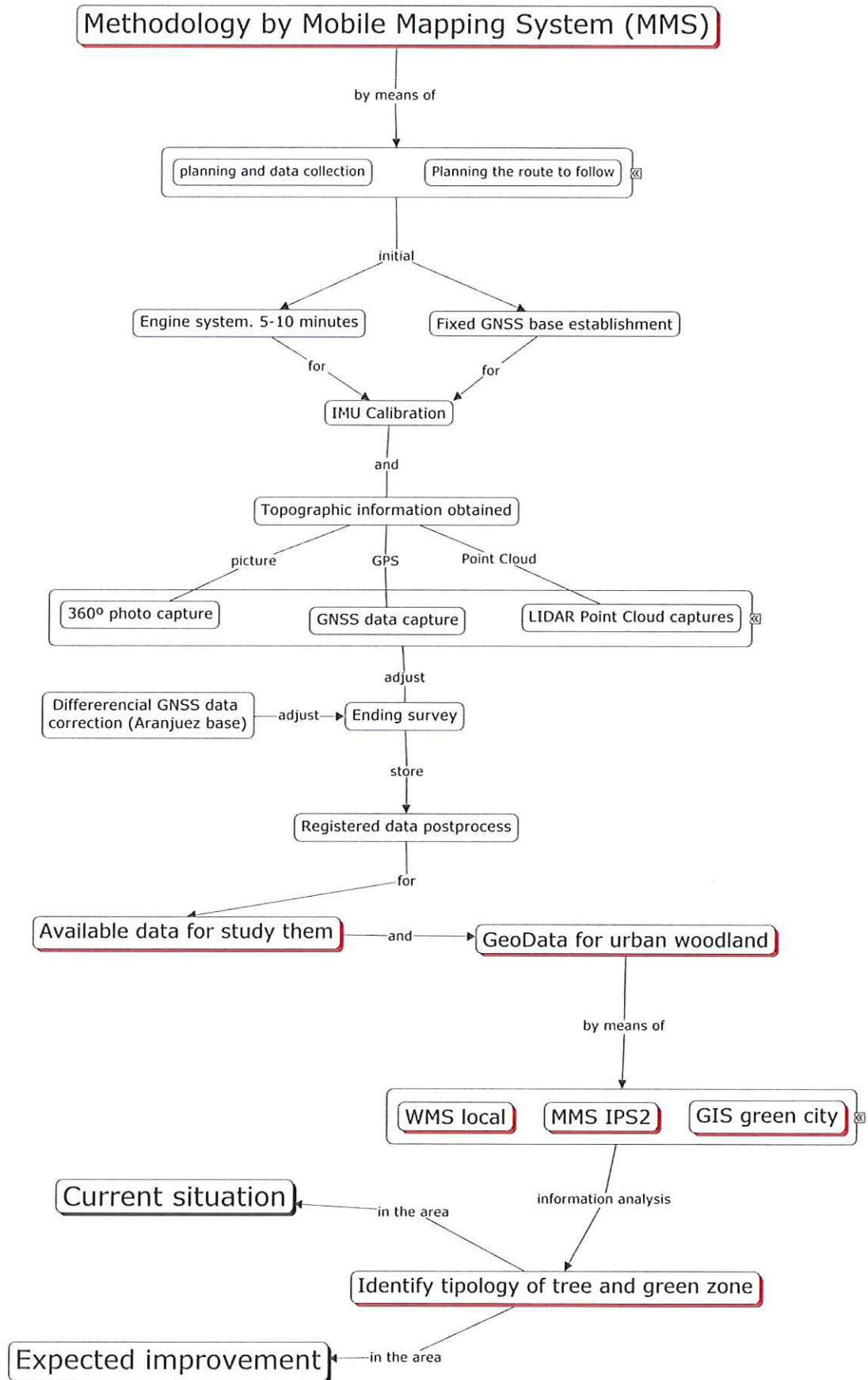
Fig. 3 Procedure for field data collection and update of the information system
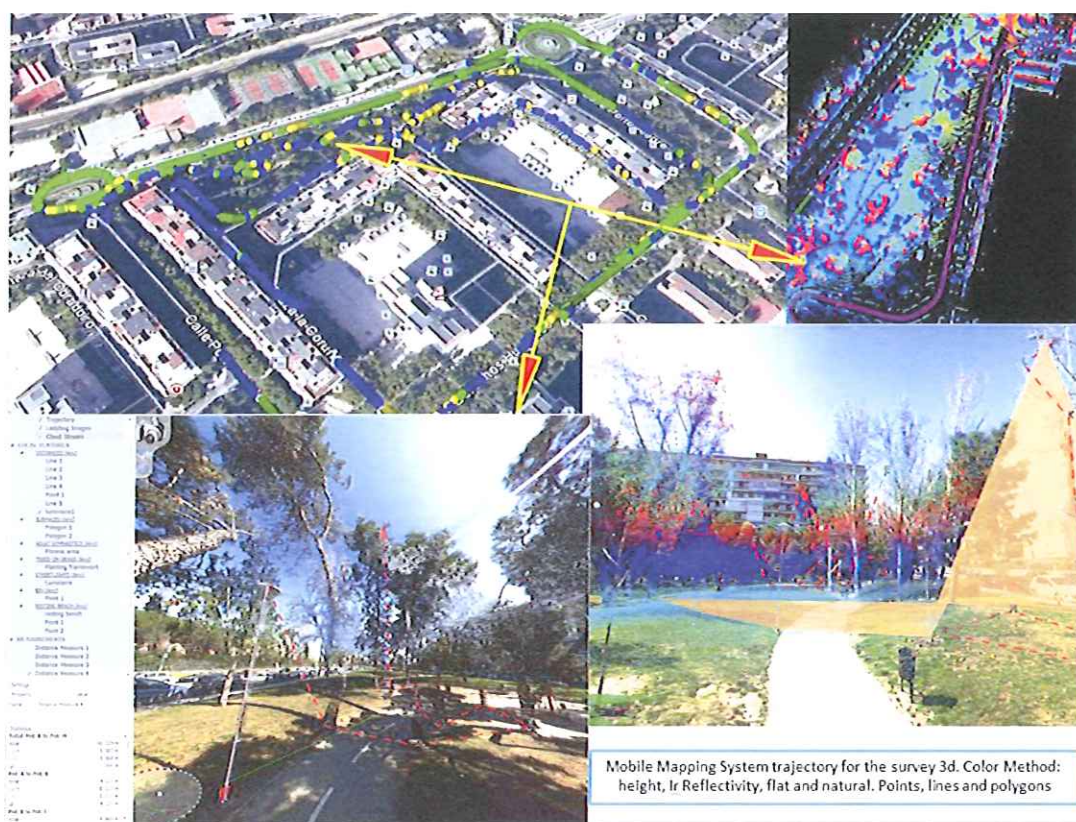
The problems identified in the urban woodland are related to the environment in which they develop and perform their functions. This methodology has been taken into account the classification according to the type of damage they can cause as [10]: a) Physical type and/or mechanical problems. b) Problems related to the health of people and C) Problems that interfere with the environment in which they develop. Also other experts use these same criteria, [11].

3   Results

It has obtained a number of geodata along with graphical and cartographic information already available allow us to intervene quickly in the daily management of this type of green areas and urban trees. The ability to visualize in 3D the main elements that are part of an urban park can create valid to modify and streamline urban planning models.

The software used in data processing can be identified by the color of the point cloud high end, middle and lower model generated in the area visited. The red color corresponds to the highest part while the blue belong to the lowest.


Mobile Mapping System trajectory for the survey 3d. Color Method: height, Ir Reflectivity, flat and natural. Points, lines and polygons

Fig. 4   Spatial Factory software: visualization of information acquired by the IPS2 system, colour of the point cloud and necessary measures

With the information obtained we can identify the species of each tree, make various measurements, such as the diameter and height of each element, minimum and maximum distances can be assessed health status and develop a comprehensive maintenance plan, Fig. 4.

From the view of the *current situation*, a new arrangement of the elements of each parterre is formulated, the closest and affected by woodland, with a new proposal to increase management efficiency. In the current situation a disorder in the distribution of urban trees is observed. For example, plantation frames inappropriate species, trees competing with each other, either in the aerial or at the radicular part, damage to the grass by trees, etc. Consequently, the *expected improvement* would be to separate one part urban trees properly ordered on the other hand, the only grass area with shrubs and flower massifs, Fig. 5.
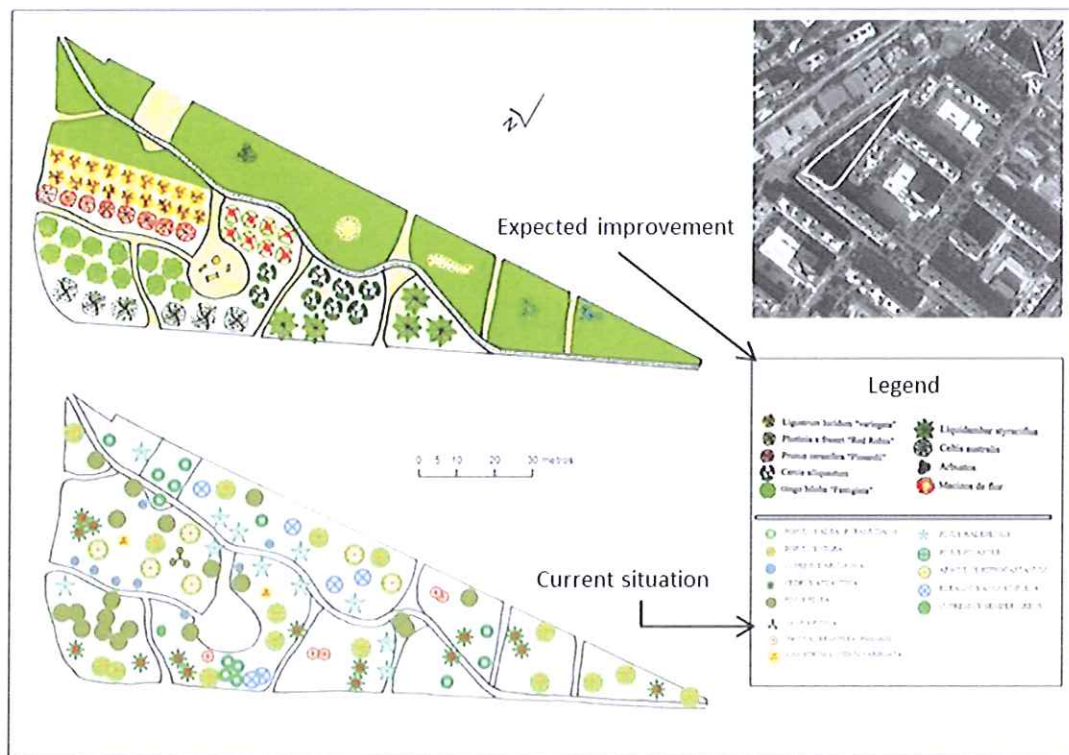
Fig. 5   Current situation and expected improvement in function of the incidences the vegetation and the urban woodland (Victimas del Terrorismo Park)

4   Conclusion

The 3D survey of urban woodland carried out by Topcon's IP-S2 Mobile Mapping System has allowed obtaining accurate models and getting an integrated visualization of reality. Mobile Mapping System technology used successfully in urban environments, offers the possibility of different applications in green areas, from the integral study of landscape network, re-designation of areas, vegetation preservation, public forest, paved surface inspection, photo-logs, simulation, etc.

Today there is still a high demand for computer tools for the realization and management of inventories of woodland and urban green areas.

The information that is provided with this way of working can be used in different formats including devices miniaturized such as smartphones and tablets, this will lead to the optimization of management.

It's easy and fast to apply this methodology. The cost however can be high because the MMS remains an inaccessible system. However in management of large areas of medium and large cities can be very efficient.

It is a noninvasive method and as such it can be recommended for this type of operation.

Acknowledgement

References

[1]   Selga J. (2010). Planes estratégicos de las calles arboladas. Libro de ponencias del I Congreso Hispanoamericano de Arboricultura Restaurando el pasado, planificando el futuro.101-105.Toledo.

[2]   Iovan, C., Boldo, D. and Cord, M., *Detection, characterization, and modeling vegetation in urban areas from high-resolution aerial imagery*, IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing 1(3), 2008, pp. 206–213.

[3]   Daliakopoulos, I. N., Grillakis, E. G., Koutroulis, A. G. and Tsanis, I. K., *Tree crown detection on multispectral vhr satellite imagery*, Photogrammetric Engineering Remote Sensing 75(10), 2009, pp. 1201–1211.

[4]   Monnier, F., Vallet, B. and Sohelian, B. *Trees detection from laser point clouds acquired in dense urban areas by a mobile mapping system*, ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume I-3, 2012 XXII ISPRS Congress, 25 August – 01 September 2012, Melbourne, Australia.

[5]   Lin, Y. and Hyyppä, J., 2011. k-segments-based Geometric Modeling of VLS Scan Lines. *IEEE Geoscience and Remote Sensing Letter,* 8(1), pp. 93-97.

[6]   Skaloš, J., Molnárová, K., & Kottová, P. (2012). Land reforms reflected in the farming landscape in East Bohemia and in Southern Sweden – Two faces of modernisation. Applied Geography, 35, 114-123.

[7]   Anttoni Jaakkola, Juha Hyyppä, Antero Kukko, Xiaowei Yu, Harri Kaartinen, Matti Lehtomäki and Yi Lin, *A low-cost multi-sensoral mobile mapping system and its feasibility for tree measurements*, ISPRS Journal of Photogrammetry and Remote Sensing, Volume 65, Issue 6, November 2010, Pages 514-522.

[8]   Kaartinen, H., Kukko, A., Hyyppä, J., and Jaakkola, A. *Benchmarking mobile laser scanning systems using a permanent test field*, International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XXXIX-B5, 2012, XXII ISPRS Congress, 25 August – 01 September 2012, Melbourne, Australia.

[9]   Herrero, T., Conejo, M., Pérez-Martín, E. and López-Cuervo, S. *Assessment of mobile mapping system: A GIS-based support methodology*, Global Journal on Technology, Vol 3 (2013): 3rd World Conference on Information Technology (WCIT-2012), pp. 1405-1410.

[10]   Calzada, P. and Iglesias, M. Evaluación de riesgo de arbolado peligroso. Asociación Española de Arboricultura, 2012.

[11]   Waldheim C. *The Landscape Urbanism Reader*. New York: Princeton Architectural Press, 2006.

GEOINFORMATION AS AN AID TO THE RESPONSE OF THE EMERGENCY SERVICES AT INDUSTRIAL PARK

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Abstract

The defense against risks that can affect the industrial buildings is one object of study in the field of civil protection at the municipal level.

Increasingly more administrations and users themselves arouse us that the same citizen which must acquire proper training to deal with any problems that arise in the field of security. Today may be timely use of information systems as an aid to emergency systems that are intended to provide service to society.

The study aims to facilitate the work of those responsible for civil protection through the optimal use of geo-information to shorten response times.

The area used for this study corresponds to an industrial park in the town of Paracuellos del Jarama (Madrid). Maps and images from different sources of information have been used. A database related to inherent risks within the companies that develop their activity within the tested polygon was subsequently designed.

We have created an information system that improves the response of emergency civil protection services by risks in industrial park.

1 Introduction

Risk assessment methods are applying for several decades, legislative obligation, both for technical reasons in order to assist security professionals in decision-making [1]. Currently, due to the technological advances in the field of the technical coordination and simulation applied [2] in a new method in Building Information Modeling (BIM) building, risk assessment methods allow model, simulate, and implement solutions to deal with the risk of fire and its spread [3]. There are different methods of evaluation of the fire risk that quantify the level of risk of the establishment and provide different protection measures to be carried out [4]. The Article 20 of the 31/1995 law of Prevention of Occupational Risks [5] set the employer must analyze possible emergency situations and take appropriate measures in the field of first aid, the fire-fighting and evacuation of workers. In the case of industrial establishments, the assessment of the risk of fire is regulated by the RD2267/2004, of 3 December, which approves the regulation of Fire Safety in Industrial Establishments [6].

When designing a plan of self-protection must pay special interest in the choice of the method of evaluation of the risk of fire. This will determine in the majority of cases the success of the analysis to be carried out. There are several methods that exist for the evaluation of the risk [6]. MESERI method, compared to others, is the most simple method and the most widely used by analysts of risks [7]. MESERI method is an initial orientation that will serve only for a quick view of the overall risk of fire in the chosen place.

On the one hand the method uses a series of factors which cause or exacerbate the risk of fire, such as installations, and other factors, factors that collaborate with the protection against the risk of fire.

Thus in the numerical value of the risk function, we obtain by using a table the risk rating. The objective of the study is to develop a map of risks of the industrial estate "El Cerbellon" to control or eliminate the most relevant risks of the various companies and the subsequent conclusions, recommendations and action plans.

Analysis of the risk of fire in an industrial area implies the fulfillment of three main stages,

- Physical inspection of the site of the potential risk
- Evaluation of the magnitude of the irrigation
- Report and response measures

Evaluates the probability of the risk occurring and the intensity and vulnerability in the event of occurrence of the same. MESERI method uses the point scheme. It is based on the individual consideration of various generators and aggravating factors and risk of fire (X) and also independently of them that reduce and protect against risk (Y). Once obtained the X and Y factors, apply the equation 1,

$$P = \frac{5X}{129} + \frac{5Y}{26} + B \qquad (1)$$

Where P is the value of the risk result. Coefficient B is the coefficient found in 2.2b and evaluates the existence of a brigade internal fire.

The method allows an overall appraisal of the risk of fire and is mainly designed for application in small and medium-sized industrial type whose activity is not inherently dangerous. A visual inspection of a number of factors of a building and its comparison with a few preset values will give us the information resources for the estimation of risk P which will be between the values 0 and 10.

Industries whose score is less than 5 should be evaluated in more detail, investigating in the first place the scored zero. On the other hand, nor it should be understood that the score greater than 5 indicates that there is no risk of fire.

2   Methodology

The zone of study (fig. 1) is located in the Industrial Park of "El Cerbellon", belonging to the municipality of Paracuellos del Jarama (Madrid).
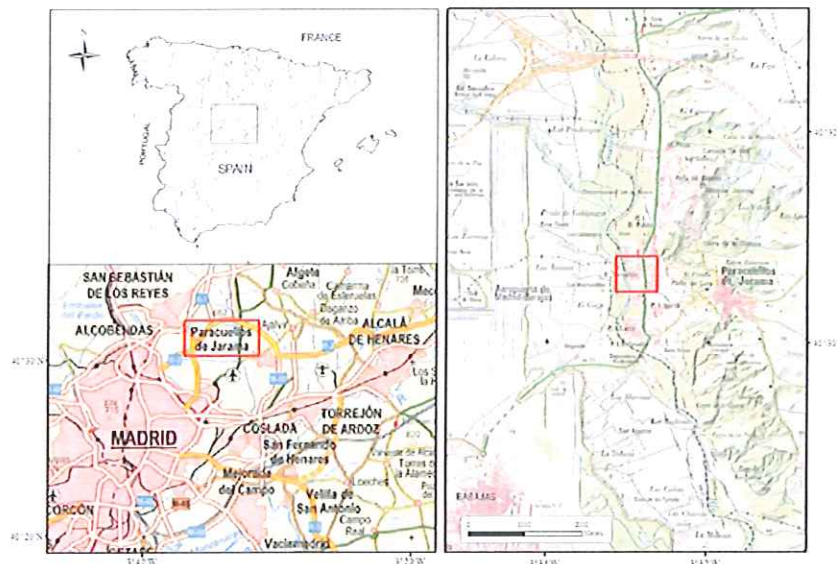
Fig. 1. Location of the industrial park used in the methodology. The industrial park "Cerbellón" is located to the West of the town of Paracuellos del Jarama, very close to the airport "(Adolfo Suarez-Madrid Barajas)."
Spatial Reference System UTM ETRS89 Zone 30N

It is obvious that a simplified method must bring together lots of information in a small space, having been necessary to select only the most important aspects and not consider other less relevant. Each of the risk factors is subdivided in turn take account of the most important aspects to consider, as we will see below.

Applies a coefficient depending on which lead to the risk of fire or don't do it, from scratch in the worst case up to ten in the most favorable case. It includes two blocks of different factors:

2.1 Generators and aggravating Factor and risk (X)

a) Construction

- Building height. Height of a building means the difference in dimensions between ground floor or basement last floor and the slab which is the cover. Between the coefficient corresponding to the number of floors and the height of the building, the child will take.

Number of floors	Height	Coefficient
1 or 2	Minor than 6 m	3
3, 4 or 5	between 6 and 12 m	2
6, 7, 8 or 9	between 15 and 20 m	1
10 or more	more than 30 m	0

Table 1. Valuation according to the warehouse height.

If the building has different heights and the highest part occupies is more than 25% of the surface in the whole plant, the coefficient will be taken at this point. If it is less than 25% it will be taken the coefficient of the building.

- Largest sector of fire. It means sector of fire for the purpose of this method, the area of the building bounded by fire-resistant elements 120 minutes. In the case that is an isolated building will take its total area, although closures have lower resistance.

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Largest sector of fire	Coefficient
Minor than 500 m²	5
From 501 to 1.500 m²	4
From 1.501 to 2.500 m²	3
From 2.501 to 3.500 m²	2
From 3.501 to 4.500 m²	1
More than 4.500 m²	0

Table 2. Valuation according to extension

- Fire resistance. It refers to the structure of the building. He understands how resistant to fire, a concrete structure. A steel structure will be considered as non-combustible and, finally, fuel if it is different from the previous two. If the structure is mixed, a ratio intermediate between the two dice will be taken.
- Suspended ceilings. He is understood as such to the coatings of the upper part of the structure, especially in industrial buildings, placed such as thermal, acoustic insulation and decoration.

Fire resistance	Coefficient	Suspended ceilings	Coefficient
Fire resistant	10	Without suspended ceilings	5
Noncombustible	5	Fireproof suspended ceilings.	3
Combustible	0	Combustible suspended ceilings	0

Table 3. Valuation according to resistance to fire and suspended ceiling.

b) Situation. They are those who depend on the location of the building. Two are:

- Distance from the fire service. Be taken, preferably, the coefficient corresponding to the response time for firefighters, using the distance to the Headquarters only orientative.

Distance	Time	Coefficient
Less than 5 km	5 minutes	10
Between 5 and 10 km	from 5 to 10 minutes	8
Between 10 and 15 km	from 10 to 15 minutes	6
Between 15 and 25 km	from 15 to 25 minutes	2
More than 25 km	more than 25 minutes	0

Table 4. Assessment by distance to firefighter service.

- Accessibility of the building. Shall be classified in accordance with the width path, provided that it meets one of the other two conditions of the same rank or higher. If not, will be lowered to the less immediate coefficient.

Wide path	Accessible facades	Distance between doors	Qualification	Coefficient
More than 4 m	3	Less than 25 m	GOOD	5
Between 4 y 2 m	2	Less than 25 m	MEDIUN	3
Less than 2 m	1	More than 25 m	BAD	1
There is no	0	More than 25 m	VERY BAD	0

Table 5. Valuation according to the accessibility of the building.

c) **Processes and/or destinations**. The characteristics of manufacturing processes that are made, the products used and the destination of the building should be collected.

- Danger of activation. You try to pick up the possibility of starting a fire. We must mainly consider the human factor which, by recklessness can activate the burning of some products. Other factors are related to the energy sources present in the analyzed risk.

  • Electrical: transformers, distribution of energy, maintenance of facilities, proper protection and design.
  • Steam and hot water boilers: fuel distribution and maintenance of burners.
  • Hazardous specifics: operations open flame, such as welding, and sections with presence of combustible powder.

Danger of activation	Coefficient
Low	10
Medium	5
High	0

Table 6. Assessment of the manufacturing process.

- Fire load. Means as weight in wood surface (kg/m²) unit capable of developing an amount of heat equivalent to the materials contained in the fire sector.

Fire load		Coefficient
Low	Q < 100	10
Medium	100 < Q < 200	5
High	Q > 200	0

Table 7. Valuation according to fire load.

- Combustibility. The ease with which materials react in a fire shall be deemed as combustibility. If there is a qualification by testing is used this as guide, otherwise, the technical evaluation criteria should be applied.
- Order and cleanliness. The criterion for the application of this coefficient is purely subjective. Means high when they exist and are respected areas delimited for storage, the products are properly stacked in place, there is no dirt or debris or cuts throughout the ship indiscriminately.

Combustibility	Coefficient	Order and cleanliness	Coefficient
Low	5	Low	0
Medium	3	Medium	5
High	0	High	10

Table 8. Valuation according to combustibility and order and cleanliness.

- Storage in height. Become a simplification in the factor of storage, whereas only the height, by understanding that a poor distribution in surface can be assumed as lack of order in the previous section.

Storage in height	Coefficient
h < 2m	3
2 < h < 4m	2
h > 6 m	0

Table 9. Valuation according to storage height.

d) **Concentration factor.** Represents the value in $/m² of the contents of installations or sectors to evaluate. It is necessary to note that protections must be higher in case of important concentrations of capital.

Concentration factor	Coefficient
Less than 1000 $/m²	3
Between 1000 y 2500 $/m²	2
More than 2500 $/m²	0

Table 10. Valuation according to concentration factor.

e) **Propagability (ability to spread).** Facility means as such to spread the fire, within the sector of fire. It is necessary to take into account the provision of products and stocks, storage shape and clearances from combustible products.
- Vertical. It will reflect the possible transmission of fire between floors, taking into account an adequate separation and distribution.
- Horizontal. You will be assessed the horizontal spread of the fire, also attending the quality and distribution of the materials.

Vertical spread	Horizontal spread	Coefficient
Low	Low	5
Medium	Medium	3
High	High	0

Table 11. Valuation according to fire propagation.

f) **Destruction.** The influence of the effects produced in a fire, on the materials, elements and existing machines will be studied. If the effect is frankly negative applies the minimum ratio. If does not affect the content, then will apply high.

- Heat. It will reflect the influence of the temperature rise in machinery and existing elements. This coefficient will hardly be 10, since heat usually affects the content of the analyzed sectors.

  • Low: when stocks are not destroyed by heat and not there is precision machinery or other items that could damage by the action of heat.
  • Medium: when stocks would degrade heat without destroying it and machinery is scarce.
  • High: when products are destroyed by the heat.

- Smoke. The damage will be studied by smoke to machinery and materials or existing elements.

  • Low: when the smoke affects little products, well because not expected its production, well because the subsequent recovery will be easy.
  • Medium: when the smoke affects the products partially or expected little formation of smoke.
  • High: when the smoke completely destroys products.

- Corrosion. It takes into account the destruction of the building, machinery and stocks as a result of oxidizing gases detached in the combustion. A product that must particularly be taken into account is the hydrochloric acid produced in the decomposition of the polyvinyl chloride (PVC).

  • Low: when not expected the formation of corrosive gases or products not are destroyed by corrosion.
  • Medium: when he is expected the formation of oxidizing gases which affect stocks nor in form important building.
  • High: when expected the formation of oxidizing gases that affect the building and machinery significantly.

- Water. It is important to consider the destruction by water since it will be the key element to get the fire.
  • High: when products and machineries are destroyed completely by water effect.
  • Medium: when some products or stocks suffer irreparable damage and others are not.
  • Low: when the water does not affect products.

By heat	By smoke	By corrosion	By water	Coefficient
Low	Low	Low	Low	10
Medium	Medium	Medium	Medium	5
High	High	High	High	0

Table 12. Valuation according to destruction by heat, smoke, corrosion and water.

2.2 Protection factors

a) Facilities

The existence of adequate protection is considered essential in this evaluation method for the classification of the risk. So much so that, with full protection, the qualification will never be less than 5. Naturally, a simplified method that intends big agility should reduce the range of fire protection measures to the indispensable minimum, by what they consider only the most common.

We have also considered the existence of media such as the protection of dangerous points with special fixtures, fixed systems of gaseous agents and the availability of fire brigades.

Factors of protection facilities	Without surveillance	With surveillance
Hand extinguishers	1	2
Fire hydrants	2	4
External hydrants	2	4
Fire detectors	0	4
Automatic sprinkler	5	8
Fixed installations	2	4

Table 13. Valuation according to means of protection.

b) **Internal fire brigades**. When analyzed the building or plant has personnel specially trained to act in the case of fire, with the equipment needed for its function and appropriate personal protection elements, the coefficient associated B adopt values:

Internal fire brigades	Coefficient
If there is a brigade	1
If there is no brigade	0

Table 14. Valuation according to existence of personal fire.

2.3   Method of calculation.

To facilitate the determination of the coefficients and the evaluation process, the required data have ordered in a form which, after completion, carries the following numerical calculation:

Subtotal X: sum of the coefficients corresponding to the first 18 factors.

Subtotal Y: sum of coefficients corresponding to the existing means of protection.

Coefficient B is the coefficient found in 2.2b and evaluates the existence of a brigade internal fire.

The coefficient of protection against fire (P) shall be calculated by eq. 1

The value of P offers numerical evaluation method, so that object:

For a qualitative evaluation:

P-value	Category
0 a 2	Very serious risk
2,1 a 4	Serious risk
4,1 a 6	Medium risk
6,1 a 8	Slight risk
8,1 a 10	Very slight risk

Table 15. Qualitative evaluation of the P index.

For an exhaustive assessment:

Acceptability	P-value
Acceptable risk	P > 5
Not acceptable risk	P ≤ 5

Table 16. Limited evaluation of the risk of fire.

When you have chosen the method of evaluation of the risk of fire (MESERI) we made the field work consisting first the on-site data collection. Therefore is fill out a form, previously designed for this purpose, which includes all the features of the company to be evaluated. There were also photographs of buildings that are subsequently included in the tab.

The next step is the study of all the variables, as well as the display of the photographic archive to reach the objective assessment of the risk "P" of each building individually.

The information produced from data of field and subsequent process of preparing industrial building has been treated by a data information system to perform the geo-visualization in the industrial area.

Risk is weighted between values from 0 to 10, constituting the value 0 to the buildings most susceptible to damage and 10 buildings more protected.

3 Results

The enclosed (Fig. 2) is the result of the field work put it in an Excel sheet designed for this purpose. The introduction of values evaluated in the sensory perception of the industrial buildings makes it possible to through the application of method of Meserí obtain rapidly the value of risk data.

Figure 2. Example of tab of industrial ship for the study of assessment of risk by fire by Meserí method.

This work provides a chromatic contribution study, which, together with the application GIS location becomes a visual approach of the problem (Fig. 3).

The Fire extinguishing media and Civil Protection and Security can check in real time and even before that the focus of the fire from reaching the characteristics of the environment. They make as well a decision what is the area with big risk or you need greater protection once the fire started, either by the constructive characteristics, by measures of self-protection that contemplate, or even by the accessibility of these media to other buildings within the industrial estate that study.
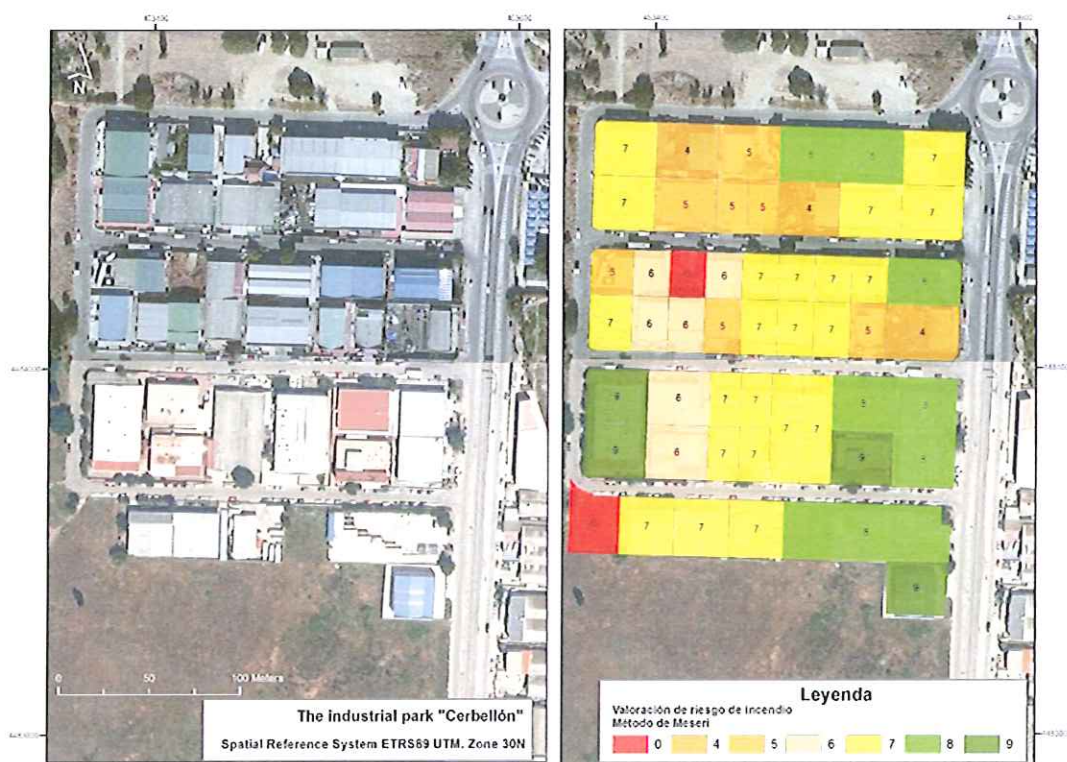
Figure 3. Analysis of the study of risk of fire from Meserí method. Location in

Spatial Reference System UTM ETRS89 Zone 30N.

4 Conclusion

La utilización del método MESERI, frente a otros, es la sencillez y rapidez para la evaluación de incendios. Resultando un método casi intuitivo para personas con experiencia en evaluación de incendios. Otros riesgos pueden aportar más información pero su complejidad en el cálculo nos lleva a desestimarlos.

The choice of method MESERI, compared to others, is the simplicity and speed for the fire risk evaluation. Resulting in a very intuitive method for people with experience in fire risk evaluation. Other risk evaluation methods can provide more information, but its complexity in the calculation leads us to reject them.

The Fire extinguishing media, Civil Protection and Security, will have an application which before leaving their bases could have a rational vision and objective of the environment and thus devise a strategy of attacking the problem.

Based on this study, we could develop one action that is to provide signals on the facades of the buildings according to the rate of fire hazard valued by the method developed, embodied in different colors according to the same.

In terms of prevention, provides a reasoning right by which companies that have proven a rate very low (red) must organize his own work guides consistent to converge towards green tones.

References

[1] Romero, J. C. R. (2004). Métodos de evaluación de riesgos laborales: Ediciones Díaz de Santos.

[2] Sakenaite, J. (2010).*A comparison of methods used for fire safety evaluation*. Mokslas -- LietuvosAteitis. Vol 2, nº 6, 36-42.

[3] Fridrich, J., & Kubečka, K. (2014). *Fire Risk in Relation to BIM*. Advanced Materials Research, 899, 552-555.

[4] INSHT (2003). NTP 599: Evaluación del riesgo de incendio: criterios. España: Ministerio de Trabajo y Asuntos Sociales.

[5] Jefatura de estado (1995). Ley 31/1995, de 8 de noviembre, de Prevención de Riesgos Laborales [en línea]. España, 10 noviembre 1995.

[6] Ministerio de industria, turismo y comercio (2004). Guía Técnica de Aplicación: Reglamento de Seguridad Contra Incendios en los Establecimientos Industriales (RD 2267/2004, de 3 de Diciembre).España.

[7] Peña, J. F., & Romero, J. C. R. (2015). Análisis comparativo de los principales métodos de evaluación del riesgo de incendio.

XXV Congreso
INGEGRAF

MULTITEMPORAL ANALYSIS OF THE USE AND LAND COVER IN ISLAND OF MARANHÃO

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Article Information

Abstract

The process of occupation of the island of Maranhão, has intensified due to the economic, political and social and became worrisome given the fragility of the natural resources to human action. Therefore, the aim of this work was to study the dynamics of landscape and occupation of physical space-territorial Island in the years 1984 and 2010 by means of TM/ Landsat 5. For the image processing was structured a database in GIS, UTM projection, Datum SAD69, using the software SPRING 4.3.3. The images were segmented and subjected to a visual classification. The time series of images showed a trend towards fewer areas of vegetation, particularly in riparian areas (45.5%), secondary forest (17.83%) and mangrove (15.02%). Sandbank areas, depending on the natural dynamics, the changes were less evident (1.5%) It was also observed that the urban area had a high growth rate (143.8%) being distributed over the north central portion of the island. Over the past 26 years, the island had a population growth rate of 112.26%, which represents 84.56% Capital. The results confirm that the analysis of satellite images is an important tool in mapping the use and occupation of land and assist in planning the physical space-territorial island.

1 Introduction

The term geo-processing denotes a discipline of knowledge which uses mathematical and computational techniques for the treatment of geographic information. These techniques become more and more influence in the areas of mapping, analysis of natural resources, transport, communications, energy, urban and regional planning. Originally designed for military purposes, and to assist in the location of minerals, Earth imaging procedures have been becoming progressively in the 1970s, for the purposes of civil engineering, very attached to agriculture and the environment.

Computational tools, such as geographic information systems (GIS), make it possible to develop sophisticated analyses, integrating data from different sources and create geo-referenced databases. Thus it is possible to automate the production of cartographic documents such as those presented in this work. The SIG has gone from being a tool in the decision-making from the academic field, to reach the market faster.

Government institutions and large companies began to invest in the use of applications available on the market, including the SPRING, software provided free of charge by the INPE. There is currently a large increase in the use of GIS in organizations, due to the decrease in hardware and software costs. Also by the emergence of alternatives more cheaper for the construction of geographic databases that facilitate actions such as urban planning, which is the process of creation and development of programs that seek to improve or revitalize certain aspects (such as quality of life) within a specific urban area.

The city of São Luís, capital of Maranhão State, has shown a continuous expansion and diversification in forms of occupation of its physical space by human action. The disorderly growth of the region has collided with the traditional forms of occupation and exploitation of land, water and forest resources, generating greater social inequality, environmental offences, the breakdown of families and the denial of human rights.

Due to the above, there is a need to obtain more specific data to study the dynamics of the landscape and of the occupation of the island, using geo-processing tools that contribute to the monitoring of this expansion, mapping of the areas occupied by the man and the remains of vegetation and its environmental impacts, seeks to improve outcomes through the use of this technology [1].

This study aims to study the dynamics of the landscape and the occupation of the space on the island of Maranhão, during the years 1984 to 2010, through TM/Landsat5 images, as well as to map and quantify the soil use and occupation classes through geo-processing techniques. In this context, the work emerges as a contribution that refreshes and enriches the existing knowledge on urban expansion on this area, at the same time warns about the severity of the current degree of changes in the vegetation of the island and its negative consequences on the environment.

2   Method

Study area

The Island of Maranhão or Upaon Açu is located in the North of the State of Maranhão, Northeast Brazil, framed between the geographic coordinates 2° 24' 10 "and 2° 46' 37" South latitude and 44° 22' 39" and 44° 22' 39" West longitude, an area total approximately 1.410,015 km^2 [2].

The island is divided into four municipalities that make up the metropolitan region of São Luis: Raposa, São Luís, São Jose de Ribamar and Paço do Lumiar [3]. The area is nowadays strongly anthropized; its natural vegetation along these decades has been replaced by housing, derived from the great increase of population of the island, as well as, also has it been cleared for other various applications. There are still areas of mangroves and also extends the appearance of babacuais (secondary vegetation) and a small forest. This vegetation is based on four major types of soil, namely: Red latosols, mangrove indiscriminate soil, Quartzipsamments neossolos and ultisols [4]

According to IBGE [2], the municipality of São Luís in 2010 had a population of 1.027.098 habitants, being the most populous island municipality in 2010. The climate of the region, according to the Köppen classification is of type Aw´, rainy, tropical with rains in the months of January to April and this is due to the fact that the city is located next to the area of Inter-tropical Convergence (ITCZ) and annual average temperature oscillates around 28°C. The hydrography of the island have as main rivers Anil, Bacanga, Tibiri, Paciência, Maracanã, Calhau, Pimenta, Coqueiro e Cachorros. They are small rivers that feed in areas of dunes, beaches and mangroves. The two largest, rivers are the Anil with 12.63 km long and Bacanga with 22 km to its mouth [5], in the Bahia de São Marcos in their areas covered with mangrove estuaries.

Work methodology

For the development of the work, we use the software Spring 4.3, images in digital format, composition of 3, 4 and 5 bands, spectral resolution (30x30m), orbit/ponto 220/062 dates of 20/06/84 up to 02/04/10, generated by the Landsat5 satellite related with the area of study, a total of a timeline of 26 years.

With the help of the software we created a database, which generates the project and has delimited with an enveloping rectangle, also were created the categories and then the Planes of Information (PI). The images were geo-referenced using as a basis a mosaic of images of the State of Maranhão. With these procedures, work by importing images, and then the interpretation of them to have a better job in the interpretation of the data, the images received a contrast suitable for work. Then became a segmentation using the method of growth, similarity = 15 regions and area (pixels) = 30.

After edit vectors, which corresponded to the category of use and coverage, is qualified to obtain the entirety of polygons using the function measures of the thematic classes in the SPRING menu bar. Finally, share the letters that were exported in the format postscrip (ps); This file has been imported and edited to improve the finish of CorelDRAW X 5 maps with a scale of work E 1: 100.000.

3   Results and Discussion

Multi-temporal analysis of the images between 1984 and 2010, it was possible to detect the urban expansion in the area of study and those areas were converted into percentages of occupation of the area studied. Through the measure of the SPRING class, two classes of plans for information were compared and it was possible to make the calculation of the areas of each polygon class km^2.

Maps

The maps generated from the information obtained by the images, demonstrate the advancement of this evolutionary process on urban expansion on the island of Maranhão, already described in figures 1 and 2.
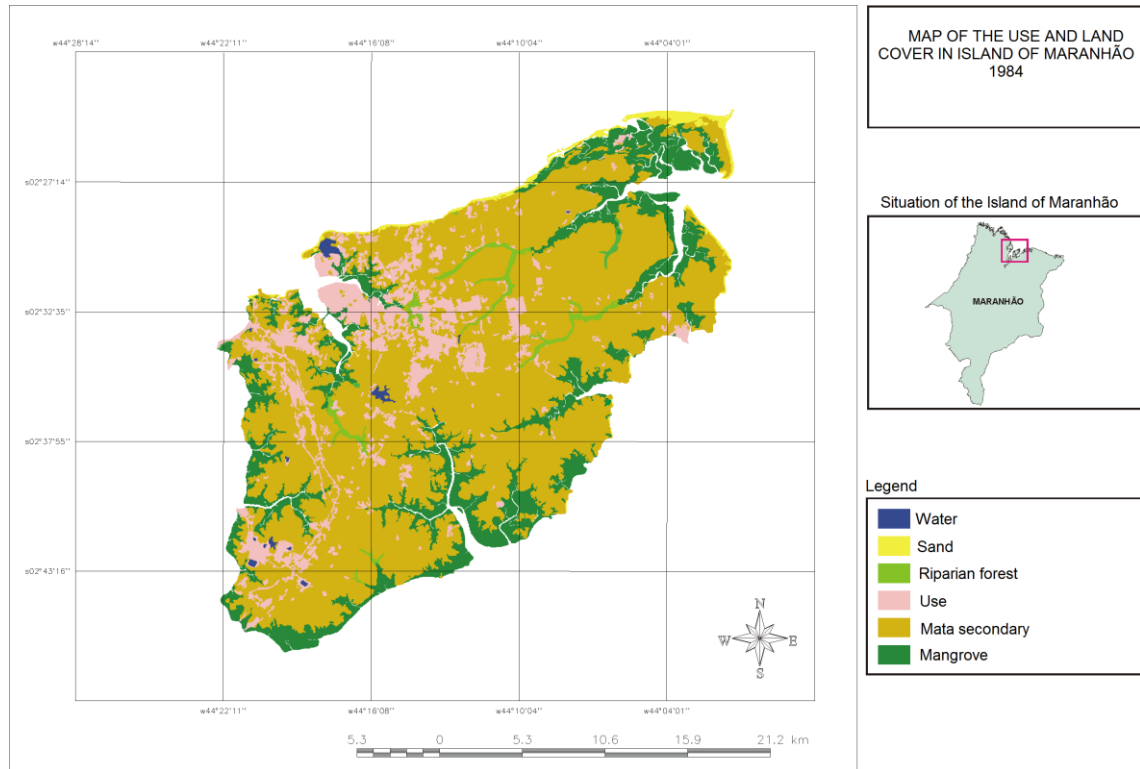
Fig.1 Map of the use and land cover in island of Maranhão (1984)

Fig. 2 Map of the use and land cover in island of Maranhão (2010)
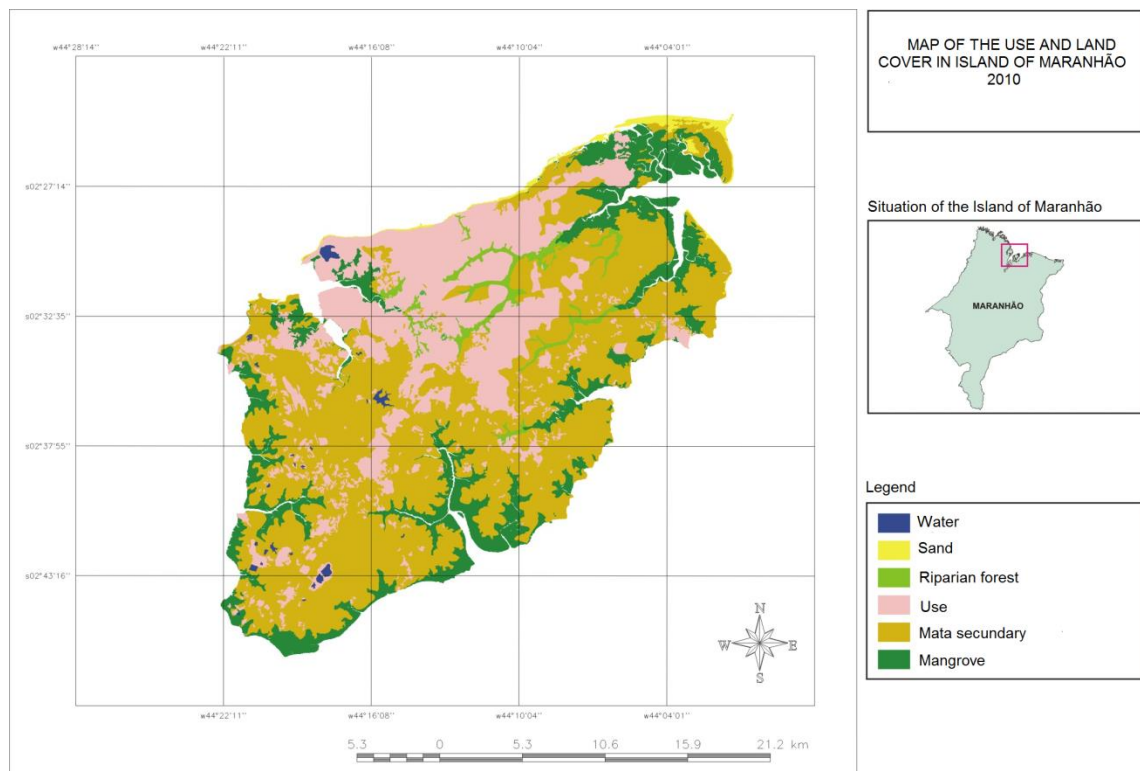
Many of the neighbourhoods had their territory invaded by families from the interior of the State, and had no place to settle. Due to the lack of planning in the Organization of these neighborhoods, these began to present several problems of a structural nature due to due to the lack of basic infrastructure and a quality educational system.

This phenomenon may be the result of advances in the projects of industrialization which intensified the process of urban occupation of the island, mainly in Sao Luis, capital of Maranhão, which in 2010 reached 1.011.943 habitants, distributed in an area of only 828.19 Km². Between the years of 1984 and 2010, the island has a rate of growth of the population of 112.26%, of whom represented capital 84.56%.

These new arrivals have managed to occupy spaces that used to have a complete vegetation cover. One of the greatest examples to quote is Cidade Olímpica, considered the second largest urban occupation of Latin America with around 65 thousand habitants [6], and now with a population of 140.000 habitants

The floras of forests and mangroves, the dominant in the past, have suffered constant transformations from speculation or even by excessive extraction of resources, which has caused a serious environmental imbalance. This process slowly triggered the destruction accelerated in these ecosystems, being replaced or modified by human action. The landscapes that were covered with plants in the past, much of the territory, during the period of 26 years between 1984 and 2010 (figures 1 and 2), have given way to built-up areas, exposed soil and or lots as shown in table 1, with areas of considerable reduction of vegetation cover, especially in the areas of vegetation riparian (45.5%), Secondary vegetation (17.83%) and mangrove (15.02%). In Restinga areas, due to the natural dynamics, changes were very little (1.5%).

In the city of São Luís, the expansion of urban areas can see along the BR-135, due to the growth of the industrial zone. Also starting from the center of the island to the Northeast along the coast to the town of Raposa, the growth of neighborhoods such as Divinéia, Santa Rosa, Araçagy e Vila Luizão besides communities and lots have contributed to the sprawl of the island. This continuous expansion of urban areas has contributed to presented a high rate of growth (143.8%) distributed more in the Center-North of the island.

Classification	Area (km²)		Area Percentage (%)		Rage of Change (%)
	1984	2010	1984	2010	
Mangrove	164,79	140,03	18,15	15,42	-15,02
Secondary Vegetation	603,27	495,74	66,44	54,60	-17,83
Urban Core	99,11	241,64	10,92	26,61	143,80
Riparian Forest	11,50	6,27	1,27	0,69	-45,50
Sand	10,94	5,42	1,20	0,60	-50,45
Water Bodies	6,34	6,42	0,70	0,71	1,15
Settling Ponds	0,52	1,14	0,06	0,13	118,59
Restinga	11,51	11,35	1,27	1,25	-1,46
Total	908,00	908,00	100,00	100,00	

Table 1. Quantification of areas use and land cover and its variations

The creation of housing estates such as Cohatrac, Maiobão, Jeniparana, Tambaú, city worker, among others was a decisive factor making it in patience, Santo Antonio basin e North Coast (Figure 3), the urbanization occurred in areas of maximum gradient, which causes problems of siltation and pollution from domestic sewage [7].
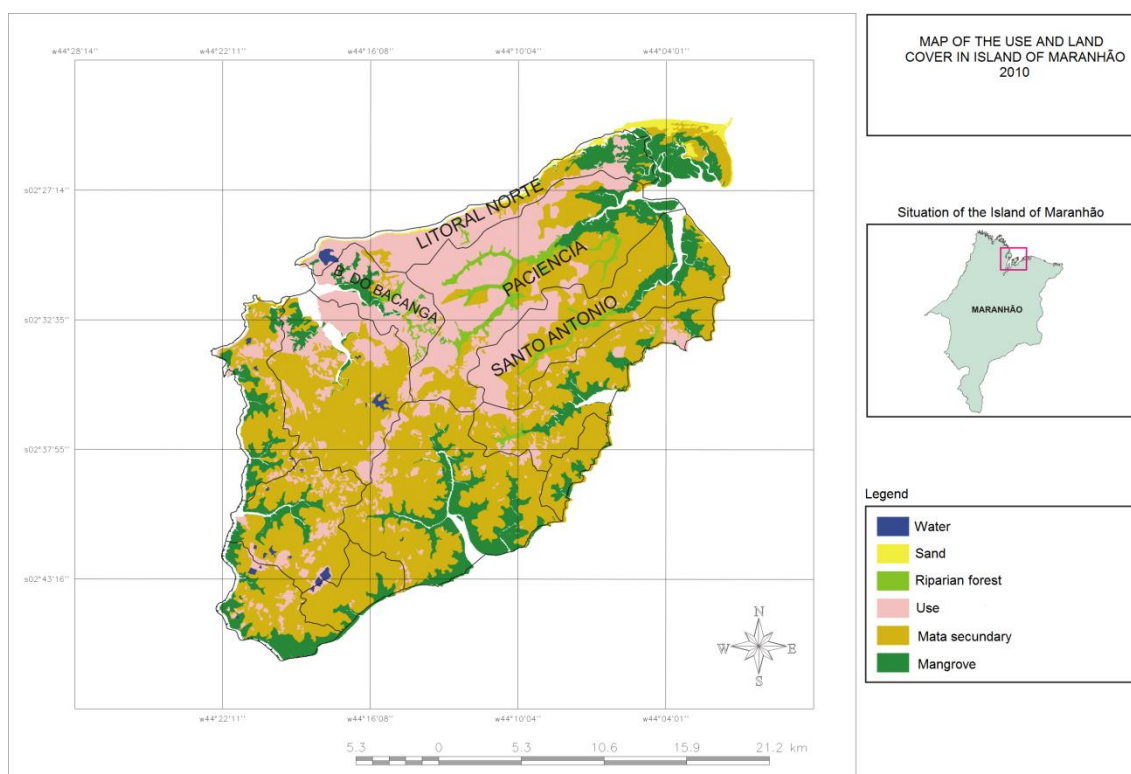
Fig. 3 Urban sprawl in the main hydrographic basins of the island of Maranhão (2010)

4   Conclusion

Based on the analysis, discussion and interpretation of results, the following considerations were obtained:

- The used Geo-technology shows its efficiency in the development and application of methods (management systems) and monitoring the evolutionary dynamics in processes of urban expansion, as well as their environmental, social and economic impacts related to the disordered occupation of the space on the island of Maranhão.
- The disordered occupation of the soil on the island and population growth have led to environmental degradation, this amplifies the risk of decrease in quality of life.
- From the evidence shown in this study, we realize how worrisome is the process of occupation and use of land in the island of Maranhão.
- We have noted that during these 26 years, there is an expansion of built-up areas that contribute to a high rate of population growth (143.8%).
- On the other hand, we observed a reduction considerable in the areas of coverage plant, especially in the areas of vegetation riparian (45.50%), Secondary vegetation (17.83%) and mangrove (15.02%). Restinga areas, due to the natural dynamics, changes were very little (1.5%).

References

[1]   MENESES, P. R. Fundamentos de Sensoriamento Remoto. Brasília: 2006.
[2]   INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. Perfil dos municípios brasileiros. IBGE: Rio de Janeiro, 2011.
[3]   CORDEIRO, E. C, DINIZ, J. S., Região metropolitana da grande São Luís: além da retórica municipalista, o que serve como entrave para sua "efetivação"? In: III Jornada Internacional de Políticas Públicas, São Luís, 2007.
[4]   UEMA – Universidade Estadual do Maranhão, NUGEO. Mapa de solos. São Luís: 2009.
[5]   ARAUJO, E.P, TELES, M. G. L, LAGO, W. S., Delimitação das bacias hidrográficas da Ilha do Maranhão a partir de dados SRTM In: Anais XIV Simpósio Brasileiro de Sensoriamento Remoto, Natal, Brasil, 25-30 abril 2009, INPE, p. 4631-4638.

[6]   REVISED   PLAN,   Ed.1,   July   2008.   Available   at:
         <http://www.plan.org.br/publicacoes/download/revista_plan_01.pdf>.   Accessed   on
         03/02/2015.
[7]   VENDRAME, I. F.; LOPES, W. A. B.. Análise do crescimento urbano e seus efeitos na
         mudança da dinâmica de escoamento superficial da bacia do Pararangaba. In: Anais do
         XII Simpósio Brasileiro de Sensoriamento Remoto. Goiânia, 2005

GEOVISUALIZATION OF GREEN SPACES WITH AUGMENTED REALITY

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Abstract

The management of green spaces in urban areas requires new techniques and instruments that provide all the information available to people.

It is intended to facilitate data-based services to citizens through the use of mobile devices in green spaces, parks and most visited public gardens. The selected area of study has been the Plaza de Oriente (Madrid) and its surroundings. Maps and images from different sources of information have been implemented in this research work. Then we proceeded to develop a database with woodland and existing cultural heritage. Finally, related this information using geolocation and augmented reality system.

We have created a system that allows the user to interact with the single orientation of the camera on your mobile device.

This application allows efficient use through the integration of mobile devices and the knowledge of the cultural heritage associated with the public space.

1 Introduction

The gardens, within cities or any other conglomerate, saved great features or references which are often unknown by the great part of the population that surrounds them as for those who visit these spaces, and often go unnoticed before them relevant aspects, that them would have known or know that they are in these green spaces. "Some parks and old gardens are home to valuable species of flora and fauna worthy of a special social care." [1]. In article 5 of the Act 8/2005 of protection and promotion of the woodland of the Community of Madrid, updated 19 June 2013 [2], indicates the priority of a full inventory of urban woodland. In this research, a database with the main features of each plant species as well as the information necessary for improved management and conservation of the study area is implemented. Intends to establish a control tool for operators in the area and locate in time, through periodic revisions, woodland conservation and health problems. In this methodology we include the cataloguing of architectural and sculptural elements of the garden under study.

The study area is part of the environment of properties declared with the figure for the protection of properties of Cultural interest (BIC) (Law 16/1985) in the Village of Madrid: Royal Theatre (declared the 30/09/1993) as the Royal Palace of the Oriente (04/06/1931) [3]. We choose a singular space green or garden of the Square East, "Lepanto and Cabo Noval", due to the movement of tourists and pedestrians that pass through this area to get to the Royal Palace [4]. This environment is appropriate for the realization of a computer application (App) about geo-location for natural green spaces, parks and public gardens.

The elements must be located in a clear and precise place, from which the system may require the information to display to passers-by. He is achieved through a well-structured database; the main thing

resides in having each element well identified with his "Shared Key". You don't need to be in the same Square East to display in our mobile device information given geo-positioned elements.

Currently there is a large amount of information, geographical, cultural, etc., relating to the architectural, sculptural, both elements that make up the green spaces, whether parks, gardens, Garden squares, etc., where sculptures, trees or shrubs copies significant and of great interest. The problem is when it comes to information of such elements, since often stroll through the parks and do not get the attention that they deserve, on the elements that surround us. It is partly due to ignorance of them have or by the lack of accurate information and easy access.

The ultimate goal is that citizen access very easily to this specific information of this type of places.

1.1   Area of study

The work area is located in the municipality of Madrid, in the downtown district, with a population of 142.270 habitants, a population density of 27.151 hab./Km2 and an area of 5.24 km2 this district. One of the most emblematic Madrid square´s and landscaping is first was the Square East, built on 1.5 hectare. It is a unique garden area, due to the movement of tourists and pedestrians that pass through this area to get to the Royal Palace [5]. This is an appropriate environment for the realization of APP's about geolocation for natural green spaces, parks and public gardens. The ultimate goal is that citizen will have easily access information specific to this type of places.
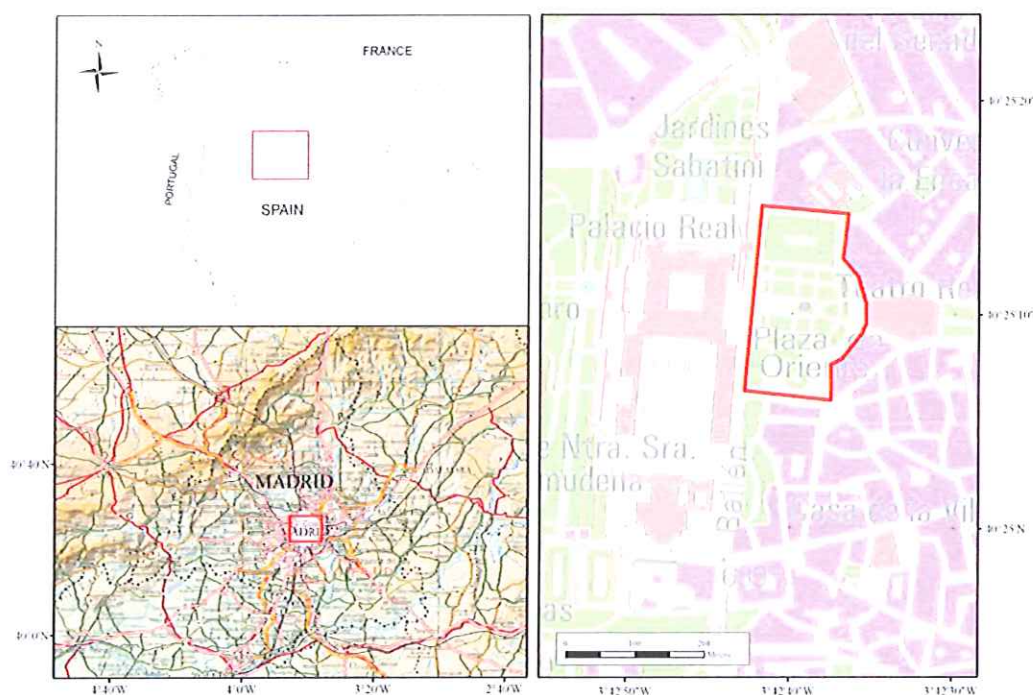

Fig. 1. Location of the study area. Spatial Reference System UTM-ETRS89 Zone 30N

2 Methodology

The methodology used to develop the proposed work is described in Fig 2. You are working in the geo-positioning of unique elements that surround us in these areas, as they are based: urban woodland, urban furniture and architectural details and aspects. The information and data obtained from the various plans of woodland and IDEE, web Map Service, historical catalogues (…) [6] along with the view that get us both any passer-by who comes to these spaces, it will offer us the possibility to keep in mind a number of clear and accurate information that will complement what we perceive with the view to walk and observe the unique elements integrated in the study area.
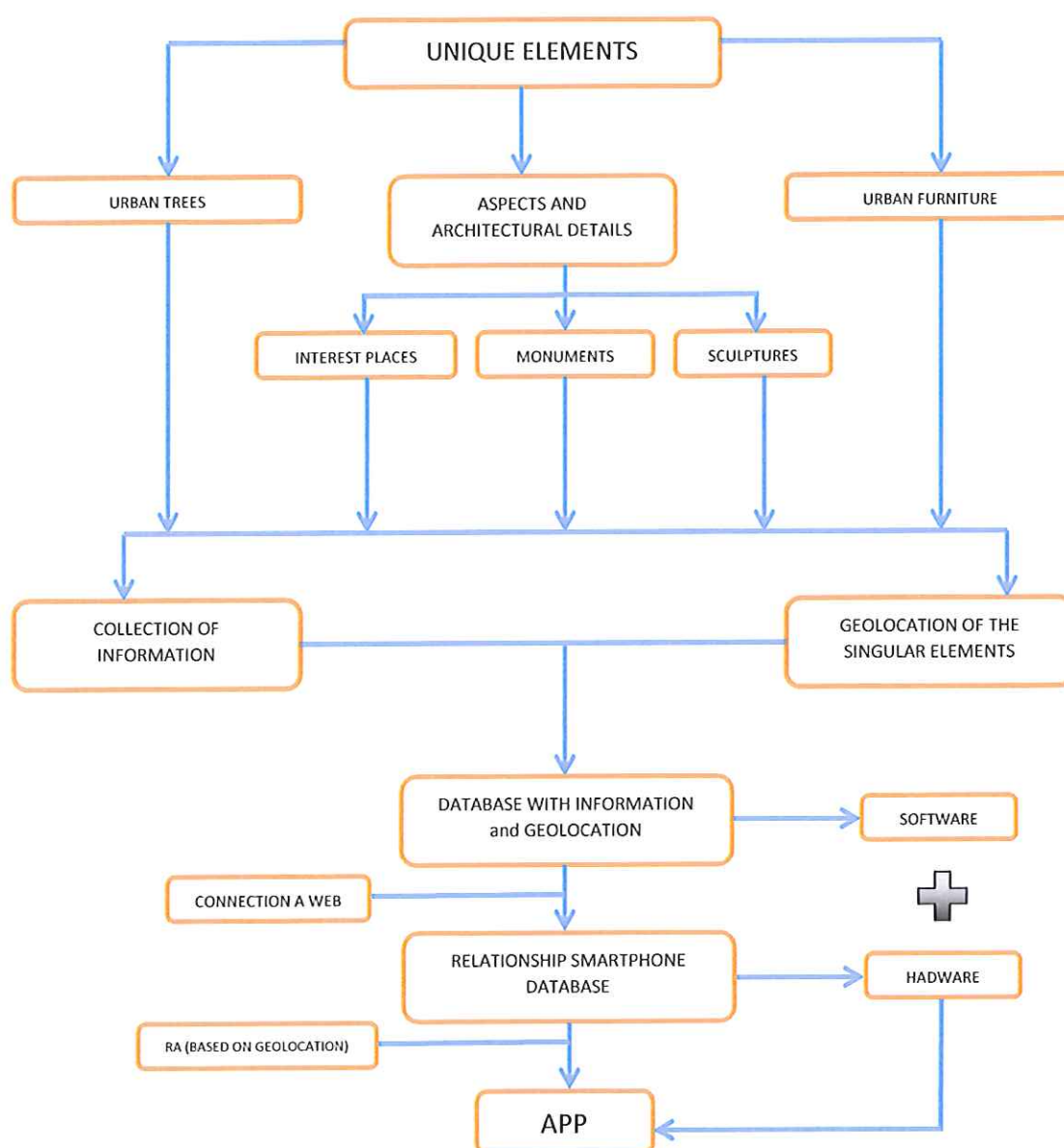
Fig. 2 Methodology for geo-positioning and display of unique elements.

For the realization of the Information System we use a mapping based on the Area of environment of the city of Madrid (Fig. 3). From the cartography and after several visits to the study area was designed a database with the required fields of the proposed Information System.

Fig. 3 Cartographic used in the preparation of the data base.

With the geo-positioning obtained from elements [7] and the implementation of data using POI's, could also offer information that can ignore about the elements that are displayed in real time, management by operators who keep these spaces, obtaining an improvement in management both area as greater precision when it comes to acting on the different elements to passers-by. The geo-positioning of elements is associated with the features implemented in the database. In the case of plant species (fig. 4) a certain fields associated with geo-location to improve the management and maintenance of the landscaped area.

Species	Image	Type pruning	Figure	Pests and diseases	Works	Appearance	Size	Other data
Magnolia grandiflora L		Rejuvenation (10/11/14)	Pyramid	Powdery mildew. Treaty	Fertilization (N/P/K) (10/03/15)	Healthy	15 m.	

Fig. 4 Table layout associated with geo-located in parkland points.

In the same way, for the information of the existing cultural heritage (fig. 5) and the management and maintenance of urban furniture (fig. 6), we designed tables related to the main fields for later use.

Identification	Image	Description	Historical data	State of conservation	Protection	Other data
Euricio (Rey Godo)		A statue that is part of a series to all the kings of Spain.	Reign: 466-484	Good	Statue outdoor	

Fig. 5 Design of table associated with geo points with patrimonial character.

Identification	Image	Description	State of conservation	Protection	Other data
Fuente ornamental		Stone fountain	Good	Protection index 2 historical	

Fig. 6 Table layout associated with urban furniture geolocalized points.

Both for the management of space, such as the display of elements with RA, is necessary to create a database containing every one of the elements which comprises it [8], main thing resides in having each element well identified with his Shared Key, is a secret key that is shared with the two parties using some secure channel until it is used. To create a shared secret key, key derivation function must be used. These systems almost always use symmetric key cryptographic algorithms. The term PSK is used in encryption for Wi-Fi such as WEP or WPA, where both the (AP) wireless access point and all clients share the same key a position [9] georeferenced that matches the place occupied in the scene of action and information we want to show [10] on the one hand to the passer-by and another area the operator actually [11].

3 Results

Pedestrians to activate the App on your Smartphone (see Fig. 7), send your GPS location, then performs a search within a range of 5 meters of perimeter (depending on the accuracy of the instrument used for viewing) the elements located on the perimeter, they appear as icons on the screen of our Smartphone. Then the user presses on the screen of your mobile device on the element which information, performing a "Query String" or request to the server with your ID, showing the details and issues previously allocated in the database to each element.
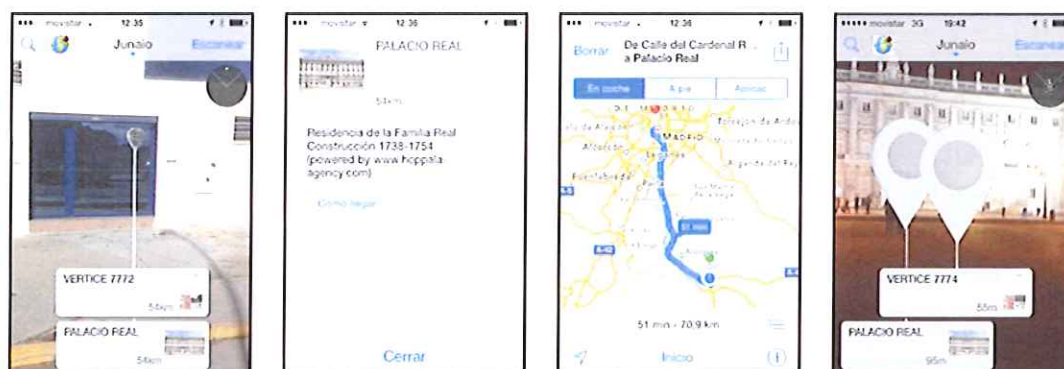
Fig. 7 Visualization in Smartphone display different screenshots with information of the POI´s.

The application may be linked to the server in various ways, contain the actual server where the information is located on the Smartphone, which leads to occupy a part of our mobile device data, either server can be remote in the only Smartphone, the requested information is stored and would be saved for future reference or otherwise in the Smartphone is not stored any information and always gets it from the remote server. This latest version has an advantage because does not collect data on the device, but on the other hand if you want to refer to information requested from the server previously, it is becoming to mobile data spending. With this process have been grouping the information and offer the users an optimal, orderly and geo-located, so you can access it from a Smartphone.

4 Conclusion

The methodology is simple and the cost is not high, as you can be seen done a test with software free to see the functioning and the impact that may result in its use. There are different ways to generate the App for these spaces, but the fortress that has is to show information that can be ignored on the elements in these areas to sensitize citizens with these spaces and get increased by the interest and care of these to passers-by. Similarly it can be used in reverse for management by operators and other personnel working in these areas.

References

[1]   Ros Orta, Serafín. La Empresa de Jardinería y Paisajismo mantenimiento y conservación de espacios verdes. Madrid: Mundi-Prensa, 2006.

[2]   http://www.madrid.org/wleg/servlet/Servidor?cdestado=P&nmnorma=3387&opcion=VerHtml. Ley de protección y fomento del arbolado urbano de la comunidad de Madrid (2013)

[3]   http://ipce.mcu.es/documentacion/archivo/fondos/inventario.html. Inventario del Patrimonio Arquitectónico. Ministerio de educación, Cultura y deporte. (2015)

[4]   López Lillo, A. Arboles de Madrid. Madrid: Mundi-Prensa, 2000.

[5]   Ceballos, L. Ruiz de La Torre, J. Arboles y Arbustos. Madrid: Mundi-Prensa, 2001.

[6]   Sancho Gaspar, J. L. La arquitectura de los Sitios Reales: catálogo histórico de los palacios, jardines y patronatos reales del Patrimonio Nacional. Patrimonio Nacional, Madrid, 1996

[7]   Arranz Justel, J.J., Soler García, C., Métodos Topográficos, 2015.

[8]   Iniesta M., Núñez A., Introducción a las Infraestructuras de Datos Espaciales.

[9]   El-Rabbany, Ahmed. Introduction to GPS the global positioning system. London: Artech House, 2002.

[10]   Fombona Cadavieco, Dr. Javier. Realidad Aumentada una evolución de las aplicaciones de los dispositivos móviles. Pixel-Bit, 2012.

[11]   Ros Orta, S. Planificación y Gestión Integral de Parques y Jardines. Madrid: Mundi Prensa, 2007

ANALYSIS OF THE RECOVERY OF THE DESIGN INTENT IN REDESIGNING OVER MESHES

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Article Information

Abstract

In reverse engineering, an approach to the generation of surfaces in the redesigning of mechanical parts is the reconstruction of the model using a CAD methodology. The geometric information that is used is extracted from the mesh, where the problem is not so much the implementation of the dimensions with the required precision, but the application of some geometric constraints of the original model such as parallelism, perpendicularity, concentricity, symmetry and tangency. However, the application of these constraints must be often compensated with the minimization of the deviation of the NURBS surface on the point cloud. This paper discusses the implementation of these geometric constraints and quantifies the resulting error. It lays special emphasis on the comparison of results using different levels of digitization quality of the mesh, as well as on the importance of the choice of reference elements.

1   Introduction

One of the objectives of the Geometric Reverse Engineering process is to obtain the CAD model of a physical part that can be analyzed and modified so that a new and improved product can be generated.

In a traditional engineering process, designing a new product requires following certain requirements of form and functionality, such as geometric and dimensional constraints, together with some aesthetic requirements [1][2]. Therefore, in any reverse engineering process, all the knowledge associated to this design, i.e. the originally intended design, should be extracted, in an effort to recover the geometry, as well as the design parameters of the original piece, always aiming at obtaining a coherent CAD model [3][4].

In practice, the reverse engineering process is a combination of two separate steps: the digitization of a real part and the processing of the digitized data to generate a corresponding CAD model. There are currently several commercial digitization equipments that can capture the digital point cloud (and even a polygonal mesh) corresponding to the geometry of a real part [5]. This is usually done by capturing multiple partial point clouds that are afterwards joined and fused. Nowadays most commercial equipments can generate a low level surface (a polygonal mesh) from the captured data. The accuracy of the measured point cloud or polygonal mesh and the detail level and the completeness of the surface will mainly depend on the technology and the characteristics of the equipment, but also in the quality of the underlying algorithms that process the captured data. The main disadvantage associated with these polygonal meshes is that they are not parametrically editable models. They can be used, for example, to produce the part in a rapid prototyping machine; but when a parametric model that can be redesigned is required, a CAD model with NURBS mathematics becomes necessary; i.e., if performing the remodelling step of the reverse engineering process becomes necessary.

Thus, it can be concluded that in practice, it is relatively easy to obtain a digital model, but the problem arises from the need for an editable CAD model and, in addition from this aiming, at verifying the originally intended design [6][7] of the model, while adjusting to the digitized mesh.

There are several commercial Reverse Engineering software that can generate a CAD model from digitized data (Geomagic, Polyworks, 3DReshaper), and even some CAD programs can integrate reverse engineering capabilities (Catia, NX, SolidWorks, etc.), but restoring the design intent of the original part continues to be challenging.

Some excellent research works have been carried out recently aiming at re-editing the shapes with respect to the geometric constraints, but at this moment they cannot be implemented in the engineering praxis [8][9][10][11].

The paper is organized as f ollows. Section 2 describes some a pproaches for geometrical reverse engineering. Then Section 3 introduces the proposed innovative methodology for restoring the design intent of the original part. Section 4 describes four case studies where the methodology has been applied. Finally, Sections 5 and 6 present the conclusions and the proposed future work.

2 Approaches for Geometrical Reverse Engineering or Digital Shape Reconstruction. State-of-the-art.

Tamás Várady [12] propose s five appro aches to the di gital reconstruction of a surface. F rom its experience, the Product Design Laboratory (PDL, www.ehu.eus/PDL) at th e University of the Basque Country agrees with this cla ssification. These five approaches correspond to a seri es of methodo logies leading to completely different results. Unfor tunately, many engineers associated to the world of product design but unrelated to geometric reverse engineering, do not fully understand these ways of work, and this leads them to mix concepts, which entails a great amount of ineffective ness in their work. In an effort t o clarify these concepts and methodologies as much as possible, the f ollowing summary of these five methodologies is included.

2.1 Polygonal Meshes

The point clouds resulting from several scan sessions are joined and converted into a polygonal triangular mesh. Multiple algorithms have been developed to repair the triangular mesh and increase its quality with little or none user interaction. Some of these operations are data filtering, outlier removal, noise reduction, smoothing, hole-filling, optimizing mesh structure so that the number of triangles is adaptive to the surfaces curvature, etc.

The construction of a trian gular mesh from a point cloud is a ver y common operation in Reverse Engineering, that can be p erformed in a ny reverse engineering commercial software, and as menti oned before, this operation is supported by most digitization equipments.

The polygonal mesh is a rigid digital model that can be used for visualization purposes and even for direct manufacturing, but is hardly editable.

2.2 Automatic Surfacing with Quadrilateral Patches

There are various algorithms for the automatic generation of complex quadrilateral or triangular NURBS patches on polygonal meshes forcing tang ent plane (G1) continuity between the surf aces [13]. This procedure has been implemented in many reverse e ngineering commercial software. The trend in the evolution of these al gorithms is orient ed towards the automatic recognition of the d ifferent areas that compose the part and the d etection of the separations between them. This is an automatic proce dure, although in some cases the expert can ad just some parameters (such as the number of patches, fitting accuracy, etc.) or can help the program by doing a manual segmentation of the surfaces and even extracting division lines on the mesh.

This solution can be useful for a subsequent use of the CAD file into an engineering finite element analysis package. It ca n be also used for the r epresentation of art objects or organic shapes. In our laboratory experience, this is the ideal appr oach for a n approximation of non-functi onal surfaces and no n-support surfaces of mecha nical parts. The most si gnificant drawback of these patches is that even if they are recognized by a CAD program, they are not editable with direct modelling tools or similar technologies.

2.3 Manually Segmented Surfaces

This methodology is the classical workflow in geometric reverse engineering. The designer must identify each surface and lays out a set of curves, which will either serve as guides and sections of the surfaces or as the limits of the quadrilateral patches. The construction of these curves is certainly the most critical step, and in addition to having a great control over the posit ion, continuity and accuracy of the curves, a ve ry skilled technician is required. It may take several weeks to obtain high-quality surfaces as class A surfaces in the a utomotive industry with G2 (curvatu re) and G3 (p lanar acceleration) continuities, and freefor m surfaces or patches with high degrees.

This method is implemented in some commercial software applications of advanced reverse engineering (as Geomagic Design X, formerly Rapidform XOR), or even some design programs.

Nowadays, despite the laboriousness of th is system, this methodology remains the only available possibility when obtaining the surface over the poi nt cloud requires a very high precision level and has a great aesthetic component (automotive industry mainly). It is common to use this workflow on a hybrid basis, i.e. the necessary part of the point cloud works in this way while the rest is rebuilt by methods that require less human intervention.

2.4 Functionally Decomposed Surface Models

This methodology is based on the dominant structure of most of the parts used in mechanical engineering, where surfaces are classifie d into three ca tegories: functional (mechanized), support (mechanized) and remainder (rough and without a special fini sh treatment). In this appro ach there ar e also prim ary and

secondary surfaces. The secondary ones are used for purposes of transition or connection: they will be the blending or union surfaces of the piece. The secondary surfaces will usually have continuity of tangency and curvature with the primary surfaces.

The main interest of this method ology lies in the capacity of the software to automatically identify and extract the primary surfaces that compose the model [14]. These surfaces must be trimmed to create the part-body and finally secondary surfaces (chamfers, rounding, etc.) can be used to finish the model.

One example of this method ology can be found in Geomagic Studio (fig. 1), where several types of surfaces can be identified and extracted, for example, planes, cylinders, cones, spheres, revolution surfaces, extruded surfaces and even freeform surfaces. Once these elements are identified, B-rep models can be created and then they can be parameterized so as to be exportable to some CAD software operations tree [15].
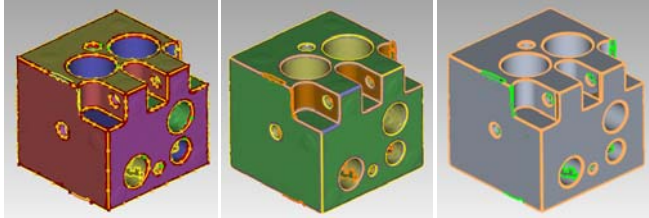

Fig. 1 (a) Boundary extraction. (b) Surface classification by type. (c) Surface generation.

While the process is theoretically semi-automatic, in practice, the real digitized meshes have defects that can hamper the process (spi kes, holes, noi sy areas, intersecting triangles, poorly defined edges etc.). Difficulties can arise in many steps of the p rocedure, and human guidance can become necessary. For example, the correct ident ification and extraction of the surfaces is critical for the success of the methodology, but mesh defects, such as noisy areas or lack of data, can lead to mistakes. Moreover, once the surfaces are generated, the part edges must be calculated, but surface deviations (which, are impossible to avoid) can cause that two surfaces that should be adjoining, don't intersect at all. Therefore this methodology requires a great deal of us er interaction when working with complex parts, especially with incomplete meshes, complex geometries, continuous surfaces and poorly defined edges.

2.5　　CAD Models Redesigned over Meshes

This methodology is based on the key idea of reconstructing surfaces following the workflow of a CAD program, but relying on the point cloud or triangular mesh [16][17]. This reverse engineering methodology (Geomagic Design X) creates sketches from the mesh using straight lines, arcs and curves that can be geometrically constrained by dimensions and prop erties of parall elism, perpendicularity, tangency, symmetry, coincidence, etc.

This method is very appropriate for complex parts designed by Boolean operations of simple parts with final rounding (fig. 2).
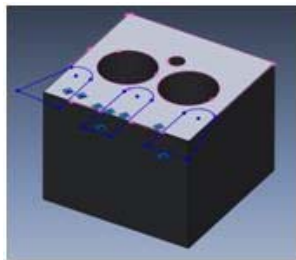
Fig. 2 Sketch created from the mesh.

One of the disadvantages of this method is that each volumetric operation must be done manually and the technician must previously have a deep knowledge of the geometry of the piece to redesign. On the other hand, this method presents the advantage that, since all operations will be parameterized and there will be an operation path tree [18], the CAD model will be editable. This model makes possible to verify the design intent of the original model.

3　Proposed Methodology

As has been mentioned before, it is possible to generate a CAD m odel starting with a polygonal mesh using commercial Reverse Engineering software. Depending on the applied methodology, there will be more or less need for user interaction, and the resulting CAD model can be editable, and even can recover some dimensional and geometric constraints. But accordi ng to the practical experience in our laboratory, the

method applied when redesigning a surface with application of geometric constraints is likely to fail in one way or another at the final requirement of capturing the design intent [19][20].

Therefore, the aim of this arti cle is to pr opose an improved methodology that, starting with the mesh, permits the introduction of geometrical parameters. Some of the aspects that will be analyzed in detail are the consequences of the imposition of certain geometric constraints on the final model, as well as how the quality of the mesh, and even the way of referencing such constraints, affects the methodology.

This methodology is applicable in cases where complex pieces are modelled with complex operations on the basis of geometrically constrained sketches, so the methodology of functionally decomposed surface models would remain sh ort. Thus, the reconstruction of parts will be pe rformed by creating volumetric operations over the mesh from geometrically constrained plane sketches.

The flow diagram in fig. 3 sums up the phases that constitute the developed methodology.
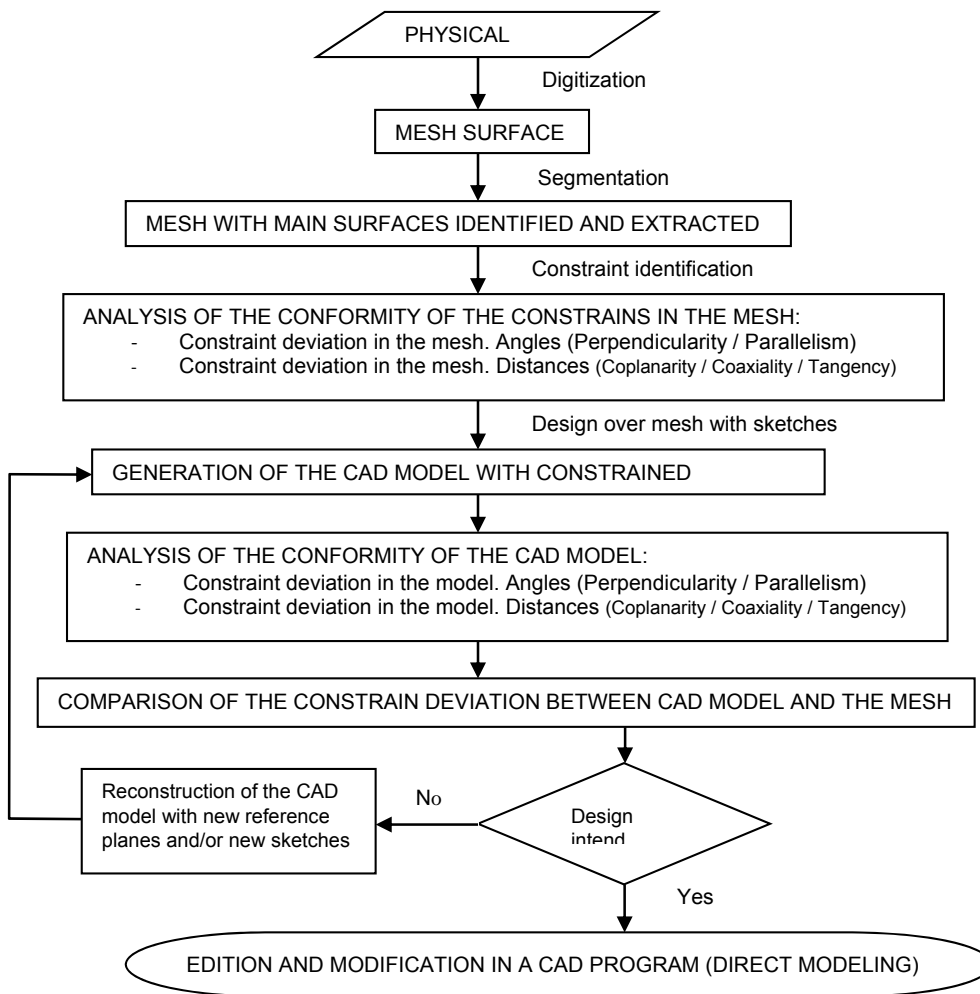

Fig. 3 Flow diagram of the proposed methodology.

3.1 Identification of the Main Surfaces in the Work Part

For this first step, it is nec essary to identify the regi ons that comprise the triangular mesh of the p iece from which the editable CAD model must be obtained. This process is called segmentation. At this phase of identification, only the main surfaces of the piec e are co nsidered, whilst edges and transiti on surfaces between them are excluded.

Reverse engineering programs permit automatic or semi-automatic segmentation. The better the quality of the digitized mesh, the more realistic the result of this segmentation, this is, the segmentation will be much more correct. T herefore, badly scanned areas, thus la cking data, toget her with the existence of no ise in certain regions of the mesh, are the main reasons why certain regions are sometimes badly identified in the segmentation.

The process includes all major surfaces that constitute the piece, indicating the type of surface, i.e. plane, cylinder, cone, torus, etc.

The outcome of this first step is the delimitation of the primary surfaces that constitute the piece, along with their char acterization (type of surface, position point, orientation characteristic vector, characterist ic

dimensions, etc.). Besides the geomet rical characteristics, a reliabi lity factor will be as signed to eac h surface, representing the expected accuracy of the calculated geometrical characteristics.

3.2 Identification of Constraints Linked to the Surfaces

The aim of this secon d step of the metho dology is to deduce the existing geometric and dimensional constraints between the previously identified main surfaces.

This work will focus in constraints that are most common in mechanic al parts: perpen dicularity (Pe); parallelism (Pa); coplanarity (Cp); coaxiality (Cx) and tangency (Tg).

In order to p erform this ana lysis, a compar ative n x n dimension table is established, where n is the number of surfaces ide ntified in the previous phase. Each cell in the ta ble relates to a co uple of surfaces. Thus, the cell i x j indic ates the c onstraint or constraints between the surfaces i and j . The restrictions identified in the table will also be symmetric (i x j = j x i), so the anal ysis of constraints is reduced to $n^2 - \sum_1^{n-1} i$ instead of n^2.

It must be taken into account that each type of relation ship is defined according to a certain magnitude. Some relationships require values of differ ent magnitudes to be full y defined. Tab. 1 shows the re quired magnitudes to be defined to measure each of the above-mentioned constraints.

	LINKED SURFACES TYPE			
	Plane-Plane	Axis-Axis (Revolution surfaces)	Plane-Axis (Plane-revolution surface)	
CONSTRAINT	THEORETICAL VALUES			MAGNITUDE
Perpendicularity	90°	90°	0°	Angle (between eigenvectors)
Parallelism	0°	0°	90°	
Coplanarity	0° / 0 mm	-	-	Angle and distance (between planes)
Coaxiality	-	0° / 0 mm	-	Angle and distance (between axis)
Tangency	-	0° / R mm	90° / R mm	Angle, distance and dimension (radio of the involved cylinder)

Tab. 1 Magnitudes and theoretical values to be taken into account when verifying constraints.

As shown in tab. 1, a perpe ndicularity and parallelism constraint between a couple of surfaces can be verified by measuring the a ngle between the characteristic vectors of the surfaces. W hen a p arallelism constraint is verified between a couple of planes, or a couple of revolution surfaces, coplanarity or coaxiality constraints must be checked by measuring the distance between the planes or the axis. When coaxiality is not verified between a couple of parallel cylinders, then a tangency constraint must be checked by comparing the distance between the axis with the cylinders radii. In the other hand, if a parallelism constraint is verified between a plane and a cylinder, then the distance between the cylinders axis and the plane and the cylinders radius should be compared to verify a tangency constraint.

The magnitudes of distance and dime nsion are different. The first magnitude refers to the valu e of the distance between two selected elements; for example, the distance between two planes, between two axes or between a plane and an axis. On the other hand, a dimension is a characteristic parameter of a surface, for example, the value of the radius of a cylinder or its height.

In addition to t he relationships appearing in the table th at shows the d ifferent types of relationships between surfaces, there are two more t ables. One of t he tables is for t he angles and the oth er for t he distances, and they have the same st ructure as the pre vious one. Each of these tables inc ludes the theoretical values of the magnitude, which will be used to verify the corresponding constraint linked to each pair of surfaces.

In order to deduce the constraints that are verified in the part, the measured values of the afore-mentioned magnitudes are calculated, following the next procedure:
- The angle θ_{ij} between the characteristic vectors of each couple of surfaces is calculated.
- Being ε_θ the measurement angle uncertainty

$$If \quad |\theta_{ij}| < \varepsilon_\theta \quad or \quad \frac{\pi}{2} - \varepsilon_\theta < |\theta_{ij}| < \frac{\pi}{2} + \varepsilon_\theta$$

then parallelism or perpendicularity between a couple of surfaces is verified.

The measurement angle uncertainty (ε_θ) must be adjusted in accordance to the quality of the scanned data (accuracy of the scanner, level of noise of the data, etc.), and the reliability of the involved surfaces.

For each co uple of surfac es that verifies the abov e condition, coplanarity, coaxiality or tan gency constraints are checked by calculating the distance between the elements.

Hence the r esult of this phase is a table containing all existing geometric and dimensional constraints linked to the previously identified surfaces.

3.3 Generation of the CAD Model

This phase of the methodology generates the CAD model of the researched part, following the parametric modelling approach of red esign over the m esh. As explained before, in this appro ach the necessar y modelling operations to gene rate the piece ("direct engineering") are p erformed with planar sketches obtained directly over the digitized triangular mesh.

To generate the CAD model a reference plane must be chosen to extract an intersection guide curve from which the initial sketch will be created (fig. 4). The selection of the reference plane is an important step, on one hand, because it can facilitate t he CAD model generation and the definition of constraints, and in t he other hand, the final result will depend on this election, as the direction inaccuracy of this surface will be transmitted to the operation. The generation of the model is reduced to the creation of constrained sketches, which will be used to perform the necessary modelling operations (extrusion, revolution, etc.).
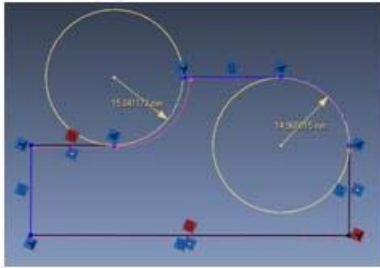

Fig. 4 Constrained sketch over a guide curve.

3.4 Analysis of the conformity in the model generated with constrained sketches

Using the same procedure of the previous phase, the surface theoretical values are compared with the real values obtained in this p hase, thus obtaining the degree of verification of the differ ent constraints for each of the used magnitudes.

The resulting data demonstrates that the generated model verifies all the constraints accurately.

3.5 Comparison of the Generated Model and the Mesh

In this phase, the vectors and distances obtained from the model generated with constraints are used to analyze the conformity of those obtained from the mesh. In this way, the methodology shows the existing deviation between the generated model and the initial mesh.

The resulting data als o demonstrates that the gen erated solid a pproximates the mesh in the desire d degree.

3.6 Working with the created model in a CAD environment

Finally, to verify that the g enerated model is editable, it is e xported to a C AD program (Solid Edge ST) and dimensional modifications are made on it (fig. 5).
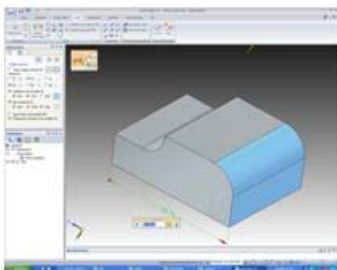

Fig. 5 Length modification of the edited part.

4 Case studies

Four case studies were completed using the proposed methodology. Each case study added complexity to the process, and this provided new details on the feasibility of the methodology.

4.1 Case study num. 1 and num.2

For these first case studies, a simple prismatic part has been digitized. In case study num. 1, a REVscan handheld digitization equipment and the Geomagic Design X reverse engineering program were employed, and in case study num. 2, the ATOS I digitization equipment and the same reverse engineering program (Geomagic Design X) were used (fig. 6).
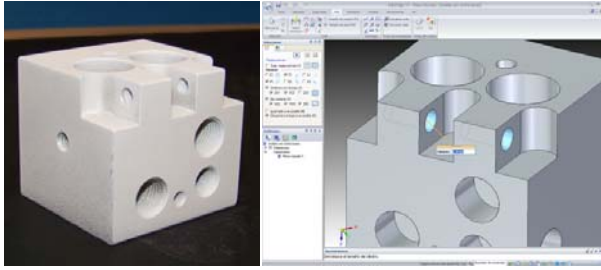
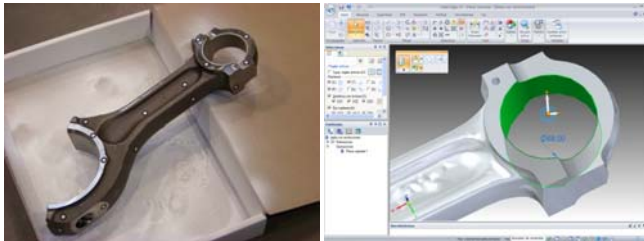*Fig. 6 Case study 1 (a) physical part. (b) editable CAD model.*

Due to th e geometric simplicity of this piece, obtaining the CAD mo del is the most b asic example of generation that may occur in practice. In this scen ario, a single reference surface is required for t he generation of the CAD mod el. As subsequent practical cases will show, depending on the geom etric complexity of the pi ece under study, the ge neration of the CAD mode l is consi derably conditioned by the reference surface, and sometimes it can even become necessary to include various surfaces of reference.

It has been pr oven that the desi gner can work with the model created in a CAD program introd ucing modifications in it. Thus, the CAD model is editable.

A comparison of these first two practical cases determines the influence of the quality of the mesh in this methodology. As exp ected, using the ATOS I digitizati on equipment, the resultin g mesh sho ws a be tter quality than the mesh achieved in the first case study using the REVscan (less noise, holes, surface quality, etc.). With a better quality in the triangular mesh, the results meet the expected improvement. However, this improvement is not as significant as to justify the use of a far more expensive scanner. Therefore, it can be concluded that to obtain acceptable results with the proposed methodology, counting on the most accurate - and expensive - equipment is not a must, provided it meets minimum requirements.

4.2   Case study num. 3

In this third case study, the ATOS I scanner and the Geomagic Design X program were used. The object of study is the rod shown in the following image (fig. 7).
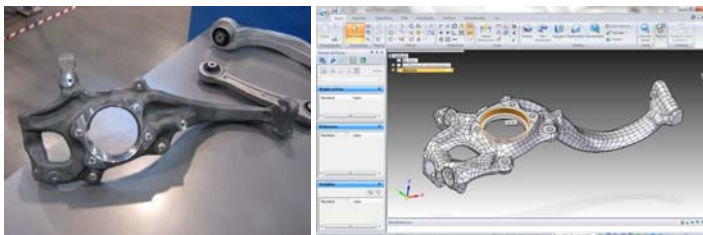

Fig. 7 Case study 3 (a) physical part. (b) editable CAD model.

In this case study, the part under study presented machined surfaces and rough foundry areas. In this case, only the machined surfaces of the piece need to be editable, so rough surfaces shall not be taken into account in the application of the methodology. A CAD model was obtained where the foundry areas were generated through the "a utomatic surfacing with quadrilateral patches" methodology, while the m ain surfaces were obtained following the direct modelling generation process.

4.3   Case study num. 4

In this fourth case study, the selected scanner was the ATOS digitizer. Geomagic Design X was used as reverse engineering program. The piece under study is a joint element that is part of the suspension system in a car (fig. 8).

Fig. 8 Case study 4 (a) physical part. (b) editable CAD model.

The selection of the refe rence surfaces is an important decision, because a proper choice of them can significantly facilitate the process of generation.

The constraints between surfaces of the same group (same reference surface) were verified accurately. However, the existin g constraints between surfaces of different groups have origi nated considerable deviations.

The restrictions that the researcher proved unable to impose will not be met accurately in the generated model. Therefore, these alleged relationships are c ertainly close to the reality of the p iece, but are not sufficiently verified to consider them full y accurate. Some possible causes can account for this situation. First, the part might not have been designed to fulfil such constraints, or on the contrary, the constraints might have been unfulfilled by failures in the manufacture of the piece. Another possible cause might be the accumulation of deviations arisen during the digitization process.

5 Conclusion

These four case studies have fully demonstrated that the developed methodology leads to the generation of an ed itable CAD model from a ph ysical piece. Likewise, the result s obtained in e ach of these ca ses confirm that the generated model fulfils all the constrai nts existing in the piec e, thus verif ying the desi gn intent. Moreover, the meth odology makes it possible to control the deviation from th e mesh, both when creating the sketches for the generation of the CAD model, and in the subsequent imposition of constraints on it, thus achieving the main objective of complying as much as possible with the available reference, i.e. the initial mesh.

The geometry of the piece and the nature of the surfaces condition the way in which the CAD generation process must be carrie d out. The researcher must be abl e to adapt the developed methodology to the characteristics of the part, through small changes in its different phases.

In this report, only angular relationships of perpendicularity and parallelism (i.e. 0º a nd 90º) have been taken into consideration, but any other angle constraint could be determined in the same way.

The selection of the reference surfaces is of the utmost importance, because an adequate choice of them can facilitate the process of generation and result in a substantial improvement in its results.

When adjusting surfaces to the mesh, depending on its characteristics, the best fitted surface can deviate significantly from its actual position and orientation. This happens or when the data is erroneous (noisy) or when there is not enough data to calculate the surface correctly. Surfaces that can lead to this situation are internal holes, partial or low height cylinders, narrow planes, etc. Therefore, these surfaces are considered low quality surfaces, and should not be used as reference elements.

6 Future Work

Further research on the influence of the selected references in the results of the meth odology must be undertaken.

A direct modelling operation requires selecting one or more reference elements (sketch plane, revolution axis, etc.), and in the proposed methodology, these reference elements are extracted from the mesh. Planes are best fitted to a plane se gment; axes are extracted from a revolution segment, etc. Since the digitized mesh have imperfections (noise, holes, spikes, etc.), so do the reference elements that have been extracted from the mesh. Thus the operations based on these reference elements can lead to an increase in the error in the resulting CAD model.

In the four c ase studies that have been discussed in this paper, the reference elements were extracted from those mesh surfaces that were considered of higher quality. Therefore, the CAD model deviation from the mesh was minimal in these particular surfaces, while it was significant in others. Our future work will propose a new algorithm for calculating the reference elements, so as to minimize the total deviation of the CAD model.

As stated before, the quality of the surfaces adjusted to the mesh depends on the parameters of the mesh segment: surface type (pl ane, cone, cylinder, etc.), dimensions, mesh density, noise level, surface edges, boundaries, etc. A further analysis must be conducted to determine the reliability of the data extracted from a surface, d epending on its characteristics. This knowledge will led to s elect the best mesh surfaces to calculate the reference elements.

The so-called "reliability factor" is intended to be used as reference plane adjusting criteria in the recovery of the originally design intent.

There are other constraints - for example, symmetry [21][22] - that are also very important when designing a mechanical part, but for the moment, they are beyond the scope of this work.

Acknowledgments

References

[1]   Várady T., Martin R. and Co x J. *Reverse Engineering of Geometric Models – an introduction.* Computer-Aided Design, 29 (1997) pp 255-268.

[2]   Werghi N., Fisher R., Robertson C. and Ashbrook A. *Object reconstruction by incorporating geometric constraints in reverse engineering.* Computer-Aided Design, 31 (1999) pp 363-399.

[3]   Barbero B.R. *The recovery of design intent in reverse engineering problems.* Computers & Industrial Engineering, 56 (2009) pp 1265-1275.

[4]   Benkö P., Kós G., Várady T., Andor L. and Martin R. *Constrained Fitting in Reverse Engineering.* Computer Aided Geometric Design, 19 (2002) pp 173-205.

[5]   Luhmann T. *Close range photogrammetry for industrial applications.* Journal of Photogrammetry and Remote Sensing, 65 (2010) pp 558-569.

[6]   Durupt A., Remy S. and Ducellier G. *Knowledge Based Reverse Engineering - An Approach for Reverse Engineering of a Mechanical Part.* Journal of Computing and Information Science in Engineering, 10 (2010) AR 044501.

[7]   Fisher R. *Applying Knowledge to Reverse Engineering Problems.* Computer-Aided Design, 36 (2004) pp 501-510.

[8]   Habbecke M. and K obbelt L. *Linear Analysis of Nonlinear Constraints for Interactive Geometric Modeling.* Computer Graphics Forum, 31, 2 (2012) pp 641-650.

[9]   Ke Y., Fan S., Zhu W., Li A., Liu F. and Shi Y. *Feature-based reverse modeling strategies.* Computer-Aided Design, 38 (2006) pp 485-506.

[10]   Wang J., Gu D., Gao Z., Yu Z., Tan C., Zhou, L. *Feature-based solid model reconstruction.* Journal of computing and information science in engineering, 13, 1 (2013).

[11]   Li Y., Wu X., Chrysathou Y., Sharf A. Cohen-Or D. and Mitra N. *GlobFit: Consistently Fitting Primitives by Discovering Global Relations.* ACM Transactions on Graphics, 30, 4 (2011) pp 52-62.

[12]   Várady T. *Automatic Procedures to Create CAD Models from Measured Data.* Computer-Aided Design and Applications, 5 (2008) pp 577-588.

[13]   Azariadis P. a nd Sapidis N. *Drawing curves onto a cloud of points for point-based modelling.* Computer-Aided Design, 37 (2005) pp 109-122.

[14]   Tran TT., Cao VT . and La urendeau D. *Extraction of cylinders and estimation of their parameters from point clouds.* Computers & Graphics, 46 (2015) pp 345-357.

[15]   Thompson W., Owen J., de St. Germa in H.J., Stark S. and Hend erson T. *Feature-Based Reverse Engineering of Mechanical Parts.* IEEE Transactions on Robotics and Automation, 15, 1 (1999) pp 57-66.

[16]   Zou HL. and Lee YT. Constraint-based beautification and dimensioning of 3D polyhedral models reconstructed from 2D sketches. Computer-Aided Design, 39 (2007) pp 1025-1036.

[17]   Mengoni M. and Germani M. Reverse Eng ineering and rest yling of aesthetic products based on sketches interpretation. Research in Engineering Design, 20 (2009) pp 79-96.

[18]   Mun D., Han S., Kim J. and Oh Y. *A set of standard modelling commands for the history-based parametric approach.* Computer-Aided Design, 35 (2003) pp 1171-1179.

[19]   Pu J. and Ramani K. *Priority-Based Geometric Constraint Satisfaction.* Transactions of the ASME, 7 (2007) pp 322-329.

[20]   Urbanic R.J., ElMaraghy W. and ElMaraghy H. *An integrated systematic design recovery framework.* Journal of Computing and Information Science in Engineering, 6 (2006) pp 318-330.

[21]   Chang M.H. and Park S.C. *Reverse engineering of a symmetric object.* Computers & Industrial Engineering, 55 (2008) pp 311-320.

[22]   Li M., Langbein F. and Martin R. *Detecting design intent in approximate CAD models using symmetry.* Computer-Aided Design, 42 (2010) pp 183-201.

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Digital Image Correlation technique to validate results and hypothesis on the tests for determination of properties of biological soft tissue

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Abstract

In this work we develop a numerical-experimental methodology to determine the mechanical properties of fascia tissue. To get the mechanical properties of the tissue, we tested fascia tissue by uniaxial tension tests and plane stress along the two preferred directions of anisotropy. Such tests were recorded using a camera system that allows us through digital image techniques obtain a distribution map of the displacements and deformation at every time.

Using the experimental data obtained by uniaxial and plena stress tests, a finite element simulation of real geometry of each test were developed in order to validate the constitutive model proposed. By graphic treatment of the deformable solid images and displacement map, we have compared the experimental and the numerical results. With this data, we are able to validate the experimental hypothesis and constitutive parameters.

Good correlation between numerical and experimental results was found for all compared tests. The displacement map of the samples obtained by numerical results is very similar to the experimental one. The most important error were found on the incompressibility condition for transversal samples.

1 Introduction

The numerical and experimental methods have been widely used in engineering for materials characterization and simulation of its behaviour in real parts or assemblies. Both methods have their limitations, experimental results are influenced by the boundary conditions of the setup affecting to the stress map tension. On the contrary, numerical results are affected by assumptions and hypotheses as well as the mathematical model used for the reproduction of the mechanical behaviour of the material.

For typical metallic engineering materials, there is huge previous experience as well as the simplicity of the linear elastic behaviour. For this reason, it is not necessary to check the applied hypothesis of computations. However for biological soft tissues, which have viscous anisotropic hyperelastic behaviour [1], the null normalized tests and the high dispersion between experimental data presented on the literature, it is necessary to analyse the methodology and validate the assumptions used in the experimental and finite element simulations. Several authors have investigated the nonlinear properties of fascia tissues [2,3,4,5].

The significant progress made in digital photography [6,7,8,9], the quality and accuracy of current cameras as well as the high computing capacities, allows the verification of the hypothesis in several cases .

DIC application [10,11] to this tissue characterization have a great future [12,13]. The application Inverse engineering in this works, implies the possibility of to determine mechanical properties of human soft tissue in vivo and the applications in medicine [14,15].

2   Digital Correlation tests biological tissue images

This job is focused to the characterization of the behavior of biological tissue as fascia. The appropriate characterization of this tissue is vital to predict their behavior when subjected to forces and displacements during normal walk.

1   Workbench

Six muscular fasciae were obtained from sheep legs by veterinaries of the Faculty of Veterinary from University of Zaragoza. Sheep were sacrificed under the approval of the Animal Experimentation Ethics Commission of the University of Zaragoza and all procedures were carried out in accordance with the "Principles of Laboratory Animal Care". The experimental tests were carried out in the Tissue Characterization Platform of the University of Zaragoza.

Uniaxial and plane stress tests were performed in a high precision drive Instron Microtester 5548 system adapted for biological specimens.. The system is very versatile, as it conducts tests at very low forces with high position resolution, and is capable of exerting loads up to 2 kN.
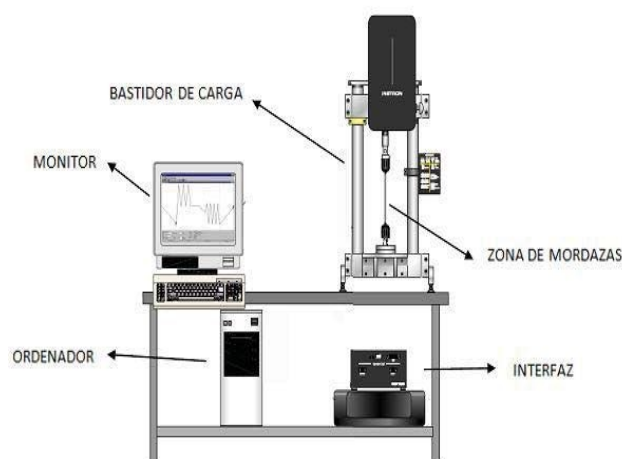

Fig. 1: LabVison System

Fig. 2: Instron 5548 setup

The software used during testing allows us to capture the load-extension curve at each time point (10 shots per second, f = 10 Hz). To avoid any mechanical interference with the specimen, the deformation gradient was measured optically by tracking the movements of markers. Several randomized markers were placed on the surface of the fascia and the lengths between the two markers in each direction were measured by a Digital Image Correlation (DIC) Strain Master LaVision System equipped with two high performance digital cameras with a megapixel sensor (2.5 μm±0.5%) during the uniaxial and plane stress tests.

2   Making experimental tests

The uniaxial Instron 5548 MicroTester machine exports all data from each time in a file that reflects the values of load, extension, tensile stress and deformation. Once known all these values, we are able to compute the stress-strain curves. The Cauchy stress in the direction of the stretch was computed using the load registered by the Instron machine and the initial thickness and width and the strain is the strain in longitudinal and transversal directions respectively measured by the video-extensometer.

σ - ε (evolvente)
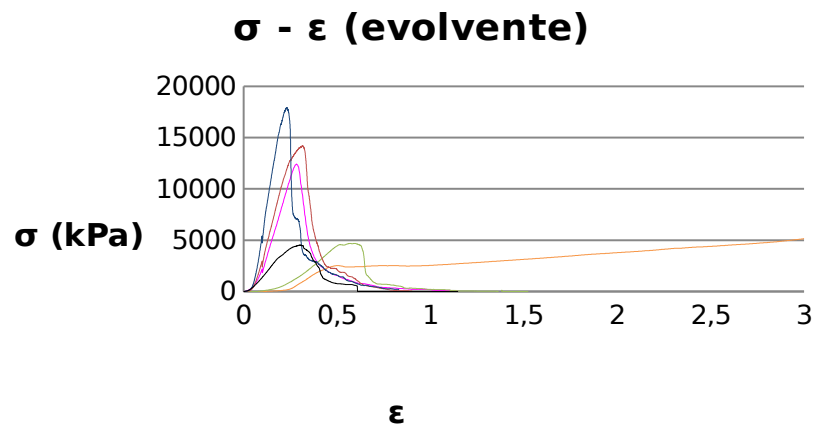
Fig. 3: Stress-strain curves for all fascia specimens under uniaxial test.

Sample Preparation
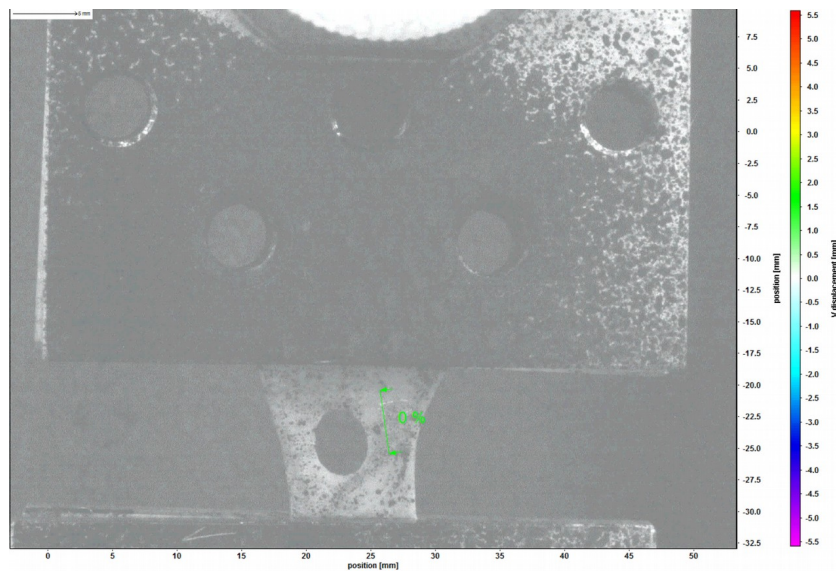
Fig. 4: Virtual gauge .

To do a study using digital image correlation, it is necessary to define a speckle pattern [16,17] that allows the recognition of outlines and by techniques briefly explained in the appendices, make the graphic treatment that involves obtaining deformation and get displacement map. Using the software LaVision Davis that allows placed imaginary gauges in the images of the trials (Figure 4) we record the deformation versus time. By post-processing, it can be estimated stress and strength in every moment captured by the camera system. Both vertical and horizontal image gauges were analyzed.
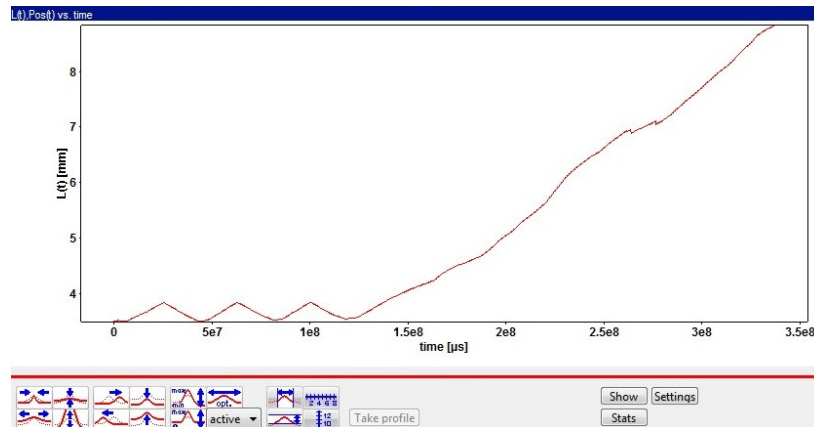
Fig. 5: Long. versus time

Image	time	L(t)	dL(t)	strain
	[μs]	[mm]	[mm]	[%]
1	68245.5	3.50946	0	0
2	401579	3.51072	0.00125615	0.0357931
3	734912	3.5091	-0.000364649	-0.0103905
,,,	,,,	,,,	,,,	,,,
,,,	,,,	,,,	,,,	,,,
29	9.40157e+006	3.55382	0.0443583	1.26396
30	9.7349e+006	3.55567	0.0462107	1.31675
31	1.00682e+007	3.56276	0.0532932	1.51856
,,	,,	,,	,,	,,
,,,	,,,	,,,	,,,	,,,
1008	3.35735e+008	8.80371	5.29424	150,856
1009	3.36068e+008	8.81213	5.30266	151,096
1010	3.36401e+008	8.81624	5.30678	151,213
1011	3.36735e+008	8.82359	5.31412	151,423
1012	3.37068e+008	8.82907	5.31961	151,579

Table 1: Experimental data gauges, LabVision

Testing hypotheses and experimental results by DIC

Data collected from the vertical gauge allows us to build a time versus strain curves that can be combined with time-stress values obtained by Instron and thus have a new stress -strain curves. The data collected by the horizontal gauge represented versus the vertical one is used to compute the Poisson's ratio.
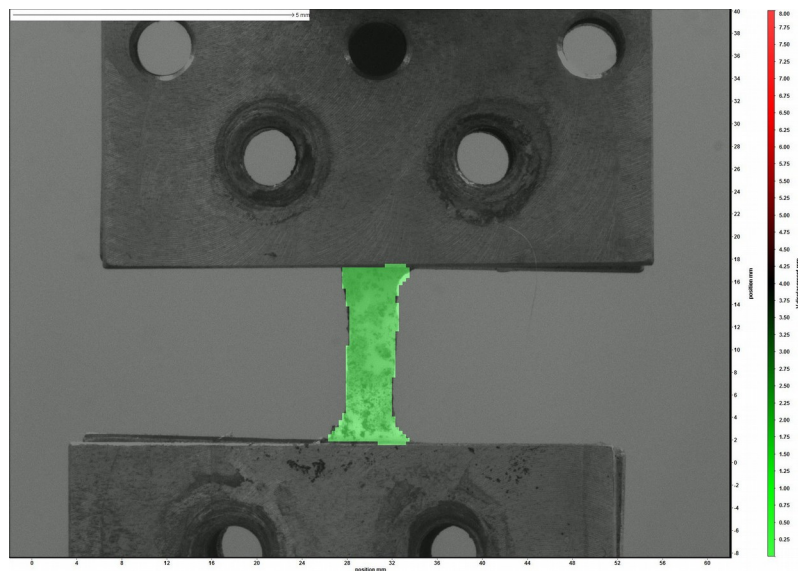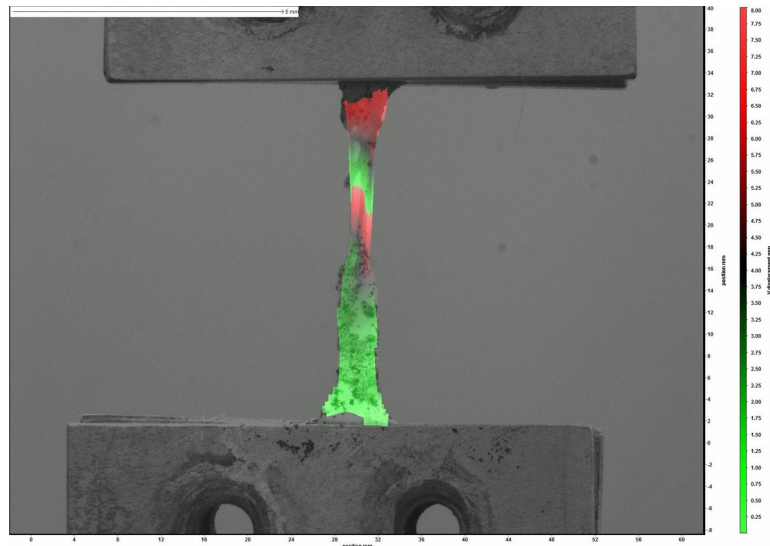

Fig. 6: Displacement map on the initial configuration

*Fig. 7: Displacement map on the final configuration. F34414 T1*

In addition to the possibility of viartual gauges, Davis software also allow us post-processing of generated images during the test to reconstruct the deformation map at all times for each specimen (Figure 6,7).

3 Hypothesis testing and numerical results by DIC

Once we have got the average properties of the fascia, we introduce these material properties on finite element model on Abaqus to verify the validity of the material model and the uniaxial and plane stress. To define and generate of the real contours of each specimen two softwares are used: the open source Inkscape vector graphics editor; and DraftSight, that lets us to create and modify various CAD files.

4 Getting the real contours

Due to small sample size of the biological tissues in general and fascia in particular, it is difficult to prepare and handle the experimental strips. Each specimen started the test with a different distance between clamps and there is a few variation between the sizes of the samples. Therefore, it was considered that the most real geometry to simulate in Abaqus should be obtained by importing curves from the exact contour of each specimen.
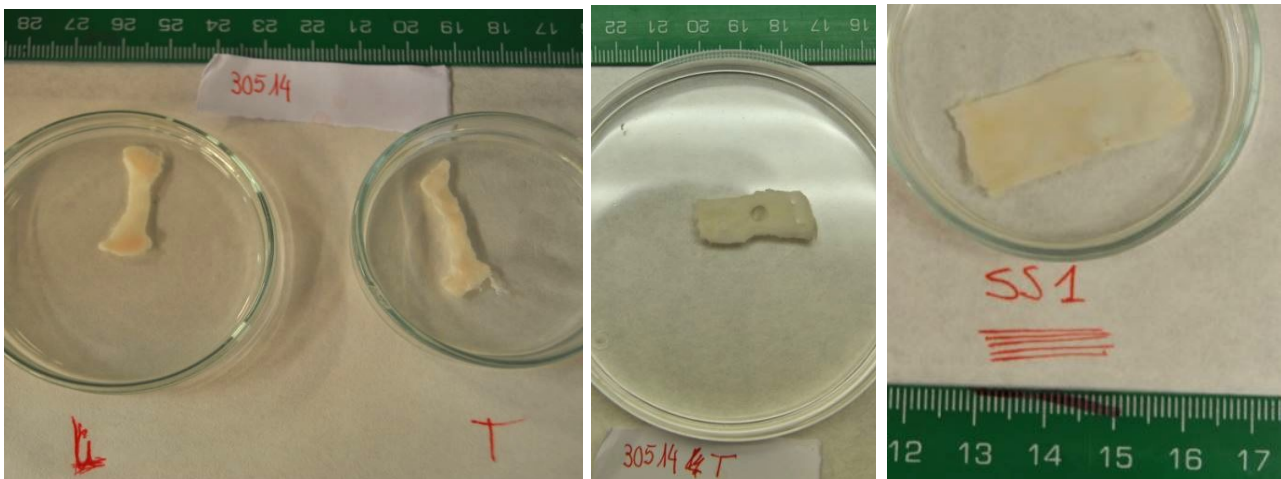
Fig. 8: Uniaxial and stress plane strips for sample FA30514

The first step to obtain the images contours was to identify the time corresponding to the beginning and end of the elastic tight curves. This is a important step because the model to be used in Abaqus has been prepared fitted based on these curves. They are treated with Inkscape for vectoring apparent contour. DraftSight were used for setting dimensional contour and graphical format compatible with FEM numerical calculation program.
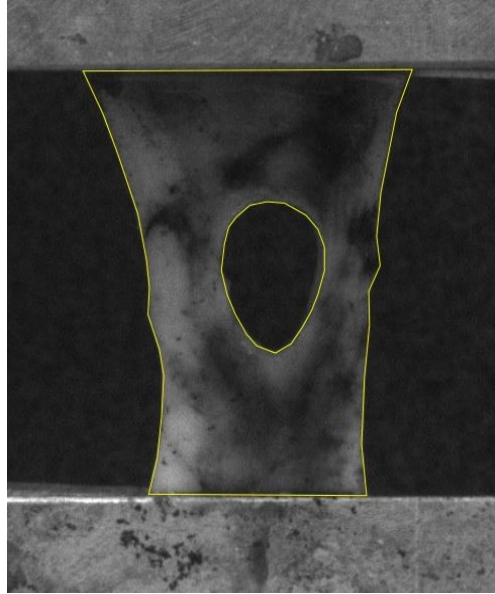
Fig. 9: Deformable shape contour of sample FA34414 2.

To faithfully reproduce the behavior of the fascia, a hyperelastic anisotropic behavior has been considered where each family of fibers is included. Hyperelastic materials behavior is defined by the strain energy function Ψ, from which we can get the stress as the derivative of this function with respect to the strain.

$$\Psi = \mu(I_1 - 3) + \sum_{i=l,t} \phi_i \Psi_i$$

with μ the shear modulus and ϕ_i the ratio of the fiber i (i=l,t) and Ψ_i the anisotropic part of the strain energy function

$$\Psi_i = 0 \qquad \lambda < 1$$
$$\Psi_i = \frac{C_3}{C_4}(e^{C_4(\lambda-1)} - C_4(\lambda-1)'1) \qquad \lambda < \lambda^*$$
$$\Psi_i = C_5\lambda + C_6 Ln(\lambda^2) + C_7 \qquad \lambda > \lambda^*$$

After the fitting procedure we obtain the material parameters presented in Table 1

	FA34414	FA35814
C_1 (kPa)	5	5
C_2 (kPa)	19.3972	12.4689
C_3	55.8489	23.7009
ϕL	0.7901	0.9711
ϕT	0.2099	0.0289

Tabla 1: Tabla con los valores de las constantes para ambos modelos

And the fitting results were presented in Figure 10,11.
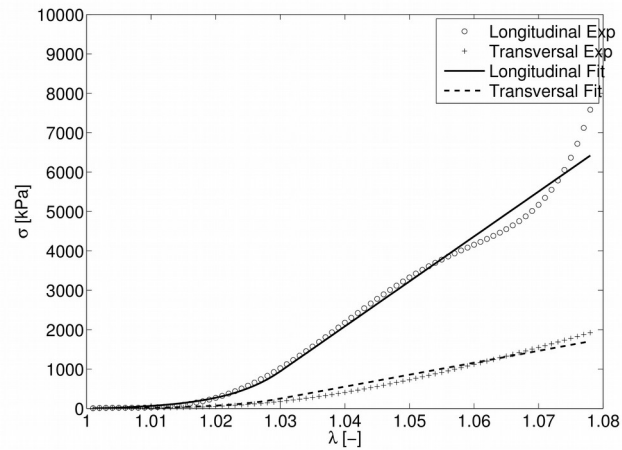
Fig. 10: Fitting results for specimens FA34414S
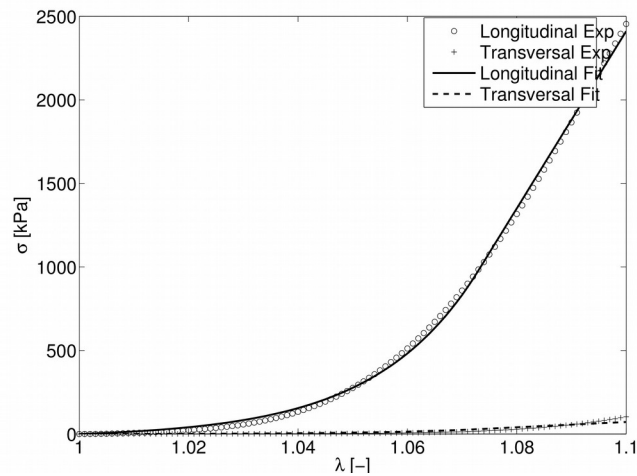
Fig. 11: Fitting results for specimens FA35814S·

5   Testing adjustments

After obtaining the final result of the simulation test, the values of load and vertical displacement at each time were obtained by numerical simulation and they were compared with those previously obtained by experimental test with Instron machine (Figure 12). In this way we can validate the proposed model to capture the mechanical behavior of the fascia.
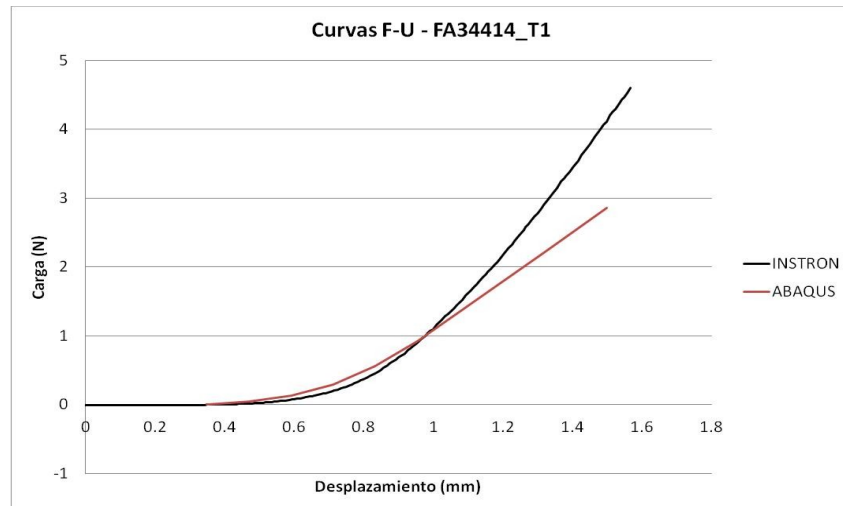
Fig. 12: Load (N) versus displacement (mm) for transversal sample

6   Displacement map

To validate the model, we overlap deformed configuration or final configuration of the FEM simulation and the final image obtained by the camera system. The comparison between the two images shows a very reliable approximation of the FEM model used. Good correlation between numerical and experimental results was found for all compared tests. The displacement map of the samples obtained by numerical results is very similar to the experimental one. The most important error were found on the incompressibility condition for transversal samples
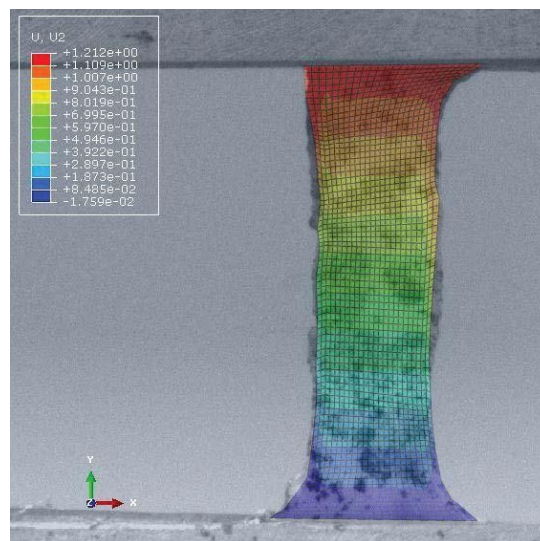
Fig. 13: Overlapping image for transversal strip of sample
FA34414 T1.
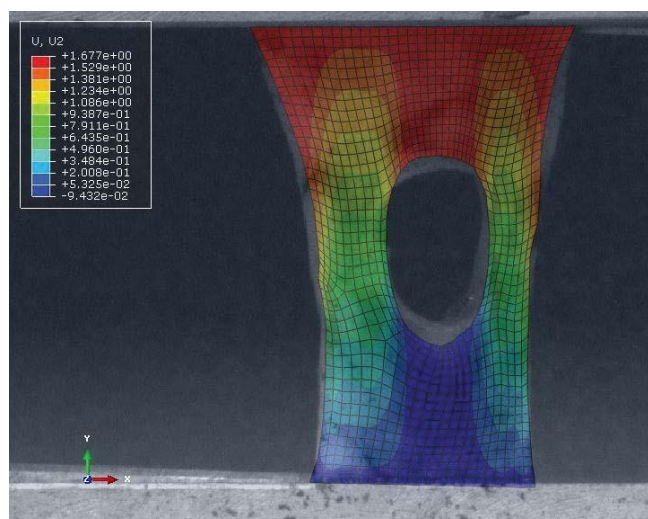
Fig. 14: Overlapping image for longitudinal strip of sample FA34414L1.

Conclusion

In this work we develop a numerical-experimental methodology to determine the mechanical properties of fascia tissue. To get the mechanical properties of the tissue, we tested fascia tissue by uniaxial tension tests and plane stress along the two preferred directions of anisotropy. Such tests were recorded using a camera system that allows us through digital image techniques obtain a distribution map of the displacements and deformation at every time.

Using the experimental data obtained by uniaxial and plena stress tests, a finite element simulation of real geometry of each test were developed in order to validate the constitutive model proposed. By graphic treatment of the deformable solid images and displacement map, we have compared the experimental and the numerical results. With this data, we are able to validate the experimental hypothesis and constitutive parameters.

Good correlation between numerical and experimental results was found for all compared tests. The displacement map of the samples obtained by numerical results is very similar to the experimental one. The most important error were found on the incompressibility condition for transversal samples. The presented study allows the characterization of biological materials in general and fascia in particular, as well as the accuracy of the experimental results. This method allows to determinate strain in experimental data without disturbances includes in classic methods. .It has taken into account previous results of researchers [18] who have studied the principle of Saint Venant and the boundary conditions in the trials of biological tissues.

As a conclusion, DIC technique is very hopefully strategy for studying biological tissues, where we can not apply the hypothesis of small strains and therefore the correlation techniques give results with a good degree of accuracy.

Acknowledgement

References

[1]   Martins. et al., J Mech Behav Biomed. 8: 111-122, 2012

[2]   F.Q. Pancheri J Mech Behav Biomed.30 306 –323,2014

[3]   C AROLINE F ORSELL,Annals of Biomedical Engineering,2012

[4]   Hai-Qiang Wang,BMC Musculoskeletal Disorders,2009

[5]   Carla Stecco,Surg Radiol Anat 36:25–32,2014

[6]   Javier Civera,2008 IEEE International Conference on Robotics and Automation

[7]   Fernando Arámbula Cosío,Annual International Conference of the IEEE EMBS,2010

[8]   Oscar G. Grasa,2011 IEEE International Conference on Robotics and Automation

[9]   Óscar G. Grasa,IEEE TRANSACTIONS ON MEDICAL IMAGING, VOL. 33, NO. 1, 2014

[10]   G. Cloud. Optical Methods in Experimental Mechanics, Experimental Technique, (2002)

[11]   Bing Pan1,4, Kemao Qian2, Huimin Xie3 and Anand Asundi1 "Two-dimensional digital image correlation for in-plane displacement and strain measurement: A review" Meas. Sci. Technol. 20 (2009)]

[12]   Kevin M. Moerman, Journal of Biomechanics, Volume 42, Issue 8,1150–1153, 2009

[13]   Dongsheng Zhang, Journal of Biomedical Optics, 9(4), 2004

[14]   M.A. Lago ,Journal of Biomechanics, 48(1),38-43,2015

[15]   Chen-Ket Chai,journal of the mechanical behavior of biomedical materials 43 59 –68,2015

[16]   Bing Pan1,4, Kemao Qian2, Huimin Xie3 and Anand Asundi1 "Two-dimensional digital image correlation for in-plane displacement and strain measurement: A review" Meas. Sci. Technol. 20 (2009)

[17]   G. Cloud. Optical Methods in Experimental Mechanics, Experimental Technique, (2002).

[18]   R. Simón-Allué, A. Cordero, E. Peña. Unraveling the effect of boundary conditions and strain monitoring on estimation of the constitutive parameters of elastic membranes by biaxial tests. Mech Res Commun, 57: 82-89 (2014).

EXPLORATION OF A REFERENCE FRAMEWORK FOR GRAPHIC COMPETENCE

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Abstract

Purpose: *This article aims to share valuable knowledge collected by the authors' broad experience as lecturers of Technical Drawing courses in Engineering and Architecture, also called, among other denominations, Graphic Expression in Engineering or in Architecture, Graphic Engineering, or Cartographic Engineering.*

Method: *We discuss the kind of relation the courses have with respect to the generic competences delivered to future engineers and therefore with the strategic, methodologies and evaluative implications in the immediate future of engineering.*

Result: *There are different levels of proficiency in the graphic language used in engineering and architecture.*

Discussion & Conclusion: *The exploration of a reference framework is proposed, which might take the form of a few questionnaires suited to certain levels of communicative competence through Technical Drawing, which, as a universal language, makes it possible to measure the graphic competence of technicians, engineers and other users.*

1 THE EUROPEAN AREA OF HIGHER EDUCATION: values and competences

The Bologna process has not only led to a harmonization of the existing principles of the so-called European Higher Education Area (EHEA), but it also marked a turning point in how education was viewed.

The construction of EHEA has meant, among other innovations, that the teaching dimension in an institution of higher education (university) has been placed in the foreground, giving faculty a full role not only aimed at the transmission of technical knowledge but also geared to the shaping of upstanding people. Therefore, universities should be responsible for providing a high quality educational level that includes two interconnected aspects: 1) delivering valuable professionals that are highly skilled in specific useful competencies, and at the same time, 2) favouring students' personal grown by enhancing all possible aspects of the person.

It is not a matter of adding a certain number of capacities and attitudes to a set of technical knowledge, but rather it is one of promoting the integrated development of capacities and attitudes that makes it possible to use knowledge in diverse situations, be they professional and personal or interpersonal, that are presented or will be presented to the students (Traver Martí, 2005).

Joan Traver Martí and Rafaela García López (Traver Martí, 2005) indicate that in the near future it would not be strange to hear opinions stating the need to include ethical education in university degrees, as well as recognising the educational role of the university lecturers. However, there are a few studies that note that the faculty members indeed see themselves not only as a beacon of knowledge, but also as an educator and therefore also a transmitter of values related to science: knowledge, know-how, knowledge of living and learning to be.

From this approach, which takes as reference the UNESCO report with Jacques Delors as President, the generic concept of 'competence' combines attributes that refer to various levels of the humans:

Knowledge and technical competencies (Learning to know)

The methodological way to carry out an activity (Learning to do)

Guidelines for understanding different forms of individual and collective behaviour (Learning to live together, learning to live with others)

Way of the organization and interaction (Learning to be)

Different functions have been assigned to the university in recent times, roles such as preparing students for the professional world, transmitting university culture, and promoting the development of society and its creative role. In addition to this traditional focus, universities must organize themselves to provide better responses to the forthcoming needs and changes in the political, social, economic and technological fields.

All these facts lead us to ask: How is the university answering all these problems?

In the last Ingegraf Conference hosted by the University of Valencia in 2014, there was a discussion session about 'teaching, planning and new methodologies' in the field of Graphic Engineering. As a conclusion, it could be seen that the presence of subjects that are identified with graphic competence in engineering is minimal and, moreover, they are tightly constrained within ambitious study programmes. Furthermore, these courses inevitably include teaching the most important software applications that are being used in all scientific sectors (aeronautical, naval, industrial, civil, agronomic, geodetic, topographic mapping, etc.), meaning that these courses must improve together with these industries, and therefore faculty must continuously revise their teaching and methodologies.

The Ingegraf Conference presented evidence that the education of graphic expression in engineering programmes has undertaken an in-depth review of its content and its methodologies in a way dissimilar and heterogeneous. These differences, along with the limited content related to graphic expression in the first year of university degree programmes, may have major implications in subsequent years, e.g. bachelor projects, or when students start working in their professional career, e.g. in a Technical Office, where there are clear examples of the lower level in students' training in graphic expression.

In order to solve this urgent matter, some universities, such as University of Zaragoza, are promoting complementary academic activities by means of volunteer lecturing, thanks to the voluntarism of teachers. It is necessary to promote specialization in the area of knowledge; this should be a requirement for teaching accreditation through Master's and PhD programmes in Graphic Expression in engineering. The situation presented here is complex and poses serious difficulties for the proper training of skills and values that can directly impact not only in the teaching of Graphic Expression, furthermore in the R+D in the area of knowledge.

From this point of view, we should remark that it is important to examine ourselves and establish how graphic competences in engineering are being taught at universities so as to identify weaknesses and strengths that allow Graphic Engineering lecturers to improve our syllabi and keep our lecturing competences up-to-date.

2 GRAPHIC COMPETENCE

The relationship between the brain and pictorial activity are complex and, in normal conditions, this pictorial skill is very variable in each individual.

A drawing can be either a physical representation of the reality or the result of human brain activity that allows a person to 'rebuild' in his mind objects that are not present with the help of only a spoken word or sound.

In both cases, the human brain is able to develop certain skills that allow it to represent a three-dimensional object on a two dimensional surface, and vice versa. From a drawing, we are able to restore and interpret what has been represented in a drawing and see that that two-dimensional drawing corresponds to a real object.

Nevertheless, graphic competence will be evaluated from two aspects:

1. The "artistic", which awakens feelings and perceptions of the reality from an intuitive and approximate shape.

2. The "technical", knowledge of which comes from the mathematical reasoning and engineering, about which a scientific knowledge was developed. Basis on this results a graphic language arise with its grammatical rules that allow communication between engineers, technicians and others.

From this latest point of view, the degree to which competence in Graphic Engineering has been acquired can be measured by answering the following question: **What is the level of knowledge in Graphic language that students are getting just after finishing an engineering degree?**

Recently, results measured by simple tests given to different engineering graduates working in a variety of technological sectors (aeronautical, naval, industrial, civil, agricultural, geodetic, cartographic and topographic, etc.) showed that, surprisingly, today's engineers are not able to communicate graphically. Their level of graphic competence is very low—virtually null.

A classification by levels could give us the opportunity to study and describe how engineering students should learn and develop graphic competences at universities in order to use the graphic language to effectively communicate their projects.

3   AN EXPLORATION OF A FRAMEWORK OF REFERENCE

A qualification framework is an internationally recognized structure where all qualifications are described in a consistent manner, which allows them to be connected and compared. In addition, these qualifications are also used to facilitate the mobility of people in the European space of continuous learning and on the international labour market (Figure 1). These frameworks range from international to national and sectorial frameworks, such as the hospitality framework, the agricultural industry framework, the Spanish framework for higher education, etc.
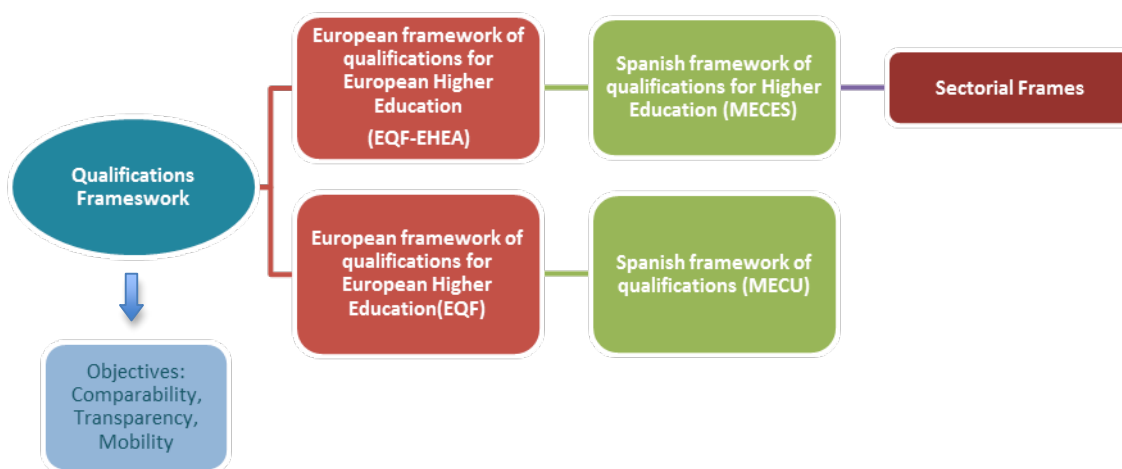
Figure 1.-Qualification frameworks

At the national level, MECES has been established in Spain and the Spanish Framework of Qualifications is going to be applied for Life-long learning (MECU).

MECES is applied to the qualifications acquired in the field of higher education. It, therefore, refers exclusively to formal education. Every level of qualification in MECES will have its reflection in MECU, which refers to all learning contexts. MECU includes both formal learning (taking into account all education system levels), and non-formal/informal learning.

From these frameworks, we could define a similar system consisting of various levels of domains linked to the Common European Framework of Reference for Languages (CEFR): learning, education and evaluation. These three domains are an essential part of the general project of language policy promoted by the European Council, which has made a considerable effort to unify the guidelines for learning and the teaching of languages within the European context.

The CEFR establishes a scale of 6 common levels of reference for the organization of learning languages and public recognition (Figure 2). This framework may be applicable to define the same levels of domain for technical drawing as a language that entails communicative competence.
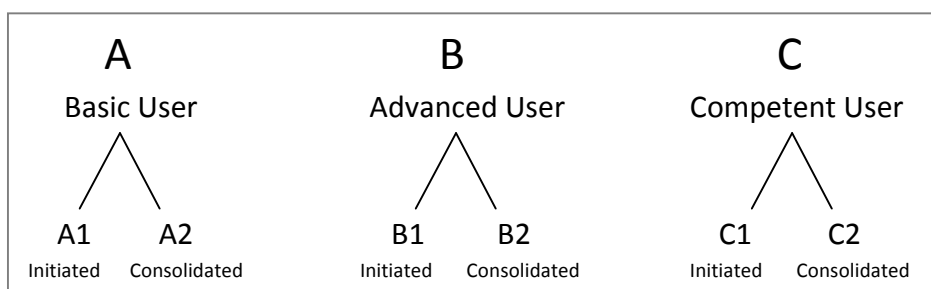
Figure 2. Common reference levels

The graphic competence that we acquire, consciously or unconsciously, in a more technological world is filled with technical drawings, might be classified in

LEVEL "A" in communicative competence through Technical Drawing:

The **Basic User**: A1 and A2. The person is able to communicate in daily situations with 2D drawings intuitively and freehand, and uses common vocabulary and basic grammar.

LEVEL "B" in communicative competence through Technical Drawing:

The **Advanced user**: B1 and B2. The person can interact with experts in technical drawing with a sufficient degree of fluency and spontaneity, such that graphic expression via freehand drawing or with technical drawing instruments enables communication without strain for either party, with 2D and 3D drawings (isometric drawing or military perspective) and geometric tracings of very frequent use, using basic vocabulary and grammar.

LEVEL "C" in communicative competence through Technical Drawing:

The **Competent user**: C1 and C2. The person with a "High level of competence" represents a higher level of competence for more complex work and study tasks involved in technical drawing, from traditional forms of metric geometry and descriptive geometry to all forms currently displayed on a computer with the use CAD 2D, 3D software (people with higher academic studies in Technical Drawing usually reach this level).

4   COMPUTER APPLICATION AND SURVEY FOR THE DIAGNOSIS THE TEACHING OF GRAPHIC COMPETENCE

A good starting point might be to know how Technical Drawing is being taught in different engineering universities. With this purpose we invite all the agents involved to use and fill out the on-line survey hosted at http://www.egrafica.unizar.es/mr/.

Here, through this on-line survey we expect to collect and analyse the different names and the URLs of all the subjects related to technical drawing programmes, their location in the study programme, their duration, the number of hours per week dedicated to lectures and practice sessions, the diversity of content, the different methodologies used by lecturers, the relative importance of practice problems and theory classes, the experiences of evaluation systems that use rubrics and other systems, etc.

Moreover, another important action could be the definition of some online questionnaires that reveal what would be the degree of agreement with regard to the definition of domain levels communicative competence that is established through the Technical Drawing, using questions as:

> What extent you consider helpful to establish common reference levels for the acquisition of the graphic competence in Engineering / Architecture?

Do you find it interesting that companies and employers would request the accreditation of a degree of proficiency of the graphic competence in Technical Drawing (A1, A2, B1, B2, C1, C2)?

To what extent does would improve the teaching and learning of Technical Drawing in Engineering establishing common reference levels for measuring the graphic competence?

Would you like to participate in the design of tests for the establishment of common reference levels?

For the definition of the levels of competence graphic could use the following questions to the survey respondent indicates to what extent it would be agree with the following definitions. Indicating whether they are appropriate to measure the level of graphic competence through Technical Drawing:

LEVEL "A" in communicative competence through Technical Drawing:

The **Basic User**: A1 and A2. The person is able to communicate in daily situations with 2D drawings intuitively and freehand, and uses common vocabulary and basic grammar.

LEVEL "B" in communicative competence through Technical Drawing:

The **Advanced user**: B1 and B2. The person can interact with experts in technical drawing with a sufficient degree of fluency and spontaneity, such that graphic expression via freehand drawing or with technical drawing instruments enables communication without strain for either party, with 2D and 3D drawings (isometric drawing or military perspective) and geometric tracings of very frequent use, using basic vocabulary and grammar.

LEVEL "C" in communicative competence through Technical Drawing:

The **Competent user**: C1 and C2. The person with a "High level of competence" represents a higher level of competence for more complex work and study tasks involved in technical drawing, from traditional forms of metric geometry and descriptive geometry to all forms currently displayed on a computer with the use CAD 2D, 3D software (people with higher academic studies in Technical Drawing usually reach this level).

With it, maybe we can initiate an investigation with which we could study how this evolves teaching graphic competence in universities. And also we could find some data that will enable us the definition of levels of dominion of this language called Technical Drawing.

In our opinion, there is an urgent need to work towards a Common European Framework of Reference that, perhaps, will allow for improvements in graphic communication and the definition of a working direction, which will have enormous relevance for the clarification of concepts in engineering graphic competence in particular and in society in general.
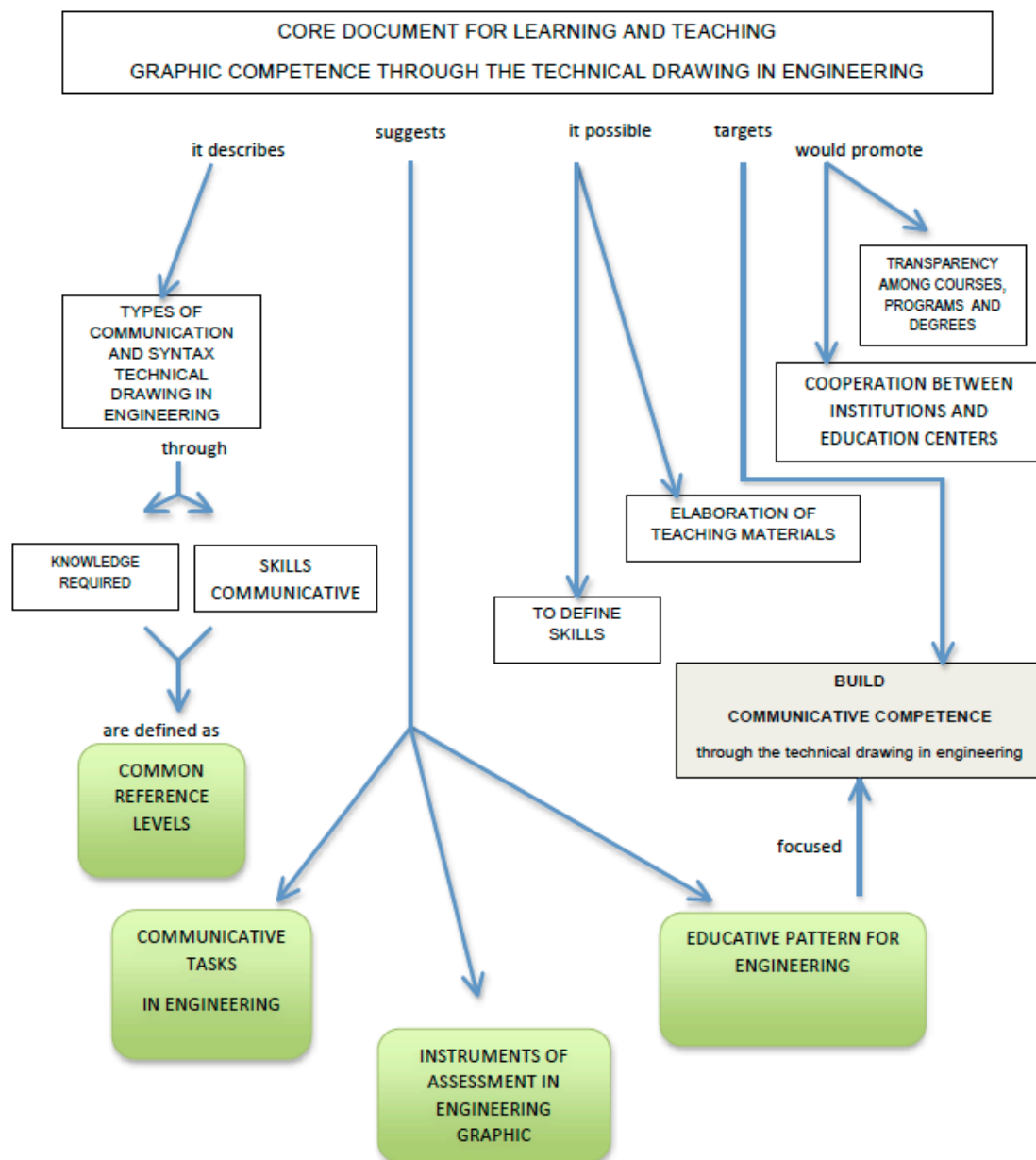
Figure 3. Conceptual map.

5 CONCLUSIONS

Based on the answers to the preceding questions, from which the strengths and weaknesses can be discovered in professionals' training, we can see the need to closely analyse other aspects which will let us define a frame of reference for the acquisition of graphic competence in engineering.

Nobody discusses the fact that nowadays engineers and technical staff need to have good knowledge of Technical Drawing and they must easily handle any CAD application. However, after the recent changes in the study programmes following EHEA, we have not recorded whether the knowledge domain reached in graphic competence levels have made it possible to achieve communicative competence or real communication between graduates and professionals.

From the information and data collected in the suggested on-line survey computer application, it could be interesting to design some diagnostic tests, so users and teachers of graphic expression have the possibility of improving their craft and taking advantage of the experiences in different spheres of economic, social, cultural and university life, all with a common objective: learn and acquire common competencies that allow the highest levels of communication and graphic reasoning to be reached in order to allow for collaborative understanding among engineers, technicians and society in general.

A framework of reference for measuring the graphic competence would result in the definition of questionnaires that would allow describe the degree of language acquisition through technical drawing, define the criteria for description and measurement, classification of users of this language and the comparison between different certificates. This would get the first steps to define a core document of reference for the learning and teaching of graphic competence through technical drawing in engineering.

References

[1]   Council of Europe (2013), the European Qualifications Framework for lifelong learning http://ec.europa.eu/dgs/education_culture, Accessed in March 2015.

[2]   Delors, J. (1996), report to UNESCO of the international commission on education for the twenty one century. Learning: the treasure within, UNESCO Ed.- Unit for Education Sector Education for the XXI century. Paris.

[3]   INGEGRAF Journey (2014). Roundtable on "teaching, planning and new methodologies". http://www.ingegraf.es/wp-content/uploads/2014/10/Resumen-MESA-REDONDA-revisado.pdf . Valencia. Accessed in March 2015

[4]   Ministry of Education, Culture and Sports of Spain, Subdirectorate General for international Cooperation (2002). Common European Framework of Reference for Languages: Learning, Teaching, Assessment. Co-published by: Secretaría General Técnica del MECD-Subdirección General de Información y Publicaciones, y Grupo ANAYA, S.A. Madrid.

[5]   Ministry of Education, Culture and Sports of Spain (2006). Qualifications Framework of the European Higher Education. http://www.mecd.gob.es/dctm/mecu/marco-europeo-es.pdf?documentId=0901e72b8090922b , Accessed in March 2015.

[6]   Miralbes R., Santolaya JL, Romero C. (2014). Learning based in rubric on the subject of Graphic Expression-II. Universidad de Zaragoza. Published by INGEGRAF Journey (2014).Valencia. Learn desing by doing - Learning from experience. http://www.ingegraf.es/wp-content/uploads/2014/11/El-aprendizaje-basado-en-r%C3%BAbrica-en-la-asignatura-expresi%C3%B3n-gr%C3%A1fica-II.pdf   Accessed   in March 2015.

[7]   Sentana Gadea, I., Sentana Cremades E. The transmission of knowledge in Graphic Engineering. Published by INGEGRAF Journey (2014). Valencia. Learn design by doing - Learning from experience. Enlace web: http://www.ingegraf.es/wp-content/uploads/2014/11/La-aplicaci%C3%B3n-de-la-ingenier%C3%ADa-gr%C3%A1fica-en-la-ense%C3%B1anza-universitaria.pdf, Accessed in March 2015.

[8]   Traber Martí, JA y García López, R. (2006). Aronson puzzle technique as a tool to develop competition "ethical commitment" and solidarity in university education. Ibero-American Journal of Education No. 40 /. Publisher: Organization of Ibero-American States (OEI). Madrid.

[9]   Ubieto P., Royo C., Santolaya JL, García C. (2014). Engineering project evaluation with feedback for continuous improvement actions. Universidad de Zaragoza. Learn design by doing- Learning from experience, http://www.ingegraf.es/wp-content/uploads/2014/11/Evaluaci%C3%B3n-de-proyectos-de-ingenier%C3%ADa-con-realimentaci%C3%B3n-para-actuaciones-de-mejora-continua.pdf. Accessed in March 2015.

A PROPOSAL FOR ACTIVE LEARNING IN GROUPS AND ROLES

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Abstract

Motivating students throughout the new learning experiences that involves skills acquisition can improve the teaching/learning process.

This paper describes the results of collaborative work in groups and roles performed by students of the Engineering Degree in Industrial Design and Product Development at the University of Zaragoza in Artistc Expresion of 1st year of the Degree.

With the development of these activities the following aims have been achieved: Detecting the mayor learning difficulties for the students; implementing the link between the contribution of contents of the subject, under study, and the further professional development of the students; developing students' creativity; encouraging the awareness towards quality and continuous improvement within work; developing skills in interpersonal relations and increasing motivation at work.

Students have developed an active role in the lectures, providing the necessary feedback, such as ideas to improve the teachers' lectures. This dynamics even though it has required an important degree of involvement, both by students and teachers, has been a positive and enriching experience.

1 Introduction

Since the establishment of the Bol ogna Plan in E uropean universities, the proposed methodological approaches have provided an identity marker that focuses mainly on students, their autonomy and on them playing active role in their lear ning. This model, based on constructivist teachi ng strategies has mobilised an important change as it proposes modifying the conceptions and teaching styles of university professors, with respect to teaching based on traditional education strategies [1]. Thus, the university system is facing the challenge of proposing a transformation in terms of the teaching-based education model, fostering a new learning-based model, which commits to the profile of an active student who can ask questions, investigate, select and organise information, analyse data, draw conclusions, express themselves adequately, etc. [2]. Fernández, A. [3] states that teaching methods with the participation of students, where the responsibility for learning depends on their activity, engagement and commitment, are more formative than informative, as they generate a more i n-depth, significant and l ong-lasting learning, facilitating the transfer to mo re heterogeneous contexts. In this regard, it is important to have an in-depth knowledge of the methodological repertoire and experiment with it to evaluate the possibilities offered by the different strategies in order to adapt them to our needs, with the aim of achieving a learning context that fosters the students' engagement. The possibility of deve loping academic and professional competences, developing interpersonal and communication skills, and even changing attitudes are attributed to these methodologies. For Ruiz [4], active methodologies promote the development of the basic competences of teacher training, and make it possible to dynamically combine attributes related to knowledge, skills, attitudes and responsibilities, thus showing

the learning results of a programme, which the students are able to demonstrate at the end of the learning process. Palazón, Gómez, Gómez, Pérez et. al., [5] point out that this type of methodology has a significant influence on the learning quality of these students and on their academic results. However, it must be taken into account that the important part of the methodology used is its adaptation to the learnings and to the intended purpose, considering the competences to be developed, if they used in a technically correct manner and if they are not used as a reaction to each other [6]. Professor López [7] indicates in his book Metodología participativa en la enseñanza universitaria (Participative methodology in university teaching) that to make the move towards participatory methodology, professors must be trained, not only in positive attitudes and values, but also in new teaching skills that will enable them to help their students change at a cognitive, emotional and attitudinal level. Likewise, the aspects of innovation and renovation are also essential, entailing changes in methodology, ideas, values and beliefs both in professors and students. In any case, as indicated by Zabalza [8], the methodological decision teeters on a tightrope, as there are variables that can be changed, but others are sometimes impossible to change.

From the view point of the teachers' motivation in applying this type of methodology, Lobato & Madinabeitia [9] point out that teachers, who are undergoing a learning process in active methodologies through the Eragin programme carried out at the University of the Basque Country, are intrinsically very motivated, and despite the fact that extrinsic motivations are present in this learning process, they are relegated to a second plane. This conclusion coincides with that obtained by Bruinsma & Jansen [10] who point out that teaching enthusiasm is positively related to the quality of the training programme and satisfactory teaching experiences in the classroom.

After more than one decade of experiences in incorporating learning strategies based on active methodologies applied to the field of university education, it is a good moment to reflect upon the possibilities offered by these methodologies. A review of the most commonly used active methodologies is shown below:

- Project-based learning. In PBL, the development of learning is reached through an experience that consists in carrying out a project. This must be perceived by the students as something attractive and feasible and it is carried out in working groups [11].

- Learning contract. This is an agreement based on communication and on trust that defines the commitments assumed by the professor and the student to ensure the quality of the training and achievement of the subject goals. To this end, the students form groups and design the exercises, learning strategies, self-assessment and the practical sessions [12].

- Problem based learning (PBL). The starting point of PBL is a problem or situation and the objective is to identify learning needs [13].

- Case study. The use of authentic cases creates group work dynamics and contributes to a good interaction with the professor. This activity encourages students as they see the real application of the knowledge acquired [14].

- Simulation. This activity is based on a real life situation, which is open-ended and where no responses to the problems or situations that may arise are more correct than others [15].

- The portfolio. This is a method that fosters the construction of own knowledge through the compilation of significant material that represents a basis for the assessment [16].

- Module work. This proposes carrying out a collaborative and interdisciplinary work that integrates different subjects, facilitating the development of transversal and specific skills of the qualification [17].

Given that the majority of the competences to be developed by engineering students have a high practical component and the future exercise of the profession entails situations where they will have to carry out an active role, this type of methodology is adequate in their university education.These methods permit associating theoretical explanations with direct application in professional situations and real-life [18]. Thus, students can see for themselves the relationship between certain theoretical aspects and their utility.

The methodology of module projects has been applied [19-20] since the implementation of the Engineering Degree in Industrial Design and Product Development (EDIDPD) of the University of Zaragoza. Here, students play an active role, associating the knowledge they acquire about the different subjects with the practical part. A way of complementing the methodological process applied in the degree has been to foster the active role of the students in acquiring theoretical contents through group and role methodology.

2   Methodological proposal

The methodological approach by groups and roles is based on the oretical content learning where the student plays an active role.

This learning experience by groups and roles has been carried out throughout the first semester of the 2014-2015 academic year, in the theoretical part of the Artistic Express ion subject. This activity requires students to carry out a collaborative work, in which 94 students, divided in group 1 (39 students) and group 2 (55 students), have taken part.

After presenting a theoretical content block, the class was divided into 5 groups (red, green, orange, white and blue) for them to u ndertake different roles, with the purpose of fulfilling a task and developing certain specific and transversal competences of the degree course. Every time a new theoretical content block of the subject was dealt with, the members of the group changed roles, so, throughout the semester, they took on each one of the roles.

The aim of implementing this methodology is to:

- Associate the contributions of the subject to the field of knowledge.

- Foster the active participation of students in the teaching/learning process.

- Get to know the students' learning difficulties and their improvement proposals.

- Increase the s tudents' engagement and responsibility in their le arning process and interest in th e contents.

The following tasks have been assigned to each one of the roles:

Red group: its mission was to detect the difficulties in learning the topic or carrying out the e xercises proposed, indicating which concepts required explanation and why they represented a difficulty. In this regard, solutions were invited to help towards understanding. The aim of the activities of this group was for the student to develop instrumental competences.

Green group: its mission was to identify the practical meaning of the content dealt with in the subject and detect contributions to the discipline of product design. The aim of the activities of this group was for students to develop specific competences.

Orange group: its mission was to propose possible activities in which the theoretical content explained is applied. The objective of this role was to develop systemic competences.

White group: this group was divided up and integrated into the meetings of the other groups, acting as moderators whenever needed. During the presentation of results of this role, the type of need that arose in each group was indicated as well as the decisions adopted to solve the problems. The aim of the activities of this group was for students to develop interpersonal competences.

Blue group: its mission was to assess the proposals/initiatives proposed by the other groups (red, green, orange and white), as well as indicate if they considered them to be adequate or inadequate, and why. The blue group intervened after listening to the contributions of the rest of the groups It had 10 minutes to prepare its presentation. The aim of the activities of this group was to develop instrumental competences.
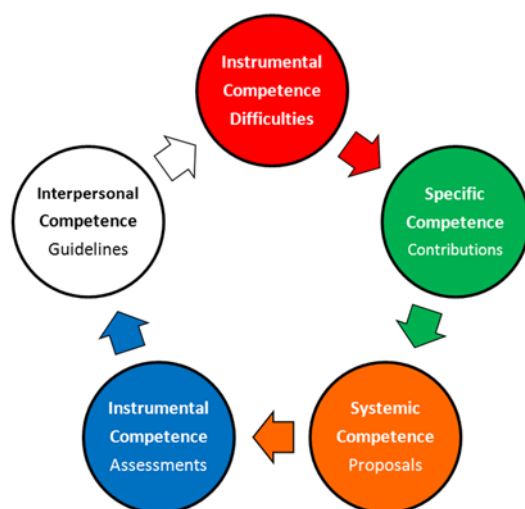
Fig. 1 Change of role in each new block of content and competence development.

At the end of each theoretical explanation given by the professor, the groups met for 15 minutes to carry out the action s corresponding to each role . After performing the task s assigned by roles, the groups presented their results orally.

The table 1 presents the Lectures and activities organization during the first semester of the Degree in Industrial Design and Product Development Engineering at the University of Zaragoza, in the field of artistic expression. The table includes the distribution of the roles between the groups, within a total of 39 students. In the table the week in which the visit of an expert is received was eliminated.
All groups are composed of 8 students except of group 5 which is composed of 7of them.

Schedule	Lectures content	Activity	Roles and Groups
Week 1	Product form and structure	Product shape and structure analysis	Group 1 - Red Role Group 2 - Green Role Group 3 - Orange Role Group 4 - Blue Role Group 5 - White Role
Week 2	Product form and structure	Work with forms	Group 1 - Red Role Group 2 - Green Role Group 3 - Orange Role Group 4 - Blue Role Group 5 - White Role
Week 3	Proportion criteria of the industrial product	Proportion criteria of the industrial product analysis	Group 1 - Green Role Group 2 - Orange Role Group 3 - Blue Role Group 4 - White Role Group 5 - Red Role
Week 4	Proportion criteria of the industrial product	Proportion criteria of the industrial product analysis	Group 1 - Green Role Group 2 - Orange Role Group 3 - Blue Role Group 4 - White Role Group 5 - Red Role
Week 5	Illumination and volumetric representation of the product	Light - dark work with different types of lighting	Group 1 - Orange Role Group 2 - Blue Role Group 3 - White Role Group 4 - Red Role Group 5 - Green Role
Week 6	Illumination and volumetric representation of the product	Light - dark work with different types of lighting	Group 1 - Orange Role Group 2 - Blue Role Group 3 - White Role Group 4 - Red Role Group 5 - Green Role
Week 7	Design of the presentation boards	Design of the products´ panels	Group 1 - Blue Role Group 2 - White Role Group 3 - Red Role Group 4 - Green Role Group 5 - Orange Role
Week 8	Design of the presentation boards	Design of the products´ panels	Group 1 - Blue Role Group 2 - White Role Group 3 - Red Role Group 4 - Green Role Group 5 - Orange Role
Week 9	Color and its perception in industrial product	Color application on the industrial product	Group 1 - White Role Group 2 - Red Role Group 3 - Green Role Group 4 - Orange Role Group 5 - Blue Role
Week 10	Color and its perception in industrial product	Color application on the industrial product	Group 1 - White Role Group 2 - Red Role Group 3 - Green Role Group 4 - Orange Role Group 5 - Blue Role

Table 1. Lectures and activities organization

The activity has been assessed with a value of 10% over the final mark of the subject and a heading was designed to assess the development of the competences.

3   Results and discussion

Students made the presentation of their work in the classroom as well as they had to submit a summary of their work in form of the presentation boards. The Table 2 shows some examples of the results of the work belonging to different groups, and Figure 2, examples of the presentation boards made by students.

Role	Lecture Design of the products´ panels
Red	To present more examples of designs of products panels that have been presented for design awards in which the use of a grid can be recognized
Green	Utility to learn to design panels for presenting product concepts. Visual perception order of the panel. Design of backgrounds for use in display panels. Perception connotations of different fonts.
Orange	Making the design of a presentation panel for a product, using the same elements in order to observe different compositional choices and graphic resources proposed by each student. Share all proposals via Dropbox
White	Red Group: they do not known design awards which could serve as examples of design panels. The mediator of the white group proposes to search for different awards to see how the products are presented.
Blue	Blue Group considers that the most interesting contribution has been made by the Orange group because of the possibility it offers to share different approaches to design panels made by each student.

Table 2. Examples of the results of the work belonging to different groups

*Fig. 2 Examples of the presentation boards made by students*

At the end of semester a questionnaire comprised of four blocks of questions was designed whose aim was to discover the following aspects: the students' perception about the organisation of this activity, the extent to which the different competences are developed, and the level of affability and difficulty of each role.

The questionnaire includes a total of 22 items and itwas completed by a total of 64 students. This sample is representative for the population of the 94 students currently enrolled in the Artistic Expression subject.

The items have been evaluated in agreement with a Likert 7-point scale, where 1 corresponds to total disagreement and 7 with total agreement. The results obtained are described in the section below.

4   Analisys of the results

The results of the research are presented in four blocks. In the first block, the students' perception about the level of affability of each role in this activity is studied fig. 3.
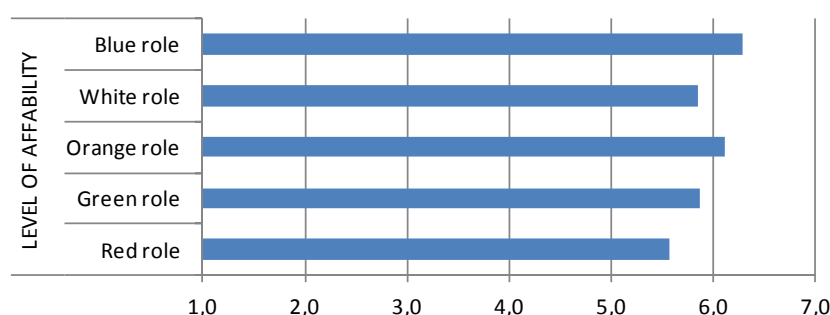
Fig. 3 *Level of affability of each role in this activity.*

Results show that the most pleasant roles were the blue and the orange ones with an evaluation of 6.28 and 6.12, respectively. The red role was the worst appraised with a score of 5.56.   In general, it can be observed that all the roles exceeded 5 on the 7 scale, indicating that none of them have been unpleasant.
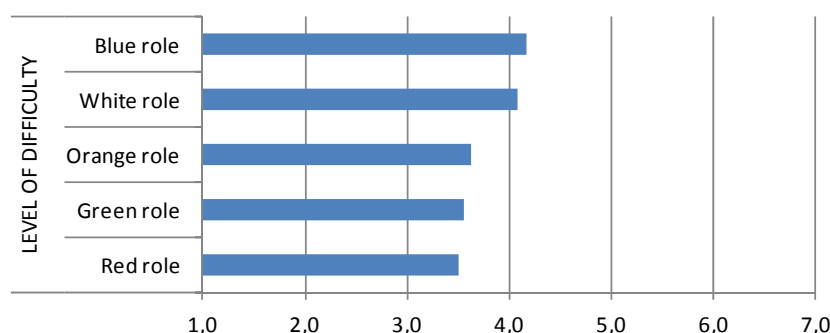
Fig. 4 *Level of difficulty of each role in this activity*

With respect to the level of difficulty, students indicated that the blue and white roles involved the greatest difficulty with scores of 4.17 and 4.08, respectively fig. 4. The role that turned out to be the simplest was the red one with a score of 3.51. Result s indicate that the group and ro le activity has average difficulty with values of between 3.5 and 4.2.

Noteworthy is the fact that the role perceived as the most pleasant, the blue role, entails greater difficulty for the students, whilst the red role, despite it not being so difficult, is the least pleasant.
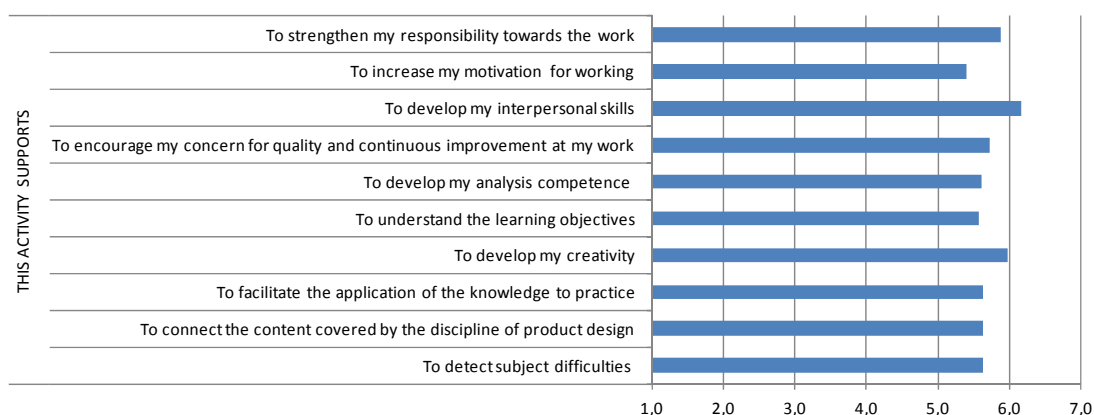
Fig. 5 Level at which the activity helps develop competences.

Students perceived that the activity mainly helped develop skills in interpersonal relations, with a value of 6.16, as well as creativity, with a value of 5.97, and responsibility towards work, with a mean of 5.89 fig. 5. However, the competence that obtained the lowest value is motivation for the work with a result of 5.40. In general, the result obta ined by the development of interpers onal, instrumental, syst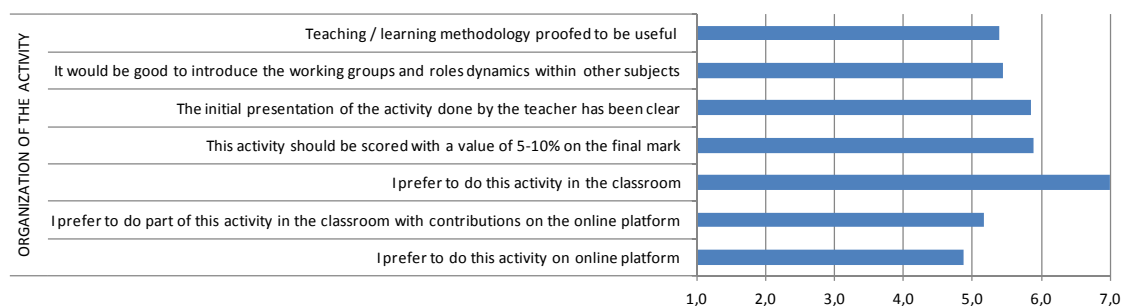emic and sp ecific competences was homogenous, positively appraising the activity, and understanding that it helps to wards developing these competences.

Fig. 6 Evaluation of the activity: usefulness and organisation

The students' perception about the usefulness of this activity fig. 6, is evaluated with 5.39, and introducing this methodology into other subjects with 5.45. With reference to the org anisation of the activity, students considered that the most ade quate place to carry it out was the classroom, opposed to the possib ility of carrying out the experience on an online platform.

5   Conclusions

The application of the metho dology to the field of Artistic Expr ession increased students interest to the subject because they were involved actively not on ly in the practical part of the classe s but als o in the theoretical once. Simultaneously this activity let the professor to know students' learning difficulties and their improvement proposals, which can be applied in the following classes.

Noteworthy among the contributions of this method ology thanks to the roles are: the application of the theoretical knowledge to real problems (green role), the development of analytical (red and blue roles) and creative capabilities (orange role), social skills and responsibility towards work (white role/all the roles).

Coinciding with Martínez, García, Robledo, Díez, et. al. [21] this experience has shown that it is possible to get the teachers to gradually adopt new teaching methods to deliver their subjects and to get students to participate more actively in their learning. The adoption of this t ype of methodology entails an increase in teaching dedication to the teaching/learning process. However, the authors consider that it is importa nt to continue motivating the students with new learning experiences that entail actions in which students actively develop the required competences.

The experience described is presented as a new active methodology that is in keeping with current work lines that offer the possi bility of improving competences, applying a system that entai ls students' active participation.

Naturally, the exper ience carried out is in a n experimental phase a nd its continu ation will permit the improvement of this method ology, both at organisational level a nd from the vie wpoint of tools for its evaluation.

References

[1] K. Caballero y A. Bolívar. *El profesorado universitario como docente: hacia una identidad profesional que integre docencia e investigación.* REDU - Revi sta de Docencia Universitaria 13, 1 (2015) pp 57-77.

[2] M. I. R. Rodríguez, B. M. D omínguez y J. I. M. Juaniko rena. *Los proyectos interdisciplinares de módulo: Una experiencia innovadora en el Grado de Educación Social de la UPV/EHU.* REDU: Revista de Docencia Universitaria 10, 3 (2012) pp 209-237.

[3] A. Fernández. *Metodologías activas para la formación de competencias.* Educatio siglo XXI 24 (2006) pp 35-56.

[4] A. P. Ruiz. *El modelo docente universitario y el uso de nuevas metodologías en la enseñanza, aprendizaje y evaluación.* Revista de educación 355 (2011) pp 231-232.

[5] A. Palazón, M. Gómez, J . Gómez, M. Pérez y J. Gómez. *Relación entre la aplicación de metodologías docentes activas y el aprendizaje del estudiante universitario.* Bordón. Revista de Pedagogía 63, 2 (2011) pp 27-40.

[6] M. Rodríguez. *Metodologías Docentes en el EEES: De la clase magistral al portafolio.* Tendencias pedagógicas 17 (2011) pp 83-103.

[7] F. López. *Metodología participativa en la enseñanza universitaria (Vol.* 9). Madrid. Narcea Ediciones. 2005.

[8] M.A. Zabalza. *Competencias docentes del profesorado universitario.* Madrid. Narcea. 2003.

[9] C. Lobato y A. Madinabeitia. *Perfiles motivacionales del profesorado ante la formación en metodologías activas en la universidad.* Formación universitaria 4,1 (2011) pp 37-48.

[10] M. Bruinsma y E. Jansen. *Is the motivation to become a teacher related to pre-service teachers' intentions to remain in the profession?* European J. of Teacher Education: 33, 2 (2010) pp. 185-200.

[11] T. Markham. *Project Based Learning, a guide to Standard-focused project based learning for middle and high school teachers.* Buck Institute for Education 2003.

[12] Martínez B. (2008) *El contrato de aprendizaje. Metodologías activas.* Universidad Politécnica de Valencia. Editorial UPV.

[13] J. Atienza. *Aprendizaje basado en problemas. Metodologías activas.* Universidad Politécnica de Valencia. Editorial UPV 2008.

[14] P. Calderón. *Estudio de casos en Ingeniería. Metodologías activas.* Universidad Politécnica de Valencia. Editorial UPV 2008.

[15] K. JONES. *Simulations. A Handbook for Teachers and Trainers.* London: Kogan Page Ltd 1995.

[16] Rodriguez, M. (2011). Metodologías Docentes en el EEES: De la clase magistral al portafolio. *Tendencias pedagógicas*, 17, 83-103

[17] A. Serrano T ierz, M. Hernán dez Giménez, E. Pérez Sinu sía y P. Biel Ibáñ ez. *Trabajo por módulos: un modelo de aprendizaje interdisciplinar y colaborativo en el Grado en Ingeniería en Diseño Industrial y Desarrollo de Producto.* Revista de Docencia Universitaria. REDU. Vol. 11, Número especial dedicado a Engineering Education (2013) pp. 197-220.

[18]   J. Benegas y M. Villegas. La Enseñanza Activa de la Física: la Experiencia de la UNSL. IX Conferencia Interamericana sobre Educación en la Física. July 3th-8th, 2006, San José de Costa Rica, Costa Rica.

[19]   E. Manchado y I. López. *Coordinación por módulos de asignaturas en el Grado de Ingeniería de Diseño Industrial y Desarrollo de Producto de la Universidad de Zaragoza*. Revista de Docencia Universitaria 10, 3 (2012) pp. 195-207.

[20]   Serrano, A., Hernández, M., Pérez, E., y Biel, P. (2013). Trabajo por módulos: un modelo de aprendizaje interdisciplinar y colaborativo en el Grado en Ingeniería en Diseño Industrial y   Desarrollo de Producto. *REDU. Revista de Docencia Universitaria*, *11*(extra.), 197-220.

[21]   B. Martínez-Cocó, J. García, P. Robledo, C. Díez, M. L. Álvarez, J. M. Marbán, A. M. de Caso, R. Fidalgo, O. Arias-Gundí n, D. I. Pache co y C. R odríguez. *Valoración docente de las metodologías activas: Un aspecto clave en el proceso de Convergencia Europea*. Aula Abierta 35 (2007) pp 49-62.

XXV Congreso
INGEGRAF

AN EXPERIMENT WITH AUGMENTED REALITY APPLIED TO EDUCATION IN GRAPHIC ENGINEERING

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Abstract

Purpose:
This work presents an experiment of Augmented Reality (AR) for improving the performance and motivation of engineering students. It was applied to a Graphic Engineering course of the Mechanical Engineering Degree at the University of Cantabria (Spain).

Method:
Conventional teaching notes were enriched with visual markers to virtually deliver 3D CAD models in mobile devices (smartphones, tablets, etc.), laptops or PCs. These tools were intended to help students in visualization tasks, spatial ability and clarification of complex concepts. A validation study was conducted to measure any positive impact on their graphical skills. Furthermore, the experiment was completed with a satisfaction questionnaire to find out if AR can be taken into consideration to enhance the subject into a more exciting and interesting course.

Result:
In general terms, the opinion about the use of AR technology was positive. The experimental group gave medium-high marks to questions related to easiness, clearness of information, quality of models and robustness of the AR tool. The highest marks were given to the attracting and stimulating benefits of the AR method.

Discussion & Conclusion:
Results show that students participating in the pilot study had a relatively high degree of satisfaction with the AR technology. Furthermore, all the students, participants or not, highlighted the interest and attraction aspects of this technology. Future works will involve more complex models and AR environments as well as a further analysis to find out if the use of AR could have any positive effect in the learning outcomes of mechanical engineering students.

1. Introduction

In recent years, the application of technology with learning purposes has increased exponentially. The so-called technology-enhanced learning (TEL) involves different applications and tools related to mobile learning (m-learning), ubiquitous learning (u-learning), virtual learning environments (VLEs), virtual reality (VR), augmented reality (AR), etc. [1]. The last two examples are different but they are usually mistaken. Virtual reality (VR) is the use of computer graphics systems combined with various displays and interface devices for providing the effect of immersion in the interactive 3D computer-generated environment. Augmented reality (AR) is, however, a technology that combines real scenes with virtual images or models, maintaining contact with the real world while interacting with virtual objects and, thus, supplementing reality [2].

Several AR learning experiences have been developed lately. In fact, Bacca [1] listed some review studies on topics related to AR in education: Martin et al [3] stated in 2011 that the amount of publications about AR was increasing continuously, even if this technology was at that moment in their initial stage in education, pointing out the potential future of mobile AR; and Radu [4], [5] demarcated the most usual benefits of AR (increased content understanding, learning spatial structures, language associations, long-term memory retention, improved collaboration and motivation) as well as the drawbacks (attention tunneling, usability difficulties, ineffective classroom integration and learner differences).

Some recent examples of these experiences in AR are found in different areas of knowledge. Bacca [1] also reports that in Sciences, for instance, some relevant works are applied to electromagnetism [6], physics of elastic collisions [7], natural science and ecology [8], field trips [9], jigsaw puzzle solving [10],

socioscientific issues on energy and pollution [11], etc. In the area of Humanities & Arts, AR has been widely used in language learning [12]–[15], visual art and painting appreciation [16], [17] and multiculturalism, solidarity and tolerance [18].

The present work focuses on the use of AR technology with teaching purposes applied to subjects related to drawing and representation of Mechanical Engineering. There have been recent studies on this field [2], [19]–[21] that have proved that AR technology had a benefit on students' spatial ability and receptive attitude.

2. Methodology

This experiment of AR was conducted for measuring the improvement of the performance and motivation of engineering students. At the moment of writing this paper the final students' results and marks were not yet available, therefore in this work only the results about students' satisfaction and motivation will be analyzed.

Conventional teaching notes have been enriched with visual markers to virtually deliver 3D CAD models in mobile devices (smartphones, tablets, etc.) and also in laptops or PCs. These tools are intended to help students in visualization tasks, spatial ability and clarification of complex concepts. A validation study with second year students of the Graphic Engineering subject, belonging to the Mechanical Engineering Degree at Universidad de Cantabria (Spain) has been designed to measure any positive impact on their graphical skills.

The chronological script of the study was as follows: At the beginning of the term, in week 1, the 58 students of the course were asked to pass a first questionnaire for initial assessment of their preferences, skills, performances and opinions. From weeks 7 to 12, a selected group of 33 students (the experimental group) used the AR tool as an additional resource to the traditional teaching notes provided traditionally. The other 25 students conformed the control group. Finally, in week 12, all of them were asked to voluntarily complete a questionnaire, which was different for the experimental group and for the control group. After week 15, when it is possible to gather data about the students' performance, it will be possible to conclude if this technology contributes any benefits to the learning process. The extended explanation of this experience is listed in following subsections.

1.1. Survey for initial assessment

Before starting implementing the AR methodology in the classroom, students were asked to pass an anonymous test to know some important factors that could have an influence in their academic behavior. The questionnaire is included in Appendix 1. In order to keep the anonymity of the participants, each one of the students was assigned with a random number, which could be used at the end of the study to relate important data between preferences/interests and academic performance/opinion.

This initial survey was also used to select the students who would participate in the pilot study. Question No. 12 asked "Would you like to participate in a pilot experience about new technologies?". Those students replying with a high or very high degree of agreement were chosen to perform the AR experience. In total, this experimental group was composed of 33 out of 58 students registered in the course. It should be remarked that they were not informed about what type of technology would be used, so no reference to AR was mentioned. The other 25 students conformed the control group, obtaining the teaching notes without any data concerning the AR information.

1.2. The AR tool

AR technology was implemented by using the software tools provided by Bienetec S.L. The solutions applied to this experiment were freely available, intuitive and very easy to use. The software "Aumentaty Author" [22] was used to create the AR scenes with all the CAD models associated to the fiducial markers. This program lets the user to decide how to show the 3D model by means of changing the relative location, rotation and scale with respect to the fiducial marker (Fig. 1). In this project, CAD models were created with Autodesk Inventor Professional (v2015), then converted to STL format and finally to OBJ format (the only one accepted by Aumentaty Author to create scenes for mobile devices). Even if the software also reproduces animated CAD models, in this pilot study only static models were generated.

Once the AR scenes had been created, they could be freely stored or shared online with the experimental group. Students of the control group were provided with traditional and conventional classroom notes. All the documents that included AR models had in their title page a QR code for loading them automatically. After capturing the scene, students could point to the markers with their handset devices and visualize the CAD models associated to them (Fig. 2). In order to do so, Bienetec S.L. solutions also provide the "Aumentaty Viewer" [23], either for PC (Windows / Mac OS) or for mobile device (Android / iOS).
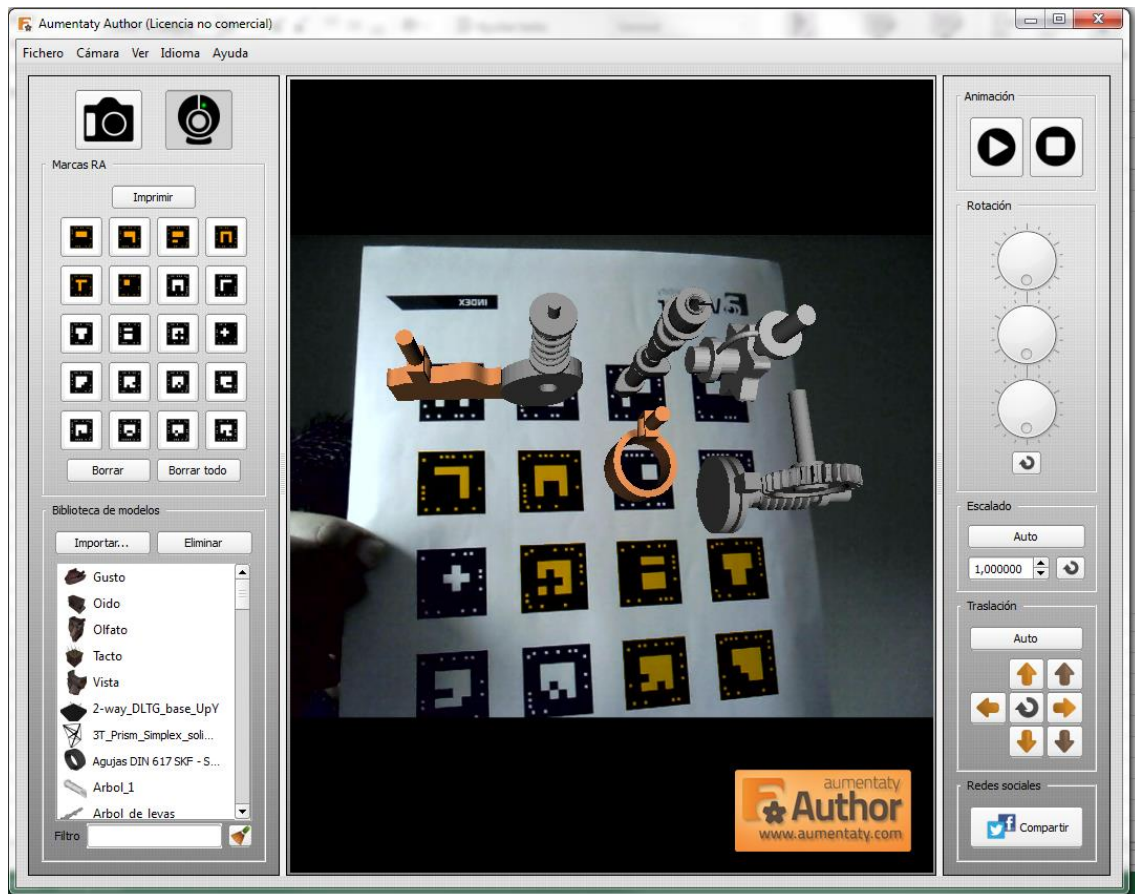
Fig. 1 Aumentaty Author: software for creating AR scenes with CAD models associated to fiducial markers.
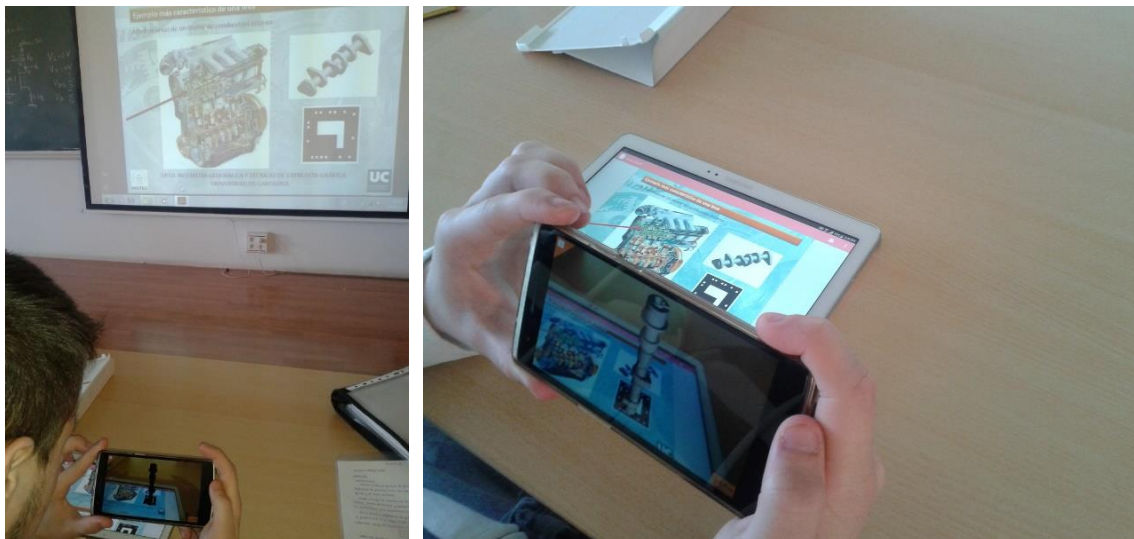
Fig. 2 Aumentaty Viewer: A student visualizing an AR scene including the 3D model of a camshaft.

The AR technology was used for adding some additional assistance in the visualization of different mechanical components: threaded connections, bearings, shafts, gears, belts, chains, cams, etc. It allowed the students to pay special attention to geometry, relations between components, details, etc., orbiting around the CAD model to analyze the 3D models from different perspectives.

The visualization of the AR contents was very direct for the students; similarly, the application of the AR techniques was very simple and straightforward for the teachers. Moreover, for the students the AR tool was

very cost-effective as it only required them to have in the classroom a mobile device (or laptop + webcam) with internet connection (usually free Wi-Fi provided by the university).

1.3. User satisfaction survey

After using the AR tool for six weeks, the experiment was completed by running a satisfaction questionnaire (Appendix 2). It was composed of 15 questions, designed to discover if AR could be taken into consideration to enhance the subject into a more exciting and interesting course. The survey had also the purpose of assessing participants' opinion about the easiness, attraction, usefulness, etc. of these virtual resources.

1.4. Survey for non participants

Finally, those students that did not participate on the study were also asked to pass another questionnaire (Appendix 3). It was very short, composed by only 7 questions. This third and last survey would help to understand the general opinion of the students better, even if they did not experience the AR methodology personally. The opinion of the students belonging to the control group was also interesting as they could have a different perspective, experiencing the technology as outsiders.
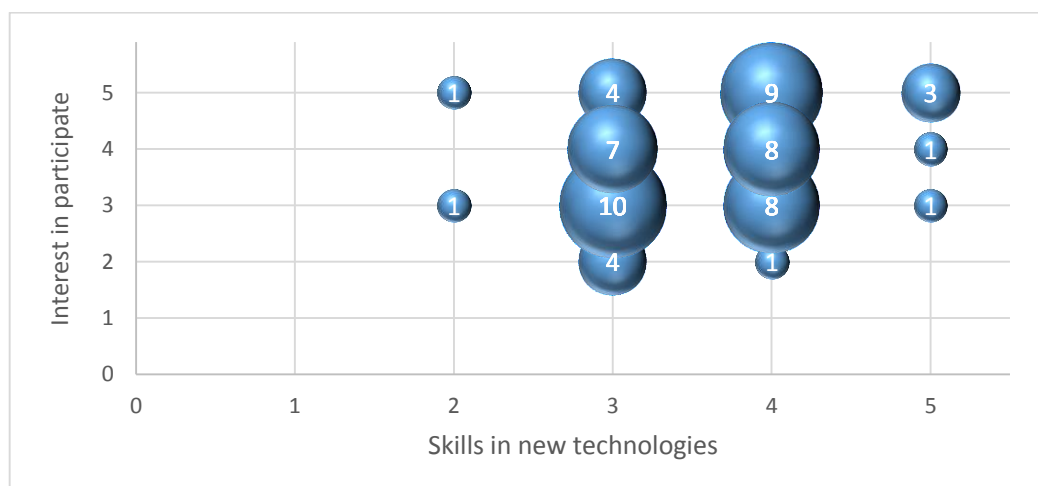
3. Results

At this point, we will present the results obtained from the different surveys carried out by the students of the subject, taking into consideration whether they were participants or not of the pilot experiment.

3.1. Results of the Questionnaire for Initial Assessment

As explained in previous sections, this first questionnaire was completed by 58 students and served to select among them those that would participate in the pilot study. Only scholars with high or very high interest in contributing to a pilot experiment in new technologies were chosen. However, there was no information about the kind of technology that would be used in the experience. In fact, question No. 11 asked for any other tools, technologies or methodologies that could be suitable for this subject, but none of the students replied considering that AR could be a good candidate for that purpose (in fact, it was stated later on that most of them did not know this technology). Only four of them replied this question, saying that they would like to explore 3D printing technology.

Question No. 4 was meant to measure the self-evaluation of students' skills in new technologies. As it can be seen in Fig. 3, there is an important correlation between the mentioned skills and the interest for participating in the experiment. In the chart, the volume of the bubbles represents the number of students repeating the same answer. The most frequent values are in the diagonal (10 for 3-3, 8 for 4-4 and 4-3 and 9 for 4-5), which confirms the argument.

Fig. 3 Questionnaire for Initial Assessment: Relationship between "Interest for participating in the experiment" and "Skills in new technologies"

3.2. Results of the User Satisfaction Questionnaire

This survey was replied by only 17 students out of 33 that originally started the experiment. It must be taken into consideration that from the original 58 students that had fulfilled the first survey, by the time this second questionnaire was passed, 6 of them had abandoned the course. In any case, as the survey was anonymous and voluntary, it was very difficult to monitor which students were not fulfilling this questionnaire.

Fig. 4 shows the mean value and the standard deviation related to questions 1 to 11. In general terms, the opinion about the use of this technology was positive, although not with the highest mark. The lowest values (2,8 and 3,3 over 5) were obtained in the first two questions (Q1 and Q2), which were related to the frequency of use of this technology. The next questions tried to query about easiness (Q3), clearness of information (Q4), quality of models (Q5) and robustness (Q6) of the AR tool. All of them had a similar positive opinion (approx. 3,5 / 5). The highest marks were obtained at the question related to the interest and stimulating factors of the AR technology (Q7), which proves the attraction that this kind of tool can generate in the scholars. In fact, most of them would like to use the AR tool for other subjects or courses (Q9). Finally, even if the participants of the survey considered that the AR tool could be suitable for acquiring knowledge related to this subject (Q10), this is not perceived as one of its major benefits.
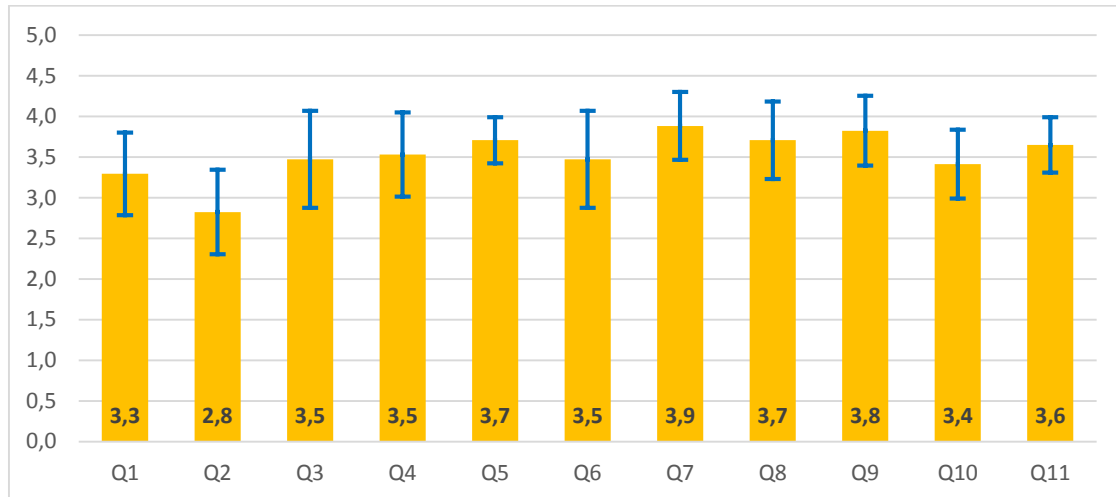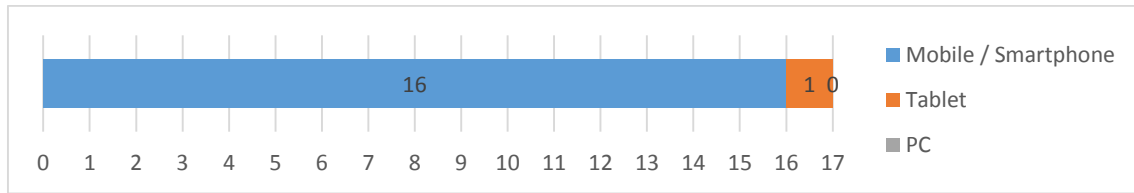

Fig. 4 User Satisfaction Questionnaire: Mean value (vertical bars) and Standard deviation (vertical segments) of answers to questions 1-11

As it can be seen in Fig. 5, there are seldom students displeased with the experience (Q11), although it is true that almost half of them have not enjoyed it especially. This could be due to the fact that using the application and the special material designed for them have meant an extra effort; in fact, access to the enhanced classroom notes was restricted and they needed to spend more time to retrieve it.
It is also remarkable that six of them had some technical problems (Q6), probably not due to the application but to the slow connections, as stated informally during the lectures. This proves that the technology is reliable and robust enough to be used for these purposes, although improvable.
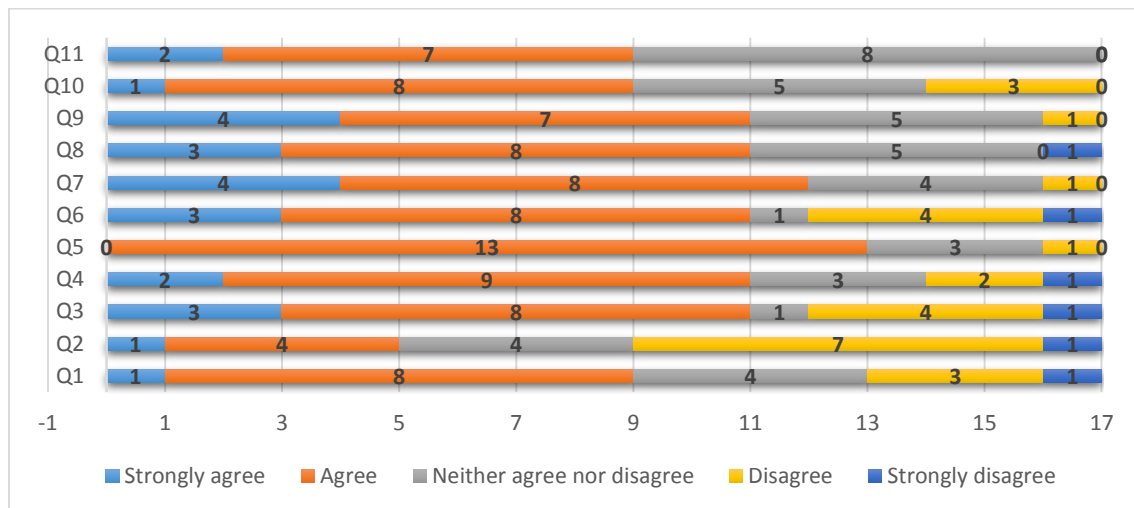
Fig. 5 User Satisfaction Questionnaire: Answers to questions 1-11

It is remarkable that, even if this technology can be also used in PC and laptops, none of the students used this devices for visualizing the 3D models included in the classroom notes (Fig. 6). All the scholars used the application on their smartphones, with the exception of one of them that had to use his tablet due to some incompatibilities with his mobile phone.

Fig. 6 User Satisfaction Questionnaire: Devices used for visualization of AR markers

Users had the option of writing their opinions about the AR tool, and they confirmed what had been gathered in the previous graphics. However some of them mentioned that the process of loading the scenes was sometimes slow. This fact was also observed by the authors of this experiment, as well as the problem of having to download the scene every time that it was going to be used, not being able to store it easily in the device with the purpose of using it offline at any time.

3.3. Results of the Questionnaire for Non Participants

It would be important to remark that non participant students were those with no special motivation to perform the pilot experiment about new technologies, so it could influence somehow their general opinion about the AR methodology. In this case, 18 students out of 25 replied voluntarily to this questionnaire.
Fig. 7 and Fig. 8 show the results of the survey passed to the control group. The general opinion is that the AR tool is interesting and stimulating (Q1). However, this fact was not relevant enough to encourage them to participate in a similar future project (Q5).
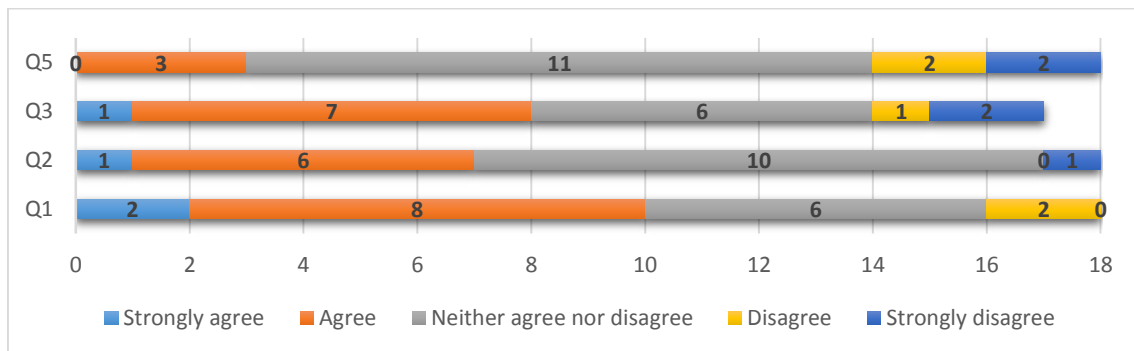
Fig. 7 Non Participant Questionnaire: Answers to questions 1, 2, 3, 5
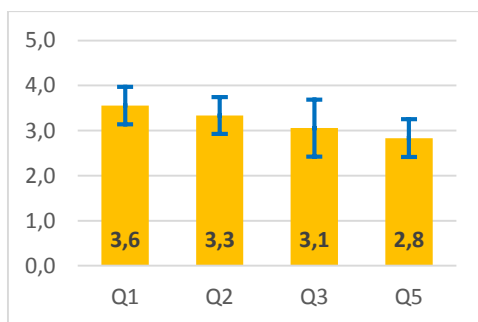
Fig. 8 Non Participant Questionnaire: Mean value and Standard deviation of answers to questions 1, 2, 3, 5

It is noteworthy that, as shown in
Fig. *9*, almost a half of the non-participant students tried the AR technology by themselves, even if they did not have a personal access to the resources (it was restricted to the participants). That means that this technology arose certain interest and intrigue among students of this course, who decided to try it "unofficially".
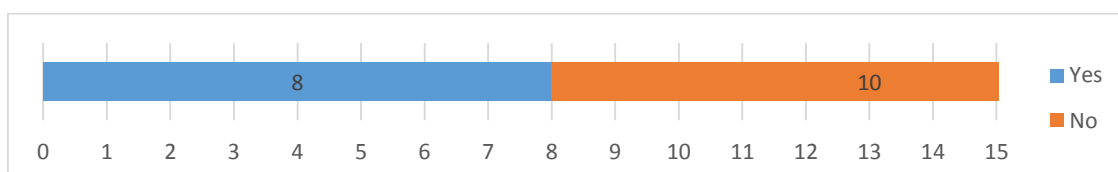
Fig. 9 Non Participant Questionnaire: Non participants using the AR tool "unofficially"

4. Conclusions and future works

In this work, we have proved that it is very easy and cost-effective to implement AR technologies in the classroom, as it is only required for students to bring a mobile device (smartphone / tablet) or a laptop with internet connection. This experience was developed in a course of Graphic Engineering, belonging to the degree of Mechanical Engineering, with the main purpose of visualizing complex 3D models generated with CAD software. The technology for creating and visualizing the AR scenes was easily and freely accessible online [22], [23].

Results show that students participating in the pilot study had a relatively high degree of satisfaction with this technology and methodology in terms of easiness, clearness of information, quality of models and robustness of the AR tool. In addition, students of this experimental group highlighted the interest and attraction inherent to this technology. Faculty members who participated in the pilot study observed a positive and receptive attitude by their pupils. Non-participant scholars, belonging to the control group, also thought that AR could be a stimulating and attractive learning methodology, although with lower levels of certitude than their classmates participating in the experiment.

The sample size was small (33 students) and future studies would be suitable to generalize the exploratory conclusions of this study. Taking into consideration the positive results obtained in this pilot experience, an opportunity is now open to explore more complex models and environments, such as dynamic cutting sections and animated models to enhance the quality of the AR scenes.

Further analysis will be carried out after obtaining the academic performance of the students in this subject, in order to find out if the use of AR could have any positive effect in the learning outcomes.

Appendix 1 - Questionnaire for Initial Assessment

For each one of this questions, select the answer that better reflects your opinion according to the importance of the issue.

Random student number:

Questions	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1 - What is your interest for subjects related to drawing and representation in general terms?	1	2	3	4	5
2 - ¿What is your interest for this subject of graphic engineering particularly?	1	2	3	4	5
3 - How were your results in the subjects related to drawing and representation of precedent courses?	1	2	3	4	5
4- How skillful are you related to new technologies?	1	2	3	4	5
5 - How skillful/familiarized are you related to mobile devices (smartphones, tablets, PDAs, etc.)?	1	2	3	4	5
6 - How skillful/trained are you related to games in videogames, computers or mobile devices, etc.?	1	2	3	4	5
7 – How would you consider your spatial visualization ability?	1	2	3	4	5
8 - How would have been your interest of performing a spatial ability test when starting at the university?	1	2	3	4	5

Last academic year, 2013-14, several tools, technologies and methodologies were used in the course: Notes and tutorials in electronic version, notes and tutorials in videos, educational versions of CAD software, online books, competitions for group participation, forums and chats, seminars, individual meetings, etc.

Questions	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
9 - ¿How suitable are, in your opinion, the use of these kinds of tools for learning purposes in this subject?	1	2	3	4	5
10 - ¿How necessary is to include some other new technologies, tools or methodologies for this subject?	1	2	3	4	5

11 - If you think there are some other tools, technologies or methodologies that could be suitable for this subject, please list them here:					
12 - Would you like to participate in a pilot experience about new technologies?	1	2	3	4	5
13 - Have you data connection on your mobile device in order to access to Internet at any moment?	Yes	No			

Appendix 2 - User Satisfaction Questionnaire

For each one of this questions, select the answer that better reflects your opinion according to the importance of the issue.

Random student number:					

Questions	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1 - I used the AR tool at every session that it was available.	1	2	3	4	5
2 - I used the AR tool very often.	1	2	3	4	5
3 – Using the AR tool was easy for me.	1	2	3	4	5
4 - Information about the AR too and user's instructions was clear and sufficient.	1	2	3	4	5
5 – 3D models represented by the AR tool had suitable quality, size and detail.	1	2	3	4	5
6 – I did not have any technical issue or difficulty.	1	2	3	4	5
7 – Using the AR tool was interesting and stimulating.	1	2	3	4	5
8 – Using the AR tool was useful for improving the comprehension of concepts and images from the lecture notes.	1	2	3	4	5
9 – I would like to use the AR tool for other subjects or courses.	1	2	3	4	5
10 - I think that the AR tool is suitable for acquiring knowledge related to this subject.	1	2	3	4	5
11 - In general terms, I enjoyed participating in this pilot experience.	1	2	3	4	5

Question	Answer			
12 – What type of device did you use for running the AR tool?	PC	Tablet	Mobile / Smartphone	
13 – In what environments did you use the AR tool?	Classroom	Library	Home	Other non academic environment
14 – What is your opinion, in general terms, about the use of AR for teaching purposes?				
15 – How could the AR methodology be improved when using it for teaching purposes?				

Appendix 3 – Non Participant Questionnaire

For each one of this questions, select the answer that better reflects your opinion according to the importance of the issue.

Random student number:					

Questions	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1 – Even if I did not participate in the AR pilot experience, I think the AR tool is interesting and stimulating.	1	2	3	4	5
2 – I think that the AR tool is suitable for acquiring knowledge related to this subject.	1	2	3	4	5
3 – I would like to use the AR tool for other subjects or courses.	1	2	3	4	5
4 – Even if I did not participate in the AR pilot experience, I have used the AR tool "unofficially" just to feed my curiosity.	Yes	No			
5 – Even if I did not participate in the AR pilot experience, I would like to participate in other AR pilot experiences that could arise in the future.	1	2	3	4	5

Question	Answer
6 – Even if you did not participate in the AR pilot experience, what is your opinion, in general terms, about the use of AR for teaching purposes?	
7 – Even if you did not participate in the AR pilot experience, how could the AR methodology be improved when using it for teaching purposes?	

Acknowledgement

References

[1] J. Bacca, S. Baldiris, R. Fabregat, S. Graf, and Kinshuk, "Augmented Reality Trends in Education: A Systematic Review of Research and Applications," *J. Educ. Technol. Soc.*, vol. 17, no. 4, pp. 133–149, 2014.

[2] J. Martin-Gutierrez, "Proposal of methodology for learning of standard mechanical elements using augmented reality," 2011, pp. T1J–1–T1J–6.

[3] S. Martin, G. Diaz, E. Sancristobal, R. Gil, M. Castro, and J. Peire, "New technology trends in education: Seven years of forecasts and convergence," *Comput. Educ.*, vol. 57, no. 3, pp. 1893–1906, Nov. 2011.

[4] I. Radu, "Why should my students use AR? A comparative review of the educational impacts of augmented-reality," 2012, pp. 313–314.

[5] I. Radu, "Augmented reality in education: a meta-review and cross-media analysis," *Pers. Ubiquitous Comput.*, vol. 18, no. 6, pp. 1533–1543, Aug. 2014.

[6] M. B. Ibáñez, Á. Di Serio, D. Villarán, and C. Delgado Kloos, "Experimenting with electromagnetism using augmented reality: Impact on flow student experience and educational effectiveness," *Comput. Educ.*, vol. 71, pp. 1–13, Feb. 2014.

[7] T.-J. Lin, H. B.-L. Duh, N. Li, H.-Y. Wang, and C.-C. Tsai, "An investigation of learners' collaborative knowledge construction performances and behavior patterns in an augmented reality simulation system," *Comput. Educ.*, vol. 68, pp. 314–321, Oct. 2013.

[8] M. Wrzesien and M. Alcañiz Raya, "Learning in serious virtual worlds: Evaluation of learning effectiveness and appeal to students in the E-Junior project," *Comput. Educ.*, vol. 55, no. 1, pp. 178–187, Aug. 2010.

[9] A. M. Kamarainen, S. Metcalf, T. Grotzer, A. Browne, D. Mazzuca, M. S. Tutwiler, and C. Dede, "EcoMOBILE: Integrating augmented reality and probeware with environmental education field trips," *Comput. Educ.*, vol. 68, pp. 545–556, Oct. 2013.

[10] M. B. Blake and J. D. Butcher-Green, "Agent-customized training for human learning performance enhancement," *Comput. Educ.*, vol. 53, no. 3, pp. 966–976, Nov. 2009.

[11] H.-Y. Chang, H.-K. Wu, and Y.-S. Hsu, "Integrating a mobile augmented reality activity to contextualize student learning of a socioscientific issue: Colloquium," *Br. J. Educ. Technol.*, vol. 44, no. 3, pp. E95–E99, May 2013.

[12] P.-H. E. Liu and M.-K. Tsai, "Using augmented-reality-based mobile learning material in EFL English composition: An exploratory case study: Colloquium," *Br. J. Educ. Technol.*, vol. 44, no. 1, pp. E1–E4, Jan. 2013.

[13] C.-W. Chang, J.-H. Lee, C.-Y. Wang, and G.-D. Chen, "Improving the authentic learning experience by integrating robots into the mixed-reality environment," *Comput. Educ.*, vol. 55, no. 4, pp. 1572–1578, Dec. 2010.

[14] C. M. L. Ho, M. E. Nelson, and W. Müeller-Wittig, "Design and implementation of a student-generated virtual museum in a language curriculum to enhance collaborative multimodal meaning-making," *Comput. Educ.*, vol. 57, no. 1, pp. 1083–1097, Aug. 2011.

[15] T.-Y. Liu and Y.-L. Chu, "Using ubiquitous games in an English listening and speaking course: Impact on learning outcomes and motivation," *Comput. Educ.*, vol. 55, no. 2, pp. 630–643, Sep. 2010.

[16] Á. Di Serio, M. B. Ibáñez, and C. D. Kloos, "Impact of an augmented reality system on students' motivation for a visual art course," *Comput. Educ.*, vol. 68, pp. 586–596, Oct. 2013.

[17] K.-E. Chang, C.-T. Chang, H.-T. Hou, Y.-T. Sung, H.-L. Chao, and C.-M. Lee, "Development and behavioral pattern analysis of a mobile guide system with augmented reality for painting appreciation instruction in an art museum," *Comput. Educ.*, vol. 71, pp. 185–197, Feb. 2014.

[18] D. Furió, S. González-Gancedo, M.-C. Juan, I. Seguí, and N. Rando, "Evaluation of learning outcomes using an educational iPhone game vs. traditional game," *Comput. Educ.*, vol. 64, pp. 1–23, May 2013.

[19] J. Martín-Gutiérrez, P. Fabiani, W. Benesova, M. D. Meneses, and C. E. Mora, "Augmented reality to promote collaborative and autonomous learning in higher education," *Comput. Hum. Behav.*, Dec. 2014.

[20] J. Dorribo-Camba and M. Contero, "Incorporating augmented reality content in Engineering Design Graphics materials," 2013, pp. 35–40.

[21] J. Martín-Gutiérrez, J. Luís Saorín, M. Contero, M. Alcañiz, D. C. Pérez-López, and M. Ortega, "Design and validation of an augmented book for spatial abilities development in engineering students," *Comput. Graph.*, vol. 34, no. 1, pp. 77–91, Feb. 2010.

[22] *Aumentaty Author v1.0 [software] http://author.aumentaty.com*. Valencia (Spain): Bienetec S.L, 2014.

[23] *Aumentaty Viewer v1.2.1 [software] http://www.aumentaty.com*. Valencia (Spain): Bienetec S.L, 2014.

REVIEW OF THE CONTENTS AND METHODOLOGY OF THE SUBJECT OF GRAPHIC ENGINEERING.

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Abstract

The CIN/351/2009 Order of the Ministry of Science and Innovation establishes the new specific competence "Knowledge and ability to apply the techniques of graphic engineering" in the Degree of Mechanical Engineering, which enables its graduates to exercise the profession of technical engineer. This degree is progressively implemented at the University of Burgos from the year 2010/2011, including in the fifth semester of its Curriculum a subject called Graphic Engineering. The contents and methodology of learning this subject are two aspects that should be investigated.

After three years teaching that subject, in the last class of the course 2014/15 are raised in writing to students answer two open questions to reflect what they would maintain of the classes and what they would change, to identify the strengths and weaknesses of the contents and the methodology employed in this subject.

Are studied and grouped responses qualitatively, developing a new questionnaire, which measured as the Likert scale their level of agreement with maintaining various aspects of the subject and introduce several proposals for change. This questionnaire is filled out anonymously through a survey enabled on the teaching platform "ubuvirtual".

The results of the statistical analysis of the 18 proposed items are the focus of this publication, confirming that students remain mostly the methodology, structure and contents of the course, but also express important aspects that need improvement.

1   Introduction

The legislation forms the profession of Industrial Technical Engineer as a regulated profession whose exercise must be in possession of the official title of Degree. It is in the Agreement of Council of Ministers of December 26, 2008 where the conditions that must adapt curricula are determined and instructed the Ministry of Science and Innovation, appointed under the Royal Decree 1393/2007, establishing requirements regarding objectives and heading of Title and planning of lessons and reflected in Order CIN / 351/2009, in which the modules that must include at least the curriculum are collected and specifically in the module specific technology in Mechanical Engineering Degree establishes a new competence to be acquired called "Knowledge and ability to apply the techniques of graphic engineering".

This specific competence is collected as ED19 in the Degree of Mechanical Engineering which began to be implemented gradually at the University of Burgos from 2010/2011, including in the fifth semester of their curriculum the subject of Graphic Engineering, being the contents and learning methodology of this course the two areas in which this research focuses, as there was no such subject in the previous curriculum. The first approaches to what should be the contents, forcing us to think first about what we would consider it exactly the Engineering Graphics and what are the fields included.

Not starting from scratch with students as these previously enrolled in the first semester of the subject Graphic Expression I in learning plane geometry contents, visualization and standardized representation of parts and systems of representation, assembly drawings and exploded and in the fourth semester taking the subject Graphic Expression II in which starting from the previous contents learn the standardized representation of connecting elements, springs, gears, bearings and reach the representation of the

design definition of finished product, and the representation various installations. In both subjects performed practice sketching and further delineated 2D CAD programs.

The contents of these two subjects would be included within the field of Engineering Graphics, but this would cover more concepts, mainly geometric modeling in three dimensions by computer, ie 3D Computer Aided Design, with the creation and manipulation of geometric models in three dimensions, through the different stages of part design (by solids or surfaces), assembly of the devices restricting degrees of freedom (assembly) and obtaining drawings.

By Graphic Engineering also should be understood:

- Concurrent Engineering. A set of applications that work with the same solid model as a common denominator. This model can be called Master Model and may be related bidirectionally [1,2]
- PDM (Product Data Management). Enables engineers to manage their documents during all stages of their development. [3,4] You should be able to manage your documents electronically to maintain, access and modify designs and technical related documents quickly, securely and cost effectively. [5]
- Reverse Engineering. It is the process of duplicating a part, component or assembly. It is always part of a physical model and engineering methods of measurement, analysis and design to finally get the same or improved replica of the object are used. [6]
- Digital Mockup (DMU). It is a tool that allows the product and design processes to be seen, simulated and evaluated in 3D in order to make information on the entire process of product development, easily understandable and accessible to all participants. [7,8]
- Rapid Prototyping (RP). Solid construction techniques based in Layer Manufacturing Technologies. 3D Printers. [9]

2   Context and Teaching Methodology.

During the year 2012-13 began to teach the subject of Graphic Engineering, adjusting to the program reflected in its teaching guide in which it is to cover all aspects listed above:

- Introduction to design with high level CAD tools.
- Design of basic parts.
- Part catalogues and design tables.
- Basics surfaces.
- Advanced surfaces.
- Creation and management of assemblies.
- Functional and assembly 3D simulation.
- Drafting and creation of drawings.
- Reverse engineering.
- 3D CAD vertical applications.
- Data management concurrent engineering.

The educational objectives to be achieved, also reflected in the teaching guide are students reach:

- To know the methodology and design process of a part or component in CAD 3D.
- To know the techniques of scanning and rebuilding models for reverse engineering.
- To know how to structure the design of an assembly and its components in 3D, in such a way that its design is flexible and robust.
- To know how to carry out computer 3D modelling of parts, using modelling tools to model solids and surfaces.
- To know how to set up parts in assemblies, taking into account the functioning of the device.
- To know how to detect and correct both assembly errors and functional errors in the different components of each device.
- Get to know the drawings of devices designed in 3D on the computer, based on the standardization of technical drawing.

As to the methodology followed in the development of classes in order to achieve those educational objectives and achieve a more effective learning of three-dimensional geometric modeling by computer we opt for the method of strategic learning.

Teaching-learning of CAD in mechanical engineering degree courses at university is evolving very quickly. At present, the 3D CAD methodology is principally based on: parametric design, feature modelling, tree use and the parent/child dependency relation of the features.

It is known that learning time is limited and CAD tools increasingly offer greater possibilities and more time is needed to exploit them to the full, although it is not available to us.

In a study divided into two parts, Hartman [10,11] sought to determine how expert designers in firms achieved their existing knowledge levels of CAD and demonstrated how new CAD students need practices where they design and alter the models, so that they may be trained in the design of complex models.

On this point, Mandorli and Otto[12] affirmed that present-day university courses should impart more strategic knowledge and understanding to enable students to use CAD systems as knowledge-intensive design and communication tools, to properly develop design intent and to be able to convey it.

Barbero and García [13] believed that learning should take place by strategic knowledge and using the problem resolution method at the design stage and the simulation of simple mechanisms, starting with the modelling of each part, through to the assembly, the simulation, the analysis and the parametric alteration of the component parts of the mechanism, and finishing with confirmation of the design intention through parametrical alterations. An efficient form of learning in CAD is to design a simple mechanism from the beginning to the end, as a practical exercise.

This is a constructivist methodology, of practical exercise-based learning in CAD through which students learn the theoretical concepts, identify the correct paths for modelling and obtain strategic 3D design rules.

For Chester [14] learning of CAD 3D should be through strategic knowledge-based learning methodology instead of a command methodology. Command knowledge is referred to as knowledge of the commands (algorithms or tools) and the procedures to use those tools within CAD software, while strategic knowledge is concerned with knowledge of the alternative methods to achieve a specific task and the process by which a choice may be made.

Chester has proven that learning based on strategic knowledge is more effective without it having to be combined with learning to specify command execution procedure, and that it is more effective in students who have less prior knowledge of CAD. He also made it clear that there are three key skills that to some extent influence whether our students are to become CAD experts through the strategic knowledge-based learning method which are: analysis, metacognition and mental imagery. This strategic knowledge should be learnt through training.

"Metacognition" [15] is understood as the capability that people have to self-regulate their own learning, in other words, to plan what strategies have to be used in each (learning) situation, to apply them, to control the process, to evaluate it so as to detect possible weak points, and in consequence… to transfer all of it to a new action or learning situation. Metacognition has four identifying characteristics [16]: 1) to know the objective to be reached; 2) to be able to choose between possible strategies to achieve the objectives; 3) self-observation of the process of knowledge preparation, to find out whether the selected strategies are appropriate; and 4) evaluation of the results to know how far the objectives have been achieved.

Students may consider that they control their cognitive acts and their learning, and that effective learning depends on how well, or badly, they apply their strategies and their knowledge, but above all, that they are the ones who can improve, by deciding on which components they have employed ineffectively, to be able to improve in the future [17].

In this way, the students create their 3D modelling strategy, for example, a strategic rule is to complete the rounding of an edge before using the shell feature.

In consequence, following a review of the bibliography, it appears that 3D CAD learning is more efficient through a strategic knowledge learning methodology, where the different CAD concepts and training in the development of the metacognitive skills are learnt through exercises[18].

Therefore, instead of focusing on explaining commands in theory and later use in practical classes, to the subject of Engineering Graphics we have been using this model of learning through exercises that are explained in the theory classes and performed by students with the support of the teacher in practical classes. In addition we also offer several practical exercises as homework[19,20] for resolution outside school hours. A continuous assessment[21] of both exercises in class, as proposed to solve outside class hours is performed. The evaluation is completed with the completion and submission of an individual work at the end of the course in which they have to 3D modeling a device using everything learned over the course work.

Between different CAD softwares senior employees in the industry choose CATIA, although the intention is not to teach to handle a specific CAD package, but students learn the concepts, philosophy and methodology of 3D[22]. To do this, students must learn a set of rules of 3D CAD, to assist in choosing the appropriate modeling strategy.

3   Experimental procedure. Method.

After three years teaching the subject of Graphic Engineering, it's time to assess what we are doing is right or some aspects can be improved, so in the last class of the year 2014/15 are raised in writing to the 73 students enrolled answer two questions open:

What'd you maintain of the subject?
What would you change the subject? and how?

The present research is that through the analysis of the answers to these questions we manage to identify the strengths and weaknesses on both the content and the methodology used in the learning of the subject, to identify areas for improvement in the way of imparting "Engineering Graphics" which can incorporate for successive courses.

Students made 107 proposals for aspects to maintain and 106 proposals for aspects to change, since each could indicate as many proposals as wanted. Are studied and grouped the answers qualitatively and a first ranking with 18 items concerning aspects to maintain and 33 items on aspects change is made, then reflecting those who were mentioned by at least three or more students.

The main proposals to maintain the course are:

1. Maintain the practical exercises of the course. (28 students).
2. Maintain learning model. (24 students).
3. Maintain continuous evaluation. (12 students).
4. Maintain the end-of-course assignment. (8 students).
5. Maintain that in practical classes, the same exercises taught in the theory classes are practiced. (6 students).
6. Maintain the delivery of practical exercises to do at home. (4 students).

The main proposals for change in the course are:

1. Teaching the theory in practical classes to allow to follow the exercises with the computer. (14 students).
2. Do not repeat in practical classes exercises done in theory (encourages absenteeism in class theory). (13 students).
3. Less time for the initial part of the course (sketcher and basic solid) and more time for complex parts. For example: product design in context, reverse engineering, kinematic, surfaces (shape design), drawings, parameterization, exercise with several skeletons. (11 students).
4. Propose and evaluate more practical exercises to do at home and not to assess those in class. (11 students).
5. Choose the end-of-course assignment to increase interest and creativity. (10 students).
6. Improve documentation on the platform ubuvirtual. Create more detailed manuals with intermediate steps of the exercises, putting solutions practices. (5 students).
7. Explain more slowly, adapting class rhythm with students even teaching less matter. (4 students).
8. The proposed end-of-course work is excessive and is much more difficult than exercises done in practices. (3 students).

In parentheses is the number of students of each proposal and sometimes the reasoning of why the proposal is made.

With these proposals and some more that has been added to consider especially interesting teachers know the views of students in this regard, a questionnaire was prepared, which are asked to evaluate according to the Likert scale their level of agreement to maintain seven aspects of the Subject and enter 11 proposals for change.

This questionnaire is filled out anonymously by a survey enabled the "ubuvirtual" educational platform, being completed by 68 students, making it the response rate of 93.15%. In the appendix we show the survey respondents students.

4 Results.

With the answers to this questionnaire statistical analysis presented in tables 1 and 2 is performed. We propose contrast hypothesis with t test for a sample with a cut in the value 3, average value of the Likert scale, where the scale of values from 1(strongly disagree) to 5 (strongly agree). The mean values of each response and standard error of the mean are shown in the tables, also the value of the statistic "t" and significance. Tab. 1 lists the proposals to maintain and Tab. 2 shows the proposed changes.

Proposals to maintain	Mean (Std. Error Mean)	Valor de prueba = 3	
		t	Sig.
Maintain the practical exercises of the course.	4,34 (0,088)	15,220	0,000
Maintain learning model.	3,62 (0,096)	6,428	0,000
Maintain continuous evaluation.	3,99 (0,119)	8,250	0,000
Maintain the end-of-course assignment.	3,85 (0,141)	6,051	0,000
Maintain that in practical classes, the same exercises taught in the theory classes are practiced.	**3,26 (0,171)**	**1,548**	**0,126**
Maintain the delivery of practical exercises to do at home.	4,00 (0,115)	8,714	0,000
Maintain the evaluation criteria.	3,34 (0,106)	3,190	0,002

Tab.1. Results of proposals to maintain

All items but one are greater than 3 at a statistically significant level of 95%. Of the seven items listed in Table 1 students remain six of them being particularly agree with maintain the practical exercises of the course, the delivery of practical exercises to do at home, the continuous evaluation and the learning model. They not maintain that in practical classes, the same exercises taught in the theory classes are practiced.

In the following graph (Fig. 1) are shown the students who score higher and lower values than the mean value (3), discarding the points that score with 3 and can be seen in a more graphically the results shown in Tab. 1. Consistent with the results in Tab.2, 60 students are in favor of "Maintain the practical exercises of the course" and 57 students with "Maintain the delivery of practical exercises to do at home". In the proposal there is greater equality in the "Maintain that in practical classes, the same exercises taught in the theory classes are practiced".
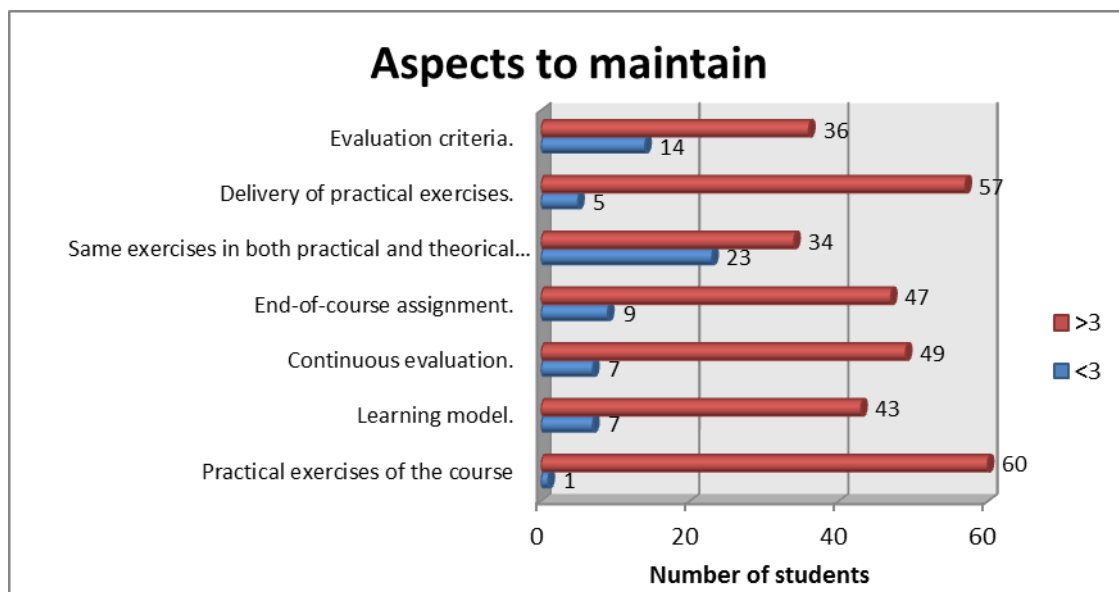
Fig. 1 Scores higher or lower than 3 from aspects to maintain.

Proposals to change	Mean (Std. Error Mean)	Valor de prueba = 3	
		t	Sig.
Teaching the theory in practical classes to allow to follow the exercises with the computer.	**4,10 (0,113)**	**9,752**	**0,000**
Do not repeat in practical classes exercises done in theory.	2,99 (0,166)	-0,089	0,930
Less time for the initial part of the course (sketcher and basic solid) and more time for complex parts.	**4,01 (0,118)**	**8,630**	**0,000**
a) More time for product design in context.	**4,03 (0,094)**	**10,994**	**0,000**
b) More time for reverse engineering.	2,54 (0,130)	-3,510	0,001
c) More time for kinematic.	**4,03 (0,127)**	**8,080**	**0,000**
d) More time for surfaces (shape design).	**4,25 (0,106)**	**11,844**	**0,000**
e) More time for drawings.	3,00 (0,124)	0,000	1,000
f) More time for parameterization.	**3,29 (0,111)**	**2,650**	**0,010**
g) More time for exercises with several squeletons.	**3,62 (0,129)**	**4,780**	**0,000**
Propose and evaluate more practical exercises to do at home and not to assess those in class, to ask more questions in class.	3,51 (0,164)	3,133	0,003
To choose the end-of-course assignment instead of doing all the same.	3,76 (0,177)	4,328	0,000
Improve documentation on the platform; Create more detailed manuals with intermediate steps of the exercises, putting solutions practices.	4,09 (0,112)	9,689	0,000
Explain more slowly, adapting class rhythm with students even teaching less matter.	3,15 (0,160)	0,920	0,361
The proposed end-of-course work of the chair is excessive and is much more difficult than exercises done in practices.	**4,53 (0,080)**	**19,189**	**0,000**
Propose some exercises where various dimensions and/or shapes are modified after design, in order to identify the most appropriate design method paths to maintain the design intention. The modifications will be made in the exercise of classmate.	3,56 (0,117)	4,761	0,000
Explain the theory by commands. Explain the options of the most important commands, instead of exercising in the theory classes where guidance on the design method and the options to use the commands.	3,25 (0,128)	1,952	0,055
Propose several practices previously and resolve in practical clases without being guided by the teacher. The teacher only answers questions.	3,01 (0,152)	0,097	0,923

Tab. 2. Results of proposals to change.

Regarding the eleven proposals for changes listed in Tab. 2, students would be in favor of seven of them, with a confidence interval of 95%, with particular emphasis on the eighth item "The proposed end-of-course work of the chair is excessive and is much more difficult than exercises done in practices", the first "Teaching the theory in practical classes to allow to follow the exercises with the computer", the sixth "Improve documentation on the platform; Create more detailed manuals with intermediate steps of the exercises, putting solutions practices". They also propose to spend more time at some of the most complex parts (product design in context, kinematic, surfaces).

Of the proposals put forward by the teachers they are in favor of "Propose some exercises where various dimensions and/or shapes are modified after design, in order to identify the most appropriate design method paths to maintain the design intention. The modifications will be made in the exercise of classmate".

Again, for better visual perception of student opinions regarding aspects of change, we have added a bar graph in Fig. 2, in which students are given a higher or lower score three listed questionnaire performed via the platform ubuvirtual, discarding those that have given a value equal to the mean (3).

In correspondence with the data of Tab. 2 the items with the greatest number of supporters of change are in first place (64) "The proposed end-of-course work of the chair is excessive and is much more difficult than exercises done in practices", and the second one (56) "Teaching the theory in practical classes to allow to follow the exercises with the computer". In third place (50) "Improve documentation on the platform; Create more detailed manuals with intermediate steps of the exercises, putting solutions

practices" and "Less time for the initial part of the course (sketcher and basic solid) and more time for complex parts".
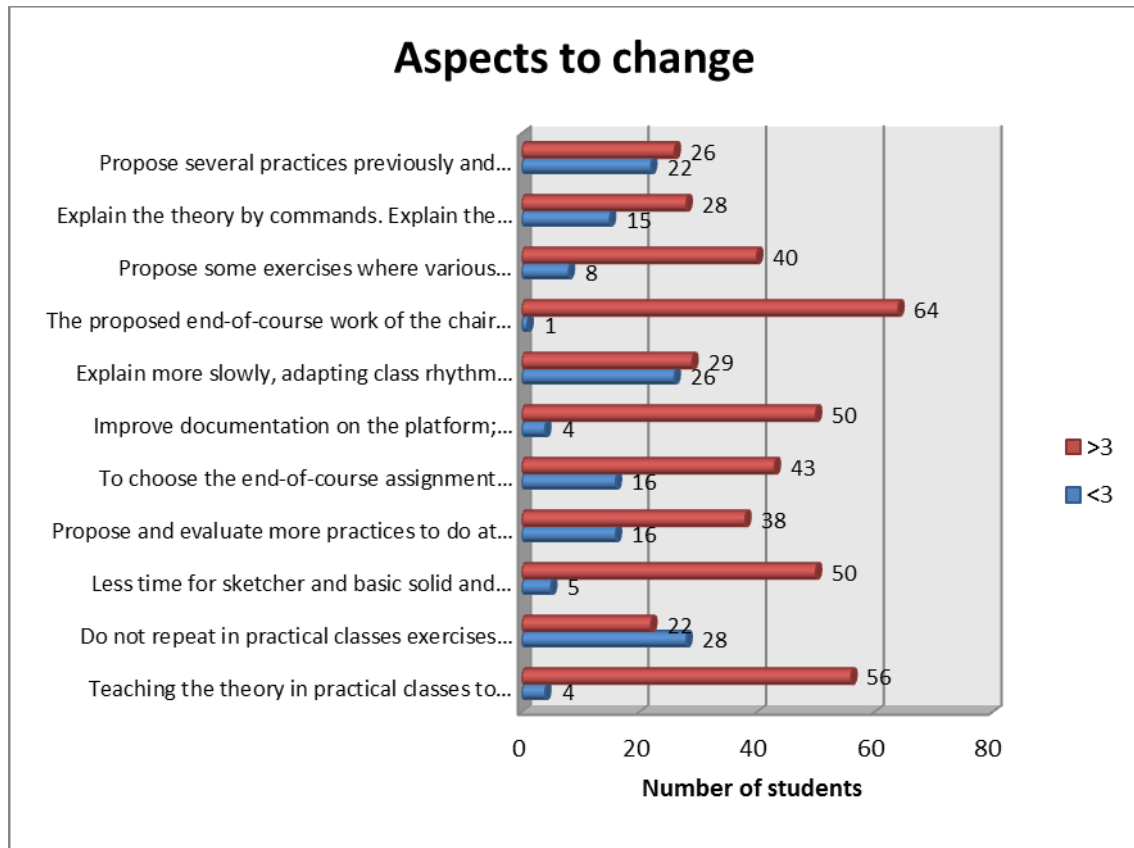

Aspects to change

Fig. 2 Scores higher or lower than 3 from aspects to change.

5   Conclusions.

Under the results obtained the conclusions of our study in order to take into account in future courses would include:

-   Students are in favor of keeping the structure of the course of Graphic Engineering (course practices, practices for home and continuous evaluation) and agree with the learning model, where the different CAD concepts and training in the development of the metacognitive skills are learnt through exercises (methodology based on strategic knowledge [9,11], instead of using learning by commands).

-   Prefer that in practical classes are practiced different exercises that in theoretical classes, otherwise delays the development of practical classes because some students do not attend the theoretical classes and also they would like to learn the theory in practical classes to track the exercises with the computer [23]. This response results in a request to the school management in order to equip a classroom theory with sufficient power sockets so that students can follow the theory class with their laptops, since are taught eminently practical, doing exercises that are introduced concepts and not by commands that can be explained in purely theoretical way.

-   On the proposal to improve the documentation provided to them through the platform, it would be interesting to develop video tutorials [24] showing the steps to resolve the different exercises to do.

-   This would allow faster progress in the course and to devote more time to the most complex parts (product design in context, kinematic, surfaces).

- Regarding indicated about end-of-course work, although students prefer not to do the same assignment all, it is more objective assessment and although think that is excessive work, this has several parts and according to which they complete get their rating.

- Students are in favor of exercise where various dimensions and/or shapes are modified after design, in order to identify the most appropriate design method paths to maintain the design intention. This concept of design intention is under further investigation by the authors of this work.

Appendix

Fig. 3 is an example of the survey respondents 68 students. Here is the survey of the aspects to maintain.

Fig. 3 Survey of aspects to maintain.

References

[1] Molina, A., Al-Ashaab, A.H., Ellis, T.I.A, Young, R.I.M, Bell R., A Review of Computer Aided Simultaneous Engineering Systems, Research in Engineering Design (1995), 7: 38-63.
[2] Molina A., Bell R., Reference Models for the Computer Aided Support of Simultaneous Engineering, Int. J. Computer Integrated Manufacturing, Vol. 15, No.3, pp 193-213., 2002.
[3] Miller, Ed (October 1998). "What is PDM" . Mechanical Engineering Magazine. The American Society of Mechanical Engineers. Retrieved 2008-01-23.
[4] Catia team PDM tutorial. Dassault Systèmes 1994-99.
[5] R. Mills, B. Beckert y L. Carrabine. The future of product development, Computer-Aided Engineering, 10: 38-46, 1991.
[6] Minguez Gabiña, Rikardo; Muniozguren Colindres, Javier; Arias Coterillo, Agustín; Barrenetxea Apraiz, Lander; Sierra Uria, Egoitz. Proyecto universidad-empresa: diseño de

nueva gama de putters mediante ingeniería inversa. XVIII Congreso Internacional Ingeniería Gráfica. Barcelona 2006.

[7]   Boussuge, F., Shahwan, A., Leon, J.-C., Hahmann, S., Foucault, G., and Fine, L. Template-based geometric transformations of a functionally enriched DMU into FE assembly models. ComputerAided Design and Applications 11, 04 (2014), 436–449.

[8]   Shahwan, A., Leon, J.-C., Foucault, G., Trlin, M., and Palombi, ´O. Qualitative behavioral reasoning from components' interfaces to components' functions for DMU adaption to fe analyses. ComputerAided Design 45, 2 (2013), 383–394.

[9]   Heynick M., Stotz I, 3D CAD, CAM and Rapid Prototyping. LAPA Digital Technology Seminar, Workshop 1, 10-11 May 2007.

[10]   Hartman NW. The development of expertise in the use of constraint-based CAD tools: Examining practicing professionals. Engineering Design Graphics Journal. 2004;68(2): pp . 14-26.

[11]   Hartman NW. Defining expertise in the use of constraint-based CAD tools by examining practicing professionals. Engineering Design Graphics Journal. 2005;69(1): pp. 6-15.

[12]   Mandorli F, Otto HE. Negative knowledge and a novel approach to support MCAD education. Computer-Aided Design and Applications. 2013;10(6):1007–20.

[13]   Barbero, B. R. and García García, R. Strategic learning of simulation and functional analysis in the design and assembly of mechanisms with CAD on a professional Master's degree course. Computer Applications in Engineering Education. 2011; 19: 146–160.

[14]   Chester I. Teaching for expertise. International Journal of Technology and Design Education. 2007; 17, 23-35.

[15]   Aldaz N. M**.** La Metacognición en la educación. [accessed 2015 27th March]. Available from:http://www.monografias.com/trabajos34/metacognicion-escuela/metacognicion-escuela.shtml.

[16]   Burón, J. Enseñar a aprender: Introducción a la metacognición. Ediciones Mensajero.Bilbao;

[17]   Ugartetxea, J. Motivación y metacognición, más que una relación. RELIEVE, vol. 7, n.2. 2001. [accessed 2015 27th January]. Available from: http://www.uv.es/RELIEVE/v7n2/RELIEVEv7n2_1.htm

[18]   Contero, M., et al. Improving Visualization Skills in Engineering Education. Computer Graphics in Education. 2005 September/Octuber 2005:p24-31

[19]   Carretero Díaz, A; Martínez Muneta, M.L.; Félez Mindán, J.; J.M. Cabanellas Becerra; J. Maroto Ibáñez; R. Alvarez García. Enseñanza de Ingeniería Gráfica Asistida por Internet. XI Congreso Internacional de Ingeniería Gráfica. Logroño 1999.

[20]   Brigos, Miguel; Torner, Jordi; Alpiste, Francesc; Fernández, Joaquín; García, Andrés; Farrerons, Oscar. Estrategias en la generación de contenidos para formación Presencial – On-line, aplicado al diseño asistido por ordenador. Actas del XVIII Congreso Universitario de Innovación Educativa en las Enseñanzas Técnicas. Santander 2010

[21]   Sánchez Sánchez, JM. La evaluación continua documentada. Actas del VI Congreso Universitario de Innovación Educativa en las Enseñanzas Técnicas. Las Palmas 1998.

[22]   Mateo Carballo, F.; Llorente Geniz, J; Sánchez Jiménez, FJ; Reina Valle, R; Fernández de la Puente, A. Docencia de Modelado Tridimensional mediante herramientas de animación asistida por ordenador. XII Congreso Internacional de Ingeniería Gráfica. Valladolid 2000.

[23]   Medeiros Filho, Dante Alves; Cintra, Jorge Pimentel. Ordenadores en la enseñanza y aprendizaje de ingeniería. XIII Congreso INGEGRAF. Badajoz 2001.

[24]   Paliokas, I.: Reinforcing metacognition in CAD education using videotutorials, ComputerAided Design and Application, 6(5), 2009, 613–623. DOI: 10.3722/cadaps.2009.613–623.

XXV Congreso
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Graphic engineering subjects in the academic curriculum in the Mechanical Engineering Degree

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Abstract

This paper is a summary about several Graphic Engineering subjects in the Mechanical Engineering degree in Spanish Universities. The study has been carried out taking into consideration those with the highest position in different international rankings as the Jiao Tong University in Shanghai, Webometrics ranking by the Cybermetrics lab (belonging to CSIC), U-Ranking by BBVA institution, and Scimago by University of Granada. The different subjects are analysed to compare and contrast the aims, course objectives, expected student outcomes, computer tools used and current trends along the selected engineering courses.
The work is based on the syllabi and course guides on the universities official websites.

1 Introduction

Deep changes in Engineering Graphic Education have taken place over the past five years due to the Bologna process, both in the different methodologies applied in the classroom and in the tools used to solve the proposed problems. Also, the time reduction applied to this field has forced to review the minimum contents for the subjects. This paper reports a comparison of the different compulsory subjects that currently exist in the Mechanical Engineering degree in Spanish Universities related to Graphic Expression, as well as the different contents, methodologies applied, and how the competences acquired by the students are evaluated.

To perform this task, we have selected some representative Universities, under the criteria of the most usual university rankings used in Spain. They are the Academic Ranking of World Universities – ARWU by the Jiao University of Shanghai [1], the ranking web of universities by the Cybermetrics lab (CSIC) [2], de ISSUE ranking of Spanish Universities by the BBVA foundation [3], and Scimago institutions ranking by Scimago Lab [4]. Table 1 shows the position in the different rakings for the top ten universities that include Mechanical Engineering in their academic studies.

University / Ranking		ARWU	Webometrics	U-RANKING	SCIMAGO
A.U. Barcelona	**UAB**	151-200 / 1	3	7	3
P.U. Valencia	**UPC**	201-300 / 5 - 8	10	4	9
P.U. Cataluña	**UPC**	401-500 / 9 - 12	5	8	6
U. Basque Country	**EHU**	401-500 / 9 - 12	11	6	12
U. Zaragoza	**UNIZAR**	401-500 / 9 - 12	13	11	13
P.U. Madrid	**UPM**	-	8	4	11
U. Seville	**US**	-	9	4	10
U. Jaume I	**UJI**	-	12	21	46
U. Salamanca	**USAL**	-	14	14	20
U. Carlos III	**UC3M**		20	15	22

Tab. 1 University position in different university rankings

2   Description of the subjects

After selecting the set of universities, we have consulted the official websites in order to find out the different compulsory subjects in each university, and get the syllabi and course guides for all of them. Both Polytechnic University of Cataluña and University of Basque Country have various schools that teach a Mechanical Engineering Degree, so we take into account the subjects for each one of these different schools.

Almost all Degrees consulted propose two compulsory subjects (except the Carlos III University, which has only one): a basic one in the first course, and a more advanced subject in the second or third course. Additionally some universities also offer some optional courses. The specific competences proposed in the compulsory subjects are quite similar; in fact nine out of fifteen schools consulted have *spatial vision ability and knowledge of graphic representation techniques, using both traditional methods of descriptive geometry and metric geometry, and through computer-aided design applications* and *knowledge and ability to apply graphical engineering technique*. Other schools have more descriptive competences, in special in the advanced subject, which can include terms as *knowledge about machinery, production, manufacturing, standardized elements* or *industrial design*. In any case, the students outcomes expected are essentially the same: spatial perception, graphic and geometric knowledge, freehand sketching, CAD, normalization (views, dimensioning and sketching according the technical standards), parts and assembling modelling (including standardized elements and materials) and other fundamentals of industrial design.

The contents and evaluation systems for the compulsory subjects are briefly described in the following sections.

2.1   Autonomous University of Barcelona (UAB)

The basic subject in the UAB, named *Graphic Representation* [5] has 6 ECTS and includes *Systems of representation, types of lines, dimensioning, particular and local views, cuts and sections, representation of subjecting elements, joints and bolts and mechanical assembling*[1]. The course comprises both theoretical and practical activities, integrating freehand sketching with 2D and 3D software along the semester. The students are evaluated throughout two activities: on the one hand group activities and individual exercises worked out across the course (50%) and on the other hand, three drawn exams and two practical tests in laboratory using CAD software (50%).

The advanced subject, called *Further Graphic Representation* [6] teaches *industrial design, including signs and formats, tolerances and adjustments, coils and springs, threaded elements, joining elements, trees and axes, bearings and transmissions*. The evaluation, as in the basic subject, mixes continuous evaluation of the students with individual exercises and group projects (50%) with four hand drawn exams and one CAD exam (50%).

There is also an optative subject named *Computer Aided Engineering* focused on static and dynamic analysis of assemblies, as well as on design optimisation, using Solidworks software.

2.2   Polytechnic University of Valencia (UPV)

UPV mechanical engineering degree includes *Technical Drawing I* in the first course [7], a basic subject with 6 ECTS, and a second one named *Graphic Expression II* with 4.5 ECTS in the third course [8]. The first subject is mainly focused on hand-written exercises, and includes *planar and descriptive geometry (diedric system), normalization (with views, cuts, sections, dimensioning), threaded elements* and includes a final unit about *computer aided systems*. The evaluation is based on four *open-answer written exams* (45%), *academic studies* (45%) and *observation* of the student (10%).

The second one extends the knowledge about *descriptive geometry (diedric and axonometric systems)* and introduces *assemblies and mechanical drawing*, using software tools in assembly generation. The evaluation and conditions for the final grade are the same than in the basic subject.

The UPV offers an optative subject, named *Computer-Aided drawing for mechanical applications*, to model and animate assemblies with Autodesk Inventor.

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[1] *Taken literally from the study guide*

2.3　　Polytechnic University of Cataluña (UPC)

UPC has also two compulsory subjects in the first and the third courses, both of them with 6 ECTS [9 – 16]. There are four different schools in the UPV, in Manresa, Vilanova, Barcelona and Terrassa, which offer quite similar subjects, but with slight differences in the contents (some of them include *planar geometry* or *topography* additionally to the chapters of *systems of representation and normalization*) and in the methodology. In Terrassa, for example, the students spend double time in laboratory than in Manresa, and in Barcelona according to the methodology described in the guide; moreover a 20% of the course is theoretically based, while the rest of the subject is completely practical. In fact, students also spend a 20% of the time in project-based learning, in which each student group should manage a project (design, planning, sketch and develop with software tools). Terrassa School makes use of different learning methodologies too, such as project-based learning. Also, the evaluation is quite different:

- In Manresa the final grade includes exams (60%) and exercises (40%). The exercises are composed of individual and group works.
- In Vilanova the final grade mixes exams (50%) with individual exercises (40%) and group project (10%)
- In Barcelona the individual work (exams and exercises) has an 80% weight and the students have to develop a group project which involves design, planning, sketching and developing with software tools (20%) using problem-based learning techniques.
- In Terrasa the final grade includes exams (75%), individual works (15%) and group works (10%).

The second subject is focused on *3D modelling, assemblies, tolerances, standardized elements, and industrial design.* The methods of assessment are different in each technical school:

- In Manresa and Vilanova the final grade comprise exams (60%) and individual exercises (40%).
- In Barcelona the exams have an 80% weight and a group project a 20%.
- In Terrassa the subject evaluation includes an exam (50%) and individual and group works (50%).

The degree also has an optative subject in some schools, as *Computer Aided Design* in Manresa, *Computer Aided Design and Simulation* using *SolidEdge* in Vilanova, *Computer Aided Design extension,* completely dedicated to computer aided tools as Autocad and Rhinoceros in Barcelona, or *Mechanical Computer Aided Design* with *SolidWorks* in Terrassa.

2.4　　University of the Basque Country (EHU)

EHU has the highest number of compulsory ECTS related with graphic engineering. The students should attend two subjects, with 9 and 6 ECTS respectively to achieve the competences [17 – 22]. The EHU offers the Mechanical Engineering Degree in three different schools and although the contents are practically the same, the methodology and evaluation are slightly different. The contents include *normalization, systems of representation, dimensioning, tolerances, materials, fastening systems, transmissions, assemblies and CAD* (CATIA, AutoCAD or SolidEdge, depending on the school). The methodology and evaluation are as follow:

- In Álava, the grading is obtained with exams (60%), projects (30%) and exercises (10%).
- In Biscay, the evaluation comprises exams (70%), group project and CAD (15%) and exercises (15%)
- In Guipúzcoa, the grading is based on exercises (20%) and several exams (80%)

 Also, the time invested in the laboratory is diverse, with 15 hours in Álava and Guipúzcoa and 30 in Biscay.

The second subject, in the third course, *includes Industrial Design, product lifecycle management* (PLM), *Mechanisms and CAD* in Álava and Biscay, and *projects in mechanical building, dimensioning, joints, tolerances, transmissions, welding and industrial buildings* in Guipúzcoa. As it happens with the basic subject, the evaluation is different depending on the school:

- In Álava, the assessment of students is a 50% with an exam, and a 50% with a group project.
- In Biscay, the evaluation mixes exams (60%) with CAD exercises (20%) and other tasks (20%).
- In Guipúzcoa, the evaluation also mix exams (50%) with exercises (20%) and other tasks (30%).

Two schools also offer optative subjects, such as *Advanced design in product engineering and graphic representation in Industrial buildings* in Álava, focused on building construction or *Computer Aided Design* in Guipúzcoa, which uses SolidEdge to modelling assemblies.

2.5   University of Zaragoza (UNIZAR)

UNIZAR includes two subjects in the first and second courses, both of them with 6 ECTS [23 -24]. The first one includes four units: *normalization, diedric system, topographic system* and *computer aided design.* The evaluation system includes a global exam about diedric and topographic systems (60% of the final grade), continuous evaluation of hand-written problems about industrial normalization (30%) and CAD exercises (10%) which are carried out by the students along the semester. In case of not getting through the continuous evaluation, the students can take another set of exams to pass the practical component of the subject.

The second subject, named *Industrial drawing* is focused on *normalization, drafting, threaded elements, joint elements, bearings, gears, roughness, materials, tolerances.* The evaluation consists of an exam (30% theoretical and 70% practical) with a 50% weight in the final grade. The continuous evaluation is based on a project made individually or in two student groups, although those students than do not pass the project work can access to a global exam to assess sketching and CAD skills. Moreover, students are monitored individually through tutoring processes.

2.6   Polytechnic University of Madrid (UPM)

UPM includes two 6 ECTS subjects in the first and second years [25 – 26]. The first subject is composed of two main parts, *descriptive geometry* and *normalization*, taught simultaneously, using CAD as the main tool to solve problems and exercises. All the evaluation activities are developed in the laboratory and the continuous evaluation propose eight partial exams along the semester; their arithmetic media gives the final grade. The students have the option to give up the continuous evaluation and take a global exam composed of the individual evaluation of each part.

The second subject includes as well an introduction to *representation systems (diedric and axonometric), tolerances and joint elements.* The exercises in the course are solved both with freehand sketching and CAD tools. The students can choose also the evaluation system, with a c ontinuous or a final option. The continuous evaluation includes grading sketching exercises (15%), theory continuous evaluation (10%), CAD exam (15%) and theoretical exams along the semester (50%). The final evaluation system consists of three final exams for sketching (25%), CAD (25%) and theory (50%).

2.7   University of Seville (US)

US has two 6 ECTS subjects too in the first and third courses [27 – 28]. The basic subject includes *planar and descriptive geometry*, and a part focused on computer aided design. In this case, the development of the subject is essentially in the traditional classroom, mixing theoretical classes with problems and exercises, and dedicating 8 hours to computer aided design. The students can be assessed through continuous evaluation, which comprises exams and practical exercises or global evaluation based only on exams.

The advanced subject is focused on normalization, including *drafting, dimensioning, tolerances, standardized elements, materials, and modelling using CATIA software tools.* The course is essentially practical, and applying teaching techniques as problems-based learning. The evaluation is based on the problems, projects and exercises developed along the semester (60%) and a final test (40%)

2.8   University Jaume I (UJI)

The two compulsory subjects in the UJI are taught in the first and the third courses and have 6 ECTS each [29 – 30]. The first course includes *planar and descriptive geometry, normalization and freehand sketching*, with a half of the class time developed in the laboratory. In this case the continuous evaluation has a 30% weight in the final grade, including partial tests and laboratory exercises. The rest of the grading is obtained with a hand-written global exam.

The second subject is mainly focused *on industrial design, normalization, elements and manufacturing*, developing almost all the contents using 3D software tools, including freehand sketching. The continuous evaluation has a bit more weight than in the first course subject (a 40%) and is mixed with a global review (60%) to obtain the final grade.

2.9   University of Salamanca (USAL)

The USAL has two compulsory subjects, with a 9 ECTS basic one in the first course, and a 6 ECTS second one in the third course [31 – 32]. The contents in the first subject comprise *planar and descriptive*

geometry (including topography) and normalization in the first semester and CAD in the second semester. This course differentiates completely between teaching traditional drawing and software tools.

The advanced subject in the third course has a deep view *into normalization, symbology and formats, freehand sketching, industrial design and standardized elements as well as tolerances and materials*. In this case the evaluation is always continuous, with the final grade distributed among online tests with a learning platform (15%), attendance and participation in the classroom (15%), exercises (20%) and a final exam (50%). It is assumed that classroom attendance is compulsory to pass the subject.

2.10   University Carlos III (UC3M)

The course guides available in UC3M are shorter than those available in the previous universities, but the big difference is that there is only a 6 ECTS specific drawing subject in the first course [33]. Its contents comprise *descriptive geometry, normalization, tolerances and CAD,* but there is not much information about methodologies or evaluation systems. It is only specified that a 40% of the final grade depends on continuous evaluation and that a 60% includes a global exam.

3   Results and discussion

We now describe the general conclusions in order to create a global view of the graphic engineering teaching. It is not exhaustive enough to enable a deep analysis, but it allows us to outline a first current status of the existing situation on this matter. It is worth recalling that all information is derived from the study guides; some of them are very descriptive and thorough, but other lack some important data, or are quite ambiguous, so the information needs sometimes more details.

Almost all the universities consulted have two compulsory subjects in the degree, with an amount of compulsory credits between 10,5 and 15 ECTS:
-    A basic subject, commonly set in the first course, which comprise the basics for descriptive geometry and normalization (6 or 9 ECTS). The biggest differences are the inclusion (or not) of planar geometry, topography, and some introduction to industrial design.
-    An advanced subject more focused in industrial design, standardized elements(joints, bolts, coils, springs, threads, trees, axes, bearings, gears, transmissions, etc...), mechanical assemblies, tolerances (size and geometrical) and materials (4,5 or 6 ECTS).

Both subjects' contents considerably converge, with minor differences.

CAD software is always used in both subjects. In the basic subject, depending on the school, it is used as an additional or complementary tool for drafting, but sometimes it is used as the main tool for solving geometric problems and exercises. It is also used for 3D modelling, mechanical assembling, and industrial design in the advanced subject. The different software programs can be Autocad, Autodesk Inventor, SolidEdge, Solidworks, CATIA or even Rhinoceros.

Tables 2 and 3 show the different distribution for both subjects in each university according to the study guides. The graphs in figure 1 show these comparison in graphic form.

University / Distribution	T	P	L	IW	GW	TU	E	HOURS	ECTS
UAB	15	15	45	52,5	45		7,5	180	6
UPV	30	20	10	90			11	161	6
UPC (1)	30		30	90				150	6
UPC (2)	30		30	30	60			150	6
UPC (3)	45			90	15			150	6
UPC (4)	60			39	51			150	6
EHU (1)	45	30	15	135				225	9
EHU (2)	45	15	30	135				225	9
EHU (3)	30	45	15	135				225	9
UNIZAR	30	15	30	70			5	150	6
UPM	18	18	36	60	18			150	6
US	30	22	8	90				150	6
UJI	28		28	90			4	150	6
USAL	36	24	12	135		6	12	225	9
UC3M								180	6

Tab. 2. Distribution for the basic subject. T (Theory), P (Problems), L (Laboratory), IW (Individual Work), GW (Group Work), TU (Tutoring), E (Evaluation). The schools with higher amount of credits are in grey colour.

University / Distribution	T	P	L	IW	GW	TU	E	HOURS	ECTS
UAB	30		45	45	45		15	180	6
UPV	22,5	7,5	15	67,5			6	119	4,5
UPC (1)	15		45	90				150	6
UPC (2)	30		30	90				150	6
UPC (3)	15		45	90				150	6
UPC (4)	15	6	45	84				150	6
EHU (1)	30		30	90				150	6
EHU (2)	15		45	90				150	6
EHU (3)	15		45	90				150	6
UNIZAR								180	6
UPM	36	18	36	90				180	6
US	15	24	21	90				150	6
UJI	28		28	90			4	150	6
USAL	24		24	90		5	7	150	6

Tab. 3. Distribution for the basic subject. T (Theory), P (Problems), L (Laboratory), IW (Individual Work), GW (Group Work), TU (Tutoring), E (Evaluation). The schools with smaller amount of credits are in grey colour.
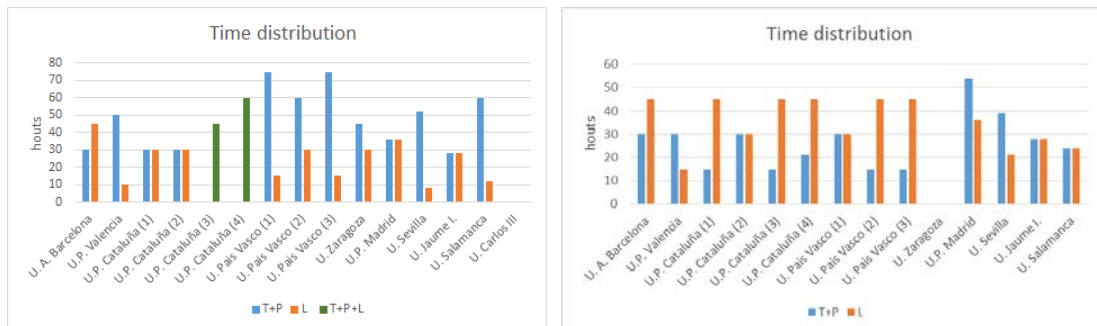
Fig 1. Bar graphs with the main time distribution (theory + problems in blue colour and laboratory in orange colour. Two schools have T+P+L in the same bar, in green colour)

Some conclusions can be extracted:

- In Spain, one ECTS credit involves between 25 and 30 student's working hours, and this generates a gap of 30 hours depending on the university according to the official information. Moreover, most of the subjects do not take into account the time spent in evaluation activities and tutoring, which should be considered in the timetable.

- EHU and USAL have a wider basic subject, with correspond to 9 ECTS, while the rest of the Universities have a 6 ECTS subjects. This fact allows them to include some extra contents about industrial design in the basic subjects (such as tolerances or standardized elements), and develop CAD contents more deeply. With respect to the advanced subject, almost all the universities have a 6 ECTS subject, except the UPV, which has a 4.5 ECTS course, and the UC3M, that does not have any a second subject.

- Big differences exist with respect to the amount of hours the students spend in the traditional classroom and in the laboratory using CAD tools. If we pay attention on the tables and graphs, we find contrast between, for example, the US, with 53 hours in the traditional classroom and 8 in laboratory, with the UAB, with 45 hours in the CAD laboratory and 30 in the classroom. In any case, the general trend is that the basic subject has a more traditional approach, including CAD as an additional unit but not as the main tool for the students (diedric system remains as the main tool for reasoning and solving geometric problems, and also to train the spatial perception), while the advanced subject uses CAD software as a key along the course.

University / Distribution	Hand-written exams	Laboratory exams	Individual exercises	Group exercises	Observation
UAB	79%	21%	50%		
UPV	45%		45%		10%
UPC (1)	60%		40%		
UPC (2)	50%		40%	10%	
UPC (3)	80%		20%		
UPC (4)	75%		15%	10%	
EHU (1)	60%		40%		
EHU (2)	70%		15%	15%	
EHU (3)	80%		20%		

UNIZAR	60%	40%		
UPM	100%			
US	100%			
UJI	85%	15%		
USAL	65%	20%		15%
UC3M	60%	40%		

Tab. 4. Evaluation system for the basic subject

University / Distribution	Hand-written exams	Laboratory exams	Individual Exercises	Group exercises	Observation
UAB	≈ 85%	≈ 15%	50%		
UPV	45%		45%		10%
UPC (1)	60%		40%		
UPC (2)	60%		40%		
UPC (3)	80%		20%		
UPC (4)	50%		50%		
EHU (1)	50%			50%	
EHU (2)	60%		40%		
EHU (3)	50%		50%		
UNIZAR	50%		50%		
UPM	100%				
US	40%		60%		
UJI	85%		15%		
USAL	65%		20%		15%

Tab. 5. Evaluation system for the advanced subject
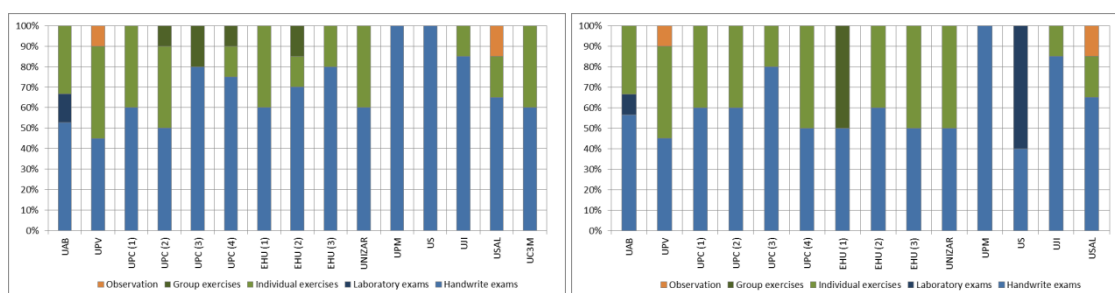
Fig 2. Comparison graphs. Exams are in blue colour, exercises and projects in green colour, and observation in orange colour.

The evaluation system is shown in tables 4 and 5, for the basic and advanced subjects respectively:

- There are also big differences among the different universities with respect to the weight assigned to exams; for example, UPV assigns a 45% to the exam. Other universities takes into account the students participation in class, like USAL or UPV. It can be notice anyway, that the evaluation in the basic subject gives a bit more importance to exams while the second subject trends to monitor the students work deeper along the semester. Note that the columns labelled "exams" include both partial and final exams.

- In general the study guides do not specify enough neither the number of exams nor type, but they suggest a prevalence of hand-written exams over laboratory exams. Almost all universities allow both continuous (in this case requiring a minimum of attendance) or global grading (usually implemented only through a final exam).

- Individual and group work is included in almost all the study guides, but in many of them it is not clear the weights assigned to each activity, and how are evaluated.

- In some cases, group projects are really relevant, especially in the advanced subject, and also have importance in some basic subject, as in one of the UPC schools, with a 20% weight in the final grade.

- Although tutoring and students observation are a must in the European Credit Transfer System, in general study guides do not consider these issues as a significant part in the final grade (even if they are surely taken into account). The individual student monitoring is certainly important, and,

according to the study guide's data, it is performed by delivering and assessing individual works and group projects.

In any case, the set of subjects proposed by all the selected universities develop the competences referred in the study guides, and assures their achievement by the students.

References

[1]   Jiao Tong University of Shanghai ranking http://www.shanghairanking.com/
[2]   Webometrics ranking by Cybermetrics lab http://www.webometrics.info/
[3]   U-Ranking by BBVA institution http://www.u-ranking.es/
[4]   Scimago Ranking. http://www.scimagoir.com/
[5]   UAB. Graphic Representation
        http://gaconline.euss.es/codi/GuiesDocents/FitxaAssignaturaGrau.php?IdiomaAss=ENG&CodiAss=200141_GME01&pla=GME01&CursAss=2014&TipusGuia=2
[6]   UAB. Further graphic representation
        http://gaconline.euss.es/codi/GuiesDocents/FitxaAssignaturaGrau.php?IdiomaAss=ENG&CodiAss=200239_GME01&pla=GME01&CursAss=2014&TipusGuia=2
[7]   UPV. Graphic Expression I. https://www.upv.es/titulaciones/GIM/menu_813244c.html
[8]   UPV. Graphic Expression II. https://www.upv.es/titulaciones/GIM/menu_813244c.html
[9]   UPC Manresa. Graphic Expression. http://www.upc.edu/grau/guiadocent/esp/330058/expresion-grafica.pdf
[10]   UPC Manresa. Graphic Engineering. http://www.upc.edu/grau/guiadocent/esp/330123/ingenieria-grafica.pdf
[11]   UPC Vilanova. Graphic Expression. http://www.upc.edu/grau/guiadocent/esp/340024/expresion-grafica.pdf
[12]   UPC. Graphic Expression II. http://www.upc.edu/grau/guiadocent/esp/340053/expresion-grafica-ii.pdf
[13]   UPC Barcelona. Graphic Expression. http://www.upc.edu/grau/guiadocent/esp/820003/expresion-grafica.pdf
[14]   UPC. Further Graphic Expression. http://www.upc.edu/grau/guiadocent/esp/820421/ampliacion-de-expresion-grafica.pdf
[15]   UPC Terrassa. Graphic Expression in Engineering.
        http://www.upc.edu/grau/guiadocent/esp/320004/expresion-grafica-en-la-ingenieria.pdf
[16]   UPC. Further Graphic Engineering. http://www.upc.edu/grau/guiadocent/esp/320055/ingenieria-grafica.pdf
[17]   EHU Campus Araba. Graphic Expression. http://www.ehu.eus/es/web/vicer.grado-innovacion/aurtengo-gradu-guztiak?p_auth=oNN18Rhc&p_p_id=upvehuapp_WAR_upvehuappportlet&p_p_lifecycle=1&p_p_state=normal&p_p_mode=view&p_p_col_id=column-2&p_p_col_count=1&_upvehuapp_WAR_upvehuappportlet_action=redirectAction
[18]   EHU. Campus Araba. Futher Graphic Expression. http://www.ehu.eus/es/web/vicer.grado-innovacion/aurtengo-gradu-guztiak?p_auth=oNN18Rhc&p_p_id=upvehuapp_WAR_upvehuappportlet&p_p_lifecycle=1&p_p_state=normal&p_p_mode=view&p_p_col_id=column-2&p_p_col_count=1&_upvehuapp_WAR_upvehuappportlet_action=redirectAction
[19]   EHU. Campus Bizkaia. Graphic Expression. http://www.ehu.eus/es/web/vicer.grado-innovacion/aurtengo-gradu-guztiak?p_auth=oNN18Rhc&p_p_id=upvehuapp_WAR_upvehuappportlet&p_p_lifecycle=1&p_p_state=normal&p_p_mode=view&p_p_col_id=column-2&p_p_col_count=1&_upvehuapp_WAR_upvehuappportlet_action=redirectAction
[20]   EHU. Campus Bizkaia. Further Graphic expression. http://www.ehu.eus/es/web/vicer.grado-innovacion/aurtengo-gradu-guztiak?p_auth=oNN18Rhc&p_p_id=upvehuapp_WAR_upvehuappportlet&p_p_lifecycle=1&p_p_state=normal&p_p_mode=view&p_p_col_id=column-2&p_p_col_count=1&_upvehuapp_WAR_upvehuappportlet_action=redirectAction
[21]   EHU. Campus Gipuzkoa. Graphic Expression. http://www.ehu.eus/es/web/vicer.grado-innovacion/aurtengo-gradu-guztiak?p_auth=oNN18Rhc&p_p_id=upvehuapp_WAR_upvehuappportlet&p_p_lifecycle=1&p_p_state=normal&p_p_mode=view&p_p_col_id=column-2&p_p_col_count=1&_upvehuapp_WAR_upvehuappportlet_action=redirectAction
[22]   EHU. Campus Gipuzkoa. Further Graphic Expression. http://www.ehu.eus/es/web/vicer.grado-innovacion/aurtengo-gradu-guztiak?p_auth=oNN18Rhc&p_p_id=upvehuapp_WAR_upvehuappportlet&p_p_lifecycle=1&p_p_state=normal&p_p_mode=view&p_p_col_id=column-2&p_p_col_count=1&_upvehuapp_WAR_upvehuappportlet_action=redirectAction
[23]   UNIZAR. Graphic Expression and CAD.
        http://titulaciones.unizar.es/admin/lectorPDFasig.php?asignatura=29703&year=2014&idioma=1

[24]   UNIZAR. Industrial drawing.
       http://titulaciones.unizar.es/admin/lectorPDFasig.php?asignatura=29714&year=2014&idioma=1
[25]   UPM. Technical drawing and computer aided design.
       http://www.etsidi.upm.es/sfs/E.U.I.T.%20Industrial/SUBDIRECCION%20OA/DOCUMENTOS/14-
       15%20GA%20565000315%20EXPRESI%C3%93N%20GR%C3%81FICA%20Y%20DISE%C3%9
       1O%20ASISTIDO%20POR%20ORDENADOR.pdf
[26]   UPM. Graphical Engineering. https://www.upm.es//comun_gauss/publico/guias/2014-
       15/2S/GA_56IM_565000344_2S_2014-15.pdf
[27]   US. Graphic Expression. http://gdus.us.es/programas/2070002_4273.pdf
[28]   US. Industrial Design. http://gdus.us.es/programas/2070027_7623.pdf
[29]   UJI. Graphic Expression. https://e-
       ujier.uji.es/pls/www/gri_www.euji22883_html?p_curso_aca=2014&p_asignatura_id=EM1009&p_id
       ioma=ES&p_titulacion=222
[30]   UJI. Graphical Engineering. https://e-
       ujier.uji.es/pls/www/gri_www.euji22883_html?p_curso_aca=2014&p_asignatura_id=EM1025&p_id
       ioma=ES&p_titulacion=222
[31]   USAL. Graphic Expression. http://www.usal.es/webusal/files/Grado_en_Ing._Mecanica_PF_2014-
       2015_0.pdf
[32]   USAL. Graphical Engineering.
       http://www.usal.es/webusal/files/Grado_en_Ing._Mecanica_PF_2014-2015_0.pdf
[33]   UC3M. Graphic Expression.
       https://aplicaciones.uc3m.es/cpa/cpa/generarReport.do?ano=2014&plan=165&asignatura=14187
       &idioma=1

SFM IMPLEMENTATION IN PRODUCT DESIGN PROJECTS WITH DERIVED SPECIFICATIONS

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Abstract

In order to adequately address the difficulty often associated with the design activity and conveniently structure the broad related information, it is necessary to apply different design strategies and support tools. This paper analyzes the initial tasks involved in a product design process in which the product specifications are derived from the factors implicated and a concepts generated analysis.

The use of a matrix-type tool is proposed to support the design process. This tool, denominated 'specifications and factors matrix' or SFM, allows to synthesize and to structure the resulting information of the design activity and previous research. It was implemented within the Engineering Degree in Industrial Design and Product Development at the University of Zaragoza for the development of module projects. The students had evaluated the experience as positive.

1   Introduction

A number of phases are involved in a generic process of product development (fig. 1). This process begins with the perception of an unsatisfied necessity or a market opportunity [1] and it finishes with the use and final disposition of the product [2]. The phases of concepts generation, detail design of the selected concept and application of the verification methods are required before the production launches and the marketing activity begins. Along this process, some phases can be simultaneously developed and feedback loops can be established between them, showing the iterative returns to earlier steps needed for its improvement.
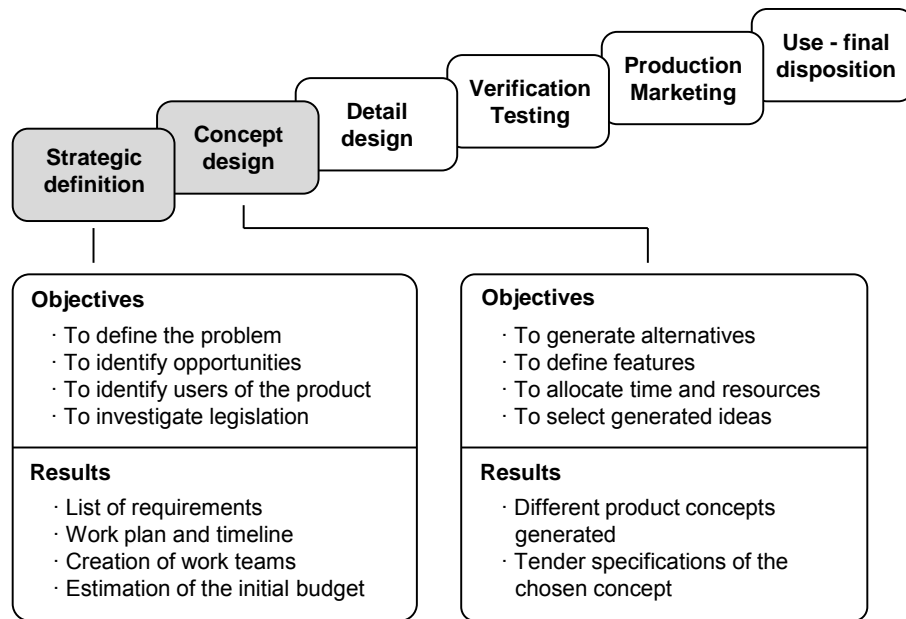
Fig. 1. Phases of the product development process.

Placing the focus on the early stages, the main objective of the strategic definition phase is to identify a problem, a need or an opportunity for the product improvement. The main actions carried out are collecting, analyzing and information processing to obtain the expected results to form a list of requirements and a work plan. In the design concept stage, the objective is to generate ideas that provide solutions to the identified problems, to propose different design alternatives or product concepts and to select the most appropriate ones. The main actions are to generate, analyze and evaluate ideas and the expected result is the definition of a product concept with its characteristic parameters.

In order to support the design process, a great number of techniques and tools are being used. Usually, these tools facilitate tasks such as the planning, the drawing user's wishes and needs, concepts generation or decisions taking processes. A detailed description of techniques and tools used in product engineering can be reviewed in certain works [3, 4]. Among these tools, the Quality Function Deployment (QFD) [5], the Kano model [6] o the conjoint analysis technique [7, 8], assist the designer when defining minimum requirements for a product, identifying opportunities for improvement and users preferences. In other cases, tools are mainly used to develop or generate concepts. This is the case of the TRIZ methodology [9, 10], based on the assumption that the principles of creativity can be applied to obtain technical innovations. The analysis of hierarchies proposed by Saaty [11] or the method developed by Pugh [12] allow the assessment of different alternatives and the selection of the best valued one, using appropriate design criteria.

In most of the considered tools, the authors turn to organize the information used in their methodology through a matrix. The QFD methodology is based on a matrix relating users' needs and design characteristics. The matrix that organizes functional and dysfunctional requirements is used within the Kano model and the design matrix formed by the attributes and their levels of evaluation is configured within the conjoint analysis technique. From the principles of contradiction, TRIZ methodology uses the Altshuller matrix to provide a number of recommendations to solve a problem. It is composed by characteristics that improve a design alternative and by characteristics that worsen it. In Saaty's analysis of hierarchies, the relative importance of each criterion is defined on a square matrix of comparisons. Pugh's method provides an overview of advantages and disadvantages of different design alternatives through a matrix where each column represents an alternative and each row an evaluation criteria.

Other researchers also use matrices with different objectives. Simon [13] uses a matrix-based approach for the decomposition of design problems. Bovea and Wang [14] propose the integration of customer, cost and environmental requirements through the green quality function deployment (G-QFD). Santolaya and Serrano [15] use matrices to integrate factors and specifications in product design projects. Thus, matrices are suitable tools to synthesize information and to illustrate the interactions between various elements [16]. Such tools can be included within the techniques referred as 'Dependency and Structure Modelling' or DSM, which take advantage of their ability to relate and structure information to manage complexity [17].

In this work, a new tool, denominated "Specifications and Factors Matrix" (SFM), is proposed to support the product design. Firstly, a methodology based on the sequential development of a series of tasks involved in the matrix elaboration process is presented. Next, the application to a product design case is described. Finally, the results of the experience are shown.

2   Methodology

A set of specifications are usually used to describe a product. In the literature [1, 18], specifications are also called requirements, technical specifications, engineer characteristics or product attributes. On the other hand, the scope of the measures taken to achieve a solution in a product design problem is limited by the ability to process information [19]. This is, in part, due to the wide variety and quantity of factors involved in this type of problems. Among other aspects, it will be necessary to take into account the users characteristics, the governmental regulations, the conditions set by the manufacturers and the social and cultural environmental.

According on how the product specifications are defined, two types of design processes can be differentiated: design processes with imposed specifications and design processes with derived specifications. In the first case, product specifications are initially established [20] and in the second one, specifications are defined along the initial stages of the product design process from the project objectives and the analysis of the factors involved. This strategy is applied usually when the client wants to introduce a new product or to expand the range of products and allows the definition of product specifications to be made by the designer.

The sequence of tasks proposed to carry out the initial development of a design problem with derived specifications is shown in fig. 2. At the same time, a matrix to facilitate the organization of the information associated to the design process is also created. The first task of the design process consists on the identification of the design factors. After its study and review, the product specifications, called 'critical' or 'general' can be defined. These are requirements needed in the development of any new product proposal.

Then, different concepts that constitute an improvement, transformation or innovation of the product are proposed. For each concept or idea, the specifications called 'desired' or 'particular' are defined. These specifications allow the differentiation over the existing products. Finally, the selection and development of one of the concepts is performed. Specific techniques can be used to select a concept. If each concept is evaluated from the point of view of specifications compliance, to emphasize the synthesized definition of the general specifications helps them not to remain forgotten or relegated to a back seat in comparison to the specifications that provide differentiation. In this case, an independent evaluation of specifications is proposed and an average rating is obtained for each concept.
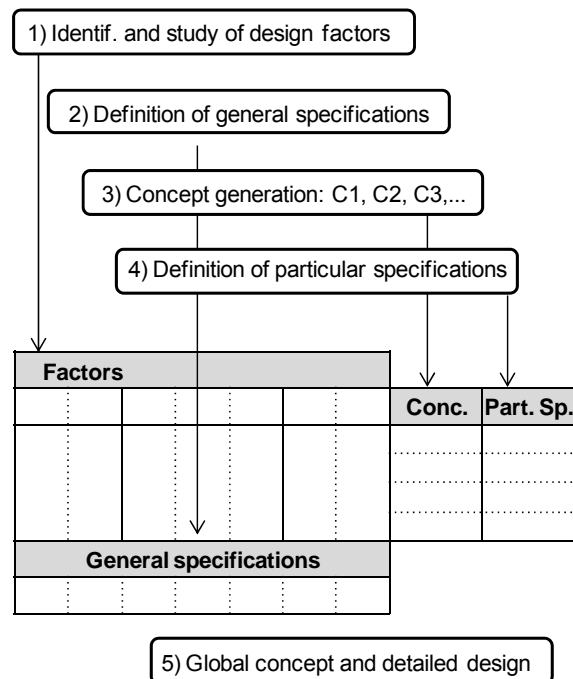
Fig. 2. Task sequence in a product design process with derived specifications.

In fig. 2, we can observe that the design factors are classified in different groups and are disposed by columns into the matrix. The general specifications are placed at the bottom of each group of design factors. The product concepts are located on the right side of the matrix and next the particular specifications for each one. Thus, the specifications and factors matrix, SF M, is able to integrate the identification and understanding of the design problem with the proposals for their solution. It is, mainly, the result of different actions of analysis and synthesis carried out along the first stages of product design process.

3   Case study

This section describes how the above presented approach can be applied to a product design project. The project consisted on the design of a coffee maker for non-professional uses and it was opened to different options for improvement or innovation of previously existing products. It did not have a prior i established specifications but it was necessary to consider the conditions initially introduced in the product definition.

The initial tasks of the project were developed according to the scheme shown in fig. 2. First, the factors that intervene in the design of this type of product were identified and grouped into three main blocks: 'operation and function', 'user and environment' and 'manufacture and market'. The factors were summarized and organized by columns in a matrix, as shown in fig. 3. In the 'operation and function' block, the 'operating principles' subgroup includes factors related to the use and transformation of electric energy to process raw materials needed to obtain coffee and the 'device composition' subgroup the ones affecting its structure. In the 'user and environment' block, the 'mode of use' subgroup includes the factors related to user preferences and to the manipulation of the coffee, and the subgroup 'characteristics of the environment', those factors related to space and the nearby furniture, environmental conditions and the aesthetic line. In the last block, all factors related to product manufacture and the current market study, are included.

FACTORS					
Operation and function		User and environment		Manufacture and market	
Operating Principles	*Device Composition*	*Mode of Use*	*Environmental characteristics*	*Materials and Processes*	*Market*
- Methods of processing and usage of electricity. - Basic processes in production of coffee: heating, vaporizing, condensing, filtering,... - Combination of raw materials or ingredients.	- Containers and storage elements. - Elements of preparation, processing and output. - Gripping and handling elements (buttons, indicators,... - Elements of support and connection.	- User profiles: age, sex, activity,... - User preferences: coffee type, quantity, time,... - Procedure for grip and use. Sequence of operations. - Anthropometry. Ergonomic principles.	- Location or area of use: work, home, vehicle, field,... - Furniture and space available - Environmental conditions: humidity, temperature, dirt,.. - Aesthetic line. Emotional elements.	- Number, type and format of materials. Normalized elements. - Adhesives, paints, finishes. - Methods of manufacture and assembly. - Methods of finishing and packaging. Production control.	- Types of product, characteristics and price. - Users needs. - Commercial agents vision. - Markets niche. - Regulations and current legislation.
GENERAL SPECIFICATIONS					
Power supply. Efficiency	*Simplicity. Non-professional*	*Safe and secure usage*	*Environment adequacy*	*Technical feasibility*	*Innovation. Regulation*

Fig. 3. Design of an electric coffee maker for non-professional use. Factors and general specifications.

From the analysis of each group of factors, the general design specifications, which are shown in the last row of the matrix of fig. 3, were derived. The power supply from electric network and the efficiency of the processes allowing the transformation of the energy supplied to the equipment represent the general specifications taken into consideration once the factors related with operating principles have been analyzed. In the case of 'Materials and Processes' factor´s subgroup, the technical feasibility of the fabrication of the product is the one proposed as the general specification because all innovative concepts rely on the materials and production processes available to transform the concepts into industrial products. In the last subgroup the innovation and regulation specifications respond to the necessity of the product to fulfill the current legislations for its introduction to the market, and the characteristic of differentiation from the products already present in the market. The general specifications set out the basic requirements for the development of new concepts of the coffee maker.

According to the scheme shown in fig. 2, the next task was to generate innovative concepts of coffee maker. In this work, three different product concepts are presented. These were called: 1) Coffeemaker - passion for coffee; 2) Coffee maker thermos and 3) Ecological coffeemaker. In each of these concepts a series of specifications were derived showing the particularity or differentiation of the proposed concept (fig. 4).

CONCEPTS	PARTICULAR SPECIFICATIONS

C1 Coffeemaker - passion for coffee	- Variety of coffees - Personalized aesthetics - Sophisticated interface - Quality finishes
C2 Coffeemaker - thermos	- Thermal control - Easy to transport - Adaptation to outdoor environments
C3 Ecological coffeemaker	- Low power consumption - Organic filters - Less amount of material

Fig. 4. Design of an electric coffee maker for non-professional use. Concepts and particular specifications.

In the case of the concept of a coffeemaker for coffee lovers, the particular specifications were defined as the possibility of preparation of a wide variety of coffees, personalized aesthetic, sophisticated interface and high quality materials and finishes. In the concept coffeemaker - thermos, the derived specifications were thermal control, easy transportation and adaptation to outdoor environments. The three concepts proposed as well as the particular specifications of each of them are shown in fig. 4. In order to select a concept of coffeemaker, an independent evaluation of specifications compliance was performed, as shown in fig. 5.

General specifications evaluation			
	C1	**C2**	**C3**
GS₁	P_{GS1}		
GS₂	P_{GS2}		
GSₙ	P_{GSN}		
Average:	$\sum \dfrac{P_{GSi}}{N}$		

Particular specifications evaluation			
	C1	**C2**	**C3**
PS₁	P_{PS1}		
PS₂	P_{PS2}		
PSₙ	P_{PSN}		
Average:	$\sum \dfrac{P_{PSi}}{N}$		

Fig. 5. Assessment of specifications compliance.

The average score was obtained for both general specifications (GS_i) and particular specifications (PS_i) of the three coffeemaker concepts considered. Finally, a balance of the assessment of the specifications compliance for each concept was made and the one that received the highest score was selected.

4   Implementation results

The methodology described above together with the SFM tool, was implemented within the university teaching practice, particularly in the Engineering Degree in Industrial Design and Product Development at the University of Zaragoza.

In the academic course 2014-2015 the students of the 3rd year made the electric coffeemaker project, applying SFM in the early stages of the design process. Their opinions regarding the development of the tasks involved in the project were collected in 22 surveys, completed by 66 students working on the project in the groups of 3. It is considered as a representative sample for the total number of 72 students following the 3rd course. These very same students made a similar design project in a previous year without using the SFM so that they could compare the experience of concept defining with and without this tool, and consider it while evaluating SFM utility. Fig. 6 shows, using the scale from 1 to 7, the students evaluation about the average degree of difficulty considered in different tasks

Tasks development	1 2 3 4 5 6 7
Design factors identification	
General specifications definition	
Concepts generation	
Particular specifications definition	
Concepts selection	
Degree of difficulty: 1- very easy; 7- very difficult	

Fig.6. Assessment of the methodology.

Fig. 7 shows the results deri ved from the students' ev aluation about the objectives achieved using the SFM tool. It indicates the degree of agreement with a series of statements regarding the use of the matrix applying assessment scale from 1 to 7.

According to the results, students scored with a medium difficulty the different tasks developed along this methodology. They also showed their agreement with most of the claims about SF M, assessing it with 5 scores on average. In particular, the overall usefulness of the tool was positively valuated. These empirical data shows that the use of the matrix had a positive effect on tasks such as classifying and identifying design factors, establishment of relationships between factors and specifications and verifying the compliance of the specifications by different concepts. Thus, SFM reinforces processes involving analysis and synthesis of information and has less impact on creative processes. It also complements other techniques and tools used along the first stages of the product design process.

SFM tool:	1	2	3		4	5	6	7
It helps to classify design factors							■	
It helps to identify design factors						■		
It helps to relate factors and specifications							■	
It helps to verify the compliance of the specifications by different concepts							■	
It helps to generate concepts					■			
It helps to evaluate and to select the concepts							■	
It facilitates the design process						■		
It allows the coordination of requirements to be met in different subjects						■		
It is a useful tool						■		
Level of agreement: 1- strongly disagree; 7- totally agree								

Fig.7. Assessment of the SFM tool.

In students opinion, the task in which SFM helps the less is the generation of the concepts, scored with 3,5 points, on the other hand, students confirm that matrix helps to evalu ate and to sel ect the concepts, evaluating this task with 6 points. When comparing the process of concepts final selection using SFM, or without it, it can be seen that a more precise definition of the specifications is achieved, a larger number of specifications to do the evaluation is available, setting differences between general and specific ones. This favors the selection process.

Among the observations made by the students in the survey, it is worth to highlight the following: "SFM helps to summarize an d to make precise definitions"; "SFM allows to encompass a nd relate wealth of information"; "SFM is useful but difficult to supplement"; "SFM covers a lot of informati on and it would be necessary to implement more fields"; "It makes you focus the concept on the essence of the factors". These observations prove that the students value as positive the use of th is tool in the project deve lopment and they even suggest some other fields for the future improvement in the design and implementation of the tool. SFM has been also implemented in the projects developed in the second semester, in which different product are being designed, in order to get information if t he results are repeat ed and to avoi d the evalu ations' dependency from the designed product type. The results are expected to be analyzed soon.

5   Conclusion

The early stages of the product design process are decisive because in them the product specifications are established, the factors are identified and new concepts are being generated. In this work, a methodology of a product design project with derived specifications development is exposed and a suitable support tool is proposed to complement others already used i n capturing needs, concept generation and decision-making.

Two types of specifications, general and particular, were differentiated in a design process with derived specifications. General specifications are obtained from the an alysis of design factors and particular specifications were defined from each ne w product conc ept. The tool denominated Specifications and Factors Matrix or SFM was proposed to facilitate the organization and the study of the information generated at the in itial stages of the d esign process. SFM encouraged the r eflection process in order to generate innovative product concepts and it was able to integrate the identification and understanding of the problem with the proposals for their solution.

This methodology was implemented within university teaching, in p articular was applied in the Engineering Degree in Indus trial Design and Product Development to devel op a coffe emaker for no n-professional uses. The students scored with a medium difficulty the d evelopment of this appr oach and showed their a greement with the overal l usefulness of the tool and cons ider it have a positive effect on different tasks associated to the project development.

References

[1] K. Ulrich and S. Eppinger. *Product Design and Development.* Boston, MA. Irw in McGraw-Hill, 2000.

[2] W. Wimmer, R. Züst, K.M. Lee. *Ecodesign Implementation: A systematic guidance on integrating environmental considerations into product development.* Springer Science Media Dordrecht, 2004.

[3] R. Ramírez. *Guía de Buenas Prácticas de Diseño. Herramientas para la gestión del diseño y desarrollo de productos.* San Martín, Argentina. Inst. Nacional de Tecnología Industrial - INTI, 2012.

[4] A. Milton an d and P. Rodgers. *Research methods for product design.* London, UK. Laure nce King Publishing Ltd, 2013.

[5] Y. Akao. *Quality Function Deployment.* Cambridge, MA. Productivity Press, 1990.

[6] S. Kano. *Life cycle and creation of attractive quality.* Proceedings of the 4th International Quality Management and Organisational Development Conference. Linköping, Sweden, 2001, September 12 th-14th, pp 18-36.

[7] A. Gustafsson, F . Ekdahl, B. Bergma nn. *Conjoint analysis: A useful tool in the design process.* Total Quality Management 10, 3 (1999) 327-343.

[8] G. Lone, S. Sanjeev. *Application of conjoint analysis in product design.* International Journal of Industrial Engineering-Theory Applications and Practice 14, 2 (2007) pp 141-150.

[9] G. Altshuller and L. Shul yak. *40 principles: TRIZ keys to technical innovation.* Worcester, MA. Technical Innovation Center, 1998.

[10] L. Miao, M. Xinguo, Z. Maokuan*. A framework of product innovative design process based on TRIZ and Patent Circumvention.* Journal of Engineering Design 24, 12 (2013), pp 83 0-848.

[11] T. Saaty, T. *How to structure and make choices in complex problems.* Human systems management 3, 4 (1982), pp 255-261.

[12] S. Pugh. Total design. *Integrated methods for successful product engineering.* Wokingham, England: Addison-Wesley Pub. Co., 1990.

[13] L. Simon. *A matrix-based clustering approach for the decomposition of design problems.* Research in Engineering Design 22, 4 (2011), pp 263-278.

[14] M. D. Bovea and B. Wang. *Green quality function deployment: a methodology for integrating customer, cost and environmental requirements in product design.* International Journal Environmental Conscious Des. Manufacturing 12, 4 (2004), pp 9-19.

[15] J.L. Santolaya and A. Serr ano. *Análisis integrado de especificaciones y factores en la realización de proyectos de diseño.* IV Congr eso Latinoamericano de Enseñanza del Diseño. Buenos Aires, Argentina, July 29th-31th, 2013, Buenos Aires, pp 26.

[16] A. Björnfot and L. Stehn. *A design structural matrix approach displaying structural and assembly requirements in construction: a timer case study.* Journal of Engineering Design 18, 2 (2007), pp 113-124.

[17] F. Deubzer and U. Lin dermann. *Functional modelling for design synthesis using MDM methodology.* 10th International Design Structure Matrix Conference. Stockholm, Sweden, 2008.

[18] G. Urban an d J. Hauser. *Design and Marketing of New Products (2 ed).* Prentice H all, Englewood Cliffs, NJ, 1993.

[19] K. Dorst and J. Dijkhuis (1995). *Comparing paradigms for describing design activity.* Design Studies 16, 2 (1995), pp 261-274.

[20] J.L. Santolaya, A. Serrano and A. Bi edermann. *Creation of specifications and factors matrices in design projects. Diseño para la vida cotidiana.* Ed. Centro Universitario UAEM, México, 2014.

XXV Congreso
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A new conceptual design of a 180º crate dumper machine

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Abstract

The installation of crate tipper machines into the production chains utilized in the horticultural industry has become imperative in this sector. However, the crate tippers existing on the market are designed to be installed in modern production chains, and its installation in older production chains results very difficult to be executed. Furthermore, most of crate tippers that exist on the market provide a rotation angle under 180º, so fruit ends up being hit during the dumping process, which is the main problem of the majority of crate tipper machines. This fact means that a custom design that perfectly fits the needs of the company must be developed. This communication presents a new conceptual design of a 180º crate tipper machine to be utilized in the horticultural industry that provides a great versatility when using crates of different sizes and that permits the fruit to be tipped without being hit.

1 Introduction

From its harvest in the field to its final consumption, fruit is subjected to different handling processes in the horticulture industry, those in which it can suffer mechanical damage [1]. This damage can affect the fruit, producing bruises and damage to the skin, which is one of the major causes of category loss in the product quality and has a noticeable impact on the final consumer's decision to buy or not [2-3], or producing wounds in the skin, which can be an entry point for pathogens [4].

One of the parts of the chain where the fruit can be damaged by impact or friction is in the so called handling or production line. This production line consists of a combination of machines which carry out specific operations, such as washing, packing and labelling the products. All of these operations are performed in a sequential order on the main line or on connecting elements, as are conveyor belts.

The characteristics of the machines on the production line vary depending on the fruit species. However there is common ground for all the production lines, the so called transfer point, which is defined by a product entrance/emptying line, and by another reception/handling line. This point is the most critical due to the high intensity of mechanical load which each piece of fruit receives [1].

For the activity carried out at this point, crates (also known as big boxes) are used. These are large plastic or wooden containers which are used to collect fruit in bulk in the fields, and whose weight and height can vary depending on the product (fig.1). These boxes are collected by a tipper machine that pours the pieces of fruit contained therein onto the production line conveyor belt. Once the entire product has been emptied onto the conveyor belt, the crates return to their initial position, before the emptying process, and are redirected to a hoarding zone to be re-used.

Fig. 1 Some types of crates and boxes used in the horticulture industry

The damages produced during the spilling operation onto the production line can be caused by an inadequate choice of tipper machine, or by a bad design of the transfer point, fundamentally with respect to the parameters related with height, width, etc [5]. The solutions to each of these cases are expensive and mean changing the tipper machine.

In this aspect, the existing tippers on the market are designed to be easily incorporated into the modern installations of production lines or chains, the majority presenting a rotation angle inferior to 180º, so the fruit ends up getting hit as it is tipped onto the conveyor belt in cascade.

On the other hand, companies in the horticulture sector have their production lines designed for their range of products. Therefore, when they decide to increase their range of products to include others with different morphological characteristics, the production line has to be adapted to the size of the new product, with the transfer point being a critical point due to the fact that the size of the crates used in the spilling operation onto the production line can vary, with their dimensions being conditioned by the size of the piece of fruit that is collected in the fields.

At this stage, the present communication proposes a conceptual design of a crate tipper machine whose goal is to execute the tipping operation with a rotation angle of 180º, with the aim of carrying out the complete emptying of the crates without damaging the pieces of fruit during this operation, all of this contained within the dimensions defined by the physical space designated to the situation of this machine in the transfer point with the production line. Furthermore, the proposed design should be versatile and adaptable to the different sizes of existing crates on the market.

2 Materials and methods

2.1 Functional structure

The design process of a new product is comparable to a technological innovation process where the development phases of the design are similar and parallel to those of an innovation program [6]. In this stage, and from the information issued by the client, the desired technical innovation to be carried out is conceptualised.

For this reason it is essential to include the client inside the functional structure of the conceptual design process of a product which is aimed at solving a problem that the client has, where there may exist various levels of integration with different degrees of intensity. In the case studied in this work, the input of the client has been essential, given their experience obtained in the horticulture industry.

In this manner, during the first contacts with the design team the client transmitted various enlightening ideas of their problem:

- *Perceived need.* The client decides to extend their range of product handling and the tipper machine that they possess in their production line performs the fruit tipping operation with a rotation angle of 135º, due to this, the new range of fruits falls onto the production line. This operation is violent for the new product, generating mechanical damage, given that the size of the piece and the hardness of the skin are inferior to the standard handling range of the company.
- *Innovation of the product.* The client informs that the new product is received into the industry in crates of different dimensions to the range of crates which the company currently works with.
- *Technical solution.* The production line is situated in a physical space perfectly defined inside the horticulture building. This line consists of a set of machines which perform perfectly their operation and do not need any technical modification that might imply a different function to that which they carry out presently. The existing tipper machine is found placed at a transfer point with the production line, with all dimensions completely known, so the technical solution to be developed must be adjusted to the dimensions of the space available and be compatible with the rest of the existing machines that make up the production line.

Once the participants in the conceptual design process have been identified, namely, the multidisciplinary team consisting of design engineers and the client, it is assumed that the decisions made in this phase will determine the rest of the process, to the point that a poor definition of the product concept will result practically impossible to improve in later stages.

2.2 Technical limitations

In the first place, the design of the new tipper machine should be versatile, in other words, it should be compatible with the dimensions of the different existing commercial crate solutions that are on the market. For this reason an adaptable and modular design of a tipper machine is proposed theoretically, which will be adaptable to the dimensions of the commercial crate solutions presented.

It should be taken into account that the new range of fruits presents a thin skin texture, with reduced dimensions, so a technical solution that minimizes the impact of the piece of fruit on the production line conveyor belt at the transfer point should be presented. Therefore a solution based on a crate tipper machine which presents a rotation angle of 180º is proposed.

There are currently very few commercial solutions on the market that perform the tipping operation with an angle of 180º, and the existing machines are designed for modern production chains, where the commercial firm integrates all the versions of their machines along the production line where the dynamic activity is performed. However, outside their range of products, these machines have a low compatibility with the other commercial firms.

Furthermore, the other existing commercial solutions on the market offer a tipping operation with a rotation angle inferior to 180º, so these are not valid solutions for the size of fruit which the new range of products includes.

Moreover, the new tipper machine must be adaptable to the existing production line, therefore it must be compatible with the supply line of the former tipper machine. This line consists of a crate unstacker, which has a supply feed for a column of two crates, from which the crates will be supplied to the new tipper.

Once the tipping operation has been performed, the production line has a system that: a) separates and redirects the crates to an accumulation zone, and b) releases the fruit onto the production line.

2.3 Design process

Taking into account the physical space available at the transfer point of the production line, the new machine must present dimensions of 1.2mx1mx0.8m.

Upon carrying into effect the design, this was divided into four main phases, taking into account the tasks to be performed within each one.

Phase 1: Reception

The new design is compatible with the supply line of the former tipper. So, in this way, the crate will reach the new tipper by means of the production line conveyor belts. The upper belt will be in the most elevated position to allow the crate to pass (Fig. 2).
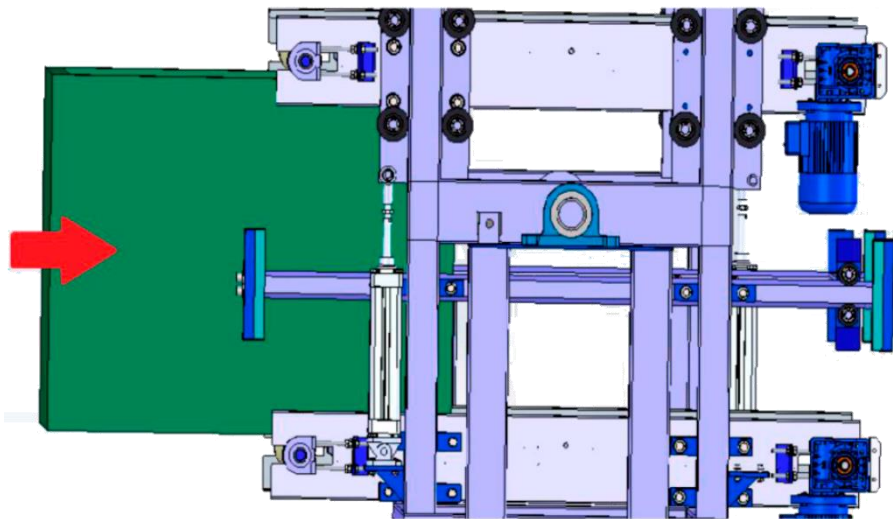

Fig. 2 Crate entry

The crate is stopped by a sliding stop once it is completely over the belts in the optimum position for rotation. In this instant the belts cease movement (Fig. 3).
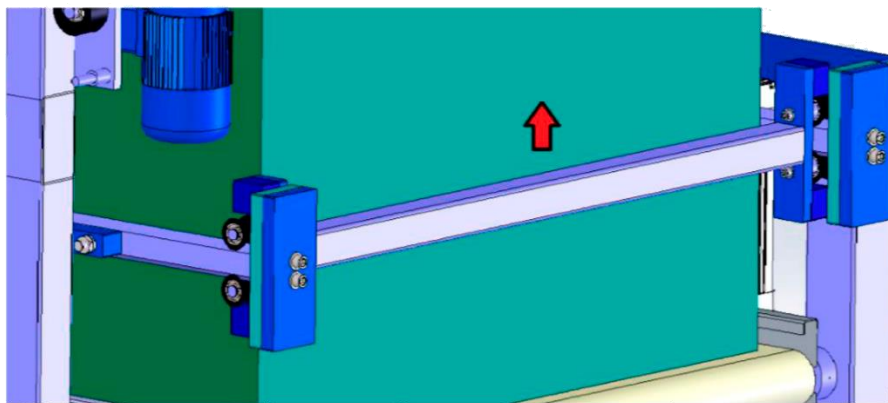

Fig. 3 Sliding stop to hold the crate

Phase 2: Campling

The new design possesses a hydraulic system composed of four double effect pistons (Fig. 4), whose stroke can be regulated, adjusting itself to the dimensions of the crates (Fig. 5). For this purpose, the pistons descend until they press lightly against the crate, obtaining a better grip thanks to the frontal stop (Fig. 3) and the pressure on the crate from the conveyor belt (Fig. 5).
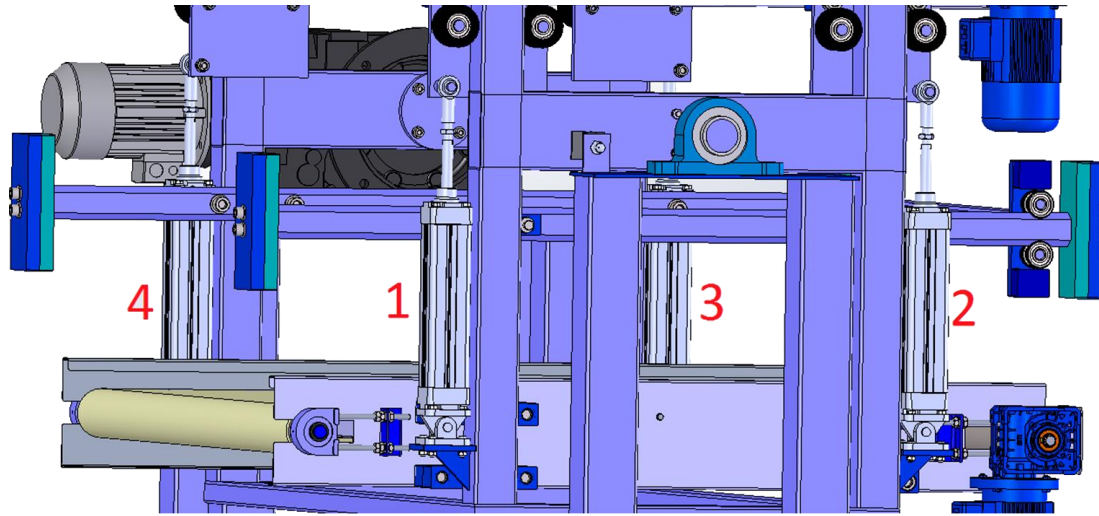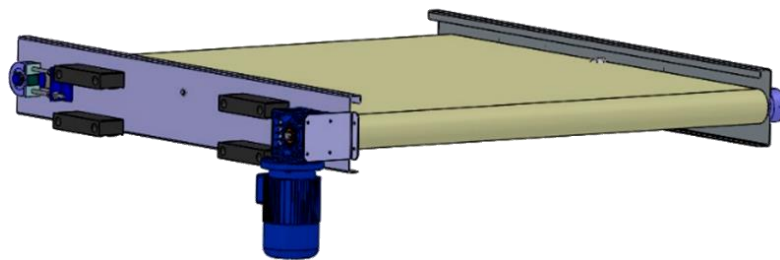

Fig. 4 Hydraulic System
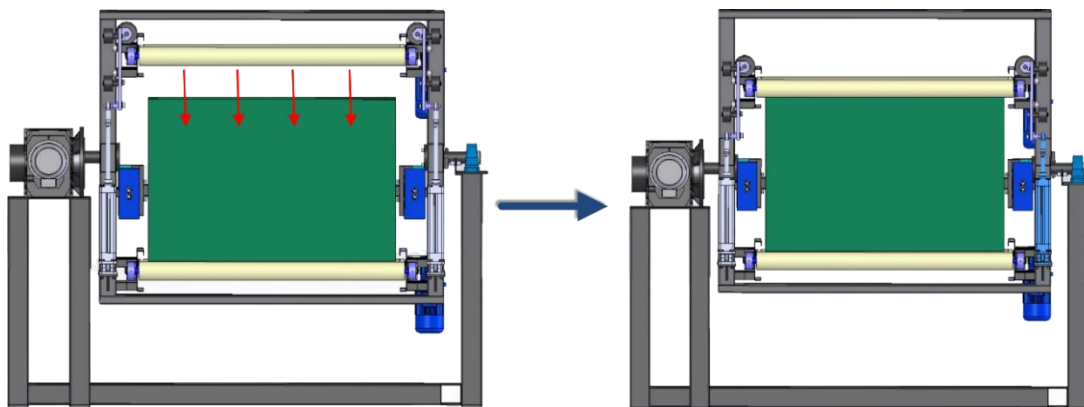
Fig. 5 Piston descent

The pistons cause an upper metallic structure consisting of a canvas to slide down (Fig. 6), adjusting this way the top part of the crate.

Fig. 6 Canvas for the transport system

The sliding of this structure is performed by two mobile supports (Fig. 7) which slide with the help of some wheels over the metallic profile of the structure until the stop defined by the piston stroke is reached.
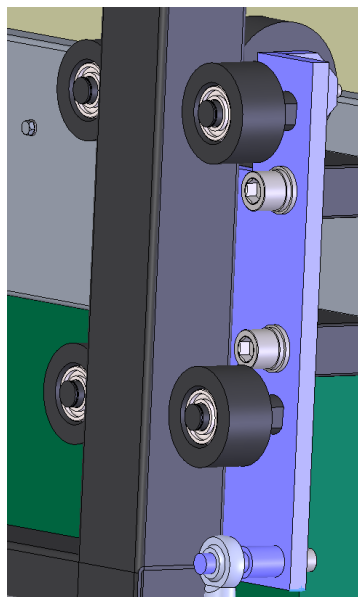
Fig. 7 Sliding structure
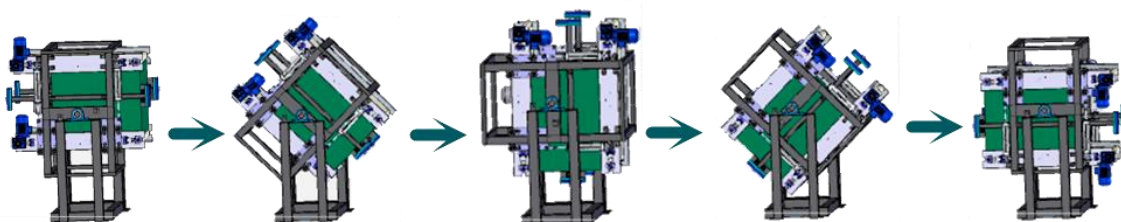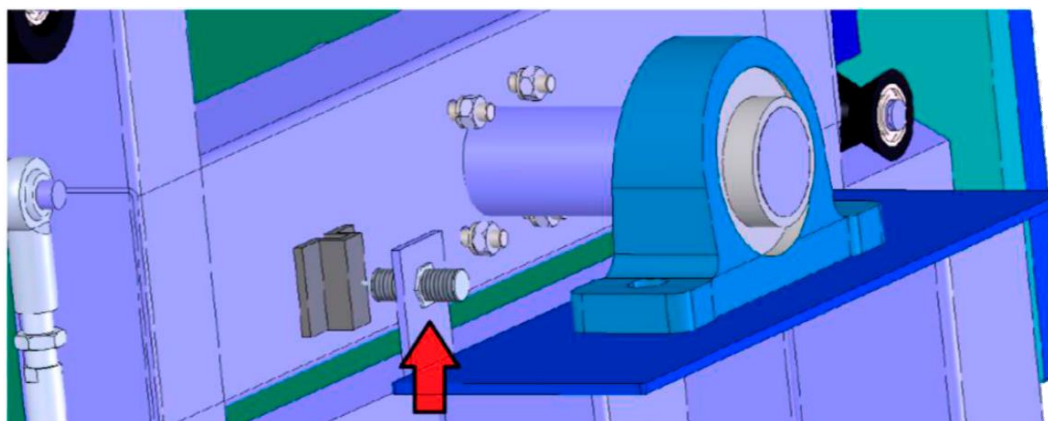
Phase 3: Rotation

The tipper starts to rotate in five stages (Fig. 8) until the proximity detector (Fig. 9) detects a rotation of 180º and comes to a halt, leaving the fruit supported on the upper belt (which will now be the lower belt) without being knocked. In this way, any imperfections in the product are avoided.

Fig. 8 Crate rotation system

Fig. 9 Proximity detector

Phase 4: Release

During this phase the pistons lift the belt releasing the crate (Fig.10).
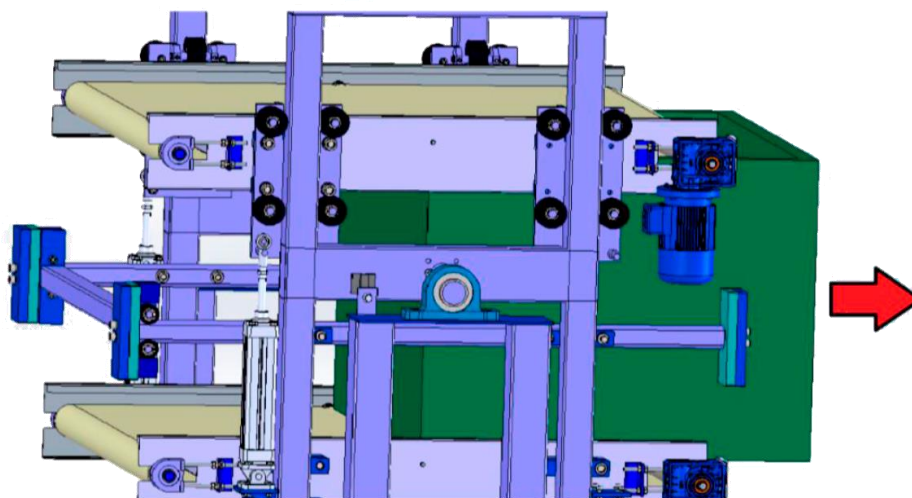
Fig. 10 Release of the crate

Once the crate has been released, the conveyor belts start moving allowing the crate to pass to the next stage of the production line, in which the crate ascends by means of the existing production line tracks until it reaches the crate stacker and the fruit continues along a different conveyor belt.

3   Results

The final design of the new crate tipper machine (Fig.11) has a simple structure, is compatible with the existing production line and is capable of performing the four stages previously described.
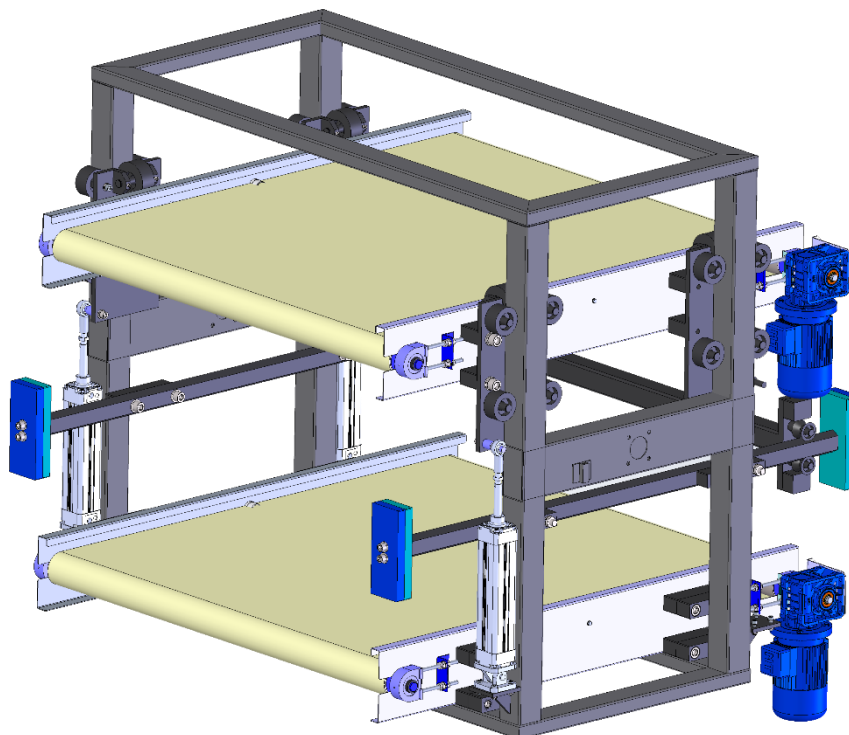
Fig. 11 Final design of the tipper

4 Conclusions

There are existing crate tipper machines on the market which perform the tipping action at different angles. Some of them perform the tipping action with a rotation angle of 135º, which tip the pieces of fruit so they fall onto the production line in cascade and, as a consequence of the impact, the pieces of fruit suffer mechanical damage. There are also others which perform the tipping operation with a rotation angle of 180º, but these are only compatible with the production lines of the same commercial firm. For these reasons in the present work the design for a new crate tipper machine is presented, which has the following advantages:

- *Functionality,* allowing the tipping of the crate with a rotation angle of 180º, so the crate is emptied completely without damaging the pieces of fruit.
- *Versatility:* the tipper can be adjusted to the different existing crate sizes that are on the market depending on the product that will be handled.
- *Adaptability:* the tipper has specific physical dimensions depending on the space available at the transfer point of the handling line of the product.

Furthermore, this conceptual design presents a real practical case where due to the low planning and the high insecurity of innovations, it is necessary to include the client as a member of the design process team.

The conceptual design proposed in this work is being developed for several regional companies which have been interested in this kind of design due to the characteristics of their installations.

References

[1] M. Van Zeebroeck, V. Van linden, H. Ramon, J. De Baerdemaeker, B.M. Nicolaï, E. Tijskens. *Impact damage of apples during transport and handling.* Postharvest Biology and Technology 45, 2 (2007) pp 157-167.

[2] F.R. Harker, F.A. Gunson, S.R. Jaeger. *The case for fruit quality: An interpretive review of consumer attitudes, and preferences for apples.* Postharvest Biology and Technology 28, 3 (2003) pp 333-347.

[3] van der Merwe, M. Muller, M. van der Rijst, I.F. Labuschagné, T. Næs, W.J. Steyn. *Impact of appearance on degree of liking and eating quality expectations of selected apple cultivars.* International Journal of Food Science and Technology 50, 2 (2015) pp 492-499.

[4] F. Hahn. *Actual pathogen detection: Sensors and algorithms - a Review.* Algorithms 2, 1 (2009) pp 301-338.

[5] Z. Li, C. Thomas. *Quantitative evaluation of mechanical damage to fresh fruits.* Trends in Food Science and Technology 35, 2 (2014) pp 138-150.

[6] M. Fossas-Olalla, B. Minguela-Rata, J.I. López-Sánchez, J. Fernández-Menéndez. *Product innovation: When should suppliers begin to collaborate?* Journal of Business Research 68, 7 (2015) pp 1404-1406.

THE USE OF MATHEMATICAL FUNCTIONS IN PRODUCT DESIGN

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Abstract

Most conventional computer aided design (CAD) systems have problems when it comes to graph a 3D surface based on a mathematical function, as an approach to these splines, NURBS and Bézier curves are used. The industry increasingly demand models based on surfaces and shapes defined by mathematical functions.

This article aims to make the study of the art of methodologies used to represent CAD surfaces and evaluate the possibilities to insert a mathematical function for use as a basis for the design of products and the exchange of files between different software.

1   Introduction

The inclusion of modules to work with surfaces in CAD programs provide a new way for products based on design surfaces. Moreover, we can not forget the objective of the designer as Gugelot says, "The aim of the designer must be to create good consumer goods that can be produced and capital goods which are to be consumed".

Based on the words of Hans Gugelot, but considering the progress and the constant change in technology, we have to find new ways and methodologies to reach this objective.

The shape is fundamental in the design but the premises to these forms vary by product design.

Therefore, we have different needs depending on the work to be done. For example, to design a bottle of cologne, have no assumption as to the shape, dimensions only to design the container.

In products where ergonomics are advisable, as is the design of a computer mouse, we have the premise of using a concrete and definite way. Therefore, we must find ways to obtain such form and integrate it into the overall design.

An example of the need of methodology is the one shown by Bao, [1] where an application for obtaining the milling path for the form of a template is explained.

In other products, for example in the design of wind turbine blades, we need a mathematical calculation to design in CAD. A mathematical function defining the form of a shovel [2, 3].

2   Generating surfaces

Aesthetics with the functionality required by the product condition the methodology used for surfaces that will be the basis of design in CAD programs.

For new designs where aesthetics is the base product may be sufficient to use already built modules to generate CAD surfaces in the majority. For example, for designing bottles of cologne (fig. 1).

Fig. 1: Bottle of cologne based on style surfaces

In the redesign of a product on the market with the premise of maintaining a certain way that distinguishes the product over the competition has a relevance that we must consider in their design. It is interesting to find simple and fast methods [4]. To do this, in reverse engineering we have many possibilities that show how to transfer a curve of a product for its design in a CAD system (figures 2, 3, 4, and 5). In this case as a result you have the curve, easy to parameterize and get the product within the CAD system.

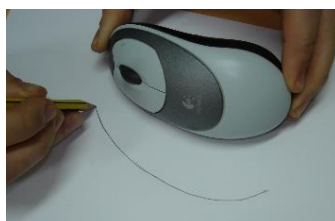Fig. 2: Obtaining a product curve
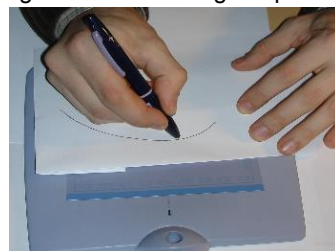

Fig. 3: Curve defining the product

Fig. 4: Step curve to cad

Fig. 5: Surfaces in CAD

These curves used in the reconstruction, in 3D CAD systems, generally tend to be simplified Bézier curves, NURBS and splines for easy graphing [5].

Another possibility for obtaining digital information of a product is the use of the 3D scanner. As a result we have a cloud of points [6] or a mesh usually based on triangles that a subsequently will be treated in a CAD system. In the first case with the help of specific software, Envolute the Geometry Expert, we can get the surface defining the cloud of points (fig. 6 and 7).
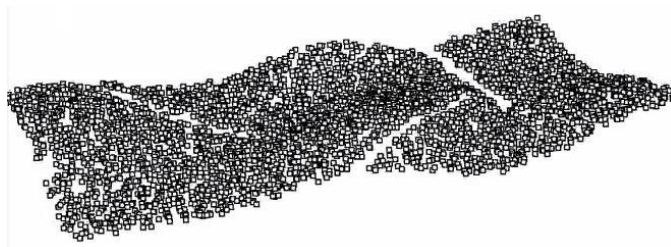
Fig. 6: Cloud of points defining a surface
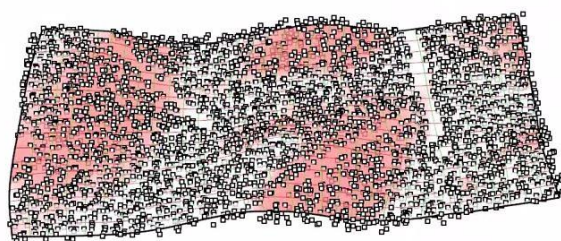
Fig. 7: Surface obtained from a cloud of points

Gálvez Akemi, et al. describe a new methodology to redefine the surface and minimize noise on the surface [7]. In the case of obtaining a mesh from a 3D scanner (fig. 8), we will have to edit the design and clean and change it [7].

Fig. 8: Triangular surface mesh

This section includes the area of medicine, where the advancement of 3D printers has meant new opportunities for this discipline. Thus, it is possible to obtain the 3D design of the human body from an

magnetic resonance (MR), so we can get an impression of both hard and soft elements of the body and allowing for a previous study of the operation. Therefore, the specific software has been developed, such as the one InVesalius (Fig. 9), which allows you to export the result to stl files; thus, the contribution that can perform design engineering has to be considered [8].
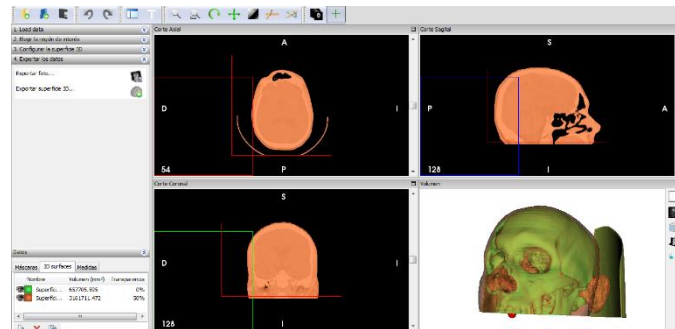
Fig. 9: 3D skeleton from an MR

Likewise, the design of the product, where design and functionality are based on a mathematical function such as a blade of a wind turbine (fig. 10), a suitable cross-sectional shape is obtained from an algorithm [2, 3].
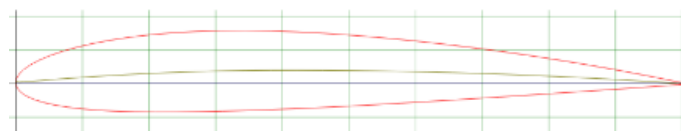
Fig. 10: section NACA 2412

These profiles after being exported to CAD, allow obtaining the shape that defines the blade of the wind turbine (fig. 11).
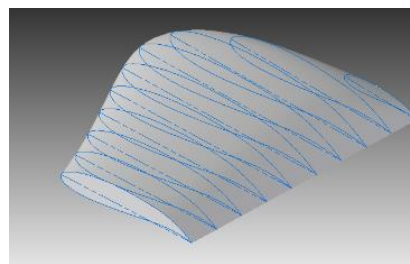
Fig. 11: Wind turbine blade with mathematical basis

So, we increasingly have more multidisciplinary work, we must be able to complete common knowledge that can be used in various developments later. For example, Liu, Yong-Jin et al. offer a new approach to clothing design based on the human body, irregular shapes to define surfaces [9].

With the methods discussed, we must consider the need-problem to obtain surfaces based on mathematical functions. This is where the limitations of CAD systems are to draw a mathematical function in 3D.

The latest versions of CAD, for example AUTODESK INVENTOR 2016, already have their module to insert functions, allowing a section defined by the exact mathematical function (fig. 12).
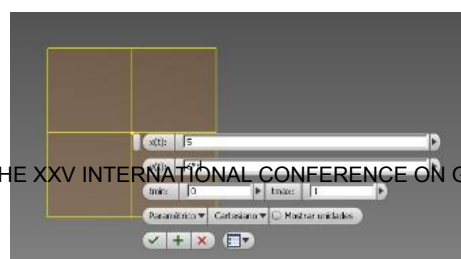
Fig. 12: Designing a mathematical curve function in Inventor

The problems arise when we have to represent the surface with a function (fig. 13); examples: $f(x,y,z)=$ Sin x·y [10].
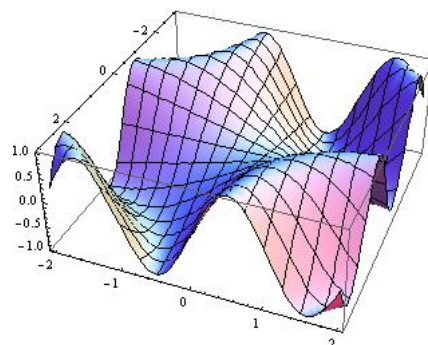
Fig. 12: Function sin x· y obtained in MATLAB

Therefore, we must find new methods to generate surfaces from a mathematical function and use these forms for the design of the product. This would simplify the designer's work. To do this, you have to find methods that integrate different software and import and export getting the best of each software package.

3   Methodology

We need to define a methodology aimed to the transfer of information between different software to enhance results. Each software has developed algorithms for the proper use within its scope, but we need multidisciplinary work, development where communication between different areas working in a project, is uniform, balanced and easy to use, without losing the information or the intrinsic characteristics that allow each software package.

We have to know how the software packages that are required in developing a product and find new ways work methodologies. For 3D mathematical functions, we have different software packages such as Mathematica, Matlab, Octave, etc., these are specialized in mathematical calculations. However, the interest for our work appears in the 2D and 3D graphical representation of mathematical functions, with the possibility to export the graphical representation of functions to a CAD system, not as a cloud of points but directly as surface. For example the function $f(x, y, z) =$ sin XY facilitates and simplifies the post processing system to DAO.

Export to stl file format, using stereolithography 3D printers [11], mathematical function to represent the surfaces obtained by specific software for such operations allows to optimize the result when using software to perform each operation that is optimized.

The disadvantage of the stl format is that divided into a mesh triangles defining the surface with the precision provided by this triangulation is obtained. It may be sufficient accuracy for a prototype, but would not be valid if a surface to produce a more detailed analysis is sought. This requires export to formats step (.stp) or SAT (.sat).

4   Conclusion

The integration of different software packages, for a more efficient design, allows us to seek new avenues for product design. The use of different specific software for each particular operation optimizes the result by using optimized software to the specific operation. If you need to insert a mathematical function to obtain a surface which defines the product, it is suitable to use the specific software for it, for example, Matlab. From the results obtained that data has to be integrated into the CAD system to give the final shape to the product, that is why it is important the process of importing, exporting between different software to minimize loss of information and quality of the result.

It is observed that the file sharing across software systems is oriented to the standard formats, stl. The problem arises when we need surfaces not defined by triangles such as the stl file represents. It is therefore necessary to find ways to export to .sat or .stp, these formats define surface without triangulation, a smooth surface. All this would facilitate and simplify the design of products defined by a surface representable by a mathematical function products.

References

[1] H.P. Bao, P. Soundar, T. Yang, "Integrated approach to design and manufacture of shoe lasts for orthopedic use", Comput.Ind.Eng., 1994, 26, 2, 411-421

[2] Airfoil Tools [online]. Available in:http://airfoiltools.com/airfoil/details?airfoil=naca4412-il

[3] WC. Hsieh, JM. Miao, CC. Lai, CS. Tai, "Experimental Study on Performance of Vertical Axis Wind Turbine with NACA 4-Digital Series of Blades", Advanced Materials Research 2012, 1055.

[4] O. Günay, K. Levent Burak, "Sketch-based surface design using malleable curve networks", Comput.Graph., 2012, 36, 8, 916-929

[5] E. Cuartas Morales, F. Prieto, "Optimización de la representación con superficies NURBS de imágenes de rango", Vol. 15 no. 2, 2007 / Energía y Computación

[6] E. Cuesta, P. Fernández, J. C Rico, B. Álvarez, D. Blanco, (2005). Aplicaciones Metrológicas y de Ingeniería Inversa de los láseres por triangulación. Deform. Met, 284, 59-73.

[7] A. Gálvez, A. Iglesias, "Particle swarm optimization for non-uniform rational B-spline surface reconstruction from clouds of 3D data points", Inf.Sci., 2012, 192, 0, 174-192

[8] T. A. C. P. Martins, A. S. Barbara, G. B. C. Silva, T. V. Faria, B. C. Dalava, J. V. L. Silva, (2007). InVesalius: three-dimensional medical reconstruction software. Virtual and rapid manufacturing, 135-141.

[9] L. Yong-jin, Z. Dong-Liang, Y. Matthew Ming-fai, "A survey on CAD methods in 3D garment design" Comput.Ind., 2010, 61, 6, 576-593

[10] C. Pérez López, (2002). Matlab y sus Aplicaciones en las Ciencias y la Ingeniería. Prentice-Hall.

[11] M. Szilvśi-Nagy, Gy. Mátyási, "Analysis of STL files"
Mathematical and Computer Modelling, Volume 38, Issues 7–9, October 2003, Pages 945-960

Review of state of art of Augmented Reality

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Abstract

In this paper the state of the art of Augmented Reality (AR), applications, advantages and limitations are studied.

1 Introduction

Augmented Reality (AR) creates an environment in where the real original information is enriched with virtual information. The first developments used markers but the advancement of technology has generated applications that need no markers. The popularization of mobile devices with high performance has enabled to AR to migrate the applications to the mobile environment to facilitate its dissemination. The AR is changing the way users interact with applications. They have developed many applications in the most varied fields such as games, advertising, travel assistants, education, medical applications, simulation, design, etc.

The aim of this paper is to highlight the current development fields of application of the AR, its advantages and limitations and the improvements to be undertaken by the current technology to be implemented in other areas.

2 Description

AR overlaps, in real time, computer-generated virtual images on real images using portable and mobile computers. There are many programs, applications, and its scope has been extended to such diverse fields as education, medicine, entertainment, car repair...

We must distinguish between immersive reality in which the user sees only computer graphics, augmented reality that combines real, and virtual images. The actual spatial and temporal images provide references the user while virtual images enrich user's experience.

3 Hardware

Usually used hardware elements are:

- Video camera. Gets the images from the real world in which the user is located. Cameras of laptops and mobile phones do not require additional investment, there are not intrusive, and therefore they are well accepted by users. AR-specific devices mounted on the user's head provide more mobility, allow the user hands be free to perform other tasks. However, they are expensive and they can be uncomfortable and limit visibility so their acceptance is more difficult.
- Computer. It generates images to be superimposed to captured by the camera and calculates the point of view of the same by using markers or by computer vision algorithms. The markers are easily recognizable geometric figures printed by the computer that are placed in the user's environment to calculate the position of objects in space and accurately superimpose real images and virtual. The use of markers simplified algorithms to compute the view so lower power calculation is required. It is crucial that they may have enough calculation power to avoid delays in the projected images and adequate immersion of the user is achieved.
- The screens of computers and smartphones or display screens mounted on the head and glasses can be used to display the images. They enable the user to view the images generated by the computer while viewing the real environment. The head-mounted displays give the user freedom of movement. Its most important features are resolution, field of view and precision. It is important to consider ease of installation and ease of use to achieve user acceptance.
- The GPS allows the user to be located in open space and develop applications in the fields of sightseeing, civil engineering and architecture. The early developments employed external antennas that made the devices bulky and heavy, but the generalization of GPS in mobile devices has facilitated their use and acceptance.
- Mobile Phone. Its features make it ideal for AR applications. Current models of smart phones are equipped with cameras, high-resolution displays, GPS, data connection and high computing power. They enable users to enjoy AR applications anywhere and interact with data servers or other users providing engaging experiences.
- Wireless networks. Allow servers to transmit data from computers or mobile phones. Also allow interaction between remote users.

4 Software

The tasks that must usually develop the AR application are:

- Scene capture using usual video systems or specific systems.
- Identification of the scene to estimate the camera position from the environment using algorithms applied to the image. They can be based on markers that allow the rapid identification or alternatively without markers, recognising the image by contrast edges or textures, in this case the algorithms are less reliable.
- Virtual image generation. To allow rapid generation and avoid delays in the projection data it is usually to generate and store previously the images. This implies that virtual content can't be modified in real time.
- Processing the scene. A virtual captured image is superimposed and projected onto the screen from the point of view of the camera.

There is a wide variety of programs ranging from bookstores to online applications. We can mention for computer-based platforms:

- ARToolKit. It is a library for creating AR applications using markers on which superimposes 3D objects.
- BuildAr. It is based on markers. You can use models created with any program and need not be programmed.
- DART. It provides a set of tools for developing applications RA.
- MXRToolkit. Provides routines in C language to develop applications based on bookmarks and simple interface applications.
- D'FUSION. Designed to create professional applications that require features such as high-resolution video, high quality three-dimensional models, gesture recognition and operation without markers.

Applications for smartphones can also use the camera, the display, the GPS receiver, accelerometer and compass to locate mobile phone position and orientation more accurately. If a search is performed in the Android shop for Augmented Reality, we obtain more than 200 applications for the most diverse application areas.

Scheduling algorithms image capture and recognition is laborious, but there are many developers' platforms that facilitate the task, for example:

- Layar. Add digital content, videos and links to print media.

- Junaio is a browser that provides an AR application-programming interface.
- Wikitude. It provides a set of tools for generating applications based on AR for mobile phone. It uses geolocation via GPS or Wi-Fi to determine the user's position and overlay information to the captured image on the screen.
- Vuforia. It provides tools to create applications without using AR markers.
- Mixare. It is a free AR browser available for iPhone and Android.
- GART can superimpose image information captured by the mobile based on geolocalicación.
- Blippar overlays commercial real images without markers.
  IN2AR. It is a platform for applications development.
- STRING AR. Another developer platform on iPhone.
- Aurasma is a development environment based on image recognition applications.

5   User Interaction

It is remarkable the ease of interaction that AR applications offers. No prior knowledge of computers or CAD is required. In many cases, the interaction is simply to move or rotate the markers, mobile phone or glasses. Matsutomo [1] used AR for students to visualize the magnetic field generated from several elements simply using shaped magnets. The student moves the shaped magnet and the magnetic field can be displayed dynamically.
As Gabbard [2] asserts is very important to design the interface to make the user to interact easily and intuitively with the application avoiding rejection. It is also important to avoid delays in the interaction and deviations from the virtual images of the real and with the aim of achieving an attractive and rewarding dive.

6   Fields of application

The ubiquity of laptops with camera and smartphones on the one hand and the ease of use and attractive applications based on AR caused the development of a wide array of applications in diverse fields from entertainment to military, education etc. All of them enrich the user experience in a simple, intuitive and attractive way. Here are the most common fields of application:

- In the area of design, it is crucial for development teams to visualize design models in different phases as exposed Yasojima [3]. In the initial stages of the design AR can be used for a group of potential users of a product to evaluate the aesthetic qualities of different design concepts. As Shen [4] indicates the use of AR in combination with the CAD allows users to view the designs using virtual interfaces. Whether users are in the same place or geographically distributed using the AR increases the attention and participation. Frund [5] applies AR based concurrent design for the automotive industry.
- Prototyping is costly in time and financial resources, using a rudimentary prototype completed with virtual elements designers can achieve satisfactory decisions in less time. Regenbrecht [6] shows an application that lets you use AR to display models for geographically distributed participants. Awareness of other participants is established and facilitates creativity. The semi immersive aspect of the AR brings more realism and facilitates the development of applications. Regarding the concurrent design, two types of applications are used: Shen [4] uses applications that only displays designs and Li [8] refers applications of co-design. Most applications only displays models that allow you to review and annotate dimensional models concurrently. Co-design applications can create, modify and manipulate models in the space of the AR during the different phases of the product life cycle reducing design time and cost. Multiple copies are synchronized through permissions. Only the user who has permission can modify a model. The application must ensure visualization, interaction with users, real-time modeling and consistency of the different copies. The current level of tracking accuracy does not meet the need to develop a detailed design. Another problem is the translation of polyhedral solid models to facilitate their representation, which hinders the spread of the amendments made in the AR environment CAD model. It is hoped that future developments will increase the accuracy and allow direct modification of solid models using AR in a collaborative environment. For example Fuge [9] has developed an application of AR focused on conceptual design to modify free surfaces.
- Different applications have been developed in the field of production. For example Nee [10] develops applications focused on simulation and learning. However, they encounter the lack of precision of the displays and the estimation of manual operations and delays in updating the images. As in previous cases, it is expected that future developments avoid these drawbacks. An example of advanced development is provided by Xi [11], he proposed AR system to provide visual feedback of transactions based on an atomic force microscope and after that, nanoparticle manipulations can be performed.

AR applied to maintenance reduces the operator's training, the operating time, and the possibility of errors. Henderson [12] shows the benefits of providing an application of AR to technical maintenance of military equipment. Reduce the time required to locate a task and the number of movements required for repair or replacement.

- For teaching applications they have been developed AR for different subjects like math, geometry, electromagnetism, biology etc. Parhizkar [13] points out that the increasing power of mobile phones makes them effective in the field of teaching, allowing access to learning materials anywhere and regardless of the hour. Although the chances of hardware and software are limited, so it is necessary to limit the content, maintaining a friendly environment. Proposes the following steps in order to develop applications: assess the capabilities of the system, analyze user needs, develop the contents and finally designing the interface. In all it highlights the ease with which students can visualize different elements, improving spatial skills and optimizing knowledge transfer. Pengcheng [14] referring to the experimental education indicates increased interest by students, simplifies shows and it does not require expensive equipment. As an example, adding a marker to a book you can visualize the three-dimensional model of a part (Fig. 1) in this case a crankshaft. This is achieved with little effort to enrich books with attractive content and effective for better viewing for students.
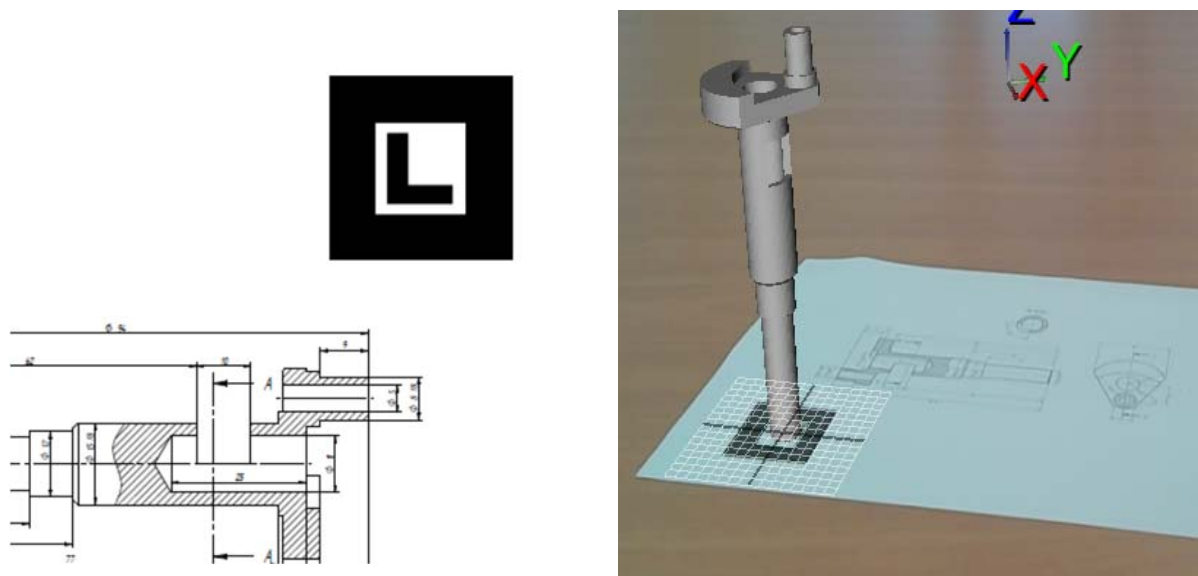

Fig. 1. Left, printed page with marker. On the right the result on screen.

- Grasset [15] describes the experience of different users with a book enriched with AR that incorporates both static visual content such as sounds and animations. It highlights the acceptance and interest shown by users. Ko [16] referred to as advantages of using the AR education geometrically easy to manipulate virtual models, the ability to replace physical models, improved interaction, ease of viewing and to promote the participation and interaction between teachers and students. In addition, Salmi [7] emphasized that the use of AR in education promotes changes in the roles of teachers and students, from teaching centred Teaching oriented to improved student participation. Wu [18] points out the successes of AR based applications to improve the teaching-learning process. The specific improvements are: improves the compression of dynamic and complex systems, promotes a clearer understanding and improves spatial skills. It also allows overcoming learning difficulties of unobservable phenomena. In addition, he points out challenges: the teacher is no longer the centre of the class; instead, a student-centred model that generates resistance among teachers is developed. Students on the other hand could be overwhelmed by the amount of information coming from different sources and multiple tasks to be developed simultaneously. Another aspect is the inflexibility of AR applications; the teacher cannot easily adapt the application to the needs of the specific teaching. A field is being developed that combines play and learning as stated Juan [19] evaluated the most noteworthy aspects of the use of an application of AR like a set of building blocks for learning about endangered animals.
- In the field of psychology Bottle [20] proposed to use the AR to treat phobia of cockroaches with positive results. Traditional therapy involves exposing the subject to cockroaches so that rejection and anxiety decrease. Many patients avoid treatment and neglect is usually high. Using AR, rejection is decreased and patient involvement increases.

- As Rankohi [21] exposes fields of application of the AR in construction focused on visualization, interaction and information transmission. For example, Kang [22] proposed to use the AR for design tasks such as road embankments simulation, alternative routes and structures. The AR design facilitates comparison between possible alternatives. Fonseca [23] states that the AR is well accepted in academic settings to display simple architectural designs but not for complex projects with large volume and details.
- Geographic information systems can also benefit the AR. Hugues [24] classifies AR applications in the field of geographic information systems into two types: AR enriched maps that allow you to explore different types of information from different viewpoints by markers and increased territory that supplies additional information to the user from the environment, for example superimposing text on images.
- A significant addition to the youth leisure is dedicated to computer games. As Wetzel [25] shows AR allows incorporating the environment of the player in the game. Combining real and virtual images a much richer content experience is achieved.
- Most used medical applications are preparation and simulation of surgical procedures, education and rehabilitation of patients. Nicolau [26] shows the current AR applications in the field of minimally invasive surgery. The first step is the visualization of patient anatomy from previously obtained data for the operation.
- The effectiveness of assistive technology and rehabilitation increases as indicated by Ong [28] by improving AR independence of users with sensory or motor impairments. For example applications have been developed to provide auditory information to the visually impaired based on computer vision that allow you to move more freely. In the case of the rehabilitation of motor skills exercises are often tedious and not very motivating. The use of overlapping images improves motivation and involvement of the subject, can also feedback on patient progress achieved and adapt the exercise to specific user needs. Applications designed can be easily customized and allow you to create controlled and adjusted to each user environments also allow more intuitive and engaging experiences with real objects.
- Regarding military applications, Livingston [29] emphasizes the training of combat units, maintenance, helmets of fighter pilots and urban combat. AR projectors mounted in the head of the soldiers allow recreate combat situations during training. In the case of the pilots it has been used since the 60s of last century AR helmets that allow the pilot visualize the environment occluded by cab from information from aircraft sensors and information about targets, points step and other useful information. Also applications have been developed to assist infantry units in urban environments that provide information for streets, indoors, targets, etc. using projectors mounted in the head.
- In the field of advertising Huang [30] states as the AR is an attractive technology for visitors of trade shows compared to static media. Also many companies have developed mobile AR applications to advertise their products.
- Geroimenko [31] shows the possibilities in the cultural field with the development-oriented tourist information display application such as applications for museum visitors that can display routes and visual and auditory information of the entries. The same applies to the ruins which can also incorporate digital reconstructions of the original monuments. It may be noted the feeling of immersion of the combination of real and virtual content.

Application fields are numerous and all of them user experience with additional projected onto the user's environment in an intuitive and attractive way information is enriched.
As quoted by Olsson [32] the best rated applications by the users are those that provide relevant and contextualized generating savings of effort and time. It has been observed that the applications are used mainly to display information for the user but are more difficult to retrofit the system because of limitations in the accuracy of the monitoring and modification of virtual information in real time.

7   Limitations and challenges

Krevelen [33], Carmigniani [34] and Erro [35] cited the following challenges to overcome to extend the use of the AR:

- Portability. Systems with viewers mounted in the head, controls, and computer backpack with batteries are heavy and not easily accepted by users.
- Delay in the projection from the current position of the user. Different techniques are being developed, for example previously calculated virtual information and prediction of the future position to reduce the errors.
- Depth perception is difficult. In this field, they are developing stereoscopic projectors.
- Information overload. The interface must be designed to prevent excess of information that could distract the user about caring for their environment or tasks to perform.

- Social acceptance. The equipment must be aesthetically appealing and discreet. They must also overcome ethical issues such recording people without their knowledge.
- The tracking and detection of objects without using markers requires the development and optimization of current software
- The use of native CAD data is complicated.

8   Conclusions

The spread of computers and smartphones combined with different AR tools enables the generation of applications for many fields that are generally accepted and valued positively. As pointed out there are challenges to overcome in order to extend applications and improve the experience and user acceptance. These challenges define lines of work such as improving the accuracy and speed of the track, removing markers and the possibility that the user modify the virtual content.

So far, user feedback has been mostly visual. Acoustic and haptic feedbacks enriches the user experience and make possible access to it for the visually impaired.

Other lines of work are automated content creation from CAD files, multiplatform applications and gesture recognition. The development of these lines would allow for example the cooperative design between the personnel involved in the product life cycle geographically remote, with different levels of knowledge of the tools of CAD, different CAD systems and different AR platforms.

References

[1]   Matsutomo, S., Miyauchi, T., Noguchi, S., & Yamashita, H. (2012). Real-time visualization system of magnetic field utilizing augmented reality technology for education. Magnetics, IEEE Transactions on, 48(2), 531-534.

[2]   Gabbard, J. L., & Swan, J. E. (2008). Usability engineering for augmented reality: Employing user-based studies to inf orm design. Visualization and Computer Graphics, IEEE Transactions on, 14(3), 513-525.

[3]   Yasojima, E. K. K., Meigui ns, B. S., & Meiguins, A. S. G. (2012, July). Coll aborative Augmented Reality Application for Information Vis ualization Support. In Information Visualisation (IV), 2012 16th International Conference on (pp. 164-169). IEEE.

[4]   Shen, Y., Ong, S. K., & Nee, A. Y. C. (2010). Augmented reality for collaborative product design and development. Design Studies, 31(2), 118-145.

[5]   Fründ, J., Gausemeier, J., Matysczok, C., & Radkowski, R. (2005). Using augmented reality technology to supp ort the automobi le development. In Co mputer Supported Cooperative Work in Design I (pp. 289-298). Springer Berlin Heidelberg.

[6]   Regenbrecht, H. T., Wagner, M., & Barato ff, G. (2002). Magicmeeti ng: A collaborativ e tangible augmented reality system. Virtual Reality, 6(3), 151-166.

[7]   Gebril, M., & L ashkari, H. (2012). Andro id mobile augmented reality application based on different learning theories for primary school children. In 2012 International Conference on Multimedia Computing and Systems (pp. 404-408).

[8]   Li, W. D., Lu, W. F., Fuh, J. Y., & Wong, Y. S. (2005). Collaborative computer-aided design—research and development status. Computer-Aided Design, 37(9), 931-940.

[9]   Fuge, M., Yumer, M. E., Orbay, G., & Kara, L. B. (2012). Conceptual design and modification of freeform surfaces using dual shape representations in augmented reality environments. Computer-Aided Design, 44(10), 1020-1032.

[10]   Nee, A. Y. C., Ong, S. K., Chryssolouris, G., & Mourtzis, D. (2012). A ugmented reality applications in design and manufacturing. CIRP Annals-manufacturing technology, 61(2), 657-679.

[11]   Xi, N., Song, B., Yang, R., & Lai, K. (2011). Augmented Reality for Nano Manipulation. In Handbook of Augmented Reality (pp. 435-447). Springer New York.

[12]   Henderson, S., & F einer, S. (2011). E xploring the benefits of a ugmented reality documentation for mainten ance and repair. Visualization and Computer Graphics, IEEE Transactions on, 17(10), 1355-1368.

[13]   Parhizkar, B., & Zaman, H. B. (2009). D evelopment of an Augmented Reality Rare Book and Manuscript for Special Library Collection (AR Rare-BM). In Visual Informatics: Bridging Research and Practice (pp. 344-355). Springer Berlin Heidelberg.

[14]   Pengcheng, F., Mingquan, Z ., & Xueson g, W. (2011, Ma y). The significance and effectiveness of Augmented Reality in experimental education. In E-Busin ess and E-Government (ICEE), 2011 International Conference on (pp. 1-4). IEEE.

[15]   Grasset, R., Dünser, A., & Bi llinghurst, M. (2008, December). Edutainment with a mixed reality book: a visually augmented illustrative childrens' book. In Proceed ings of the 2008 International Conference on Advanc es in Co mputer Entertainment Technology (pp. 292-295). ACM.

[16]   Ko, C. H., Cha ng, T. C., Chen, Y. H., & Hua, L. H. (20 11). The application of augmented reality to design education. In Edutainment Technologies. Educational Games and Virtual Reality/Augmented Reality Applications (pp. 20-24). Springer Berlin Heidelberg.

[17]   Salmi, H., Kaasinen, A., & Kallunk i, V. (2012). Towards an open learning environment via augmented reality (AR): Visualising the invisible in science centres and schools for teacher education. Procedia-Social and Behavioral Sciences, 45, 284-295.

[18]   Wu, H. K., Lee, S. W. Y., Chang, H. Y., & Liang, J. C. (2013). Current status, opportunities and challenges of augmented reality in education. Computers & Education, 62, 41-49.

[19]   Juan, C. M., Toffetti, G., Abad, F., & Cano, J. (2010, July). Tangible cubes used as the user interface in an augmented reality game for edutain ment. In Advance d Learning Technologies (ICALT), 2010 IEEE 10th International Conference on (pp. 599-603). IEEE.

[20]   Botella, C., Breton-López, J., Quero, S., Baños, R. M., Garcia-Palacios, A., Zaragoza, I., & Alcaniz, M. (2011). Treating cockroach phobia using a serious game on a mobile phone and augmented reality exposure: A single case study. Computers in Human Behavior, 27(1), 217-227.

[21]   Rankohi, S., & W augh, L. (2013). Review and analysis of augmented reality literature for construction industry. Visualization in Engineering, 1(1), 1-18.

[22]   Kang, L. S., Moon, H. S., Dawood, N., & Kang, M. S. (2010). Development of methodology and virtual system for optimised simulation of road design data. Automation in Construction, 19(8), 1000-1015.

[23]   Fonseca, D., Martí, N., Redondo, E., Navarro, I., & Sá nchez, A. (2014). Relationship between student profile, tool use, participation, and academic performance with the use of Augmented Reality technology for v isualized architecture models. C omputers in Human Behavior, 31, 434-445.

[24]   Hugues, O., Cieutat, J. M., & Guitton, P. (2011). Gis and augmented reality: State of the art and issues. In Handbook of Augmented Reality (pp. 721-740). Springer New York.

[25]   Wetzel, R., Blum, L., Broll, W, & Oppermann, L. (2011). Designing mobile augmented reality games. In Handbook of Augmented Reality (pp. 513-539). Springer New York.

[26]   Nicolau, S., Soler, L., Mutter, D., & Marescaux, J. (2011). Augmented reality in laparoscopic surgical oncology. Surgical oncology, 20(3), 189-201.

[27]   Alaraj, A., Charbel, F. T., Birk, D., Tobin, M., Luciano, C., Banerjee, P. P., ... & Roitberg, B. (2013). Role of cranial and spinal virtual and augmented reality simulation using immersive touch modules in neurosurgical training. Neurosurgery, 72(0 1), 115.

[28]   Ong, S. K., Shen, Y., Zhang, J., & Nee, A. Y. (2011). Augmented reality in assistive technology and rehabilitation engineering. In Handbook of Augmented Reality (pp. 603-630). Springer New York.

[29]   Livingston, M. A., Rosenblum, L. J., Brown, D. G., Schmidt, G. S., Julier, S. J., Baillot, Y., ... & Maassel, P. (2011). Military applications of augmented reality. In Handbook of Augmented Reality (pp. 671-706). Springer New York.

[30]   Huang, Y., Jiang, Z ., Liu, Y., & Wang, Y. (2011). Augmented reality in exhibition and entertainment for the pu blic. In Handbook of Augmented Reality (pp. 707-720). Springer New York.

[31]   Geroimenko, V. Augmented Reality Technology and Art: The Analysis and Visualization of Evolving Conceptual Models. 2012. Information Visualization (IV), 2012 16th International Conference on. Pág. 445 – 453

[32]   Olsson, T., Kärkkäinen, T., Lagerstam, E., & Ventä-Olkkonen, L. (2012). User evaluation of mobile augmented reality scenarios. Journal of A mbient Intelligence and Smart Environments, 4(1), 29-47.

[33]   Van Krevelen, D. W. F., & Poelman, R. (2010). A survey of augmented reality technologies, applications and limitations. International Journal of Virtual Reality, 9(2), 1.

[34]   J Carmigniani, J., Furht, B., Anisetti, M., Ceravo lo, P., Damiani, E., & Ivkovic, M. (2011). Augmented reality technologies, systems and appl ications. Multimedia Tools and Applications, 51(1), 341-377.

[35]   Erro, A. M., Escuder o, María del Mar Espinosa, Domínguez, M. (201 4). Aplicaciones industriales de entornos de realidad virtual y de realidad aumentada. Dyna, 89(4), 382-386.

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Design and development of a modular recumbent trike for different working scenarios

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Abstract

Today recumbent trikes manufacturers are producing high quality products with several models to choose from. However most of them are developed to run in particular scenarios, causing the disuse of the trike for different conditions. This communication presents the design of a modular recumbent trike that enables multiple configurations by switching between the developed modules. This manner, the proposed design permits to obtain different characteristics and overcome situations that would not have been possible before. The product design consists on a main trike structure and 7 modules classified in three blocks: Front, suspension and traction. Furthermore, 3 assemblies are proposed to cover all the possible scenarios. The obtained results demonstrate that modularization can be applied to recumbent trikes with only some small changes and that the adaptability of the proposed design benefits both the companies (they can reach the necessities of more users) and the riders (they can use it on much more situations).

1   Introduction

A recumbent trike is a three wheeled vehicle where the driver is seated in a recumbent position, facing the body upwards and with the crank-set on the front part (Fig. 1). Recumbents are considered an alternative to bicycles, because of its better aerodynamics and comfort. These advantages are popularizing them and in recent years the interest in recumbent trikes has been growing progressively.

Fig. 1 Recumbent trike

However, each rider tends to use the recumbent trike according to his habits and preferences, for example transportation, leisure, touring, or racing. This enlarges the necessity to produce multiple models, with different characteristics to satisfy the desires of potential consumers. Moreover, designing customized models for an optimal performance on particular applications diminishes its versatility, making them inappropriate for other ones.

Another limiting factor is the weather and seasonal changes: standard trikes are thin wheeled vehicles which compromise its performance on winter conditions; snow and ice can make them unusable and end up stored in garages. These reasons arise the necessity of creating a new concept of trike which can be run on a larger number of situations.

In order to define this new design, two production strategies must be considered: integral and modular [1]. In Integral design each component may implement many functions and each function is implemented by many components and as a result more compact architectures can be achieved. Taking this into consideration, integral production strategy will be preferable when the important functions depend on size,

shape or mass. On the other hand, modular product design aims at reducing the complexity of the product in order to reduce the uncertainty in product development activities. In this case a number of relatively closed systems of independent parts are created, which means that the product will have more components. Whereas this modularized architecture results on less elegant and compact products, with a more advanced modularization strategy, simple but adaptable products can be designed [2]. Some advantages of modularized product development are:

- *Covering more demand*: industry tries to focus on a high volume production in order to reduce costs [3], so the creation of different models of the same product would deplete this capacity. The concept of modularity arises in order to produce families of products capable of ensure a wide range of characteristics and thus cover more demand only by removing some modules of the main product [4].
- *Reducing costs*: Modular Concepts are important for the companies to reduce costs. In order to keep costs down while increasing product variants, concepts of modular design are used.
- *Flexible products:* The market is not only wide ranged in interests, but there are also a lot of competitors trying to be the first on offering what consumers desire. In this sense, modularization can help on the process of developing products to adapt to the new preferences reducing its risk, costs and time when only a simple module of the product can be developed to make the old product suitable again, instead of designing it from scratch. Some of the design decisions can also be delayed because of their lower impact on the product. An agile product will also be capable of adapt to new manufacturing technology or last minute changes which also means an easier job for the designers [5]. Controlling the impact of changes and being flexible to respond to changes are the benefits of product agility.
- *Customized product*: Another advantage of modularity is that the consumers can take part on the product customization, by picking from the existing modules the ones that are most suitable for them, or by proposing or creating their own. That is quite common nowadays: internet has approached the design process to everyone's house, and you can for example select the characteristics of your new car seated in your desktop.
- *Upgradable products*: Modular products are designed to be updated to newest requirements by replacing some of the modules, contrary to integral products that have to be replaced throughout the whole. This characteristic enlarges the product life.

Considering all the mentioned above, this communication presents the design of a modular recumbent trike, named UPTRIKE, that enables multiple configurations by switching between the developed modules, obtaining different characteristics and overcome situations that would not have been possible before.

2   Materials and methods

The surface quality and the climatic conditions are two factors that affect the designs of a trike. It is not the same to drive through a path with gravel than a paved highway. The climate can force the trike to face unfavourable conditions such as snow or ice. The best way to face these situations is creating different modules to meet the customer´s needs. This leads to the definition of two kind of modules: the permanent or fixed modules that will be present in all the configurations, and the variable modules that could be selected according to the scenario and weather conditions.

2.1   Permanent modules

During the modularization of a product, a main objective is to have the highest number possible of common parts. In the UPTRIKE product family, these fixes parts are the following:

Trike frame and crank

The frame is the biggest part of the trike and acts as the point of attachment to the rest of the parts. The prismatic crank containing the pedals is also part of the central bone of the trike and will be part of all the assemblies. The retractable frame (Fig. 2) requires a chain capable of varying its length.

Rear frame and brake disc pads

It is essential that the rear part of the frame to stay the same, regardless of the other modules and parts. Hence, the rear frame (Fig. 3) has been designed in detail adapting it to the traction and suspension modules on the simplest way possible. Moreover, the brake disc pads are always fixed to it making them also a permanent part.
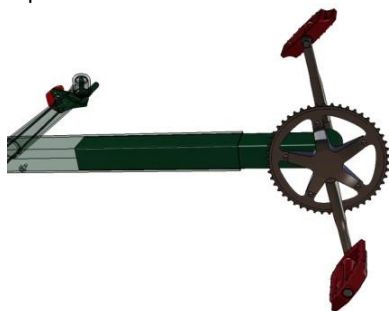

Fig. 2 Retractable frame   *Fig. 3 Rear frame*

Steering system

The steering systems designed for all the UPTRIKE family products have been unified on a polyvalent system, which means that the handlebars and steering control rods are permanent and only the different kingpin design makes the difference (Fig. 4).

Motor and free wheel

Due to the simplicity to disassemble hub motors (Fig. 5), it enables the shell to split from the motor using fewer screws. This advantage is useful on terms of modularity. The shell will vary depending on the module, but the motor will remain on them, which saves a significant amount of money. Given that the free wheel is coupled to the motor it also becomes a permanent part of the UPTRIKE product. This component has been dimensioned in order to guarantee that the rider will be able to help the motor on a wide range of speeds.

Battery, controller and cycle analysis

Batteries are plugged into the controller and then to the motor so these can be kept in all assemblies simply by disconnecting the wire that connects one to another. Although the controller is screwed to the frame and will stay attached, the battery is removed when it needs to be recharged through the guide (Fig. 6).

Fig. 4 Steering mechanism	*Fig. 5 Hub motor exploded*	*Fig. 6 Controller and battery*
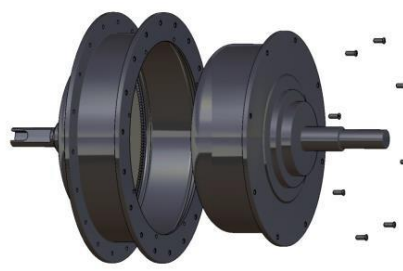
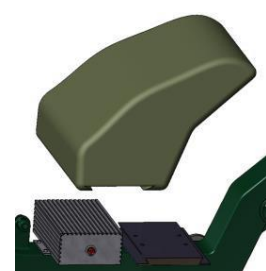## 2.2   Selectable modules

All the desgined selectable modules that comprise the product family of the UPTRIKE can be divided into the three sets shown in Fig. 7 depending on the zone of the frame where they are nested. In the following lines, the two front axis modules are first analysed, then the suspension modules, and finally the three traction modules.
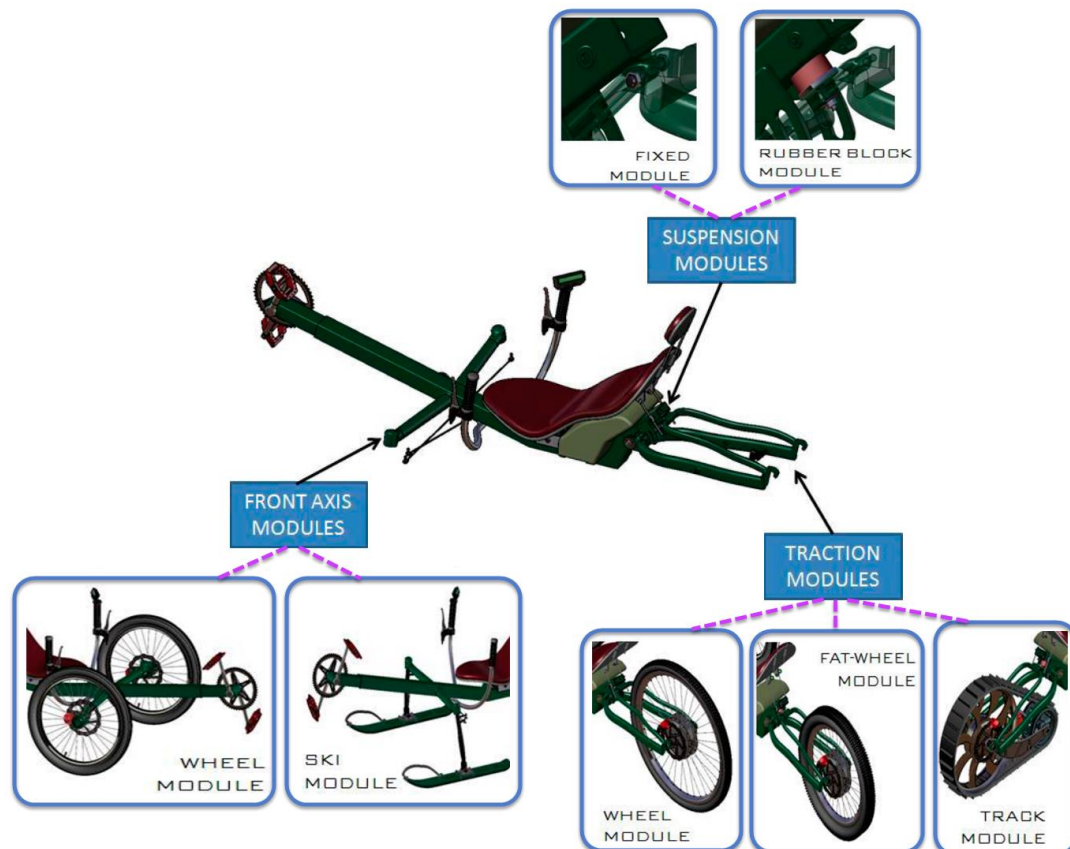
Fig. 7 UPTRIKE selectable modules

2.2.1   Front axis modules

Wheel module

It is foreseen that will be the most used module for the front axis. This one works on the majority of the scenarios except when there is a large amount of snow. The wheel module has two 20" diameter wheels as the majority of recumbent trikes do (Fig. 8). The kingpin is included in the module because of it has a completely different geometry from the one used with the ski. However both have been designed on a way that can be adapted to the same steering system, only by adjusting the length of the steering rods.

Ski module

With an abundance of snow the front wheels end up unusable. This is why the creation of this module with two skis without brakes, similar to the snowmobile ones, is necessary. Its main function is to produce the trike steering with the least friction as possible. Furthermore, to permit a higher adaptability to different ground profiles the ski is able to pitch (Fig. 9).
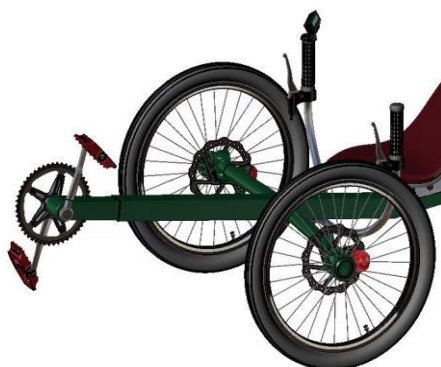

| *Fig. 8 Wheel module* | *Fig. 9 Ski module* |

2.2.2   Suspension modules

The frame and rear frame have been designed to allow the user to decide if install suspension between them or to have them fixed. In some riding conditions a little bit of suspension (Fig. 10) is responsible of the rider's comfort, since dissipates the energy of the vibrations produced. However, when riding on perfectly pavement paths, a rigid frame is more optimal (Fig. 11). The two suspension modules have been designed to be easily switchable and adaptable. In fact, they can be fixed only by screwing up a couple of nuts.
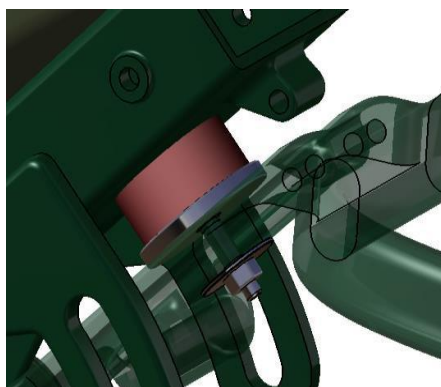
| *Fig. 10 Rubber block suspension module* | *Fig. 11 Fixed frame module* |
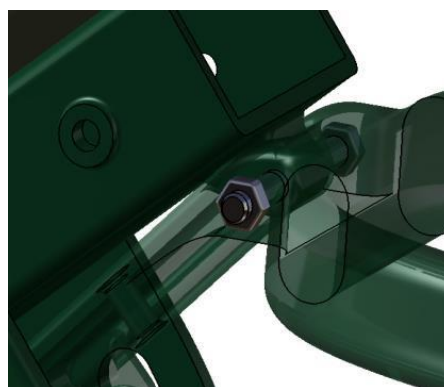
2.2.3   Traction modules

Wheel module

This is the optimal alternative for paved roads. Its appearance is very similar to the rear part of a common trike, with a much wider frame than required for being able to hold the other modules (Fig. 12).

Concerning the wheel size, the 26" wheel is considered as the optimum size because this module provides less friction and inertia that allows the surplus-power to acquire higher speeds.

About contact surface, this module is intended to achieve a small and centred contact surface so the friction and the roller friction losses are as small as possible to let the driver reach higher speeds. This is obtained with thin wheels and with a high pressure on them.

Fat wheel module

This is the all-terrain module and it can work both asphalted roads and snow conditions but not as optimally as the wheel and track traction modules. Its strengths are on irregular paths, wet surfaces, on the grass and terrains with a thin layer of snow and therefore it is designed to be used on routes through the countryside or mountain roads.

This module requires more torque than the wheeled and due to the worst ground conditions the top speed can be reduced. In this case a fat-wheel 20" size instead of the usual 26" has been mounted (Fig. 13). The fact of having a smaller wheel reduce the inertia increasing the torque available. Another reason for this size is that wider tire has a better rolling performance at the same pressure, so a better comfort is obtained because the tyre absorbs better the ground irregularities and has a better protection against punctures [6].
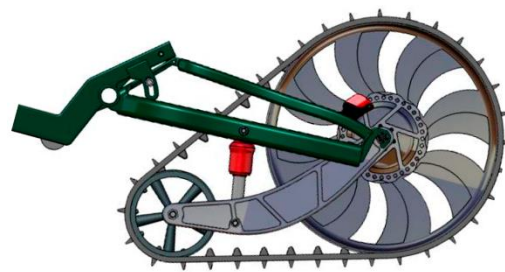
The selection of a smaller wheel means a reduction of the contact surface. Given that, a 80 mm width fat-wheel is chosen to get a bigger contact surface. That also guarantees the extra grip in soils with water, snow or gravel.

Fig. 12 Wheel module   Fig. 13 Flat wheel module   Fig. 14 Track module
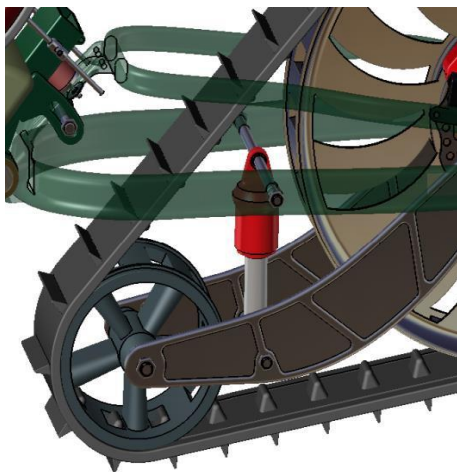
Track module

This module was created for thick ice and snow conditions. After researching on different systems to generate traction on snow, a system similar to the snowmobile was chosen (Fig. 14), since it has a contact surface 20 times bigger than a fat wheel. That provides good operation in presence of large amount of snow, increasing the scenarios where the UPTRIKE can work.

Besides the other rubber block suspension module placed between the two parts of the frame, the Track module has an inner suspension (Fig. 15) fixed on one side to a bar screwed to the rear frame and another bar that also helps coupling the two lateral-bars. This suspension is responsible of maintaining the pressure over the soil as uniform as possible and guarantee the contact of both wheels to it (Fig. 16).

Fig. 15 Inner suspension   Fig. 16 Forces diagram on the track module
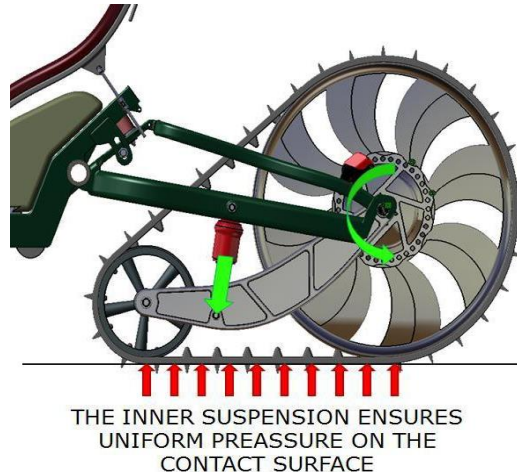
The Track model was studied and designed carefully to reach a higher adaptability to the ground. The geometry of all the parts has been taking in account to ensure a relatively high adaptability to different slopes and bumps.

The inner suspension and the rubber block not only ensures a comfortable ride and a more homogeneous pressure on the contact surface, but also are responsible of giving some margin to the track to change its orientation. They are useful to land on a ditch and to diminish the impact with a bump, holding the required grip to surpass them.

3   Results

In the present work, three possible configurations have been developed using both the permanent and variable modules described in the previous chapter (see Tab. 1): UPTRIKE-Road, UPTRIKE-Grave and UPTRIKE-Snow.

	Front axis	Suspension	Traction
UPTRIKE-Road	Wheel module	Fixed frame module	Wheel module
UPTRIKE-Grave	Wheel module	Rubber block module	Fat-wheel module
UPTRIKE-Snow	Ski module	Rubber block module	Track module

Tab. 1 Assembly configurations

UPTRIKE-Road

The UPTRIKE-Road is considered as the principal assembly. It will cover the functions of a standard three-wheel recumbent trike and will provide the optimal conditions for the majority of the uniformly paved roads and paths.
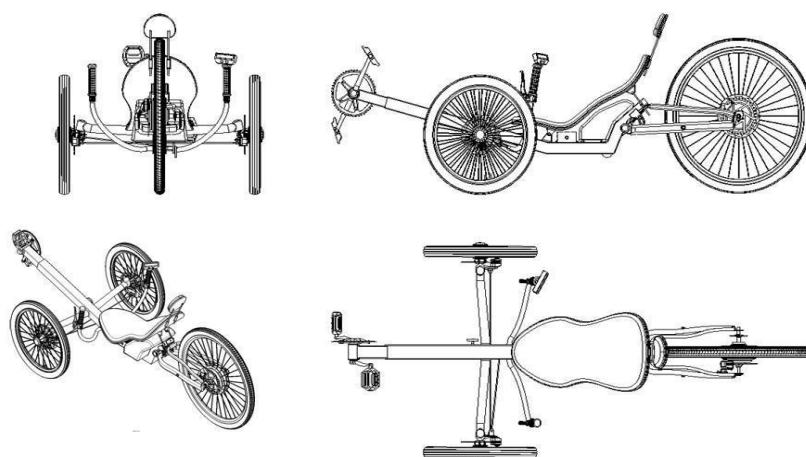
Fig. 17 UPTRIKE-Road layouts

UPTRIKE-Grave

This configuration is aimed for gravel driveways, grassy terrains and irregular paths, among others. The suspension and fat-wheel modules provide a higher cushion effect than on the UPTRIKE-Road version. It can also work over a thin layer of snow or ice.

The implementation of a front suspension module could be analysed in case of necessity, varying the existing front module and increasing the flexibility of the product family.
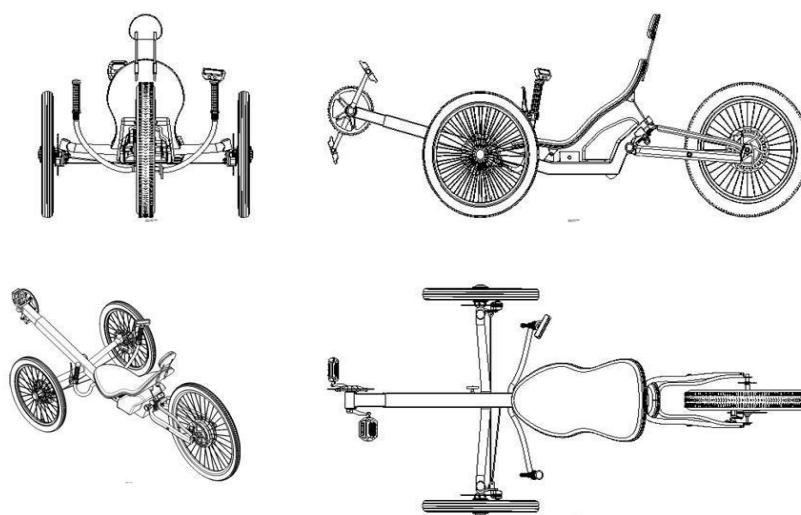
Fig. 18 UPTRIKE-Grave layouts

UPTRIKE-Snow

This is the most original assembly of the UPTRIKE family and it has been specifically designed for extreme snow conditions. While the Track module provides the required grip on the unpredictable snow surfaces, the two skies provide stability and directional control to the trike.
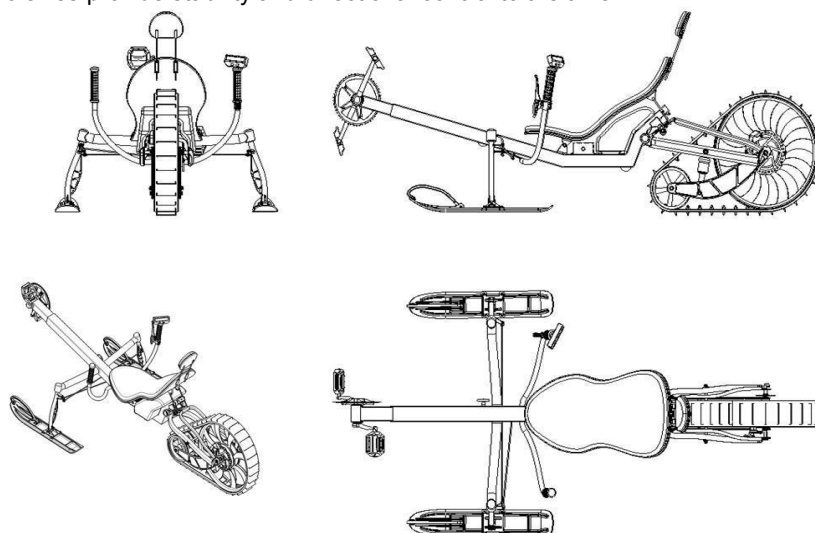
Fig. 18 UPTRIKE-Snow layouts

Comparison

Several possible scenarios have been analysed in Tab. 2, showing that all scenarios have at least one or two modules that have an optimal performance on it.

	UPTRIKE-Road	UPTRIKE-Grave	UPTRIKE-Snow
Paved road	Optimal	Regular	Bad
Flat trail	Optimal	Optimal	Bad
Deep snow layer	Bad	Bad	Optimal
Thin snow layer	Bad	Optimal	Optimal
Wet road	Optimal	Optimal	Bad
Path	Regular	Optimal	Bad
Grassy terrains	Regular	Optimal	Bad

Tab. 2 Assemblies performance on the stated scenarios

4   Conclusions

The results provided in this communication demonstrate the benefits of applying a modular design strategy to a particular product, the recumbent trike. In this case, the trike adaptability to different ground and weather conditions has been improved by dividing the product in three module areas: front wheel, rear wheel and suspension. This is how, by combining the different module of each area, the UPTRIKE is able to be used in scenarios so different as paved flat surfaces or irregular snow paths, preventing temporary disuse.

References

[1]   K. Ulrich, S. Eppinger. Product Design and Development. McGraw-Hill/Irwin 2011.

[2]   K. Foss. Modular Product Design: Creating "Technologically Separable Interfaces". Copenhagen Busines School 1998.

[3]   Y. Wany, B.O. Nnaji. *Functionality-Based Modular Design for Mechanical Product Customization over the Internet*. Journal of Design and Manufacturing Automation 1, 1&2 (2001) pp 107-121.

[4]   P. Hallberg, M. Näbo, P. Krus. Modular sustainable light multi-purpose vehicles. 3rd European Ele-Drive Transportation Conference (EET-2008), 2008, Geneva, pp 11-13.

[5]   J.K. Gershenson, G.J. Prasad, Y. Zhang. *Product modularity: measures and design methods*. Journal of Engineering Design 15, (2004) pp 33-51.

[6]   Sobre neumáticos MTB ¿Es verdad que las cubiertas finas ruedan mejor? http://www.biciclicks.es/2012/10/sobre-neumaticos-mtb-es-verdad-que-las.html   accessed April 2013.

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Designing for the real workforce: Human factors and ergonomics for the new workforce inclusivity

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Abstract

Purpose:
The population is ageing and so is the workforce. Where intellectual and/or creative work (a.k.a. Knowledge work) is demanded, we can benefit from the best of the knowledge and experience acquired though a lifetime, while physical demands are lower. However, current trends present a real challenge for ergonomics and human factors at all levels (physical, cognitive and emotional) which the users are forced to deal with in practice. The current study presents a theoretical framework in order to face the challenge of inclusivity by implementing design changes based on an ergonomics and humans factors perspective.

Method:
The relevant related literature review has been reviewed in order to acquire a vision of the state- of-the-art, covering ergonomics and human factors, inclusive and universal design related works and field studies that cover the issue of the workstations adjustment.

Result:
For this purpose the benefits for the whole workforce and in ergonomics implementation, the current recommendations review, how ABW makes this issue more relevant and how universal design and inclusive design can contribute for this purpose are exposed. A smart system theoretical framework is proposed.

Discussion & Conclusion:
In the discussion the proposed smart system framework and examples are discussed from the Universal Design perspective. Thus a framework for further development of a smart and inclusive workstation system has been exposed. This can serve as a base for the future development and improvement of the proposed system.

1 Introduction

Society is facing a mayor global challenge which affects sustainability, especially from the social point of view The inversion of the population pyramid is predicted for the 2050 [1-3]. In recent years there has been an increase in lifespan which together with a recessing birth rate and the maturity of baby boom offspring brings as a result a population which is aging faster than ever before. According to Eurostat data, senior workforce between 65-74 years of age has increased dramatically by 15 per cent between 2006 and 2011 in the EU (EUROSTAT) while opportunities become scarcer due to economic crisis. As a result, many spend long periods without work or part time job [4]. This phenomenon without precedent, sets a trend which though it will impact will be most accused in a near future, is predicted to remain [5].

There has been a shift from manufacturing to a service-oriented economy. There has been an increase in scope and importance of knowledge based industry [6]. Older persons are highly valuable in this Knowledge work context, for being able to provide the experience, know-how and social skills learned through a living. But the current office environment needs to evolve in order to accommodate a more mature workforce and new work trends.

2   Workstation, ergonomics and new trends

Lack of ergonomics in workstations, regarding layout and design is an old problem in office context which affects the whole workforce [7-9]. Musculoskeletal diseases can appear as a result causing pain and reduced physical functioning, affecting the quality of life [10] and resulting in absenteeism and associated costs for the organization.

If Conscious, (i.e. when pain is too much) then Coping strategies and action can be adopted by the users, such as changing the workstation components (i.e. a more adjustable chair, using a footrest) for more ergonomically designed facilities, or better layout or different strategy (i.e. meeting in person and using telephone calls instead of emailing, or printing instead of reading on the screen).

Results show that users are conscious of health effects of prolonged use and in certain cases the users have adjustable furniture and some users have other items that can benefit a correct posture (i.e. document holders, keyboard tray, height adjustable desk, footrest, etc.). However the results show that the users have limited training on how to improve the situation and there is a limited application of ergonomic practices [7,8]. There are three main recommendations. One is training and education of workers. Secondly it is recommended is to apply recommendations, guidelines and standards in the lay out of the office. Thirdly, it is recommended to supply the appropriate ergonomically designed facilities (workstation components) to better maintain and follow ergonomics standards.

The reason behind why the ergonomics based criteria is not applied to the selection, arrangement of the workstation components and training of the users is not contemplated in these studies. The problem of training is too often a big effort and brings a human cost associated [11,12] as well as costly and not always taken care of or efficient enough. The persons behind product selection and layout implementation in the organizational context is management, who if not aware of the economic impact that the workstation components investment in ergonomics based design might bring is unlikely to invest in such preventive measures [13].

Natural age changes appear at different times for each user the detriment of physical or motor skills [14], like reaching, bending, dexterity and sight [15], or perception, memory and understanding among other changes [16]. These minor ability losses (i.e. long sightedness or arthritis) may not be severe enough to call them 'disability', but may cause significant difficulties when interacting with products [17] such as the workstation and current standard office equipment.

While Knowledge workforce is growing, part time job numbers have raised due to the economic crisis [4]. One of the emergent trends in the workspace is the unassigned workstations, a.k.a. hot desking, or activity based workspace (ABW). Each workstation is available to be shared by any user at a time. Some organizations allow reservations, and then ABW is called Hoteling. And other organizations provide ABW with just the basic elements to accommodate the user for a short time usually to work with a laptop, also known as touchdown area.

It is clear that one-size does not fit everyone. For a short time such as touchdown areas, this lack of fit, might not be a problem. But lack of ergonomics is a problem when used for more than for hours, which is considered to be long in other studies, then ergonomics does become more relevant. When a different user leaves the workstation, the next user is very unlikely to find a workstation that fits his or her preferences and fits properly in order to give support for the body and activity without a change. Diversity regarding physical characteristics becomes even more evident with age, as it is influenced by the result of a living.

Inclusive and universal design can often be used as a synonymous. They both maintain that all mainstream products should be accessible to as many people as technically possible [17]. Universal design can be defined as follows: "The design of mainstream products and/or services that are accessible to and usable by as many people as reasonably possible… without the need for special adaptation or specialised design" [18]. According to the Centre for Universal design, the principles of Universal Design are the following: 1) in use, 2) in use, 3) Simple and intuitive to use, 4) Perceptible information, 5) Tolerance for error, 6) Low physical effort and 7) Size and space for approaching and use [19].

However, as OCAD University points out product design, unlike in the building environment context where Universal Design was born, does not need to come up with a one-size-fits-all solution. While Universal Design is about creating a common design that works for everyone, Product Design has the freedom to create a design system that can adapt, morph, or stretch to address each design need presented by each individual.

However when referring to ABW workstations, where the product is not intended to be used by one person, but by different users and adapt to each of them, the line that separates Universal Design form Inclusive design becomes blurry.

Current workstation components (WoCos), are designed with a single user in mind. And thus assume that they only need to be adapted once. Thus the accessibility, user friendliness and attractiveness of the WoCos are low. And in the ABW workstation case, this combination of lack of usability results in the user not caring, knowing or being able to adapt the WoCos accordingly with ergonomics standards.

3 Proposal: Smart Workstation

In this direction of inclusive design, a smart system that can self-adapt based on ergonomics principles without giving the user the responsibility of adjusting the system, would be interesting, for better addressing the equity in use, simple and intuitive use and low physical effort principles of Universal Design[19].

For this purpose, to design a smart system that can adapt the workstation components to the user condition and preferences first the interaction needs to be defined.

In order to obtain the information for a suitable adjustment of the workstation (weather this adjustment is manual, or by a smart system) the following information is required: physical parameters, different capabilities and personal preferences. This information which is used as an input for the adjustment process flows through the steps described on the following lines.

The physical parameters and the WoCos parameters need to be related to define which information variables should the system control.
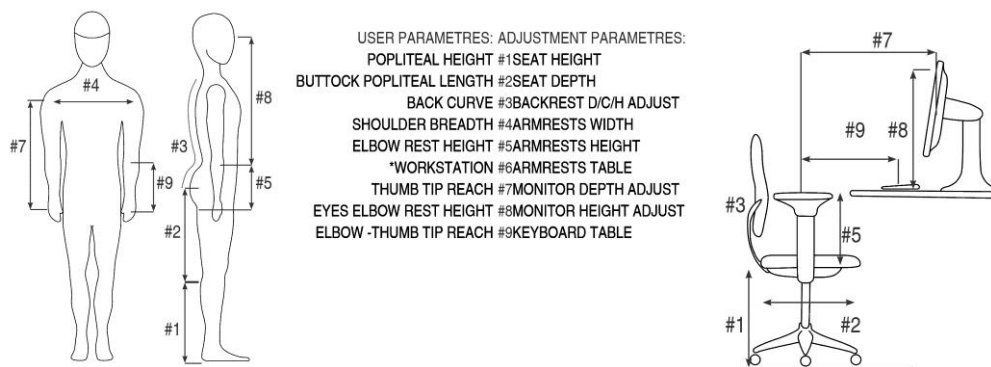
Figure 1 WoCos and User parameters relation

Firstly the information needs to be retrieved from some reliable source. Usually, this information is a product of the user's impression and how well this is interpreted and executed in the system's adjustment. For the physical parameters also active information reading [20-22] is possible. Figure 1 illustrates different information source possibilities (Figure 1). These are based on Users perception and impression, active measuring or stored information. Stored information would add one more step to the process, first measure, which could be done by a professional ergonomist or at a different time and the second step would be the retrieval from storage.
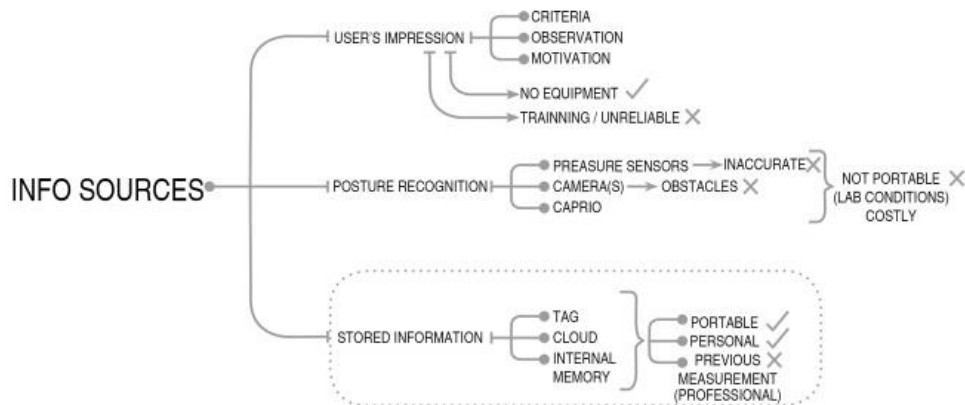
Figure 2 information sources

The information retrieved then needs to be communicated through any of the different mechanisms to the information processing responsible actor. This information processing responsible actor is the person or processor who executes the adjustment action and movement. The actor could be the user, as it is expected in current traditional office furniture, or in case the workstation was smart enough, the actor could be the workstation smart system (through an automated, or semi-automated process). In case the adjustment was to be manually executed accessibility mapping by posture illustrated in Figure 2 are especially relevant (Figure 2), together with other sensory and cognitive factors.
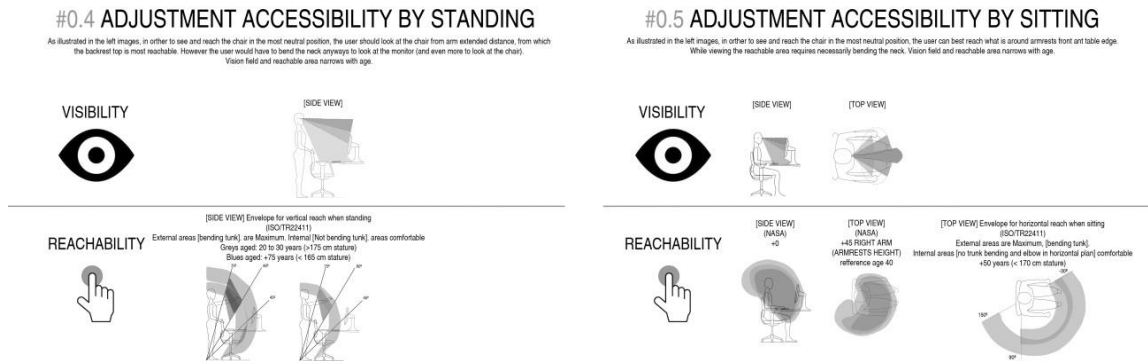
Figure 3 Accesibility by posture

Manual adjustment process timeline illustrates how the adjustment process is usually executed to avoid interfering in previous adjustments and a logical order for the minimal steps amount (Figure 3.).

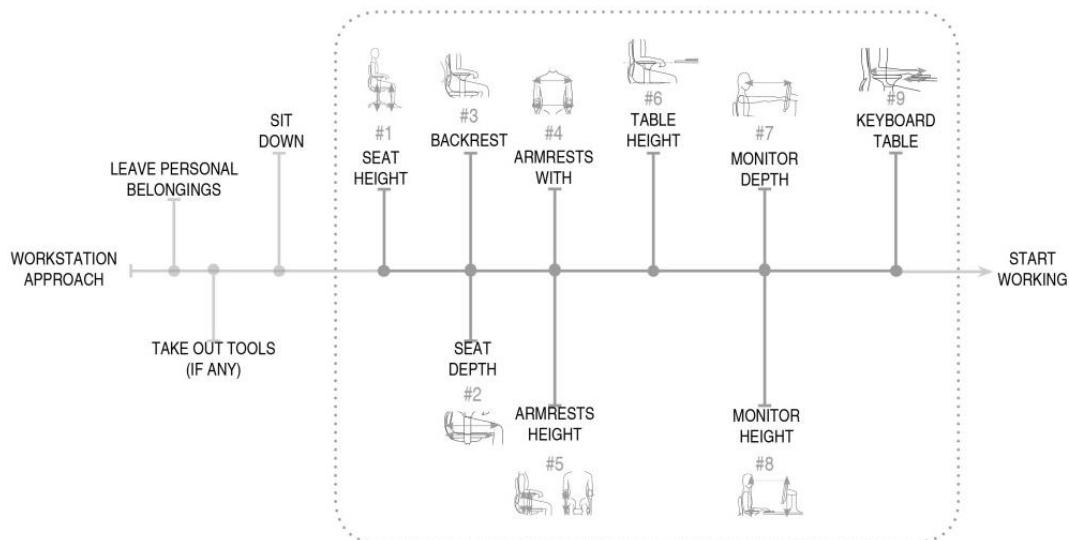*Figure 4 Manual adjustment process timeline*

4   Discussion

In case the adjustment process would be done automatically, the order would depend of engineering of the system. For example if the process was requiring the user to sit at some point of the adjustment process, some designers have thought of using the weight for the rest of the body's anthropometrics estimation [23], and thus the user would be asked to sit at the beginning of the process.

Bonomie et al. have developed a seating system that follows the above described smart system applied to a chair. This smart seating system allows the user to override the smart systems results with manual adjustment and provides a display and interface mediation through a screen [23]. This allows the other two principles of Universal design to be contemplated in the design Flexibility in use and perceptible information.

The manual override of the predefined smart system result provides the user the freedom to readapt the WoCos, not only to the ergonomics, if the provided result by the smart system is not acceptable enough. However, it also provides the user, the possibility to misadjust the WoCos which can go against physical ergonomics principles. Tolerance for error is one of Universal Design's principles. This Tolerance for error refers to the minimization of hazards and adverse consequences of accidental or unintended actions. Thus, apart for limitations, the communication of this tolerance for error should be perceptible by the user.

It is clear that the user plays an important role in the final result of the WoCos adjustment. Thus a deeper study on the users perceptions and responses (i.e. preferences of adjustment, acceptability of the automatic response, usability, etc.) to different Workstation systems, how to communicate the whole arrange of information effectively should be further explored.

5   Conclusion

How can Design contribute in order to face the challenge of the ageing of population, retain and enjoy the advantages of a more mature workforce in the knowledge work has been presented in the current study.

The benefits for the whole workforce and in ergonomics implementation, the current recommendations review, how ABW makes this issue more relevant and how Universal design and inclusive design can contribute for this purpose have been exposed.

The information contents, information flow and system development and examples have been discussed from the Universal Design perspective.

Thus a framework for further development of a smart and inclusive workstation system has been exposed. This can serve as a base for the future development and improvement of the proposed system

Acknowledgement

References

[1] Jackson, R.; Initiative, C.G.A.; Plan, O.T. The Challenge of Global Aging. Center for Strategic and International Studies, National Press FoundationMay 2011, 22.

[2] Serrano, J.P.; Latorre, J.M.; Gatz, M. Spain: Promoting the Welfare of Older Adults in the Context of Population Aging. Gerontologist 2014, gnu010.

[3] Helander, M.G. Forget about Ergonomics in Chair Design? Focus on Aesthetics and Comfort! Ergonomics 2003, 46, 1306-1319.

[4] Eurofund. Working Longer, Living Better: Work After Retirement. 2011.

[5] Fasbender, U.; Deller, J.; Wang, M.; Wiernik, B.M. Deciding Whether to Work After Retirement: The Role of the Psychological Experience of Aging. J. Vocat. Behav. 2014.

[6] Grant, A.M.; Fried, Y.; Parker, S.K.; Frese, M. Putting Job Design in Context: Introduction to the Special Issue. J. Organ. Behav. 2010, 31, 145-157.

[7] Karoney, M.; Mburu, S.; Ndegwa, D.; Nyaichowa, A.; Odera, E. Ergonomics in the Computer Workstation. East Afr. Med. J. 2010, 87.

[8] Shikdar, A.A.; Al-Kindi, M.A. Office Ergonomics: Deficiencies in Computer Workstation Design. Int. J. Occup. Saf. Ergonomics 2007, 13, 215-223.

[9] Fernandez, J.E. Ergonomics in the Workplace. Facilities 1995, 13, 20-27.

[10] Picavet, H.S.; Hoeymans, N. Health Related Quality of Life in Multiple Musculoskeletal Diseases: SF-36 and EQ-5D in the DMC3 Study. Ann. Rheum. Dis. 2004, 63, 723-729.

[11] Tsai, W.; Rogers, W.A.; Lee, C. Older Adults' Motivations, Patterns, and Improvised Strategies of using Product Manuals. International Journal of Design 2012, 6, 55-65.

[12] Porter, J.M.; Case, K.; Marshall, R.; Gyi, D.; Sims neé Oliver, R. 'Beyond Jack and Jill': Designing for Individuals using HADRIAN. Int. J. Ind. Ergonomics 2004, 33, 249-264.

[13] Rose, L.M.; Orrenius, U.E.; Neumann, W.P. Work Environment and the Bottom Line: Survey of Tools Relating Work Environment to Business Results. Human Factors and Ergonomics in Manufacturing & Service Industries 2013, 23, 368-381.

[14] Smith, J. Welcoming Workplace: Designing Office Space for an Ageing Workforce in the 21st Century Knowledge Economy. Helen Hamlyn Centre, Royal College of Art, London 2008.

[15] Maguire, M.; Peace, S.; Nicolle, C.; Marshall, R.; Sims, R.; Percival, J.; Lawton, C. Kitchen Living in Later Life: Exploring Ergonomic Problems, Coping Strategies and Design Solutions. International Journal of Design 2014, 8, 73-91.

[16] Chavalkul, Y.; Saxon, A.; Jerrard, R.N. Combining 2D and 3D Design for Novel Packaging for Older People. International Journal of Design 2011, 5, 43-58.

[17] Waller, S.; Bradley, M.; Hosking, I.; Clarkson, P.J. Making the Case for Inclusive Design. Appl. Ergon. 2013.

[18] British Standards Institute. British Standard 7000-6:2005. Design Management Systems - Managing Inclusive Design - Guide. 2005.

[19] Mace, R. What is Universal Design. The Center for Universal Design at North Carolina State University.Retrieved Retrieved November 1997, 19, 2004.

[20] Martins, L.; Lucena, R.; Belo, J.; Almeida, R.; Quaresma, C.; Jesus, A.; Vieira, P. Intelligent Chair Sensor–Classification and Correction of Sitting Posture. In XIII Mediterranean Conference on Medical and Biological Engineering and Computing 2013; pp. 1489-1492.

[21] Wongpatikaseree, K.; Kanai, H.; Tan, Y. Context-Aware Posture Analysis in a Workstation-Oriented Office Environment. In Digital Human Modeling. Applications in Health, Safety, Ergonomics and Risk Management.; Anonymous .; Springer, 2014, pp. 148-159.

[22] Haveman, S.; Kant, G. Smart Monitoring of Worker Posture in an Office Environment. 2008.

[23] Beck, R.L.; Bonomie, A.J.; Kuiper, D.R.; Kurrasch, A.J. Office components, seating structures, methods of using seating structures, and systems of seating structures 2011.

XXV Congreso INGEGRAF

From Rapid Prototyping to Additive Manufacturing

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Abstract

In this paper the development of additive manufacturing technology, its advantages, limitations and application areas facing the manufacture of functional products is studied.

1 Introduction

Rapid prototyping systems can generate physical prototypes directly from digital 3D models. The first commercial systems sold in 1980 produced prototypes with geometrical and physical characteristics that limited its application to design and organs visualization fundamentally. The evolution of technology has increased the quality of produced elements so actually it is possible to manufacture functional products in certain fields of application. It has gone from rapid prototyping to additive fabrication. The American Section of the International Association for Testing Materials (ASTM) has recently developed the Standard F2792-10 "Standard Terminology for Additive Manufacturing Technologies" additive manufacturing defines as "the process of joining materials to make objects from 3D models, usually layer upon layer, as opposed to subtractive manufacturing technologies".

The additive technology can modify the centralized fabrication paradigm in large factories with specialized machinery to manufacture a custom geographically distributed [1].

2 Description of additive manufacturing technology

The process of obtaining a product by additive technology usually follow these steps:

- Creating a 3D digital model.
- Conversion to STL format and transmission to the machine describing the outer surface of the model.
- Construction of the model through an automated process that requires no supervision usually by overlapping layers.
- Postprocess. Eventually the products may require further treatment such as curing, removing support surfaces, painted, machining, etc.

Among the advantages that it offers over other technologies is the possibility to generate more complex geometries and freedom between shapes and manufacturing method. Berman [2] cites among its general advantages:

- Suitable for short runs with high customization
- No need for expensive tools

- The excess material can be easily recycled

The more important limitations of initial 3D printing systems were:

- The high cost for large series compared with other manufacturing processes such as moulding
- Reduced range of colours, materials and surface finishes
- Low dimensional and geometric accuracy than other technologies
- Limited mechanical and thermal characteristics
- Dimensions of the products obtained limited

The initial developments of 3D printing systems offered advantages in the field of design, for example great possibilities of customization, greater geometric flexibility and reducing the need for elements [3]. However, they suffered from poor tolerances and surface finishes, in addition to limitations of size and characteristics of the materials that were not valid for generation of final products.

Bak [4] raised in 2003 the choice between rapid prototyping and rapid manufacturing. It identified as key elements to improve in order to use rapid prototyping systems for short production, the cost of equipment, surface finish, tolerances and mechanical properties of materials and element.

3   Development

The development of additive manufacturing has been determined on one hand by improving the technology used and on the other the introduction of the same in different industrial fields allowing the possibility of producing functional objects in certain cases.
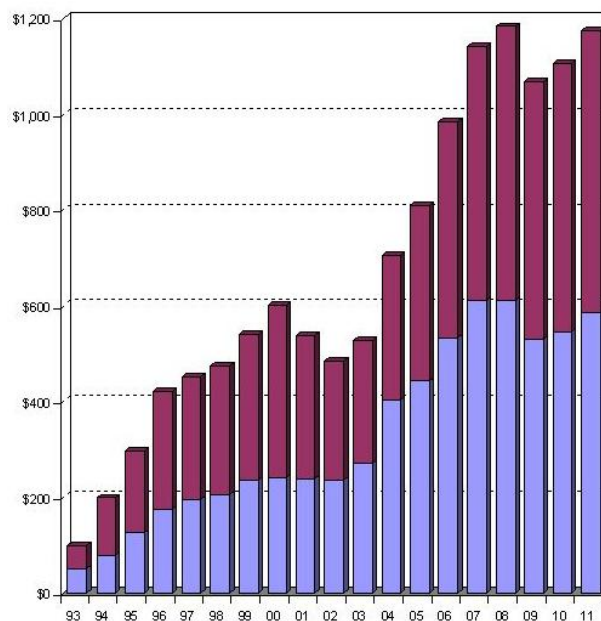
Fig. 1. Estimated income (million US dollars) generated by additive manufacturing. The bottom of the bars indicates superior products and services. Source: http://wohlersassociates.com/growth2010.htm

Figure 1 shows the upward trend in the revenue generated by additive manufacturing

Among technological improvements, increasing the dimensions of the parts obtained the substantial increase in available materials and improved post-processing treatments that improves the texture and dimensional tolerances of the products are fundamental.

Regarding the size limitations, the commercial printers Object1000 Stratasys is able to create models 1.000x800x500 mm.

A point of breakthrough has been the development of new materials with mechanical, thermal and improved aesthetic characteristics. These days the range of materials has been greatly extended. flexible materials can be used, combining various materials of different properties.

Fig. 2. Product manufactured on a stage with different materials.

There are wood-based materials [5] and copper [6]. As an application for production of functional products we can mention the generation of printed circuit boards [7].

The latest developments allow [8] multimaterial print [9]. Also as 3D printers that can print Connex3 hundreds of colors currently exist.

Wang [10] shows clear progress with the design of a hybrid printer that can print a flexible material such as silicone and metal possible to create functional products. Several systems offer the ability to print multiple materials on the same part with different aesthetics and mechanical properties. We have also developed new materials with improved thermal characteristics. Berman [11] shows results obtained with aluminum.

The dimensional accuracy has improved significantly. For example, photopolymers based technology allows tolerances and excellent surface finishes. Models like the Connex1 based on photopolymers work with horizontal layers up to 0,016mm. The chemical treatment can further improve the surfaces so that by suitable coating products are obtained with an unbeatable aesthetics.

One of the possible strategies for improving the dimensional accuracy is to combine the additive with the machining technology to increase the accuracy of the functional surfaces. The latter requires foresee an excess of material for subsequent machining. Gibson [12] proposed that material texture improvement by manual or automated process.

Postprocess techniques have also improved. They include various processes such as:

- Machining to improve the texture and tolerances.
- Curing to improve the mechanical characteristics. Using photopolymers based systems, in the construction phase materials deposited do not acquire optimum cure. Subsequent treatment with UV radiation improves mechanical characteristics.

- Improved aesthetics by painting or deposition of metal layers.
- Improvement of properties by non-thermal treatments. Products created are often porous. Such porosity can be used to infiltrate chemicals to improve their mechanical and chemical properties.
- Improvement of the properties by heat treatment. In the case of using metals, a heat treatment allows to obtain the desired microstructure and relieve stresses.

Fig. 3. Case Mouse made with additive technology. Left result of additive technology. Right same element subjected to post-processing.

As shown in Figure 3, it is possible to obtain products with very successful aesthetic characteristics.

4   New applications

3D printing has been used to create prototypes in the field of consumer goods, electronics, automotive, industrial machinery, sports, toys, architecture, entertainment, education etc. New developments are making it possible to create functional products in several of these areas, such as:

- Aerospace. An example of a new field of application is the three-dimensional printer installed on the International Space Station [13]. NASA is studying the additive technology in microgravity, having achieved positive results in the production of components and systems with embedded conductive channels. The ability to manufacture parts in situ is valued as essential to raise travel to Mars for example.
- Dentistry. The Align Technology Company uses 3D printing to create custom braces [14]. The additive technology has enabled replace metal by a series of orthodontic braces transparent teeth progressively corrected.
- Assistive technology. Siemens Hearing Inc. manufactures half of the casing of their hearing aids in the United States using additive technology [15] .The rejections of customers were drastically reduced.
- Airline Industry. Saab Avitronics used to manufacture laser sintered box telecommunications antennas for aircraft, resulting in a more compact design and a 45% reduction in weight compared to other manufacturing processes [16].
- Sport. The British firm Prior 2 Lever used additive technology to create personalized sports footwear for professional athletes [17].
- Prostheses. Adler Ortho Group create prosthetic with superior osseointegration.
- Automotive industry. Bentley and Rolls-Royce used additive manufacturing to obtain certain parts which are then coated with leather or other materials [18]. The Renault Formula 1 team uses about 900 parts manufactured by TA each season. Furthermore, they develop aerodynamic studies with models manufactured using additive technology [19].
- Electronics industry. They have developed technologies to make products with embedded electronic systems [20].
- Decoration. MGX used additive technology to make furniture and lighting elements of complex geometry.

Additive manufacturing is being implemented in areas with high value added, complex geometry and highly personalized.

5 Conclusions

Additive manufacturing is no longer used only to manufacture prototypes. Instead, it is used in many different fields to produce highly customized and functional products in small series. In a few years, the technology available to additive manufacturing has overcome the initial obstacles that limited its scope to not functional prototypes. Currently the characteristics of the created elements allow to use it as functional products.

The implications of a more extensive use of this technology can shift the paradigm from mass production in specific geographic locations to a personalized and geographically distributed manufacturing. This may involve economic and environmental savings by decreasing transportation needs.

The possibility of manufacturing the objects locally promotes the entrepreneurship. The production is closer to the end consumer. The need for inventories of raw materials and final products that may not be sold are not necessary. Instead, the products are manufactured on request.

Success depends on the scope, with very different manufacturing costs, transportation and customization. In the coming years it may be assessed if 3D printing causes a worldwide economic change.

Future development lines pass through the development of materials with improved thermal and mechanical properties, the decrease of manufacturing cost and extent of the additive to mass production manufacturing.

References

[1] Manfredi, D., Calignano, F., Krishnan, M., Canali, R., Ambrosio, E. P., Biamino, S., Fino, P. (2014). Additive manufacturing of al alloys and aluminium matrix composites (AMCs).

[2] Berman, B. (2012a). 3-D printing: The new industrial revolution. Business Horizons, 55(2), 155-162

[3] Zhai, Y., Lados, D. A., & LaGoy, J. L. (2014). Additive manufacturing: Making imagination the major limitation. Jom, 66(5), 808-816.

[4] Bak, D. (2003). Rapid prototyping or rapid production? 3D printing processes move industry towards the latter. Assembly Automation, 23(4), 340-345.

[5] Henke, K., & Treml, S. (2013). Wood based bulk material in 3D printing processes for applications in construction. European Journal of Wood and Wood Products, 71(1), 139-141.

[6] Hong, S., Sanchez, C., Du, H., & Kim, N. (2015). Fabrication of 3D printed metal structures by use of high-viscosity cu paste and a screw extruder. Journal of Electronic Materials, 1-6.

[7] Kim, M., Chu, W., Kim, Y., Avila, A. P. G., & Ahn, S. (2009). Direct metal printing of 3D electrical circuit using rapid prototyping. International Journal of Precision Engineering and Manufacturing, 10(5), 147-150.

[8] Wang, L., & Liu, J. (2014b). Compatible hybrid 3D printing of metal and nonmetal inks for direct manufacture of end functional devices. Science China Technological Sciences, 57(11), 2089-2095.

[9] Espalin, D., Muse, D. W., MacDonald, E., & Wicker, R. B. (2014b). 3D printing multifunctionality: Structures with electronics. The International Journal of Advanced Manufacturing Technology, 72(5-8), 963-978.

[10]   Wang, L., & Liu, J. (2014a). Compatible hybrid 3D printing of metal and nonmetal inks for direct manufacture of end functional devices. Science China Technological Sciences, 57(11), 2089-2095.

[11]   Berman, B. (2012b). 3-D printing: The new industrial revolution. Business Horizons, 55(2), 155-162.

[12]   Gibson, I., Rosen, D. W., & Stucker, B. (2010a). Design for additive manufacturing. Additive manufacturing technologies (pp. 299-332) Springer.

[13]   Espalin, D., Muse, D. W., MacDonald, E., & Wicker, R. B. (2014a). 3D printing multifunctionality: Structures with electronics. The International Journal of Advanced Manufacturing Technology, 72(5-8), 963-978.

[14]   Freitag, D., & Woh, T. (2003). Rapid Prototyping: State of the Art Review,

[15]   Masters, M., Velde, T., & McBagonluri, F. (2006). Rapid manufacturing in the hearing industry. Rapid Manufacturing: An Industrial Revolution for the Digital Age, , 195-209.

[16]   du Plessis, P., Avitronics, S., & Arena, R. (2008). A functional application of RM in a military environment. Paper presented at the TCT Conference,

[17]   Gibson, I., Rosen, D. W., & Stucker, B. (2010b). Direct digital manufacturing. Additive manufacturing technologies (pp. 378-399) Springer.

[18]   Stahl, H. (2013). 3D Printing–Risks and opportunities.

[19]   Kochan, A. (2003). Rapid prototyping helps renault F1 team UK improve championship prospects. Assembly Automation, 23(4), 336-339.

[20]   Joe Lopes, A., MacDonald, E., & Wicker, R. B. (2012). Integrating stereolithography and direct print technologies for 3D structural electronics fabrication. Rapid Prototyping Journal, 18(2), 129-143.

[21]

[22]

[23]

BRAINWRITING AS A METHOD TO FOSTER CREATIVITY IN PRODUCT DESIGN

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ABSTRACT

A group of people is generally involved in the design of a new product. Their ability must be oriented and focused on the form and the functionality that the product should have. The nature of the product characteristics must be constantly present during all the design phases, and specifically during the conceptual phase, when the innovative aspects are enhanced. From this point of view the creativity of the design team should be guided or oriented.

The concept design phase must involve all team members and each should consider him/herself part of the creative process. In order to pursue this aspect it is important to create the best conditions concerning the composition of the design team and the relation among its components.

Brainwriting is a method by which everyone can freely explain his/her own ideas and interact with and integrate the ideas proposed by others. It creates a "democratic" environment that is a necessary condition by which thoughts can be expressed.

The paper deals with a revised form of the brainwriting method in which a different sequence and timing of the steps has been verified in a master level class, in a Product Design and Development Course. The main motivation and the new schedule of the method will be reported and discussed.

1 Introduction

Product development is an almost tedi ous and boring, long pr ocess, because the solution under construction must be checked in several contexts. Many people consider this phase of dimensioning and optimization as the real and b asic aspect of design. In a certain sense th is is right, consideri ng that an y design solution must perform as designed, verifying that the behaviour of the device (the system) is in strict relation to its f unctionality. The model FBS (Function-Behaviour-System) by John Gero [1] describes this aspect. The early design phase is, on the contrary, that in which the strategic decisions must be taken in an attempt to identify the solutions that are really the most promising.

The early design phases are therefore c haracterized by a high level of uncertainty and the c oncepts generation is the mome nt when much imagination is required of designers. Inventive strategies must be pursued so designers are guided towards design alternatives that must be consi dered really upgrading of existing ones or completely original solutions to a new kind of problem.

The concept design phase has b een investigated from different p oint of vie ws, because not only technological aspects are involved in the process. Psychological aspects have been taken into account, in an attempt at identifying the mental process that leads to the conception of solution ideas [2]. Since 2010, a new research community has been established around the ICDC conferences, discussing about design creativity, the most recent held in Bangalore [3].

Focusing the research on the mechanism that happens in a team of designers during conceptual design the brainwriting method [4] has been investigated in order to confirm its validity during this phase. The choice to organize the work in team was supported by the results of Paulus and Yang [5] that demonstrated how concept generation is fostered if performed in groups. Further, the specific context of product des ign has naturally directed towards the employment of brainwriting, that is able to create the better condition among team members in order to fre ely express and exchange their ideas and reflect on the ideas prop osed by others. In an y case the effectiven ess of brain writing with respect to brain storming must be eval uated in relation to the conte xt in which it is emplo yed, as suggested by Heslin [6], even if in the case of produ ct design, where sketches are predominant, brainwriting is more fruitful [7].

The method was proposed to teams of students attending the course of Product Design and Development held at the University of Calabria, during the phase of conceptual design of a mechanical device able to store the extra electrical energy generated by removable sources.

The problem compl exity and the relative inexperience of the peopl e would have created grea ter inconvenience if the conception phase had not been pursued by brainwriting. Its main characteristic to put all the people involved on the same level, avoiding supremacy and/or blocking, was verified by a survey that followed the conclusion of the examination. All the people considered themselves part of the process and described the conceptual phase as a profitable moment, considering the work in team as a valid experience. This is an u nexpected result mainly due to the sharing of the design solutions generated, which all the people considered fruit of their creativity.

2   The revised brainwriting method

The method employed during this experiment was a revised form of brainwriting, mainly considering the skill of the people involved. All the methods brain-x (brainstorming, brainwriting) have been proposed with the main intent to obtain solutions in a short pe riod of time, typically 30 minutes [8]. In the specific context of design education it is more important to put peo ple in an emotional state, not stressed b y too ri gid scheduling.

The basic element of the method was respected. It requires that all the peop le involved are sufficiently informed about the problem to be solved. In this spec ific case all the people have the same knowledge of the problem, because this was the result of a previous study and deeper examination, in collaborative work. Then to be pe rformed, brainwriting requires a group of people that is n ot too big (ra nging from 3 to a maximum of 6) sitting around a table.

The method is divide d into two phases: first, when each person is free to expla in his/her ideas on an A3 sheet of paper with drafts, notes and/or symbols, without interaction with the others; after a certain time each team component pass the sheet of paper to his/her colleague on his/her right and continues to add suggestions to the ideas previously expressed by the others; the duration of this first part is strictly related to the number of team members and the number of problems that have to be treated.

In the second phase each team discusses the design solutions proposed, and the discussion involves the team all together.

The brainwriting method employed is derived from the 635 method [9], which suggests that the optimum number of people involved in the process should not exceed 6; that the number of solutions required of each team component for the solution of one problem is 3; the round passing necessary to complete the process by which every person has the possibility of interacting with the ideas suggested by all other members of the team are 5. Considering only one problem for which 3 ideas are required and that the time available for each step is e stablished in 5 minut es, the process comp letes in 6*5= 30 minutes, and 6*3 *6=108 ideas appears on each sheet of paper.

Considering that the right dimension N of a team for educational purposes can vary validly from 3 to 5 people the method can be described as N*3*(N-1).

In relation to the complexity of a problem it is necessary to have a first breakdown of the main function into more sub-functions and the brainwriting session is fruitful if it considers all the n sub-functions. The method is described by N*n*3*(N-1). Also the number of ideas generated is not banal, since N^2*n*3 are all the notes present on each sheet of paper. The duration of this phase must be calibrat ed properly. At the start of the procedure each team member has 10 minutes to generate 3 alternatives for each sub-function. Then, when the round passing starts, 5 minutes per each sub-function can be used to propose 3 alternatives.

The second phase lasts 30 minutes during which all team members discuss all the proposed ideas. A first classification of all the material conceived starts and the discussion requires that all members take part in it. Everyone has the emotional status to sustain the discussion among pairs. In a certain sense the material proposed cannot be related to each single person, the one who originally proposed the ideas, but all team members consider him/herself as co-author. This approach is opposite to that proposed in [5], where each team member uses a different coloured pen to be able to identify his/her own ideas in this second phase. During the discussion only the solutions and their possible combination must be studied in deep. The pruning of the produced material will require more time, but the first ideation of possible design alternatives has been done and the design space in which the search for a possible design solution has been traced. This is the moment in which the team cements the relations and the basis on which all work of design will continue. It is not guaranteed that one leadership will emerge during the time, but at this moment all has been shared.

In Figure 1 some pictures of the first and the second phase describe what happened during the class of the last course.

3   Fostering innovation

Before starting with concept generation it is necessary that all the people are conscious of which matter they apply to new ideas. To be solved every problem requires a certain degree of study. The methodology that gives a higher degree of knowledge about a design problem is the so-called "product functional analysis". There are even slight differe nces in all the several product functional analyses proposed in the literatu re, the author suggests that it be represented by data structures that can be employed during all the design phases. This should consist mainly of a graph, with several levels (each for the exchanges of energy, mass, signal), it describes the interrelation among all the sub-functions in which the main function can be broken

down. Then a tree in which the father-son relations between function and sub-functions are reported. Both data structures are necessary to clarify the nature of the problem to be solved and give a first identification of the context in which the search for the solution must be pursued.

This phase m ust be d one within each design team, even for educ ation purposes a certain degree of homogeneity among all teams is needed. It is recognized that product functional analysis does not produce only one data structure and that there is a certain d egree of variation, but this instead of invalidating the methodology highlights the strict nature of design, for which there is no single solution to a problem [10]. In short, even though different data structures are tolerated, they must be coherent. In any case, only after product functional analysis is completed can concept generation start.

The problems to be faced during brainwriting must be limited to a number that can be dealt with fruitfully in a given period of time. This has been quantified best as two hours. The calibration of the amount of time for the brainwriting session h as been dec ided on the basis of the time generally reported in literatu re. Considering that this is an activity with high cerebral energy consumption a longer lapse of time could induce collapse of attention. Further must be considered, incidentally, that the timetable is with slots of two hours, typically.

So the number of sub-functions to be investigated in two hours cannot be greater than 3.

Considering to set up teams formed of 4 pe ople (on average), the organization of the brainwriting session requires:

- 4 people per team: (N),
- 3 sub-problems to be solved (each for single sub-function): (n),
- 3 concepts per each sub-problem,
- 10 minutes available per sub-problem (first study),
- 5 minutes available per sub-problem (other studies).

The time necessary for the first phase is: n*10 + n*5*(N-1). For the case study 30 + 45 minutes is required. During this time much concentration is necessary, and the people are invited to work in silence, trying to express his/her major strength toward the perfect success of brainwriting.

After this time a break is mandatory. Then the second phase can start for another 30 minutes.

In Figure 2 the general organization of the exchange of materials is represented, in the case of a team formed by 4 people. Please note that different colours have been used only to enhance the chromatic effect of the image.

The number of ideas gathered at the end of the process is not banal. It is, for the case of a 4-person team, equal to $4^2*3*3 = 144$. So each sheet of paper contains approximately that number of data, which each team must select, evaluate and order. This process requires a lot of work because several alternative solutions must be d esigned and compared by standard MCDM (Multi-Criteria Decision Making) methods. The completion of this part is extremel y interesting for the general purposes of the course. People that at the beginning had few ideas about the possibilities of solving a problem suddenly realize that several different ways can be explored and that assessment strategies must be careful defined.
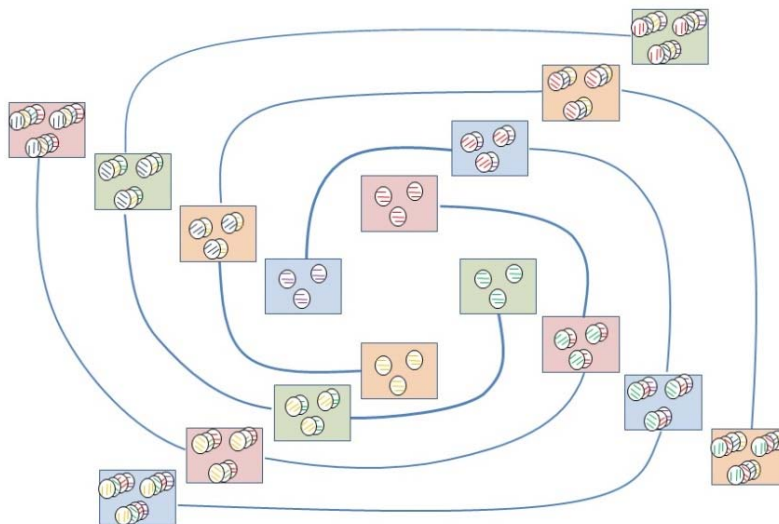

Fig. 1 Images from the brainwriting session.

Fig. 2 The exchange of material during brainwriting session.

4   *The investigation on creativity*

At the end of the semester and after the conclusion of the examination, all students were required to fill out a questionnaire focused on the peri od during which they were involved in concept generation. The title of the survey was: "me and creativity". It was designed to perceive the degree of involvement of each person in the te am and how he/she considered his/her own work. The brainwriting method induces a sort of depersonalization of the initial ideas and it is i mportant to evaluate how the work of each person is still identifiable, when the idea is changed and/or sometimes distorted.

The survey was conceived as the answer to a set of seven questions with four kinds of answer: yes, a lot; yes, enough; a little; not at all. A second pa rt required students to de scribe their e xperience. Even thi s second part of the survey involved many personal reflections that hardly can be grouped in a statistical manner, the first offers the hint for some general considerations.

The questions were:

1) Were the ideas you proposed accepted by your team?
2) Did you accept the ideas proposed by other members of the team favourably?
3) How much did you suffer the solution proposed by others?
4) How much did you uphold your design solution?
5) Do you think that working in team was a positive experience?
6) How easy was it for you to abandon the initial solutions and venture towards new horizons?
7) Do you think that the design solution your team developed is qualitatively better than the single initial ideas?
8) Do you think that bra inwriting for co ncept generation, and the r evised 6-3-5, is a valid tool, with respect to other methods you have employed in the past during your studies?

In Figure 3 all the histograms of the answers to each question are reported. 36 students were involved in the survey. A common data is present in all the questions: no one opted for the answer "not at all", in th at no one person considered him/herself outside the design process. Everyone answered in the way best suited to how they experienced the project.

The answers to the first four questions can be grouped together, because, in a certain sense, they describe how all students, and each individually, behaved during concept generation.

The answer to question 1 shows that a lmost all the students perceived that their o wn first ideas were accepted by the team (35/36). This aspect is easily verifiable checking how many integrations to the initial idea was added by the other components of the team.

The answer to question 2 reveals, at the same time, that all students were sufficiently at ease in accepting the ideas proposed by all the other m embers of t he team. Everyone was pressed to add new original elements to the ideas proposed by others.

The answer to question 3 reveals a great difference between two groups of people, of the same size (18 people) who declared to have suffered or not for the ideas proposed by others. Perhaps this point should have been explored further, because this emotional status could h ave been du e mainly to the kin d of relations that were established among the people of the teams.

The answer to question 4 reveals that almost all the students were aware of having to fight to sustain their ideas. Considering the answers to these two latter questions, it can be imagined that the discussion inside

the team must have bee n really strong, and that the c onflict among id eas did n ot generate states of frustration but on the contrary that each one compares well with respect to each other.

The answer to question 5 de scribes definitively how each student perceived the work in a team. Still the large majority declares that the experience was positive in a broad sense, considering the share of work along all the time of product development (and not only in relation to the marks obtained at the examination).

The answer to question 6 is interesting, because it reveals a certain level of conservatism to abandon the initial trials. Only 7 (over 36) people declares to have suffered a little having to abandon the first ideas and to start with new design solutions. In thes e cases a n ew trial of a br ainwriting session was applied autonomously by the team in order to investigate new kinds of solution. The majority of the answers (29/36) reveals that a certain fear to fa il the exam induc ed students to guarantee better performances to the first ideas, even being conscious that these were already tested by others and the content of originality was limited.

The answer to question 7 reports the general consciousness that a lot of work had been done in order to present a design solution that passed a great number of tests related to all aspects of the product life cycle. A great majority of people (23/36) considers that the final result is surely better than the initial ideas, even implicitly realizing that a great influence was exerted by the right starting point.

The answer to question 8 reveals that the activity performed at the early stages of design has been valid. The questionnaire was submitted at the end of the semester and not close to the brainwriting, so the answer must be considered as global and in re lation to all design activities. In a certain sense br ainwriting is also considered a good method to collect all possible materials and design solutions that would have been retrieved, if necessary, during embodiment, in order to solve possible architectural design problems.
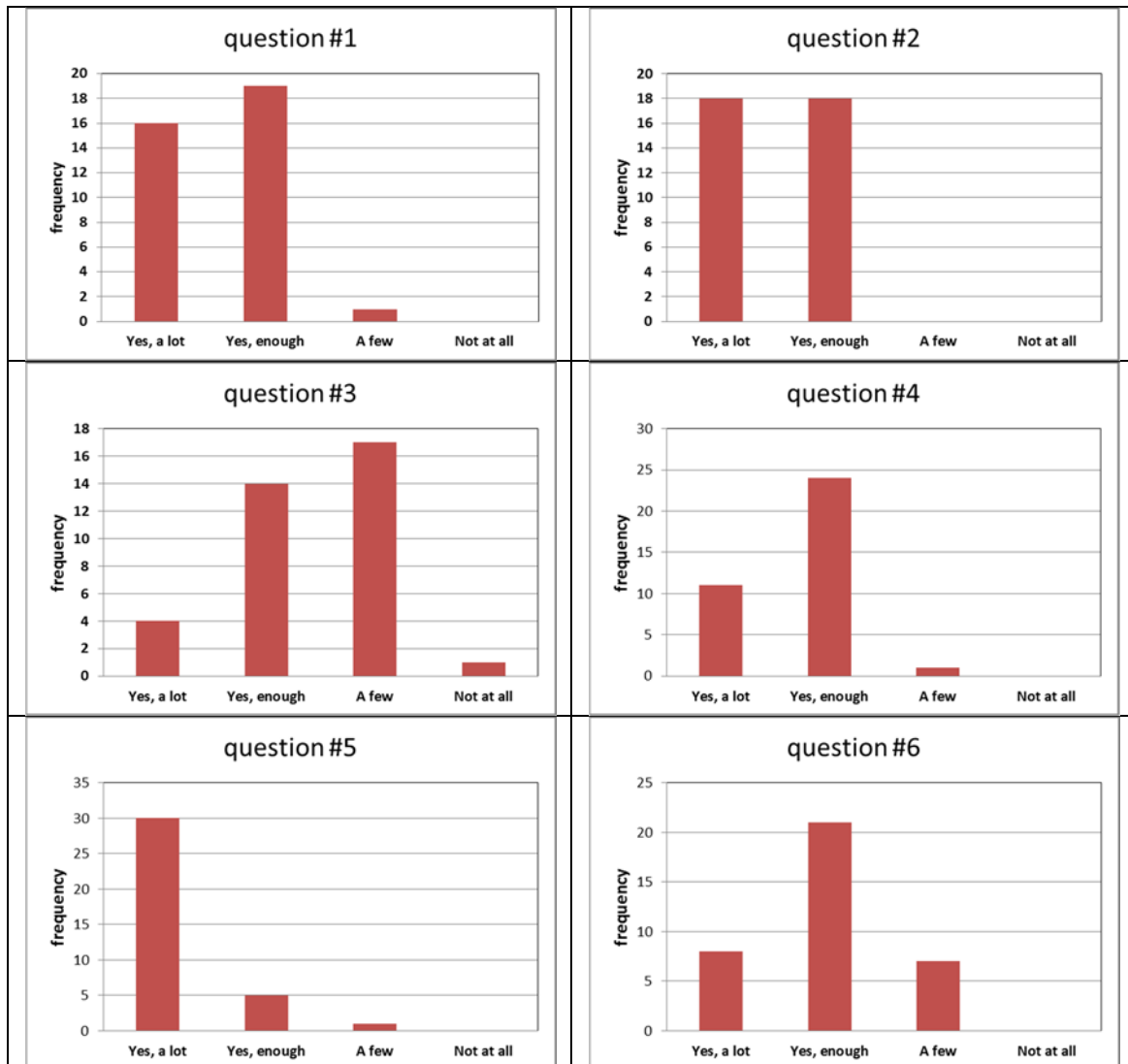

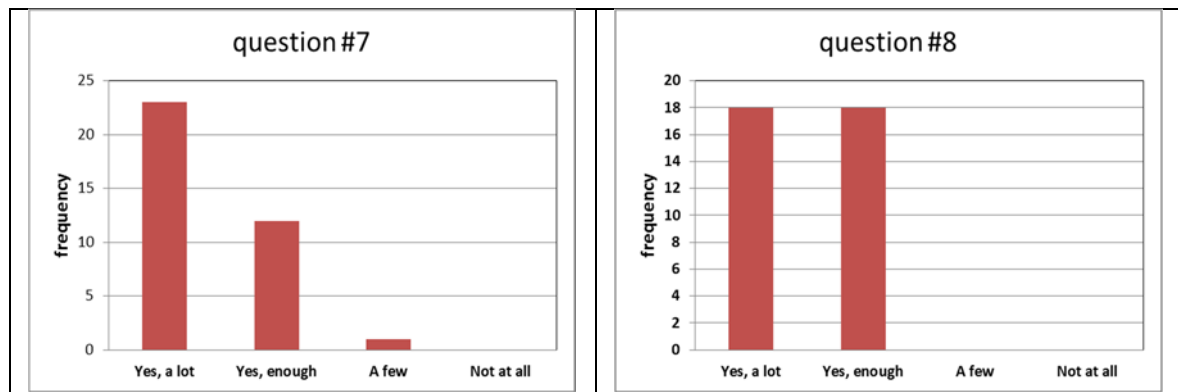Fig. 3 The results of the survey on "me and creativity".

Fig. 3 (cont.) The results of the survey on "me and creativity".

5 Discussion

The application of the brainwriting method in conceptual design has a great chance, be ing a methodology that puts all the participants on the same level: the main condition that creates the right circumstance to free creativity.

Team work during design is complex when considered along all the design cycle, since definition of problem up to detailed design of the definitive solution. Then a certain complementarity among the people involved is a characteristic that can aid the respect of the schedule. If this is true in a professional environment, this is not sufficient in an educ ational context, because all the team mem bers must contrib ute with their knowledge, as pairs.

One of the drawbacks of the method consists in its use of written elements, and mainly drafts, recognizing that not all people are familiar with using this kind of operation. Considering that all the people involved are students of engineering science and that this is their natural way to communicate, brainwriting can be used without inconvenience of communication.

6 Conclusion

The author hopes that the method can be used more widely, in an academic context.

In the near future attention will be focused on the mechanism of the method, quantifying the times of ideas generation, and verifying the relation between the number of problems to be solved and time assigned to do this. The quality of the solutions proposed should be also evaluated.

Further it will be verified whether a more relaxed environment aids ideas generation.

ACKNOWLEDGEMENT

REFERENCES

[1]   J. S. Gero, U. Kannengiesser. The situated function-behaviour-structure framework, Design Studies 25 (2004) 373-391.

[2]   T. Amabile. Creativity in context, 1996, Boulder, CO: Westview Press.

[3]   A. Chakrabarti, T. Taura, Y. Nagai. Editors. Proc. 3rd International Conference on Design Creativity (ICDC), Jan 12th-14th , 2015, Bangalore.

[4]   A. B. VanGundy. Brainwriting for new product ideas: An alternative to brainstorming, Journal of Consumer Marketing,1 (1983), 67-74.

[5]   P. B. Paulus, H-C Yang. Idea generation in groups: A basis for creativity in organizations, Organizational Behavior and Human Decision Process, 82 (2000), 76-87.

[6]   P. A. Heslin. Better than brainstorming? Potential contextual boundary conditions to brainwriting for idea generation in organizations. Journal of Occupational and Organizational Psychology, 82 (2009), 129-145.

[7]   J. S. Linsey, B. Becker. Effectiveness of brainwriting techniques: comparing nominal groups to real teams. In Design Creativity 2010 (pp. 165-171). Springer London.

[8]   K. N. Otto, K. Wood. Product Design, 2000, Prentice Hall, New Jersey.

[9]   B. Rohrbach. Creative nach regeln: Me thode 635, eine neue tech nic zum losen von problemen. Absatzwirtshaft,12, (1969), 73-75.

[10]   N. Cross. Engineering Design Methods, Strategies for Product Design, 3rd Ed., 2000, John Wiley & Sons, Chichester - UK.

XXV Congreso INGEGRAF

GENERATION OF SURFACE PATTERN DESIGNS AND THEIR APPLICATION TO PRODUCTS OR ENVIRONMENTS: AN INTERDISCIPLINARY AND CREATIVE ACTIVITY IN THE ENGINEERING DEGREE IN INDUSTRIAL DESIGN AND PRODUCT DEVELOPMENT AT THE UNIVERSITY OF ZARAGOZA (SPAIN)

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Abstract

In this paper, we present a learning experience based on the generation of surface pattern designs and their application to various products or environments. This activity is aimed at students of the Engineering Degree in Industrial Design and Product Development at the University of Zaragoza and is integrated into the work by modules in the first semester; composed of the following subjects: Artistic Expression, Aesthetics and History of Design, Mathematics and Computer Science. The task aims at the integration of the students in the different learning results achieved in the works by modules in a creative and interdisciplinary fashion, applying them to the production of surface pattern designs for a product or environment. Thus, this activity allows students to work both, specific and transversal grade skills and connect the contributions of different subjects to the discipline of product design, facilitating the application of knowledge to practice and apply the creative component to their design proposals.

1 Introduction

Work by modules consists in a project that focuses on one or several common elements, proposing to students the possibility of solving different problems by combining the specific competences of each one of the subjects involved in the module with the transversal competences of the degree in which it is framed. This type of study permits integrating the knowledge acquired in the different subjects, fostering both collaborative and interdisciplinary learning.

This is the case of the Engineering Degree in Industrial Design and Product Development (EDIDPD) at the University of Zaragoza, which is presented as a highly creative technical degree whose curriculum includes scientific as well as humanistic and artistic contents. The Degree is organised into biannual modules of subjects belonging to different knowledge areas, which are coordinated to obtain common educational objectives and learning results [1]. Within this context, a work by modules is designed that involves all the semester's subjects and is carried out within the same time frame.

The experiment designed herein focuses on the first degree module, comprised of the subjects of Artistic Expression, Aesthetics and History of Design, Mathematics and Computer Science. The work by modules of this first semester is proposed as a group activity. It focuses on an Industrial Design object or product, and addresses the solution of problems or questions raised by each one of the subjects [2]. Within this working environment, we programme a final task, proposing the generation of a surface pattern design and its application to the product (or its environment) selected for each module work, and whose objective is for students to reflect upon the connections between the set of subjects in which they have intervened and to develop their creativity.

Surface pattern design is a technical and creative activity, aimed at developing a basic pattern or patterns which, appropriately combined, permit coating a surface. This appears in a great variety of disciplines related to the field of design, such as textile, graphics, product or even urban and landscape design, and its main purpose is to provide aesthetic solutions to the different materials involved in industrial and traditional productions.

The activity consists in designing a pattern based on the learning results that each group has attained after executing all the proposed tasks. The final result is expressed on a presentation panel where the group must integrate the initial object together with its surface pattern design. They must correctly contextualise it in agreement with the designer's characteristics or the design current it belongs to. Thus, the proposed activity is presented as a clearly practical experiment that allows students to put their theoretical knowledge into practice and generate new ideas based on this knowledge. On the other hand, the activity provides students with the possibility of exploring creative processes based on tools that originate from very different areas of their curriculum, enabling them to provide aesthetic design solutions in their professional future.

2   Surface pattern designs and Design

Pattern designs became popular in the 19th century as they expressed the tastes of the new bourgeois society. After being rejected by the formalist and austere ideology of the Modern Movement, they made a powerful comeback in the sixties and seventies of the 20th century, associated with the more radical design movement, which sought to undermine the immovable principles of modernity. Today, they are still present in design and their aim is to make a product greater fun, modern or single it out from the series it belongs to.

The progress of industrialisation and technological development gave rise to a new way of treating material such as cotton, paper, pressed tiles or wood. This led to the appearance on the market of products such as the "Indiana" products, cotton prints, wallpaper, ornamental mosaics and linoleum, among others. Compared with the characteristics of traditional products, they are characterised by their mass presence on the market and therefore their lower economic value, as well as the pattern design on their surface that enriches them from the aesthetic viewpoint.

These products were not held in high esteem by the artistic theoreticians of the time, as seen by the criticism conferred on them by John Ruskin, who considered them to be inadequate for a genuine and honest artistic work. However, for others, such as the group of British reformers (Dyce, Redgrave, Jones and Wornum), or Augustus Pugin, and, above all, William Morris, these objects are able to assume the decorative nature that characterises the majority of consumer goods. Thus, a large sector of nineteenth-century society introduces them into their houses and, thanks to them, both the homes of the middle classes and the homes of the wealthy bourgeoisie, reached the required levels of well-being.

On the other hand, the products that we are referring to pose some innovative and specific design problems as the way they are produced and their function in the homes entails a change in design concepts and criteria. Thus, the pattern designs that decorate the "Indiana" products, cotton prints or wallpaper are based on modulated and combinable elements due to the repetition of the basic module which is juxtaposed to infinity. In this way, the aesthetic effect depends on the result obtained from the combinatorial analysis, based on the notion of an unlimited surface. Furthermore and thanks to this design solution, these products can be presented in stock and sold by metres or by pieces, compared with the unique and artistic character that is typical of decorative arts [3-4].

From the viewpoint of styles, the aforementioned reformers together with Augustus Pugin imposed a two-dimensional and geometric style that was associated with the Victorian taste that was so typical of the sixties of the 19th century. This was followed by the naturalist and organic style of William Morris (seventies and eighties) and of the Arts and Craft and Art Nouveau movements (nineties of the 19th century and first decade of the 20th). In the thirties of the 20th century, pattern designs were banished from domestic interiors and from daily objects as a result of the ideology imposed by the modern movement. The object of use became an intellectual and abstract phenomenon, as expressed by Le Corbusier in his texts. It was replaced by the notion of ornament, taking advantage of the decorative effects of industrial materials and their textures, and extracting them from their technical and material capabilities. Thus, the ornamental is spurned in favour of the decorative and the weight of the design falls upon the definition of the shape understood as an exterior silhouette.

However, this renunciation does not last for long and the Pop movement, in the sixties of the 20th century, as well as the avant-garde styles of the radical design of the seventies and eighties of the same century (e.g., Alessandro Mendini), recuperate the taste for ornamental patterns, on this occasion with a fun and

colourful style that was typical of the time, although based on similar design principles to those commented on above.

Over the last few decades, the introduction of computer tools into the execution of projects, or the diversification of materials used as a surface, have represented a substantial evolution in surface pattern design. At the same time, important changes have also occurred in the graphic patterns used, which now depend on different factors: the surface on which they are going to be applied (fabric, ceramic, furniture, construction materials, etc.), the technique (printing, sgraffito, applied graphic computing programs, etc.), production processes, fashion, culture universalisation, the demands of different industries, artistic trends, etc.

In this new context, science and technology have significantly contributed to the design and applications of pattern designs. Many patterns can be generated from mathematical concepts, such as geometric transformations or the use of appropriate mathematical functions. Over the last few years, fractal works (Mandelbrot set, Julia set, etc.), have been used to design new patterns, combining creativity and science. The development of software to generate fractals, combined with a wide variety of initial designs has opened up the possibility of new and interesting ideas, such as for instance, in textile design [5-6]. Within this same field, mathematical regression models have been used to solve the complicated problem of designing patterns on elastic and tight fabrics [7].

The potential of pattern design lies in its capacity to generate attractive projects with a high visual impact, in the variety of application fields and in the possibility of personalising any product used on a daily basis. All of these are factors that have led this design discipline to become a modern matter to research and work with. In this sense, many of the research studies carried out recently address the creation of patterns as a resource to improve competitiveness in different design fields. Thus, some of the applications studied have focused on their incorporation into product design [8-10], textile design [11-14], interactive web application or multimedia contents [15], design of systems to generate patterns [16-19], or even urban design [20-21], architectonic [22-24], or landscape [25] design applications. Another aspect to be highlighted about pattern design is its capacity to change the style of a product without changing its original shape. Thus, a large number of companies apply different surface pattern solutions to their products to offer the market a more extensive range of novelties [26-27].

From an academic viewpoint, the speciality of surface pattern design has become an emerging area of the curriculum in different design study plans, and it has opened up as a field that arouses a great deal of interest. This situation reflects how education is able to deal with specific teaching contents that respond to industrial and market demands, as well as to different user profiles.

In fig. 1, we show a timeline that summarizes the main events and trends in the context of surface pattern design.
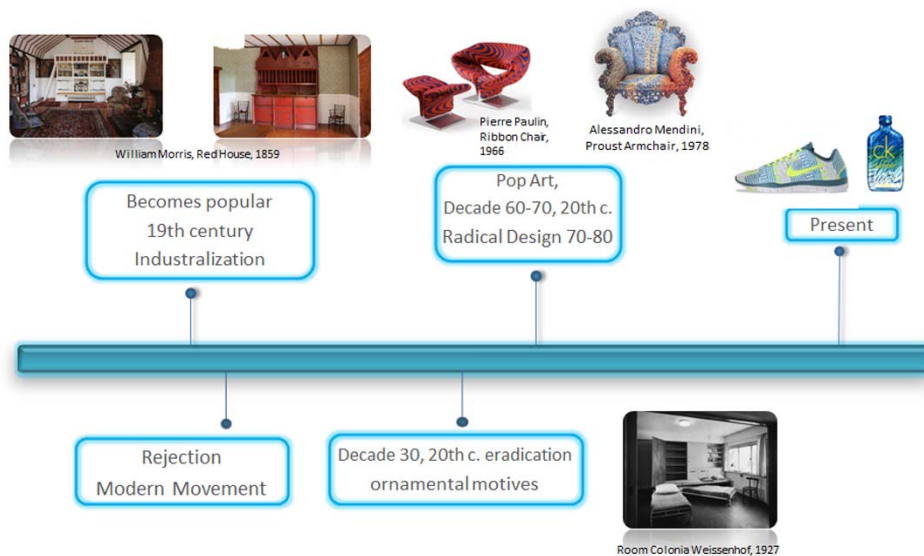
Fig. 1 Timeline that summarizes the main events and trends in the context of surface pattern designs.

3 Activity proposal and case analysis

A total of 80 students divided into 26 work groups, composed by 3 or 4 members, have taken part in this works by modules, within the academic year 2014-2015. The students belong to the two groups of the first semester of the first year of EDIDPD. The groups have been distributed as follows: 10 groups have worked with the 4 subjects contained in the first semester (Artistic Expression, Aesthetics and History of Design, Mathematics and Computer Science), 6 groups have worked with 3 of the 4 subjects contained in the first semester (Artistic Expression, Aesthetics and History of Design, Mathematics) and and 10 groups have worked with the 4 subjects contained in the first semester, but working separately on two different works by modules on which the subjects were grouped as follows: on the one hand, Artistic Expression and Aesthetics and History of Design and, on the other hand, Mathematics and Computer Science.

As indicated in Section 2, the teaching team has designed a learning activity that permits providing the work by modules carried out by the students with a practical sense, at the same time as it fosters their reflection on the contribution of each subject to the final result. The activity consists in generating a surface pattern design and applying to a product or environment, based on the learning results reached by the students after solving previous activities. This type of activity has been chosen due to the numerous applications of pattern design in the different disciplines related to Design.

After carrying out the work, each group must suggest the design of a final presentation panel, where, based on the selected product, the learning results are expressed in a holistic manner. To this end, they are asked to generate a pattern design that they must apply to the product they have worked with or on the environment where they incorporate it.

The results obtained in the Mathematics and Computer Science subjects are the starting point to create the surface pattern design. The content referring to the subject of Aesthetics and History of Design is studied through the selection of a font that adapts to the style of the designer or recalls that era; by incorporating some elements that are related to their style or are typical of the socio-cultural context, such as, for example, a highlight background designed with some representative motif from that period (or the actual surface pattern design); selection of furniture, etc. The knowledge acquired in the Artistic Expression subject permits integrating these elements into the panel, the choosing the compositional grid and the graphic technique used.

This learning activity allows working with the following competences:
- Capacity to generate new ideas.
- Capacity to solve problems.
- Capacity to implement knowledge.
- Analysis and synthesis capacity.
- Decision taking.
- Motivation towards work.
- Capacity to work in teams.
- Capacity to communicate orally.
- Basic skills to manage the computer.

   The following criteria have been taken into consideration in order to assess the panel:
- Originality when it comes to incorporate into the panel design, the learning results of the subjects contained in the module.
- Appropriateness of the chosen product: Criteria for the selection of the product when applying the pattern design.
- The aesthetic component of the pattern design or of the surface graphic obtained.
- Impact of the panel: Graphic resources used (typographies, backgrounds, etc.) and composition structure.
- Communication of ideas, structure of the oral presentation, connection between ideas, appropriate vocabulary of the subjects in the panel dissertation.

By way of an example, we show two panels where we have included a brief summary of the initial work proposal, as well as an analysis on how the students have designed and integrated their surface pattern design, into a product or environment, materialising their results on the composition of a panel.

3.1 Case 1. Verner Panton and Pop Design
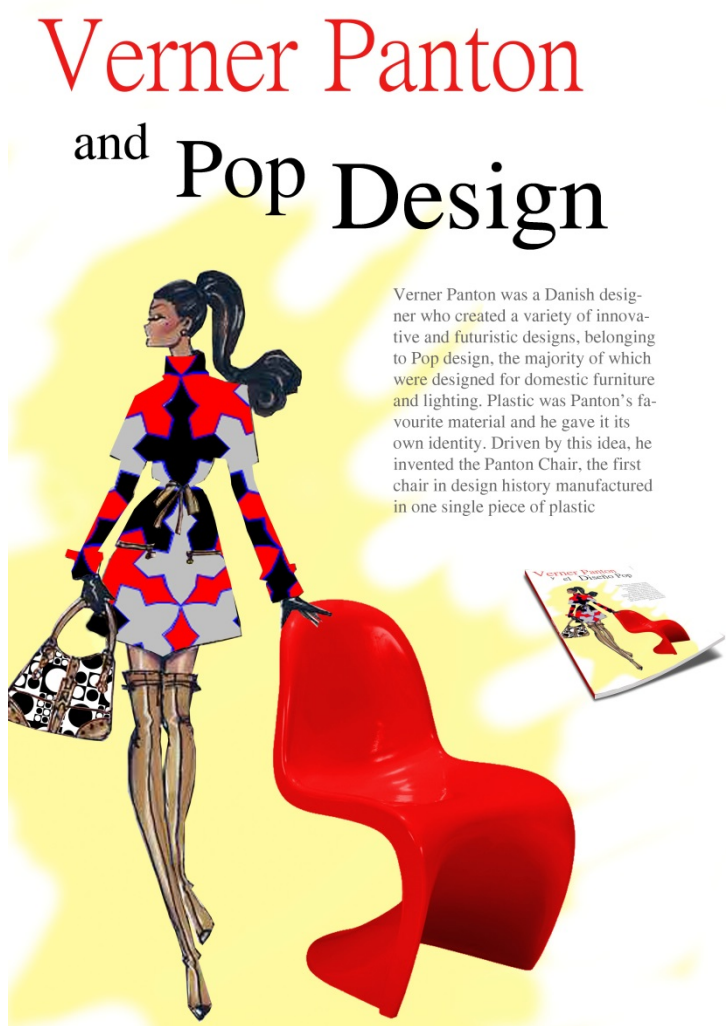
Fig. 2 Panel made by the students, Alicia Cazorla, Marta Germán and Lidia Gonzalo based on the Panton chair by Verner Panton.

This first example corresponds to a 3-subject module work (Artistic Expression, Aesthetics and History of Design, and Mathematics). The series of activities are organised around the Panton Chair by the designer, Verner Panton, belonging to the so-called Pop design. The repetition of patterns was a technique used in this current, recovering the taste for colour and creation of personal environments. The Mathematics subject contributes with how to work these concepts through the use of isometric transformation matrices, with direct application to the generation of mosaics, whilst the objective of the Aesthetics and History of Design subject focuses on investigating into the novelties of Pop Design and its aesthetic characteristics compared with the functionalist current.

The panel designed by the group (fig. 2) shows a representative view of the Panton chair. Next to it appears the image of a woman whose coat and bag have a pattern. Based on the work carried out in the Mathematics subject, and making use of some of the mosaics that the students had generated using mathematic tools, in particular, the fish mosaic by the artist, Escher, they applied this pattern design as a pattern of the gabardine that the woman in the panel is wearing. In addition, one of the well-known mosaics of Verner Panton has been chosen to cover the bag. The mathematical recurrence concept is used in the design of the panel based on the Droste effect (a picture appearing within itself, and so on and so forth), including the idea of repetition that was so commonly used in the Pop current. The font selected, as well as the black and red colours that prevail on the panel are aesthetic nuances linked to this current. On the other hand, the selection of a model on a catwalk and the presence of the magazine, refer to the cultural context of the Pop Design and point to the pre-eminence attained by the mass media in that era.

3.2   Case 2. Lisa Johansson-Pape and the Scandinavian design

SCANDINAVIAN SIDEBOARD

Scandinavian style TV module with structure in wooden fibre and lacquered in matte. Doors and drawers made of American walnut panel. Feet made of solid American walnut.
Dimensions: Width 150 cm; Depth 40 cm / Height 54 cm Colour: Light grey

Fig. 3 Panel made by the students, David Lacasta, Hugo Lázaro and Irene Montañés, based on the hanging lamp made of opal glass by the designer, Lisa Johansson-Pape.

The second case that we present (fig. 3) is a work by module carried out among the 4 subjects of the semester. The design object based on which the set of activities is established is a hanging lamp made of opal glass by the designer, Lisa Johansson-Pape, representative of Scandinavian Design. The symmetry of the majority of her lamp designs has served for the Mathematics subject to propose to the students how to generate some of these objects as revolution solids, introducing different interpolation techniques to previously recover their profile. The connection between the Computer Science subject and the module is established in the design and programming of an application based on an image processing graphic interface. In this case, the implementation of noise insertion and softening filters has been proposed. On the one hand, the Aesthetics and History of Design subject investigates into the characteristics of this design current and its association with the cultural context of the countries that integrate it (Denmark, Sweden, Norway, Iceland and Finland).

The panel proposed includes the lamp generated by applying the mathematical tools learned and which replaces the original one. On the other hand, students have used some of the filters implemented in Computer Science on the flat silhouette of the lamp, recovered in the Mathematics subject. These images have served to design their pattern design. Taking advantage of the appropriate transfer of the pattern, they have generated a patterned detail included in the front right-hand part of a piece of furniture whose characteristics are typical of the Scandinavian current. With this, they have also managed to copy the shape of the original lamp. The students have also included a highlight background with natural motifs. The choice, both of the sideboard and of the highlight backgrounds, is related to the aesthetic characteristics of this current: furniture with straight, simple lines; presence of bright colours; mixture of natural materials (wood) with modern finishes (patterned details); and outstanding presence of nature (both in the materials and in the background pattern). All of this generates a warm atmosphere typical of this design.

4 Conclusion

Due to its tradition, its ability to generate attractive projects with high visual impact, its application field potential or the possibility of personalising any product used on a daily basis, pattern design becomes a modern material to be studied. In this work, we show the application of the results obtained in the different subjects that make up the work by modules, developed during the first semester of the first year of the Engineering Degree in Industrial Design and Product Development at the University of Zaragoza, and which, creatively, have helped generate pattern designs applicable to different products or environments. The learning activity proposed to the students allows working both specific and transversal competences of the degree, connecting the different learning results, helping put knowledge into practice and applying a creative component to their design proposals. This practical nature of the activity also provides students with tools to look for design solutions in other contexts, as well as to become aware that the training they receive is closely linked to what their professional activity will be like.

Thus, pattern design is presented as an activity that reflects how, in an education environment, it is possible to deal with specific teaching contents, which, addressed in an interdisciplinary manner, provide an answer to design options for different user profiles, responding to market needs.

Acknowledgement

References

[1]   E. Manchado and I. López. Coordinación por módulos de asignaturas en el Grado de Ingeniería de Diseño Industrial y Desarrollo de Producto de la Universidad de Zaragoza. Revista de Docencia Universitaria, 10, 3, (2012) pp 195-207.

[2]   A. Serrano, M. Hernández, E. Pérez and P. Biel. Trabajo por módulos: un modelo de aprendizaje interdisciplinar y colaborativo en el Grado en Ingeniería en Diseño Industrial y Desarrollo de Producto. REDU. Revista de Docencia Universitaria, 11, extra, (2013) pp 197-220.

[3]   Barcelona 2010 website.
        http://tdd.elisava.net/coleccion/14/calvera-es/ accessed 15 Feb 2015.

[4]   F. Hernández. *Las antiguas fábricas de mosaico hidráulico en Navarra*. Cuadernos de Etnología y Etnografía de Navarra (CEEN), 88, (2009) pp. 55-95.

[5]   Z. Heng and L. Suyi. Pattern Design of Textile Printing Based on The Transform of The Julia Set. 2009 IEEE International Conference on Virtual Environments, Human-Computer Interfaces and Measurement Systems, May 11th-13th, 2009, Hong Kong, China, pp 164-167.

[6]   R. Hou, Y. Li and L. Cao. Study on Textile Pattern Design Based on Mandelbrot Set. Proceedings of the 2010 International Conference on Information Technology and Scientific Management, December 20th-21th, 2010, Tianjin, China, pp 875-878.

[7]   Y. Yan and S. Yu. Research on Mathematical Model of Jeans' Pattern Design Made in Elastic Fabric. Proceedings of the 2008 International Conference on Advanced Textile Materials and Manufacturing Technology, October 15th-19th, 2008, Hangzhou, China, pp 377-380.

[8]   K. Kim. A Study on Pattern Design Development basing on a Natural Plant, Crape Mytle. Journal of Korea Design Forum, 44, (2014) pp 39-48.

[9]   H. Yangsunyoung. *A Study on Pattern Design Based on Heo Nanseolheon's Caligraphy.* Journal of Korea Design Forum, 40, (2013) pp 185-194.

[10]   H. Yangsunyoung. A Study of Coffee cup Pattern Design based on Nanseolheon's Calligraphy and Art Deco's Geometric Patterns. Journal of Korea Design Forum, 44, (2014) pp 195-204.

[11]   A. Jang. Textile Pattern Design Applied by Jeju Language -Focused on Typographic expression-. Journal of Korea Design Forum, 41, (2013) pp 185-194.

[12]   E. Lee. An Exploration of Textile Pattern Design Among Three main Categories of Children's Fashion Brands Spun off from Adult's Fashion Brands. Journal of Korea Design Forum, 34, (2012) pp 457-466.

[13]   L. Mao and Y. Lian. Study on Pattern Design of the Wave General Style Sweater. Proceedings of the 5th International Symposium of Textile Bioengineering and Informatics. August 9th-10th, 2012, Ueda, Japan, pp 529-537.

[14]   S. Kim. *A Study on Emotional Image of Floral Pattern Design.* Journal of the Korean Society of Design Culture, 19, 4 (2013) pp 753-755.

[15]   J. Lee. *A Development of an Interactive Web Application Generates Pattern Design Utilizing Processing Javascript.* Journal of Digital Design, 13, 4 (2013) pp 881-891.

[16]   D. Andrade and K. Shimada. *Automatic Generation of a Pattern of Geometric Features for Industrial Design.* Journal of Mechanical Design, 135, 11 (2013) pp 115001-115007.

[17]   L. Berdun, A. Amandi and M. Campo. *An intelligent tutor for teaching software design patterns.* Computer Applications in Engineering Education, 22, 4 (2014) pp 583-592.

[18]   Y. Kamahara, H. Aoyama and T. Oya. Emergence System of Pattern Design Showing Natural Impression. In ASME 2012 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference. American Society of Mechanical Engineers. August 12th-15th , 2012, Chicago, IL, pp. 637-644

[19]   S. Lu, P. Mok and X. Jin. *From design methodology to evolutionary design: An interactive creation of marble-like textile patterns.* Engineering Applications of Artificial Intelligence, 32, (2014) pp 124-135.

[20]   M. Jevrić, M. Knežević, J. Kalezić, N. Kopitović-Vuković and I. Ćipranić. *Application of fractal geometry in urban pattern design.* Tehnički vjesnik, 21, 4 (2014) pp 873-879.

[21]   M. B. Grath and V. Marshall. *New patterns in urban design.* Architectural design, 202, (2009) pp 48-53.

[22]   C. H. Huang and S. C. Yu. *A Study of Environmental Perception Patterns of the Visually Impaired and Environmental Design.* Indoor and Built Environment, (2012) 1420326X12456317.

[23]   G. M. Montuori, E. Mele, G.Brandonisio and A. De Luca. *Geometrical patterns for diagrid buildings: Exploring alternative design strategies from the structural point of view.* Engineering Structures, 71, (2014) pp 112-127.

[24]   J. Vincent. *Biomimetic patterns in architectural design.* Architectural Design, 79, 6 (2009) pp 74-81.

[25]   J. Perez *Morphological patterns in landscape design.* EGA Revista de Expresión Gráfica Arquitectónica, 22, (2013) pp 100-111.

[26]   S. Park-Hae. *A qualitative Study of Applying Creative Thinking Methods to Surface Pattern Design developments -Focused on Methods of Scamper, Synectics and Forced Connection-* Journal of Korea Design Forum, 44, (2014) pp 281-294.

[27]   E. Kyoung-Hee. *A Study of the development of textures and pattern design resources for textile fashion CAD program -Centered on the usage of TexPro design system.* Journal of Korea Design Knowledge, 22, (2012) pp 179-190.

**XXV Congreso
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INTRINSIC RELATIONS BETWEEN THE ORTHOGONAL AXONOMETRIC SYSTEM AND ITS ASSOCIATED OBLIQUES. ANALYTICAL PROPOSAL AND GRAPHIC OPERATIONS

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Abstract

The knowledge related to the axonometric perspective is considered bounded and standardised, from the point of view of its well-known and studied analytical approach as well as from its practical applicability as a system of representation. However, if we reflect critically on the traditional way of transmitting the geometrical knowledge already established, we may delve into some constructive aspects. The aim is to open a new approach, an analytical rewriting of the system, capable of supporting and verifying the validity of the new proposed graphic operations. In line with previous studies, this paper shows some graphic constructions that allow a single joint description of invariant relations between an orthogonal axonometric system, its related orthogonal views, and the axonometric oblique systems associated with it. We have started from a unit trirectangular trihedral and have chosen a mobile picture plane containing the vertex of the previous trihedral. Logically, we start from the perpendicular direction to the picture plane, characteristic of the orthogonal axonometric, and from any other direction from which to obtain the oblique axonometric related to the former. This criterion is the unusual starting point that allowed rethinking the described problem and obtaining the intrinsic axonometric relations that are presented.

1. Introduction.

Among the scientific literature of classical authors who studied the systems of projection representation, the mathematical type is predominant [1-2]. These studies allowed at the time the completion of a body of knowledge that was until then intuitive [3]. In the field of art and technology, the need for expressive graphics never prevented its use, with or without constructive geometric rigor [4]. Leaving aside other studies on descriptive geometry that deal with theories of visual perception, or the symbolic value of the graphical representation of spatial forms [5-6], we can glimpse in the development of prior knowledge, a certain distancing between the study of the constructive aspects and the rigorous mathematical analysis advances in the field of descriptive geometry. The systematization of the graphic operations has allowed applying the representation systems in the space description and technical shape on the drawing plane in the fields of engineering and architecture. But also the not very frequent research work relating to these fields has evolved today towards the field of computational geometry [7], showing a strong algebraic component with a double purpose:

On the one hand, these studies aim to adapt a basic geometrical knowledge to a writing that would sustain the improvement of tridimensional modeling tools [8]. This may be because it is now impossible to separate CAD CAE technologies from the technical and creative activity of project and design.

On the other hand, other lines of study enhance procedures to create tridimensional geometries from bidimensional representations, obtained by various means [9]. In this sense, some authors have for some time now developed concepts of restitution, recognition of technical drawings, or 3D reconstruction [10].

Another line of work studied as a reference for this research is the one related specifically to the oblique cylindrical projection, which over time has sought to express graphically the Pohlke-Schwarz theorem; thus attempting to provide an operational graphic sense to the more general axonometric approach. [11] In a line of research that seeks to integrate analytical and constructive views of the representation systems, the above referenced knowledge was resumed with *Main Axonometric System Related Views as Tilt of the Coordinate Planes* [12].

It is common in the analysis and representation of this system to fix the projection plane and assign a free position to the projection trihedral. To this end, it is usual to take as a reference system another orthogonal trihedral coincident with the projection plane in one side.

This choice does not initially involve practical graphic difficulties in co nstructing orthogonal axonometries. But not matchi ng the refere nce trihedral with the proj ection trihedral does involve som e analytical complexity when expressing the relative position between the trihedral and the projection plane. When attempting to int egrate the a nalytical and constructive approaches, we noted advantages and simplifications derived from two unusual starting choices.

The first was using as a reference system the trirectangular triedral itself to be pro jected. The second choice, once a direction of ar bitrary orthogonal projection is established, was to use as a picture pl ane the one containing the trihedr al vertex. Once t he system elements and th e relations between them are determined and formulated, graphic operations were developed consistent with the st arting choices and with the previous analytical approach in order to draw the projection. With the projection built the problem of the true ma gnitude comes first. It is not abo ut the me asuring problem of any system of representation (obtaining the distance between two points, or obtai ning the true sha pe of a plan e figure). What matters here is obtaining the orthogonal views of the object to be imaged, as this is the information necessary for the metric control of the constructing projection [13]. Therefore, included in the mentioned paper are those graphic operations consistent with the previous approach that can obtain orthogonal views related to t he axonometry.

In turn, in *New Constructions in Axonometric System Fundamentals* [14] this study was extended, presenting new construction operations of the projection from the peculiar arrangement of the orthogonal views that still applies in this study.

This paper aim s to exte nd this approach, which puts in p arallel analytical and co nstructive aspects of axonometric system, from the orthogo nal to the obl ique, and synthesize as far as possib le their algebraic expression and its traces. T o accomplish this objective we seek to us e among other a spects, geometric potentials detected in the use of the intrinsic axonometric triangle. We also aim to use the main pro jective and metric relations [15] th at can be seen on the studied figures, to dev elop new axonometric constructions. The authors intended with this study to help understanding and how to apply techniques in Engineering Graphics. As a working tool, and to re duce the d ifficulty of describing certain axonometric concepts from a projection representation system, sometimes a me asuring representation system is used for the grap hic description of the elements and relations to study. In this paper, the word construction is understood as a set of traces or sequence of drawing operations derived from the metric geometry used in descriptive geometry. Also, we call analysis the use of the algebraic writing to mathematically express the geometric elements and describe their relations in space in a given system of representation.

2. Bases of the orthogonal axonometric system.

This section presents the already known elements of the orthogonal axonometric system and the basic relations established between them. It is k nown that, in this representation system, the control of the relative position of the ortho gonal views in respect to the a xonometric axes all ows constructing t he projection. But if instead of using any plane, parallel to the picture to rabatte the l evels of the trihedral, we choose the projection plane itself g oing through the origin, the projection can be built from other less common outlines. This section pres ents the alr eady known elements of the orthog onal axonometric system and the basic relations established between them. It is kno wn that, in this repr esentation system, the control of the relative position of the o rthogonal views in resp ect to the a xonometric axes allows constructing the projection. But if instead of using any plane, parallel to the picture to rabatte the l evels of the trihedral, we choose the projection plane itself going through the origin, the projection can be built from other less common outlines.

2.1. Definition of the projection's elements.

First we choose an orthogonal trihedral $Oxyz$ as a reference system. Points $\mathbf{I}$, $\mathbf{J}$ and $\mathbf{K}$ are obtained by measuring a unit magnitude u from the vertex O on the axes x, y and z respectively.

The aforementioned points' coordinates are:

$$\mathbf{O}=O=[0,0,0] \; ; \; \mathbf{I}=[u,0,0] \; ; \; \mathbf{J}=[0,u,0] \; ; \; \mathbf{K}=[0,0,u] \tag{1}$$

Then the mini mum geometric elements that make up the projection are noted (figure 1). The standard equation of the chosen projection plane π_p, containing the vertex O is:

$$\pi_p \equiv a_x x + a_y y + a_z z = 0 \tag{2}$$

where the orthogonal projection direction is $d_\pi \equiv [a_x, a_y, a_z]$ and $\sqrt{a_x^2 + a_y^2 + a_z^2} = u$.

The outlines of the trihedral with reference $Oxyz$, on the main projection plane c_x, c_y and c_z, have the following directions:

$$d_{cx} \equiv [0, -a_z, a_y] \; ; \; d_{cy} \equiv [a_z, 0, -a_x] \; ; \; d_{cz} \equiv [-a_y, a_x, 0] \tag{3}$$

The lines x_π, y_π and z_π that intersect on the vertex O, are obtained from the orthogonal projection of the trihedral with reference $Oxyz$, on the projection plane π_p. And the orthogonal projections of points $\mathbf{I}$, $\mathbf{J}$ and $\mathbf{K}$ on the projection plane, give the points I, J and K, whose coordinates are:

$$I=[u^2-a_x^2, -a_x a_y, -a_x a_z]/u \; ; \; J=[-a_y a_x, u^2-a_y^2, -a_y a_z]/u \; ; \; K=[-a_z a_x, -a_z a_y, u^2-a_z^2]/u \tag{4}$$

The axonometric orthogonal scales can be noted as:

$$\left|\overline{OI}\right|=u_x=\sqrt{u^2-a_x{}^2} \; ; \; \left|\overline{OJ}\right|=u_y=\sqrt{u^2-a_y{}^2} \; ; \; \left|\overline{OK}\right|=u_z=\sqrt{u^2-a_z{}^2} \tag{5}$$

where $u_x{}^2+u_y{}^2+u_z{}^2=2u^2$.

The angles formed by the axes x_π , y_π and z_π are:

$$\alpha_z=\mathrm{acos}\left(-a_x a_y/u_x u_y\right) ; \; \alpha_x=\mathrm{acos}\left(-a_y a_z/u_y u_z\right) ; \; \alpha_y=\mathrm{acos}\left(-a_x a_z/u_x u_z\right) ; \; \alpha_x+\alpha_y+\alpha_z=2\pi \tag{6}$$
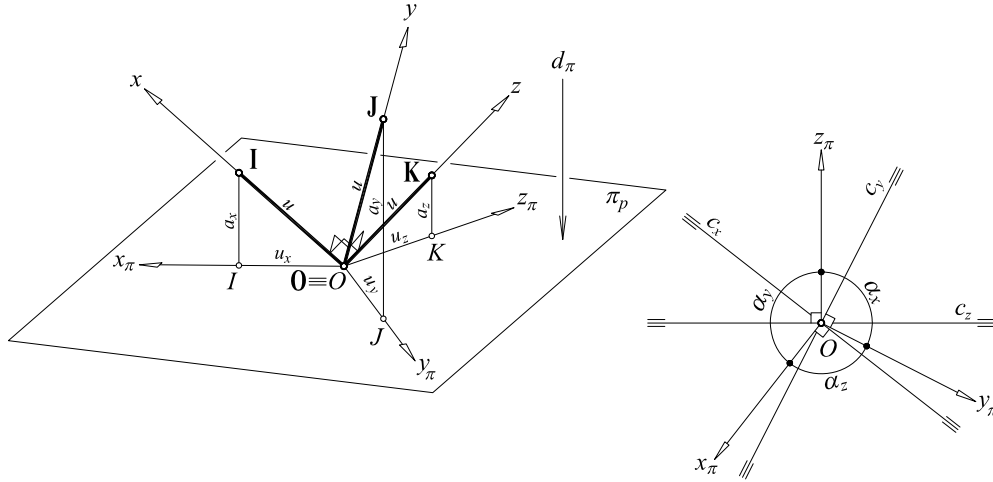

Fig. 1. Orthogonal axonometric system.

These relations are the i ntrinsic parameters of the orthog onal axonometric projection. Other expressions not noted here s uch as the components of the orthog onal projection direction with respect of the axonometric scales, or th e geometric properties of per pendicularity between trace and axes can be found in Gim ena et al. 2012 [1]. So far we have expressed all data, relations and starting conditions that allow constructing the orthogonal axonometric projection of a generic three-dimensional object.

2.2.   Measuring operations.

To describe the true e xtent of the proposed operations, we start here from the orthogonal axonometric projection of a unit cub e, and we aim to obtai n from it the interre lated orthogonal views that a llow measuring and delimiting the object. The aim is therefo re to obtain the true shape of what is projected on the three faces of the space trihedral.
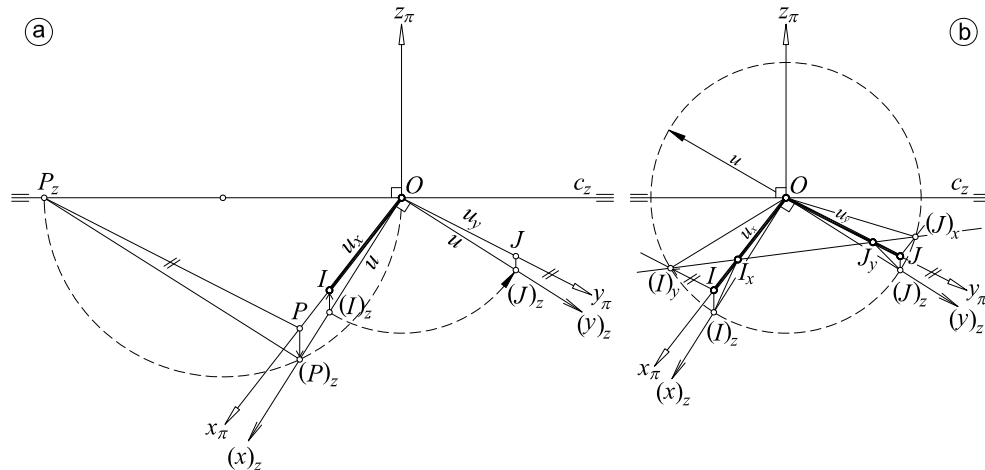

Fig. 2. Rabattement of the reference trihedral planes on the projection plane.

The measuring operations and expressions presented are: A line par allel to the a xis y_π is traced through a ge neric point P of the axis x_π . The intersection of t his line with the trace c_z determines the point P_z . In space, the ang le between the segments $\overline{OP}$ and $\overline{PP_z}$ is straight, so the points O , P and P_z form a right triangle that is rabatted on the picture plane π_p , taking the trace c_z as a hinge.

To this end, the arc of segment $\overline{OP_z}$ is traced under a right angle. The intersection between this arc and the line that passing through the point P, is perpendicular to the hinge c_z (parallel to z_π) determines the rabatted point $(P)_z$. The segment $\overline{OP_z}$ determines the rabattement of the axis x and sets its direction $(x)_z$. On it, and from the point O, the segment $\overline{O(I)_z}$ with size unit u is located. By unrabatting $(I)_z$ we get a point I on the axis x_π, which determines the distance u_x from the point O. These first operations can be seen in figure 2.a. The line $(y)_z$ perpendicular to $(x)_z$ is drawn through the point O. These two lines represent the rabattement of the plane xOy on the projection plane. As in the case of the point I, if we measure a unit magnitude u from O on the rabatted line $(y)_z$, the point $(J)_z$ is obtained. The line through this last point, which is perpendicular to the hinge c_z, determines the point J on the axis y_π. The distance $\left|\overline{OJ}\right|$ equals magnitude u_y on the axis y_π. If the unit circumference with the centre O is drawn, it intersects the lines that passing through the points I and J are parallel to the axes y_π and x_π. With this operation the points $(I)_y$ and $(J)_x$ are obtained respectively. The intersection of the segment of these two points with the axes x_π and y_π determine the points I_x and J_y. This construction can be seen in figure 2.b. Finally, the intersections that occur between the unit circumference and the lines connecting points $(I)_z$, I_x and $(J)_z$, J_y determine the points associated with the axis z, i.e. $(K)_x$, $(K)_y$ and K_z. By paralleling with the axonometric axes, we can obtain the point K, orthogonal projection of point $\mathbf{K}$ in space, as shown in figure 3.a. The distance $\left|\overline{OK}\right|$ determines the magnitude u_z on the axis z_π.

The coordinates of the rabatted unit points I, J and K are:

$$I_x = \left[\frac{u^2 - a_x^2}{u + a_x}, \frac{-a_x a_y}{u + a_x}, \frac{-a_x a_z}{u + a_x}\right]; \quad (I)_y = \left[\frac{a_z^2}{u + a_y} + a_y, -a_x, \frac{-a_x a_z}{u + a_y}\right]; \quad (I)_z = \left[\frac{a_y^2}{u + a_z} + a_z, \frac{-a_x a_y}{u + a_z}, -a_x\right] \quad (7)$$

$$(J)_x = \left[-a_y, \frac{a_z^2}{u + a_x} + a_x, \frac{-a_y a_z}{u + a_x}\right]; \quad J_y = \left[\frac{-a_y a_x}{u + a_y}, \frac{u^2 - a_y^2}{u + a_y}, \frac{-a_y a_z}{u + a_y}\right]; \quad (J)_z = \left[\frac{-a_x a_y}{u + a_z}, \frac{a_x^2}{u + a_z} + a_z, -a_y\right] \quad (8)$$

$$(K)_x = \left[-a_z, \frac{-a_y a_z}{u + a_x}, \frac{a_y^2}{u + a_x} + a_x\right]; \quad (K)_y = \left[\frac{-a_x a_z}{u + a_y}, -a_z, \frac{a_x^2}{u + a_y} + a_y\right]; \quad K_z = \left[\frac{-a_z a_x}{u + a_z}, \frac{-a_z a_y}{u + a_z}, \frac{u^2 - a_z^2}{u + a_z}\right] \quad (9)$$

As synthesis of the above operations, figure 3 presents the orthogonal views associated with the three planes of the reference trihedral, and also represented are the unit edge squares, constructing a unit cube as an elemental, orthogonal axonometric projection.
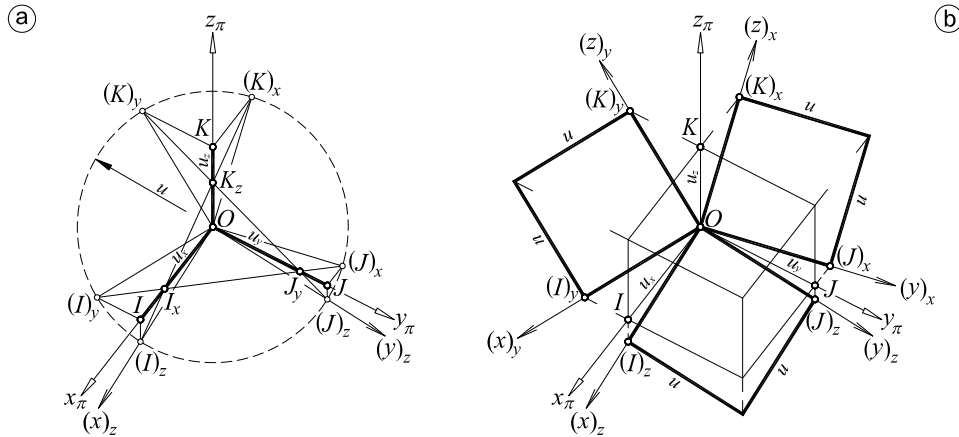

Fig. 3. Orthogonal axonometric projection of a unit cube.

It should be noted that in the sequence of procedures described in the figures there is no use of any auxiliary plane parallel to the reference on which to rabatte the trihedral faces. The direct use of the projection plane as a fixed tilted plane, or place of the true flat shape, allows appreciating directly the graphic and metric relations established between the obtained orthogonal views. In turn, it can be said that the measurement operations carried out constitute the determination of the metric and descriptive problem. That is, the results (relations between axonometric scales and angles, and true magnitudes in orthogonal views) were obtained from the data (trihedral, projection plane, and relative position between them).

2.3. Construction operations.

In a free orthogonal axonometric projection, where the position of the axes is initially dispensed with and therefore some specific angles are n ot used, we can start from an arbit rary arrangement of ortho gonal views of the object to be repres ented directly on the projection plane. The only constraints are t he consistency in the orie ntation and th e coincidence relation between them in the ori gin (must share that point). Figure 4 shows that under this arrangement, and under any angles, it is possible to deduce the position of the axonometric axes and associated scales, thereby determining a pa rticular axonometric projection.
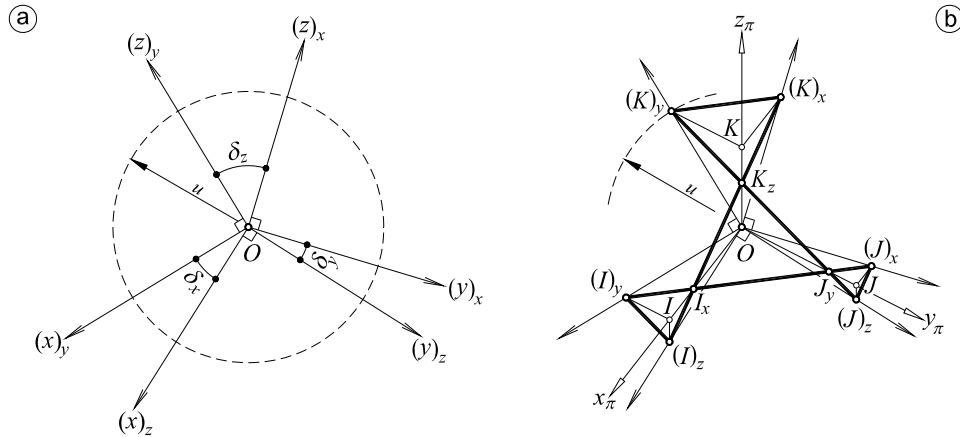

Fig. 4. Axonometric construction from orthogonal views.

As an analytical approach, we take the angles (arbitrary in principle) δ_x, δ_y and δ_z that together form the axes of the planes of the reference trihedral rabatted on the projection plane (figure 4.a.). We aim to determine the projection direction of the unit cube in space on the projection plane, which would correspond to the arrangement of orthogonal views. The relation between the aforementioned angles and the direction components of the projection plane is noted by the equation:

$$\frac{1-\cos\delta_x}{a_x^{\,2}\left(u+a_x\right)} = \frac{1-\cos\delta_y}{a_y^{\,2}\left(u+a_y\right)} = \frac{1-\cos\delta_z}{a_z^{\,2}\left(u+a_z\right)} \tag{10}$$

From this expr ession, the pr ojection axes, angles and scales are determined analytically. To deduce graphically the position of the axonometric axes from the orthogonal views we may proceed as follows:

The unit circu mference with the ce nter O and th e radius u (figure 4.a.) is drawn. The intersection between the axes of the orthogonal views and this circumference determines the points $(I)_y$, $(I)_z$, $(J)_x$, $(J)_z$, $(K)_x$ and $(K)_y$. In turn, as sho wn in figure 4.b. the intersections between the segments $\overline{(I)_y (J)_x}$, $\overline{(I)_z (K)_x}$ and $\overline{(J)_z (K)_y}$ determine the points I_x, J_y and K_z that are in the axonometric axes x_π, y_π and z_π, thereby their position is graph ically determined. It can also be noted that on the same figur e the formation of four simil ar triangles $\Delta I_x J_y K_z$, $\Delta I_x (I)_y (I)_z$, $\Delta (J)_x J_y (J)_z$ and $\Delta (K)_x (K)_y K_z$, and th at the points O, I, J and K associated with them are homologous.

3. New constructions in the oblique axonometric system.

The study of geom etric and graphic projection properties can also re ly on analytical and metric geometry, like done here, trying to break the ambiguity that involves researching the projection from within, especially when the aim is to visualize the relations between two or more projections on the same figure or representation. From the analysis of the gr aphic relations observed on the simultaneous representation of the orthogonal axonometric projection and some associated obliques, we conclude also the convenience of placing some system elements in certain positions to facilitate the operations required. This choice of the initial arrangement of th e system elements is what allows sometimes seeing those properties of t he figures that remain, or not, on the step from space to the plane and vice versa.

3.1. Relations observed on the orthogonal axonometric projection.

The expression of geometric properties and relations need not be performed in the projection system itself given the construction difficulties that it sometimes entails. The graphic analysis of the basic elements of the axon ometric system in this paper relies on a s ystem of m easurement representation (dihedral system). The horizontal projection as a r eference plane is used. The vertical projection is reserved to facilitate the deduction of properties.

Figure 5 shows the relation between the unit plane π_u, the intrinsic plane π_i and the projection plane π_p.
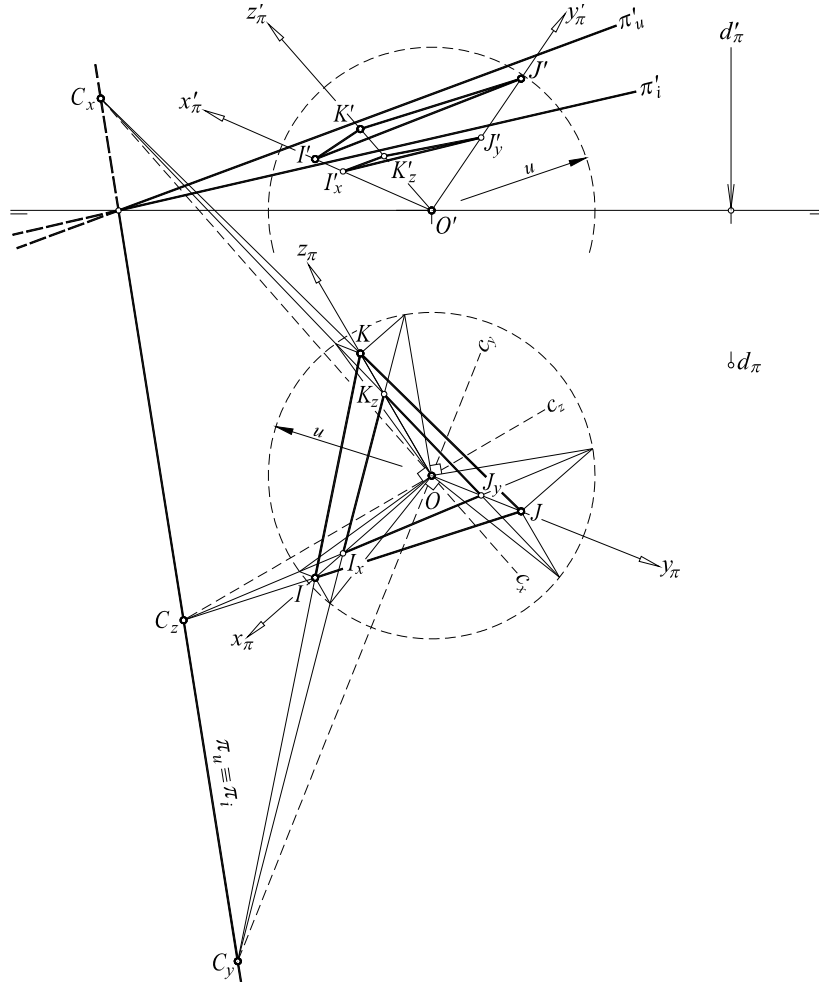
Fig. 5. Relations in orthogonal axonometry.

The unit plane equation that contains the points **I**, **J** and **K** is:

$$\pi_u \equiv x+y+z-u=0 \tag{11}$$

The equation of the intrinsic plane containing the points in space whose orthogonal projections are I_x, J_y and K_z is noted:

$$\pi_i \equiv \left(a_x+u\right)x+\left(a_y+u\right)y+\left(a_z+u\right)z-u^2=0 \tag{12}$$

The projection plane expressed in equation (2) is coincident with the projection's horizontal plane. These three planes have a common line, horizontal trace $\pi_u \equiv \pi_i$, expressed in parametric form as:
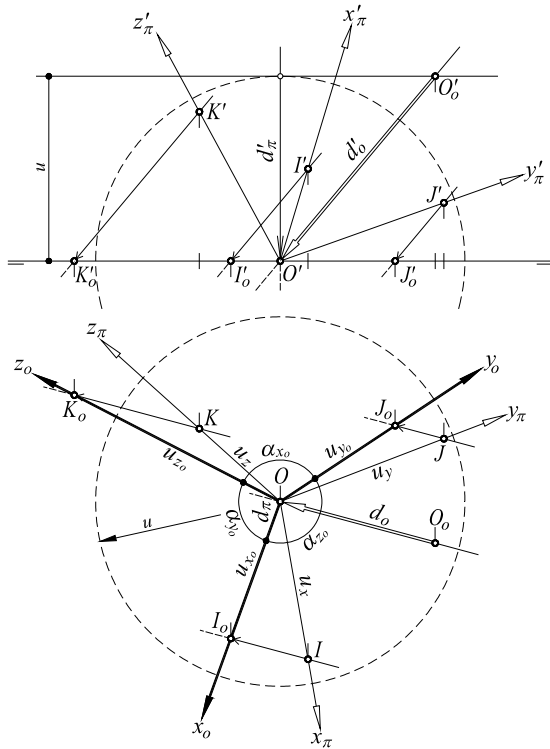
$$
\begin{aligned}
x &= \left(a_y-a_z\right)t+a_y a_z u \big/ \left(a_z-a_x\right)\left(a_x-a_y\right) \\
y &= \left(a_z-a_x\right)t+a_z a_x u \big/ \left(a_x-a_y\right)\left(a_y-a_z\right) \\
x &= \left(a_x-a_y\right)t+a_x a_y u \big/ \left(a_y-a_z\right)\left(a_z-a_x\right)
\end{aligned}
\tag{13}
$$

Figure 5 sh ows also the p oints C_x, C_y and C_z, which are on sa id trace. In them concur the   lines corresponding the sides of the triang les of the intri nsic and unit p oints associated with each axis of th e trihedral and their respective ordinary traces c_x, c_y and c_z.

3.2.   Definition of oblique axonometric projection.

If the a xes of the reference trihedral $Oxyz$ are pr ojected on the projection plane π_p under a direction d_o, its obl ique projection is obtained. This oblique projection direction is $d_o \equiv \left[a_{xo}, a_{yo}, a_{zo}\right]$, when $\sqrt{a_x a_{xo}+a_y a_{yo}+a_z a_{zo}}=u$. The module of the vector associated to this direction is $\sqrt{a_{xo}^2+a_{yo}^2+a_{zo}^2}=e_o u$. The endpoint associated with the pr ojection direction is O_o, and its orthogonal projection onto the projection plane is $O_o=\left[a_{xo}-a_x, a_{yo}-a_y, a_{zo}-a_z\right]$.

Figure 6 shows that the coordinate of said point is always the unit.

Fig. 6. Elements of an oblique axonometry.

The distance from this point to the origin is:

$$\left|\overline{OO_o}\right|=u\sqrt{e_o{}^2-1} \tag{14}$$

The oblique projection of the points **I**, **J** and **K** are the points I_o, J_o and K_o. Its coordinates are noted as:
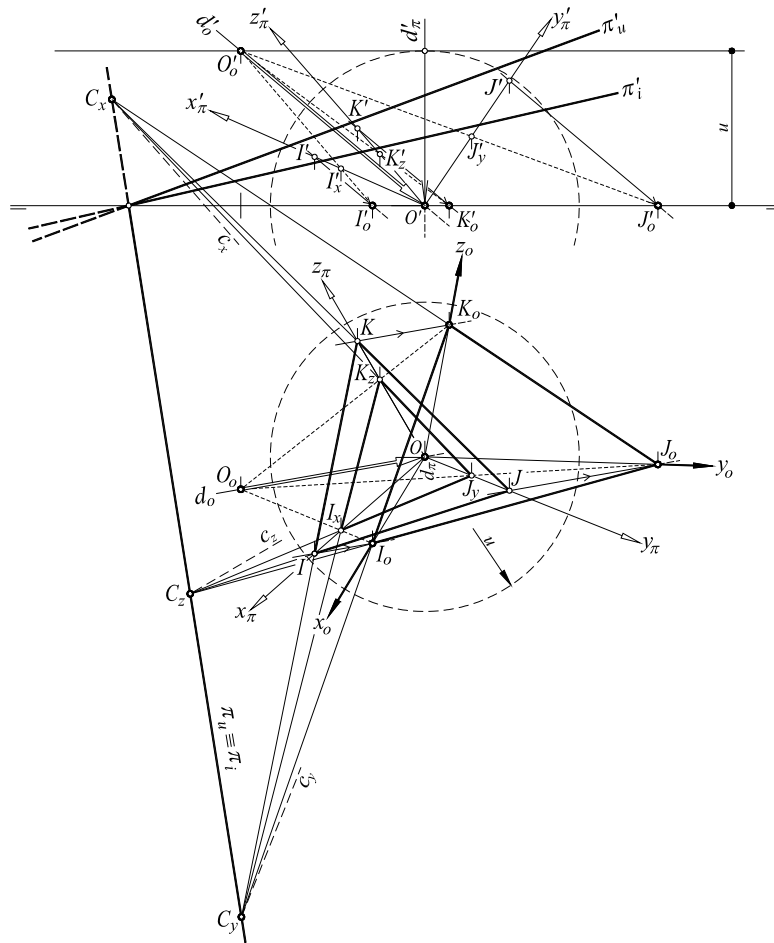
$$I_o=\left[u^2-a_x a_{xo},-a_x a_{yo},-a_x a_{zo}\right]/u$$
$$J_o=\left[-a_y a_{xo},u^2-a_y a_{yo},-a_y a_{zo}\right]/u$$
$$K_o=\left[-a_z a_{xo},-a_z a_{yo},u^2-a_z a_{zo}\right]/u \tag{15}$$

The oblique axonometric scales can be written as:

$$\left|\overline{OI_o}\right|=u_{xo}=\sqrt{u^2+a_x{}^2 e_o{}^2-2a_x a_{xo}}$$
$$\left|\overline{OJ_o}\right|=u_{yo}=\sqrt{u^2+a_y{}^2 e_o{}^2-2a_y a_{yo}}$$
$$\left|\overline{OK_o}\right|=u_{zo}=\sqrt{u^2+a_z{}^2 e_o{}^2-2a_z a_{zo}} \tag{16}$$

The relation between the oblique axonometric scales is:

$$\sqrt{u_{xo}{}^2+u_{yo}{}^2+u_{zo}{}^2}=u\sqrt{e_o{}^2+1} \tag{17}$$

The angles between the axes x_o, y_o and z_o are:

$$\alpha_{zo}=\mathrm{acos}\left(\left(a_x a_y e_o{}^2-a_{xo}a_y-a_{yo}a_x\right)/u_{xo}u_{yo}\right)$$
$$\alpha_{xo}=\mathrm{acos}\left(\left(a_y a_z e_o{}^2-a_{yo}a_z-a_{zo}a_y\right)/u_{xo}u_{yo}\right) \tag{18}$$
$$\alpha_{yo}=\mathrm{acos}\left(\left(a_z a_x e_o{}^2-a_{zo}a_x-a_{xo}a_z\right)/u_{xo}u_{yo}\right)$$

when $\alpha_{xo}+\alpha_{yo}+\alpha_{zo}=2\pi$.

Only the minimum observed relations, necessary to note analytically the oblique axonometry, have been noted here.

3.3. Construction of the oblique axonometric projection from the orthogonal.

This section shows the relations that allow associating the construction of an oblique axonometry with a preselected orthogonal one. To this end we use line radiations that relate unit and intrinsic points and the corresponding sides between projection figures. Figure 7 shows the set of graphic relations.

To construct an oblique axonometry from an orthogonal one, we may proceed as follows:

– Firstly, once the elements of the orthogonal axonometric system are located and represented, it is necessary to choose and represent an oblique line d_o as a projection direction.

– Next, the point O_o of the line with the unity coordinate must be projected onto the projection plane.

– After the radiation of lines that relate endpoint O_o with the intrinsic points I_x, J_y and K_z is constructed.

– Such lines' radiation is cut by the lines parallel to the direction d_o passing through the unit points of the orthogonal axonometry I, J and K in the unit points of the oblique axonometry I_o, J_o and K_o.

Thus, the axes of the oblique axonometric projection x_o, y_o and z_o are graphically established.

It can be noted that the relations of correspondence between the sides of the unit and intrinsic triangles in the orthogonal axonometry (figure 5) can be extended to the oblique one. The lines of the sides of the oblique unit triangle concur also on points C_x, C_y and C_z of the unit plane trace.

Fig. 7. Construction of an oblique axonometry.

3.4.   Bunch of oblique axonometric projections.

Through the proce dure described in the previous section, we have obtained a ge neric oblique axonometry of projection direction d_o. Figure 8 shows that in order to obtain the oblique axonometries of directions d_1, d_2 or any chosen one, we can proceed analogously. The radiations relating the endpoints of unit coordinate O_1, O_2 with the intrinsic points I_x, J_y and K_z are always used. All these oblique axonometries together with the in itial orthogonal make u p a proj ection bunch ass ociated with a si ngle spatial trirectangular trihedral.
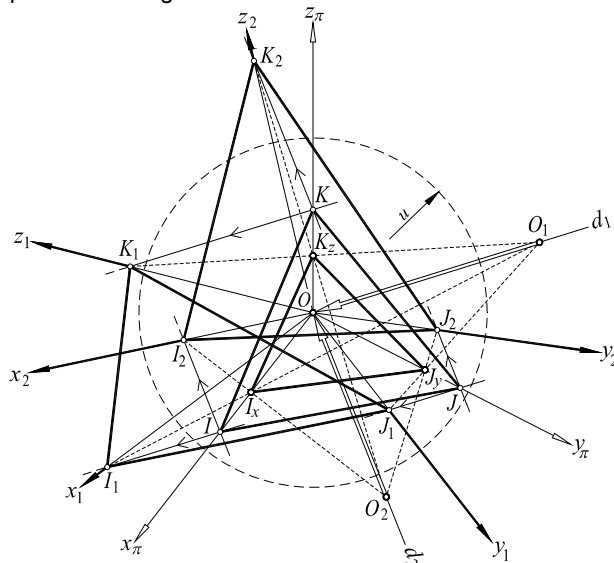
Fig. 8. Oblique axonometric bunch.

The orthogonal axonometric projection is sti ll a bunch of oblique projections. By using the radiations through the intrinsic points, one can use one obtained previously to construct any other, as shown in figure 9.
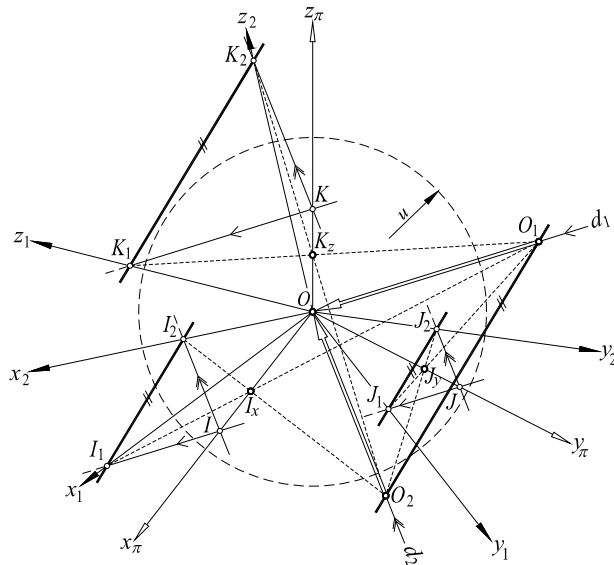

Fig. 9. Construction of related oblique axonometries.

The corresponding points of t wo projections in the bunch are in p arallel lines to the one joining the endpoints of the unit coordinate.

4. Conclusions.

The choice of the projection trihedral itself as a refere nce system, regardless of the projection plane chosen, allows the an alytical writing of t his representation system and exploring new traces in the construction of the projection.
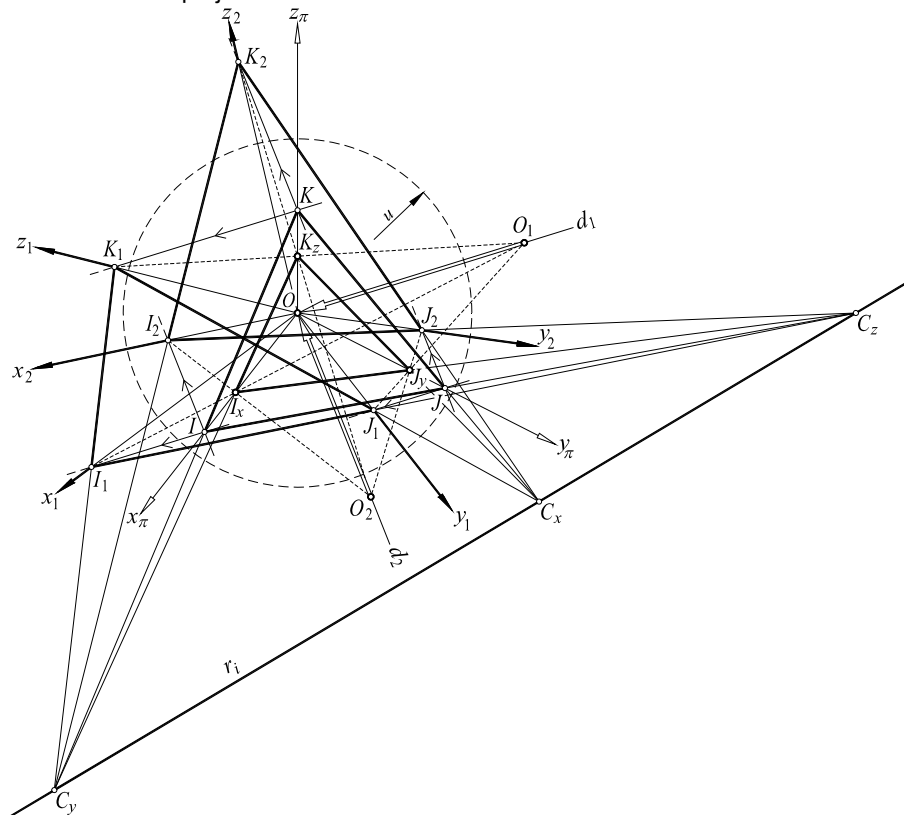
Fig. 10. Projective relations in the axonometric bunch.

As seen in section 3.1., in an orthogonal axonometry in which the projection plane is placed through the vertex of the space trirectangular trihedral, the unit plane and intrinsic plane intersect on the same l ine r_i on the projection plane (see figure 10).

In turn, using graphic operations developed in section 3.3., one can construct an oblique projection from an orthogonal one, once the intrinsic triangle is known and its projection direction is established.

From all points in any direction of oblique projection, the point with the unit coordinate with respect to the projection plane is the one that, when projected on, allows the construction of the oblique projection by the radiation method developed (see sections 3.2. and 3.3.).

From the aforementioned constructions we conclude that if the corresponding sides of the unit triangles of two axonometric projections are cut in three aligned points, such axonometries come from the same spatial trirectangular trihedral, projected onto the projection plane. Such oblique axonometries relate to one and only orthogonal axonometry.

The axonometries associated with different projection directions, including the starting orthogonal one, make up a bunch in which the figure contained in the unit plane of each projection is homologously related with the one contained in the intrinsic plane. As shown in section 3.4., the intrinsic plane is invariant on the projection plane. It is common to all plane homologies established in the above-described relation.

From a projective point of view figure 10 shows the following correspondence or projection relations:

- Centers' homologies O; O_1; O_2; … and axis r_i between the points of the unit figures I, J, K; I_1, J_1, K_1; I_2, J_2, K_2; … and intrinsic I_x, J_y, K_z.

- Oblique directions' affinities d_1; d_2; …; d_o and axis r_i between the points of the unit figures I_1, J_1, K_1; I_2, J_2, K_2; …; I_o, J_o, K_o and orthogonal I, J, K.

- Directions affinities $\overline{O_1 O_2}$ and axis r_i between the points of the generic oblique unit figures I_1, J_1, K_1 and I_2, J_2, K_2.

As a metric conclusion it can be said that the ratio between the segments resulting from joining the endpoints of two oblique projections of the bunch and the unit points thereof is constant.

$$\frac{\overline{OO_1}}{\overline{OO_2}}=\frac{\overline{II_1}}{\overline{II_2}}=\frac{\overline{JJ_1}}{\overline{JJ_2}}=\frac{\overline{KK_1}}{\overline{KK_2}}=cte$$

The research method followed to develop this proposal aims to adopt an overview of the various knowledge that form the geometry, with constructing purpose or meaning. The analytical and graphic languages, both projective and descriptive, complement each other when designing the spatial form and representing the same with geometric rigor.

References.

[1] J. L. Weisbach. *Die monodimetrische und anisometrische, Projectionsmethode (Perspective)*. Polytechnische Mitteilungen von Volz und Kamarsch, Bd I, Tubingen 1844.

[2] R. Schüssler. *Orthogonale Axonometrie, Ein Lehrbuch zum Selbststudium*. Teubner, Leipzig, 1905.

[3] W. Farish. *Treatise on isometrical perspective*, The Transactions of the Cambridge Philosophical Society. Vol. I, 1822.

[4] E. Caridad Yáñez. *Axonometría como sistema de representación*. Boletín Académico (E.T.S.A. de La Coruña) 18 (1994) 18–23.

[5] M. Scolari. *Oblique Drawing: A History of Anti-Perspective*. The MIT Press, 2012.

[6] F. Agrasar Quiroga. El valor simbólico de la axonometría. Boletín Académico (E.T.S.A. de La Coruña) 16 (2) (1992) 50–55.

[7] F.P. Preparata and M. Shamos. *Computational Geometry: An Introduction*. Springer-Verlag, Berlin, 1985.

[8] D. Hildenbrand. *Geometric computing in computer graphics using conformal geometric algebra*. Computers & Graphics 29, 5 (2005) pp 795–803.

[9] J. Conesa, P. Company, A. Piquer y N. Aleixos. *Ampliación del método de inflado axonométrico para la reconstrucción de poliedros*. Proceedings of XIII ADM - XV INGEGRAF, June 3th – 6th, 2003, Cassino, Napoli, Salerno.

[10] P. Company, M. Contero, J. Conesa and A. Piquera. *An optimisation-based reconstruction engine for 3D modelling by sketching*. Computers & Graphics 28, 6 (2004) pp 955–979.

[11] M. Pémová. *Theory and practice of the representation of space objects in the school mathematics*. Acta Didactica Universitatis Comenianae, Mathematics, 8, (2008) pp 79–101.

[12] L. Gimena, P. Gonzaga and F.N. Gimena. *Main axonometric system related views as tilt of the coordinate planes*. Proceedings of IMProVe 2011, ADM – INGEGRAF, June 15th – 17th, 2011, Venice. pp 748–752.

[13] J. Aubert. *Axonométrie: Théorie, art et pratique des perspectives parallèles: Axonométrie Orthogonale, Axonométrie Oblique, Perspectives Cavalière et Militaire*. Editions de la Villette, Paris, 1997.

[14] L. Gimena, F.N. Gimena and P. Gonzaga. *New Constructions in Axonometric System Fundamentals*. Journal of Civil Engineering and Architecture 6, 5.54, (2012) pp 620–626.

[15] D.J. Struik. *Lectures on Analytic and Projective Geometry*. Addison-Wesley Publishing Company, Cambridge, Massachusetts, 1953.

DEVELOPMENT OF FINAL DEGREE´S PROJECTS IN THE FIELD OF GRAPHIC EXPRESSION IN ENGINEERING

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Abstract

Final degree projects could become a useful tool for developing complementary research and lines of investigation within any field, but graphic engineering is often forgotten by students when they have to choose the topic of their own project. Some reasons can explain this situation, as for example the fact that graphic engineering teachers often investigate in other fields of engineering. The facts that most of the subjects belonging to graphic engineering area are taught during the first years of the degrees, and many times are considered as merely "instrumental", only worsen the situation. In this context, this paper shows a comparison of the final projects carried out in graphic engineering and other related fields. It is pretend to be useful for teachers for proposing topics that could contribute to encourage students for developing more and better final degree projects in the field of graphic engineering.

1   Introduction

There is a long tradition of developing a final project in the field of engineering studies. Nonetheless, the establishment of the European Higher Education Area (EHEA) after the beginning of the convergence process that started from the Sorbonne Declaration of 1998 and the Bologna Declaration of 1999 [1] has implied a redefinition of Final Degree Projects (FDP).

In this context, FDP involves students developing an original project under the supervision of one or more directors with the main objective of showing that they have reached the competences foreseen by their specific curriculum [2][3]. As the achievement of the competences must be clearly displayed, students are particularly concerned of selecting a project that allows them to prove this fact.

The FDP is developed during the last year of the Degree, and as a consequence, when seeking for a topic for their project, students usually turn to the subjects they have studied recently. In addition, students usually perceive that the higher the year in which a subject is taught, the bigger the acquisition of degree´s competences.

As subjects comprised within Graphic Expression in Engineering (GEE) use to be taught during the first years of the degree, many students don´t have them in mind when facing their FDP. Consequently, FDPs in this area are not as many as they could be, especially if considering the real scope of the competences provided by the subjects related to GEE.

1.1   Definition and objectives of GEE subjects

Drawing, both technical and artistic, constitutes a universal language, and remains one of the primary ways in which Engineers communicate their ideas. The denomination of GEE comes from the process of teaching and learning through technical drawing and computer aid design (CAD) and other modelling tools resulting in the representation of 3D products over a flat surface (a plane, a screen, a picture). This representation sometimes materialise in a project, through the conventions of Technical Drawing or by other means such as modelling, rendering or simulations.

This GEE definition has allowed both naming an specific field of knowledge as well as identifying the first year subjects within Engineering Degrees formerly called Drawing or Technical Drawing.

In most of the academic guidelines of engineering studies [4][5][6] the objectives of GEE are:
-   Developing the capacity of efficient and rational representation of products,
-   Fostering the spatial vision necessary for solving professional problems,
-   Promoting creativity.

1.2 Competences developed by GEE

The competences developed by GEE subjects results from the exposed objectives:
- Problems solving skills,
- Understanding design as an artistic-technical creation,
- Capacity to apply theoretical knowledge in practice,
- Three-dimensional design and visualization skills,
- Advanced use of new technologies and applications.

The development of these competences overcomes the traditional target of GEE subjects, comprising skills related to the wider engineering field. In fact, there are some degrees, as Design Engineering [7], in which GEE subjects represents great part of the general curriculum.

The consequence of the range and variety of GEE competences is that the fields in which the investigation in GEE is developed is really broad, ranging from Computer Science to Neurosciences or Psychology [8]. The skills provided by GEE have proved to be a strong indicator of success in engineering, science and a variety of other degrees [9].

Nonetheless, it is still difficult for many graphic expression teachers to motivate students for developing research in this field.

1.3 Research fields in GEE

In recent years, the research fields in GEE have been mainly those related with computer science in general, and software engineering in particular. The generalization of CAD and 3D programs in engineering have motivated the research in this area to be wider than in other fields [8][10].

The prominence of these investigation fields is reflected in the key topics in the main specific congresses and publications, in which Computer Aid Design, Virtual Prototyping and Robotics are usually some of the main themes. But the investigation in these fields requires the collaboration of GEE specialists with experts from other areas of knowledge, which it is not always easy. It becomes an almost impossible task if the aim is to develop a project of the size of a FDP.

On the contrary, the problem is often the opposite: projects that should have been developed with the collaboration of teachers of GEE are developed under the only direction of specialists from other fields. This translates sometimes into a devaluation of the graphic quality of the projects, understood in the sense of lack of analysis and development of key factors, a problem that could be solved by establishing a more active collaboration between areas.

1.4 Research objectives

For all the reasons exposed, it seems necessary to redefine and establish new areas of research for developing FDP in GEE, to value the contribution provided by the subjects included in this field. Establishing them also might provide the creation of new collaborative networks and the subjects which would be more suitable for it, and perhaps could inspire new lines of investigation [11].

This article proposes an analysis of the FDP presented at the University of Zaragoza within Design and Manufacturing Engineering Department (DMED), which includes apart from GEE, Manufacturing Processes for Engineering (MPE) and Engineering Projects (EP) areas. This paper focuses on the study of the presence and importance that GEE projects have out of the total amount of the department projects as a first step to open new perspectives for FDP in GEE field.

2 Methods

The FDP are relatively recent, since they are linked to a category of studies, such as Degrees, new in Spanish Higher Education Area. The first Degree, Industrial Design and Product Development Engineering (IDPDE), was introduced in the School of Engineering at the University of Zaragoza in 2008-2009, and the rest of the Degrees were introduced two years after, in 2010-2011. Therefore, there is still few data about FDP at University of Zaragoza, apart from those of IDPDE.

This kind of project, however, is not new in this field, as the development of a Final Thesis (FT) that was very similar to current FDP, was compulsory for completing the former Engineering studies. This is why data has been adopted both from FDP and FT. This fact will also allow us to study the evolution of the FDP in GEE area due to the change motivated by the establishment of EHEA.

2.1 Information sources

The data for this study were provided by the DMED secretary and includes information since the 2010-2011 academic year to the 2013-2014 course, i.e. four years. These data were used for computing the dedication of the teachers to FDP and FT within their schedule, and were initially provided by the University and subsequently reviewed by teachers and the department itself.

The information for the year 2010-2011 only includes FT, for the first class of the new curriculum came out the following year. There were two types of FT that year, those of the three-year Technical Engineering studies and the FT of the five-year Engineering studies.

From that year on there were both FT and FDP directed by teachers from the Department, although as years went by there were fewer FT and much more FDP every year. There were, despite of this, still 72 FT the last of the four years studied, which is yet a significant amount.

2.2   Data size and other relevant information collected

The total amount of FT and FDP directed by teachers of the DMED during the four years studied was 586, as it is shown in Table 1. It can be seen there were still much more FT than FDP, being FT the 73% of the total, although the increase in the number of FDP is obvious as years pass. Thereby, FDP reached 58,86% in the last period considered.

Course	FT 3-year Technical Engineering	FT 5-Year Engineering	FDP 4-Year Degree	Total
2010-2011	131	14	---	145
2011-2012	81	19	3	100
2012-2013	79	32	55	166
2013-2014	42	30	98	170
Total	333	95	161	581

Tab. 1 FT and FDP developed at DMED.

These projects were classified depending on the director´s area, and a comparison between the areas was made regarding the number of projects. This operation was repeated for each academic year analyzed, obtaining information both corresponding to each year and establishing the comparison between different academic courses.

Apart from the total amount and the type of project developed each year, information was collected about the degree in which the FT or the FPD had been carried out, but complete data were only available for the last two academic courses. Therefore, this fact was only studied for those two periods.

3   Results

The projects developed every year, classified by type of project and area, are shown in Table 2, from which some conclusions can be extracted:

- Firstly, GEE has been very relevant in 3 year Technical Engineering, being the area with the larger amount of FT within the Department, with 62,46% of the FT developed,
- Secondly, FT in 5 year Engineering have been developed almost exclusively by MPE teachers, reaching more than 83%,
- Thirdly, neither FT nor FDP developed by EP area are relevant in number overall,
- Finally, although FDP developed by GEE started being more than the ones developed by MPE, there is an upward trend in the number of FDP developed by MPE that suggest that they could exceed GEE in a short period .

	FT 3-year Technical Engineering			FT 5-Year Engineering			FDP 4 Year Degree		
Course	GEE	MPE	EP	GEE	MPE	EP	GEE	MPE	EP
2010-2011	87	44	---	---	11	3	---	---	---
2011-2012	42	38	1	4	13	2	1	1	1
2012-2013	60	19	---	3	25	4	45	7	3
2013-2014	19	22	1	---	30	---	50	47	1
Total	208	123	2	7	79	9	96	55	5

Tab. 2 FT and FDP developed by area.

The importance of GEE in 3-year Technical Engineering compared with the less relevance appreciated in 5-year Engineering is because the relative weight that GEE subjects had in those qualifications was much higher. The shorter duration of studies also allowed a more sustained contact between students and GEE teachers, which increased the probability of developing a FT in this area.

On the other hand, 5-year Engineering didn´t allowed this closeness between students and GEE teachers, as the subjects taught by GEE in these studies were mostly taught during the first years, just the opposite of the subjects given by MPE teachers.

This fact could also explain the trend that can be appreciated in FDP, with MPE projects rising significantly in the last period studied, perhaps related to the structure of 4-year Degrees being more similar to 5-year Engineering.

This increase also has direct relationship with the output of the first class of most of new degrees in 2014. By analyzing the degrees in which these projects have been developed, the variety of fields covered by FDPs developed by MPE comes clear. Instead, most of the FDP directed by GEE teachers correspond only to one degree, IDPDE, the first one introduced. This data is shown in Table 3.

2013-2014	FDP 4 Year Degree		
Degree	GEE	MPE	EP
Industrial Design and Product Development Engineering	87	29	---
Mechanical Engineering	3	6	1
Industrial Technologies Engineering	4	8	---
Electric Engineering	2	2	---
Chemical Engineering	---	1	---
Biomedical Engineering	---	1	---

Tab. 3 FDP by Degree developed in every area in 2013-2014.

The number of FDP in Degrees apart from IDPDE is expected to increase in next years, as in the first ending year of a Degree not all the students are expected to be finishing their projects. Therefore, this difference in variety between GEE and MPE, and thus in the total number of projects, is expected to grow.

We can compare the information from FDP with the data from the 3-year Engineering FT developed during the same academic course, as it is shown in table 4. Although the number of projects is much smaller, it can be observed that the range of Degrees involved is higher.

2013-2014	FT 3-Year Engineering		
Degree	GEE	MPE	EP
Industrial Design Engineering	4	---	1
Mechanical Engineering	1	19	---
Electronics Engineering	8	3	---
Electric Engineering	5	---	---
Chemical Engineering	1	---	---

Tab. 4 FDP by Degree developed in every area in 2013-2014.

Thereby, we can conclude that the variety of Degrees in which the FT were developed, that used to be a characteristic of projects directed by GEE teachers, could be no longer true if the current trend consolidates.

4 Conclusion

The study of the Final Projects developed in the DMED for the last four academic courses show that the number of those directed by GEE teachers is declining, and tends to concentrate in an specific Degree. This fact can be clearly appreciated analyzing the data collected, and could rise dramatically in next years considering the growing of FDP from new degrees in which apparently the presence of GEE is not very marked.

This trend would limit the future possibilities of investigation in the field of Graphic Engineering, due to the lack of students developing new lines of investigation within their FDP, a very interesting possibility brought by these type of projects.

It would be necessary for GEE teachers to adopt a more active role in promoting the work in this area, which could be done in many ways, such as:
- Keeping a higher level of contact with students of those degrees in which GEE is less relevant,
- Offering FDP topics for students from those degrees,
- Promoting collaboration and/or co-direction of FDP with areas with common interests, such as Computer Engineering, Machine-Person Interaction or Economics.

This study is, however, just a first approach to a problem that might be analysed with a bigger range of data, and for a longer period, to confirm the trends detected.

It would be also interesting to wider the study to the whole Engineering School, to value the real presence of GEE in the general context of Engineering FDPs.

References

[1] European Ministers of Education. The Bologna Declaration of 19 June 1999, 1999. http://www.ehea.info/Uploads/Declarations/BOLOGNA_DECLARATION1.pdf accessed 30 April 2015.
[2] Reglamento de los trabajos de Fin de grado y de fin de master. http://wzar.unizar.es/servicios/coord/norma/traba.pdf accessed 15 April 2015
[3] Normativa de trabajo Fin de Grado y Master de la Universidad de Extremadura http://www.unex.es/organizacion/gobierno/vicerrectorados/vicealumn/normativas/normativas_generales/normativaTFG_TFM_definitiva, accessed 24 April 2015

[4]   Expresión Gráfica (Grado en Ingeniería Mecánica), Universidad de Sevilla
        http://www.us.es/estudios/grados/plan_207/asignatura_2070002, accessed 27 April 2015

[5]   Grado en Ingeniería de Organización Industrial, Universidad a distancia de Madrid
        http://www.udima.es/es/expresion-grafica.html accessed 27 April 2015

[6]   UNED
        http://portal.uned.es/portal/page?_pageid=93,8050703,93_20551135&_dad=portal&_schema=PORTAL&idAsignatura=0152104-&idPrograma=-1 accessed 27 April 2015

[7]   Profesorado. Grado en Ingeniería de Diseño Industrial y Desarrollo de Producto.
        http://titulaciones.unizar.es/ing-dis-industrial/profesorado.html accessed 15 April 2015

[8]   J. Rojas-Sola, J. Navarrete-Cortés, J.A. Fernández-López and J.A. Chaichio-Moreno.
        *Science production in the graphic expression in engineering área at the Spanish
        Universities: An approach to ISI Database.* Revista española de documentación científica
        31, 2 (2008) pp 190-204

[9]   C. Melgosa Pedrosa, B. Ramos Barbero, A. Román Miguel. *Spatial visualization learning
        in Engineering: Traditional methods vs. a Web-based tool.* Educational Technology &
        Society 17, 2 (2014) pp 142-157

[10]   O. Farrerons Vidal, N. Olmedo. Análisis histórico de la influencia de las tecnologías de la
        información y la comunicación en el aprendizaje de las técnicas de ingeniería gráfica en
        España. Proceedings of "XXI Congreso Universitario de Innovación Educativa en las
        Enseñanzas Técnicas (CUIEET)". Valencia 2013, p. 612-623

[11]   M.A. Caro Gutiérrez, A. Rodríguez Ríos, C. Calero, E. Fernández-Medina, M. Piattini.
        *Análisis y revisión de la literatura en el contexto de proyectos de fin de carrera: una
        propuesta*. Revista Sociedad Chilena de Ciencia de la Computación, 6, 1 (2005),
        http://users.dcc.uchile.cl/~mmarin/revista-sccc/sccc-web/Vol6/CCESC08.pdf accessed 13
        April 2015

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Cross-cultural product design: How to sensitize students of Industrial Design Engineering?

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Abstract

Purpose:

It is indisputable that companies competing in a global marketplace have an emerging interest in design professionals that are able to understand the impact of cultural dimensions on the experiences and interaction between people and products. This means that in order for students of industrial design engineering to succeed in their chosen career, in addition to their technical skills must also develop cross-cultural competence to interact effectively in today's global world. To sensitize students to the importance of the cultural dimension of design, in summer 2014 the Degree in Industrial Design at Tecnun, in partnership with Zhejiang University from China, organised its first cross-cultural experiential learning event through an intensive two-week design workshop. These two universities exchanged a group of 10 design students that were challenged, both from a technical and cultural perspective, to work in an immersive experiential learning approach built around a collaborative design project.

Method:

From the methodological point of view, the key to successfully organising and carrying out this experience was the close collaboration between the teaching staff of both universities, as well as the participation of local companies with interest or experience in the internationalisation of their services and/or products in the host country. Professors from both universities co-taught the programme, which allowed closer partnerships and increased trust and exploration of further collaboration for future. In parallel, each group of 10 exchange students attended the workshop in the other university's facilities, where they collaborated with a similar number of local students. Students attended interactive classroom sessions, visited local companies at both locations to learn about product development, participated in cultural visits to local museums, which helped them to deepen their understanding of the local culture, and worked in

collaborative cross-cultural teams to tackle a design challenge, which included a final presentation and a proof-of-concept prototype.

Result:

The students' feedback and the companies' evaluation of the results of the design challenges indicate the programme's in providing a positive learning experience in cross-cultural design. Moreover, both universities agreed to continue with the organisation of this workshop in the following years, and other opportunities arose from this experience. As an example, two students from Tecnun went to Zhejiang University to carry out their final degree project in the autumn semester of 2014, one student from Zhejiang applied in 2015 to do a PhD at Tecnun and two mixed groups of students from Tecnun and Zhejiang, who met at this workshop, participated in an international design competition sponsored by a Basque company in the automotive sector. Moreover, from this experience, the Industrial Design team at Tecnun designed an Honours Programme that is focused on cross-cultural design, in order to complement the regular bachelor's degree programme. The Honours Programme will be implemented in 2015-2016.

Discussion & Conclusion:

A workshop of two weeks may seem a priori too short to sensitize a group of industrial design students to the importance of cultural variables in product design. However, our experience with this workshop shows that a short but really immersive experience provides benefits for all the agents involved: students, universities and local companies. In addition to these direct results, the collaborative dynamics leads to the generation of new forms of collaboration between universities and even among students.

1   Introduction

In most th eories [1, 2, 3] c ulture has been defined as a system of shared beliefs, values, customs, behaviours and artefacts that members of a society use to cope with their world and with one another, and that are transmitted from generation to generation through learning. Culture, therefore, is not genetic or defined by birth. Culture manifests itself both in visible (art, language, etc.) and non-visible ways (habits, preferences, experiences).

There is a n emerging interest in th e impact of cu ltural dimensions on the experience and interaction between people and products [4, 5]. Glo balisation has led to a situation in which product design teams from one culture or context often have to develop a product which will be used in a totally different cultural environment. Globalisation also forces companies to decide between "global" or "local" featured design of products. A company's failure to acknowledge cultural diversity often limits its products' marketability [6]. As a result it has become essential for the industrial design profession to take the c ontext and culture of the end-users more seriously and to look for consequences regarding industrial design. Therefore, cross-cultural product design is increasing in value and interest within the education programmes of industrial design, and students are increasingly seeing the need to develop cross-cultural competence along with their technical skills in order to succeed in their future career and be able to interact eff ectively in today's global world [7, 8].

In 2013 Tecnun, the School of Engineering of the University of Navarra, established contact with Zhejiang University in China, thanks to a local design studio that was in the process of opening an office in China. This Chinese university is one of the universities from around the world that have won the largest number of Red Dot Awards, a total of 68. In 20 13 students and teachers from the College of Computer Science and Technology at Z hejiang University won 16 a wards, 3 of which were jointly won by students from Industrial Design and Digital Media.

Taking advantage of this opportunity, the International Relations Department at Tecnun established a first contact to explore possible collaboration activities with this Chinese university with the involvement of the staff of Tecnun's Industrial Design Area, which coordinates the Degree Programme in Industrial Design and Product Development Engineering. The objective was to look for collaboration modes that could be of interest for both universities. The collaboration strategy proposed by Tecnun was based on a progressive model, starting with more informal and short-term collaboration activities, such as design workshops, that could evolve with time to more formal and long-term collaboration activities.

In July 2013 one representative from T ecnun's International Relations department visited Z hejiang University, and as a result of this contact they agreed to si gn a collaboration agreement between both universities and to start working on the design of the first editi on of a j oint Summer Design course. Once the collaboration agreement was defined and accepted by both instituti ons, one representative from the Industrial Design Area at Tecnun travelled to Zhejiang University to meet in person the team that would be involved in the preparation of the first edition of the Summer Design course, and to visit their facilities and accommodation for international students.

From July 2013 to March 2014, the tea ms from bot h universities worked intensively to design the workshop format and define its contents, looking for an immersive cross-cultural learning experience built around a collaborative design project. One of the main decisions during this process was to simultaneously develop two courses, one at each location, where local students and students that arrived from the other university could collaborate on design teams. This allowed students that did n ot have the fin ancial resources to cover the travel and accommodation costs in the foreign university to participate in the course in an affordable way. Also, it would be helpful for some students that would prefer to have a cross-cultural experience in their own country prior to deciding to travel to the foreign university. Both universities also agreed to exchange teachers, who would lecture during the course and include in their lectures references to cultural differences and their influence on the design context.

Students from both universities showed interest in the course, and all spaces were filled. In July 2014 the Design Summer courses were run in parallel in both locations. Despite cultural differences and communication problems, the common la nguage of the de sign process and its tools, such as sketchin g and 3D modelling, enabled students to collaborate intensively in this short period of tim e and to achieve very innovative design concepts. Section 2 below presents a detailed programme overview and section 3 discusses the outcomes of the course a nd the benefits for universiti es, students and collaborating companies.

2   Programme Overview

To meet the goals of this cross-cultural experience, the programme was designed to bring students together for a n intensive two-week design interaction during the first h alf of Jul y 2014. Prioir to th e

beginning of the course each local organising team discussed the contents of the design challenge that would be proposed at their location. To make the final decision they took into account two main issues:

- The subject should be familiar for students of both countries, despite their cultural differences.
- The subject should be of interest for local companies (design studios and/or manufacturing companies that have a design department).

The proposed challenges were the following:

Zhejiang's challenge was "Lighting and emotion". This challenge asked students to explore the interaction between the user and light, considering the emotional responses that are involved. Also, one of the key requirements was to use Arduino technology to connect sensors (motion, temperature, light etc.) with actuators that could give products a movement and sensory response.

Figure 1. Group of students and teachers that participated in the Design Workshop at Zhejiang University

Tecnun's challenge was "Improve the urban cycling experience". The objective of this challenge was to design and prototype an accessory that would improve the urban cyclist's experience. The origin of the idea came from the coincidence that the bicycle is the main mean of transport for students on the campus of Zhejiang University and the fact that the local government in San Sebastian, the city where Tecnun is located, has been promoting policies to facilitate and improve conditions for cycling in the city, which has resulted in an increase of this means transport in the city and the emergence of many business and services related to it.

Figure 2. Group of students and teachers that participated in the Design Workshop at Tecnun

At each location, on the first da y of the workshop, the teachers in charge of each local organisation put together the working groups. At Zhejiang, each working group included two local students and one Tecnun student and at Tecnun each working group included two Zhejiang students and one or two local students. One month prior to the workshop, both groups exchanged a file that included the following information about each student and teacher that travelled from one university to the other: a photo, name, e-mail, date of birth, a brief explanation of the reasons why they wished to attend the Summer course, whether they had any knowledge of Spanish/Chinese and if so what level, and what their main hobbies were.

This information helped teachers to s et up working groups and it also was useful for local students to better know the foreign students with whom they would work. The Chinese students included in their files their Western name, something that is t ypical for st udents from Chin a in order to m ake it e asier to communicate with Western people, who usually have difficulty pronouncing and remembering Chinese names.

The course was designed to have a s imilar structure at both locations, as ca n be seen in Table 1 and Table 2. The interactive lectures were concentrated in the first week and covered topics related to design process and tools alo ng with features of Chinese design and Spanish design and designers' competencies. The second week the student groups carried out the 3D modelling and prototyping phase and they prepared their final presentations and posters. They also visited some local design studios and local companies whose products or services were related to the challenge proposed and sold or offered in international markets. Moreover, both programmes included cultural activities, such as visits to l ocal museums and free time to continue working on their projects in the university's labs.

Starting with the first week some major differences between the t wo design approaches were already apparent. Professor Ying Fangtian's lecture in the Zhejiang workshop was very revealing for understanding contemporary Chinese design. He reflected upon and critiqued what Chinese design means nowadays, and he described it as design that is committed to society and the environment and that reflects the essence of culture. But th e meaning that the concepts of committed to societ y and the environment has in Chinese design differs from the meanings that those concepts have in Western design. In Chinese culture, the commitment to society refers to the search for applicability and usefulness in design, in a more practical way that goes beyond the aesthetic point of view. The commitment to the environment refers to the value and respect that was given to resources in traditional Chinese culture, and it is considered a tradition that fell into disuse. Professor Ying Fang Tian gave the example of chairs from the Ming dynasty, which can be seen in Figure 3, which minimized material use to perform their function and have inspired designers worldwide. An important feature of this classical Chinese furniture is that it was made without nails, because by the Ming period, Chinese furniture makers had developed highly sophisticated systems of joinery, such as tongue and groove.

Figure 3. Example of Ming dynasty chairs

Moreover, when Professor Ying Fangtian spoke to express the essence of culture, he explained that this is far from be ing a su perficial look, such as painting Chinese characters on the surface of a product, but instead it means that t he designer has to evoke Ch inese culture at a richer an d deeper level of significance.

This was in fact, the main di fference identified by Zhejiang's students and Tecnun's students during the concept generation phase. Zhejiang's students always looked for insp iration in the ir traditional Chinese culture, all their concepts had their roots in some kin d of cultural manifestation, be it a poem, a tale o r a song, while Tecnun's students had a m ore user-centric view, looking to solve potential users' needs,

desires and emotions. The Tecnun students did not usually see cultural background as a source of ideas unless the product being designed had some relation with a specific cultural issue or set of issues.

Another remarkable part of Professor Ying Fangtian's lecture, in relation to this workshop's objectives, was the explanation about the evolution of Industrial Design in China. He explained that the emergence of Industrial Design was in the 80's, with the 2D design, then in the 90's they evolved from 2D to 3D design and now they have arrived to what they call 4D design, which is related to Interaction Design and the use of technological platforms like Arduino. This concept of 4 D design was clearly reflected in the process followed by students from Zhejiang University during the concept generation phase in this workshop, who first sought inspiration in traditional Chinese or Spanish culture, then quickly they drew concepts in their sketchbooks, sharing them with their group and looking to re-invent every concept by adding interaction and technology.

Another remarkable experience for the group of students that were working at Zhejiang university was the contact with local design studios: Tao Design, Hot Design and Neocross. Tao Design was founded in 2007 and they now have a team of 15 designers and 4 engineers and work for international customers and they are also product editors. Hot Design focus their activities on product design and market research. They have 30 people on staff, including engineers, designers and researchers, and they consider themselves a small studio. They work for international customers such as Motorola, LG, Samsung and Electrolux. They have created their own line of products and they think that this makes them more innovative. They argue that a good designer must also be a good product manager, with a broader vision beyond aesthetics and able to advise clients by covering the three following dimensions: technical engineer, market strategy and being innovative and inspiring for the customer. Finally, Neocross was founded in 2009. Its name speaks of crossing borders. Although their customers are largely Chinese companies, such as Huawei, China Telecom or Alibaba, their products are sold in Europe. They are located in Hangzhou and Beijing and have a staff of 150 people, and their main activity nowadays is the design of Smart home appliances.

Finally, in relation to local companies of Hangzhou, the group of students from Tecnun had the opportunity to visit the headquarters of Alibaba, the world's largest e-commerce company, whose CEO was born in Hangzhou. Alibaba is also participating on a research project that one of Zhejiang's students is developing for this company, which is looking for new tools to measure how users' eyes scroll on web pages.

Design phase	Date	Topics	Key instructor
Research	Day 1	Welcome and introduction to Zhejiang University Yuquan campus	Professor Sun Bixie (Zhejiang)
		Workshop objectives, agenda and materials kit	Professor Sun Bixie (Zhejiang)
	Day 1	Chinese design	Professor Ying Fangtian (Zhejiang)
		Spanish design	Professor Adrian Larripa (Tecnun)
	Day 2	Context research – ID EO Method Cards	Professor Itziar González Professor Adrian Larripa (Tecnun)
		Work in groups. Context research	Professor Itziar González Professor Adrian Larripa (Tecnun) Professor Sun Bixie (Zhejiang)
	Day 3	Problem statement review with faculty	Professor Sun Bixie (Zhejiang) Professor Adrian Larripa (Tecnun) Professor Itziar González
		Visit to Tao Design (local design studio)	Professor Sun Bixie (Zhejiang) Professor Adrian Larripa (Tecnun) Professor Itziar González
Concept Generation	Day 4	IDEATIPE session (Practical exercise tutoring by Prof. Adrián Larripa to explain the importance of the Made on concept generation phase)	Professor Adrian Larripa (Tecnun)
	Day 4	Work in groups. Idea generation	Professor Adrian Larripa (Tecnun)
	Day 5	Visit to the company Alibaba	Professor Adrian Larripa (Tecnun) Professor Itziar González
Concept Selection	Day 5	Presentation of results from concept selection tutoring by Prof. Ying Fangtian	Professor Ying Fangtian (Zhejiang)
	Day 6	Tour of Hangzhou, including West Lake, China Academy of Art, Wushan Square and Leifeng Tower	Professor Adrian Larripa (Tecnun) Professor Itziar González

	Day 7	Free time	
Modelling and prototyping	Day 8	3D Modelling and prototyping	Professor Sun Bixie (Zhejiang) Professor Itziar González
	Day 8	Presentations of 2 l ocal design studios: Hot Design and Neocross	Professor Sun Bixie (Zhejiang) Professor Itziar González
	Day 9	3D Modelling and prototyping	Professor Sun Bixie (Zhejiang) Professor Itziar González
	Day 10	3D Modelling and prototyping	Professor Sun Bixie (Zhejiang) Professor Itziar González
	Day 11	Prototyping	Professor Sun Bixie (Zhejiang) Professor Itziar González
		Preparing final exhibition	Professor Sun Bixie (Zhejiang) Professor Itziar González
	Day 12	Exhibition of project results	Professor Ying Fangtian (Zhejiang), Professor Sun Bixie (Zhejiang) and Professor Itziar González
		Diplomas and closing	
		Farewell lunch	

Table 1. Zhejiang's workshop schedule

In the co urse taught at Tecnun, during the first week the lectures, vis its and working in gr oups were focused on research in context, which helped students to apply a user-centric perspective to the project, and fostered the use of creativity techniques that promote divergent thinking in order to generate as many innovative concepts as poss ible. Being aware that this way of working was not familiar to C hinese students, teachers from Tecnun provided in their lectures many examples of projects deve loped in their university where user-centric design has provided new insights about the users and their interaction with the product to design, from very industrial products to consumer products. Some initial barriers such as the tendency of Chinese students to meet with their group, share tasks and work individually afterward, were reduced with intensive supervision of the groups by the teachers.

One of the most successful activities from the perspective of the students was the cycling tour of th e city, during which students could experience urban cycling in San Sebastián first hand, observe other users engaged in the same activity, and identify unmet needs that could be potential sources of id eas for the design of accessories for urban cycling. Figure 4 shows the group that participated in this activity on a typical rainy day in San Sebastián.

Figure 4. Bicycle tour in San Sebastián

Some cultural issues were discusses during this first week. One example comes from the lecture given by Professor Leijing Zhou from Zhejiang University, where she noted some cultural differences that co uld provide important insights in relation to the challenge proposed by Tecnun's team. The photo included in Figure 5, which was included in her presentation, was used to explain that in Chinese culture, tanning is

not socially well regarded, an insight that could be very valuable for a designer of bicycle accessories that comes from another culture.

Figure 5. Woman cycling in China that uses different accessories to cover her body to keep from tanning

Other content in the course at Tecnun that was very innovative for C hinese students was an on-line interactive class taught by Professor George Torrens from the Loughborough Design School (UK), which focused on User-centred design. This class included practical activities for developing empathic research activities that focused on the activity of locking and unlocking a bicycle lock. Each member of the gr oup played the role of user, i nterviewer and observer. The user had t o carry out the activity in t wo different situations: one without any impediment and another in which the user wore gloves and glasses covered with cellophane so as to hindered the movement of the fingers and vision, in order to simulate extreme users, such as an elderly person. Figure 6 shows some stages of this activity. At the end of the class the students filled in a feedback survey to evaluate the on-line interactive class, which was then sent to Professor Torrens, who in turn used this information as a part as his research on on-line methodologies for teaching design.

Figure 6. On-line interactive class taught by Professor George Torrens

Also, the interaction with local companies was very fruitful. They visited ORBEA, a local manufactur er of urban bicycles that sel l their products worldwide and Chinese students were very surprised about the capacity of th is company to commercialize its pr oducts worldwide despite of its small dimension. The second company that they meet was LUMA, a local manufacturer of accessories for bikes and bicycles, mainly for security, that also commercialize its products worldwide. The CEO of this company explained to the students some of the new product developments that they are working on and the latest trends in this sector. Finally they were in contact with Dhemen, a local design studio that has recently open a delegation in China, that gave th em feedback on their concept selection. This was an opportunity for the Ch inese students to meet a design studio that could be a future employer for some of them.

During the second week students worked on t heir prototypes, and the Chinese students were very interested in prototyping with the 3D printing machines in Tecnun's laboratory; although there was a 3D printing machine at their university, they did not have much experience with it. Also during the second week, the group visited a local museum, the San Telmo Museum, which includes a permanent exposition titled "Awakening of Modernity" that contains many objects designed in the Basque Country in the 19th and 20th centuries, representing the transition from a rural soci ety to an industrial society. This visit was very

interesting for the Chin ese students and also for t he local students, who realized that the y lacked knowledge about their cultural roots that could be a source for inspiration. The local students realized that they usually did not use the history and traditional culture as a source o f inspiration in their designs, and they found that giving more weight to their cultural roots could enrich their designs.

Design phase	Date	Topics	Key instructor
Research	Day 1	Welcome and introduction to Tecnun	International Relations Department (Tecnun)
		Workshop objectives, agenda and materials kit	Professor Mabel Rodríguez (Tecnun) Representative from LUMA (loca l manufacturer of accessories for bikes a nd bicycles).
		Tour of Design Area facilities	Professor Aitor Cazón (Tecnun)
		Visit to Sa n Sebastian (tour and overview of the city)	International Relations Department (Tecnun)
	Day 2	Visit to ORBEA, local manufacturer of bicycles	Professors Mabel Rodríguez and Aito r Cazón (Tecnun)
	Day 3	Context research and empathic design lecture	Professor Mabel Rodríguez (Tecnun)
		Designer's competencies	Professor Leijing Zhou (Zhejiang)
		Work in g roups. Context research during a tour bike in San Sebastián	
Concept Generation	Day 4	User-centred design (On-line interactive class)	Professor George Torrens (Loughborough University)
		Concept generation techniques	Professor Marta Rois (Tecnun)
		Idea generation. Work in groups	
Concept Selection	Day 5	Concept selection techniques	Professor Marta Rois (Tecnun)
		Concept selection. Work in groups	
	Day 6 and Day 7	Free time	
	Day 8	Student presentation of results of concept selection	Tutoring by Dhemen (local design studio)
Modelling and prototyping	Day 8	3D Modelling – CREO parametrics	Professor Aitor Cazón (Tecnun)
	Day 9	3D Modelling. Work in groups	Professor Aitor Cazón (Tecnun)
		Visit to Museo San T elmo, Museum of Basque culture and local history	Professor Aitor Cazón (Tecnun)
	Day 10	3D Modelling. Work in groups.	Professor Aitor Cazón (Tecnun)
		Prototyping and photo-realistic rendering	Professor Aitor Cazón (Tecnun)
	Day 11	Prototyping and photo-realistic rendering. Work in groups	Professor Aitor Cazón (Tecnun)
		Preparing final presentation and posters for exhibition	Professor Aitor Cazón (Tecnun)
	Day 12	Exhibition of projects' re sults with the participation of local experts	Dhemen (local design studio) LUMA (local manufacturer of accessori es for bikes and bicycles)
		Diplomas and closing	Benicio Aguerrea coordinator of EIDE
		Closing lunch	(Basque Association of Designers)

Table 2. Tecnun's workshop schedule

The final deliverables of both courses also reflected some of the main differences from the cultural point of view of each venue. At Zhejiang each group had to deliver a working prototype of its product as well as a poster and a video explaining the concept. The prototype and poster were displayed on the last day of the course in an exhibition held in the lobby of the building where the course was held. Many professors and students from the university were invited to visit the exhibition.

At Tecnun, each group had to deliver a proof-of-concept prototype and to present their product in front of an evaluation committee made up of teachers participating in the course, the CEO of LUMA, a designer from the design studio Dhemen and the coordinator of EIDE, the regional association of designers. Every member in th e group took part in the final presentation, highlighting their contribution. After the fi nal presentation, all the participants attended a lunch, where students inter acted with the members of th e evaluation committee and discussed some details of their projects and also gave their feedback about the course.

3   Course Outcomes

The objective of this p aper is not to pr ovide details on course assessment as th at is planned for f uture work. However, it is imp ortant to hig hlight that the outcomes obtained from this first edition of the joint Summer Design Course organised by Zhejiang University and Tecnun far exceed our initial expectations and we realized that the problems that could have derived from the cultural distance between both working teams were successfully overcome. Although this first edition was designed and launched in a short period of time, almost a year after making the first contacts, we have already obtained benefits of great interest, as explained below.

3.1   Benefits for students

This programme provided several common benefits to students from both universities, as well as to those who travelled to a nother country as well as to thos e who stayed at their university working with foreign students. The experience allowed students to.

1. Understand the importance of using the cultural dimension in product design as a s ource of inspiration and to gener ate empathy with users. Exposure to another c ulture helps students to develop respect and appreciation for ot her economic, historical, social and political views that differ from their own.
2. Learn to appreciate working on a desi gn project with students from d ifferent cultures, which means working with people who think and act differently than they do and with who they have to discuss and negotiate, arriving at agreements and achieving solutions that satisf y their design brief.
3. Identify the m ain differences between design process in China and in Western countries, understand the strengths of each approach and learn how to l ook for complementarity on a multicultural team work.
4. Discover that, despite cultural differences and communication problems, the common language of the design process and its tools, such as sketching and 3D modelling, have enabled students to develop very innovative concepts in a very short time.
5. Begin to u nderstand how product design is done by successful global product development companies.
6. Gain a visi on of glob al opportunities that are avail able for well-prepared product design engineers.
7. Establish a ne twork of conta cts with designers from othe r cultures (not only students but also designers from companies that collaborated on the course in both locations) that could enrich their professional career in this globalised world.

Moreover, in some specific cases, students obtained additional benefits:

- One of the working groups from the course held at Zhejiang, which was made up of one Tecnun student and two Zhejiang students, presented their project to the R ed Dot Awards 2015 edition and they were selected as finalists in the students' category. The results will be announced in July 2015, but certainly to h ave been selected as finalists in this award is already an important merit on their curriculum.
- Two students that travelled to Zhejiang University from Tecnun had the opportunity to stay there and carry out their fina l degree projects in the l aboratory at the Univer sity of Z hejiang. They returned to Tecnun in December 2014 and defended their final degree projects in January 2014, obtaining the highest grade in both cases.
- After completing the course, two mixed groups of students from Tecnun and Zhejiang participated in an int ernational design competition for MAIER, a Ba sque supplier of plastic part s for the automotive sector. The results of this competition will be announced at the end of May 2015.
- One of the students from Zhejiang University who participated in the course in Tecnun applied to the doctoral programme at Tecnun. The group of professors from Tecnun's design area who had direct contact with this student during the summer course valued her candidacy positively and this speeded up t he positive response from the h uman resources department, together with the analysis of her curriculum and portfolio.
- Several of th e students who completed their degree in Ind ustrial Design and Product Development engineering at Tecnun in 2014 and who participated in this Summer Design course

stressed that their participation in the course has been key to their early work experiences, as it is an aspect of their curriculum that garners significant attention in selection processes.

3.2 Benefits for companies

Companies involved in this course in b oth locations also had the opportunity to obtain some interesting benefits from their partic ipation. The local design studios (Tao Design, Hot Desi gn, Neocross and Dhemen) had the chance to explain their business models to students that in the future could be interested in applying for a job at these studios. Moreover, in the case of Dhemen, which participated actively in the supervision of student projects, they were able to detect future talented designers that they could hire for their headquarters in Spain or their new office in China.

The product manufacturers that participated in Tecnun's challenge, LUMA and ORBEA, benefited from the students' uncovering of n ew needs and the innovative ideas they generated. These ideas could be a source for ne w product development or for improvem ent of their exi sting products. As an illustra tive example, at the end of the final project presentations at Tecnun, the CEO of LUMA, the S panish manufacturer of accessories for bikes and bicycles, told the audience that after 30 years of experience in the sector he was very impressed by the level of innovation of the projects presented by the students but even more because they all had a high level of industrial viability, something very remarkable when the work was carried out with only two weeks of work.

In the case of Alibaba, they had the opportunity to include the Tecnun students in their research on new tools for measuring eye scrolling on web pages. Moreover, they told the students that soon they would open their new offices in Europe, and they invited Tecnun students to send their curriculums and portfolios in order to participate in the selection processes.

3.3 Benefits for universities

This programme was valued by both universities as a first outstand ing step in a long and fruitful collaboration. Firstly, the feedback from the students and the evaluation of companies indicate the positive results this pr ogramme had in prov iding a learning experience in cross-cultural design and g enerating innovative design concepts

Secondly, the Design Summer course provided a flexible model for involving internal teaching resources, for collaborating with external agents such as design studios or industrial companies, and even incorporating professors and experts from other universities, as Tecnun did with Professor George Torrens from Loughborough University.

Thirdly, the programme's duration and schedule, being short and not coinciding with regular scheduled classes during the semester, allowed professors from both universities to actively participate and attend all class sessions. Thanks to this clos e interaction, both te aching teams achieved a deep understanding of the main differences in the field of industrial design in China and Wester n countries. T his was also an opportunity to learn from oth ers whose teaching strategies are different and to sh are best practices in design teaching.

Fourthly, the f ormat of this course allowed both universities to pr ovide cross-cultural experiences to students that d id not h ave the financial resources to tr avel to a forei gn country. Moreover, this format of running simultaneous courses in both loc ations certainly contributed to the increased commitment of both universities to make the arrangements for obtaining visas and accommodation and to organise a complementary programme of cultural activities for the foreign students that they host.

Finally, from the marketi ng point of vie w, this ex perience has h elped both u niversities differentiate themselves from their main competitors, not only in looking for new students but also for establishing new collaborations on education and research with companies.

Acknowledgement

References

[1] Hofstede, G. (1991). Cultures and organisations: Software of the Mind. London: McGraw-Hill.

[2] Trompennaars, F. and H ampden-Turner, c. (2002). Riding the waves of cu lture. 2nd ed. Lo ndon: Nicholas Brealey Publishing.

[3] Laroche, L. (2003) Managing successfully across cultures. Boston, Butterworth-Heinemann.

[4] Diehl, J. C . (2006). Gl obalization and cross cultural product design. In INT ERNATIONAL DESIGN CONFERENCE-DESIGN 2006.

[5] Christiaans, H. H. C. M., & Diehl, J. (2 007). The necessity of design research into cultural aspects. Proceedings of International Association of Societies of Design Research, 2007.

[6] Rutter, B. G. and D onelson, T. H (2000). Measuring the impact of cultural variances on product design in Medical Device & Diagnostic Industry Magazine.

[7] Lohmann, J. R., Rollins, H. A. & Hoey, J. J. (2006). Defining, developing and assessing global competence in engineers. European Journal of Engineering Education, 31 (1), 119-131.

[8] Roehl, S. R. L., Kucko, J., & Laura Prest wood, A. (2013). The Importance of T eaching Cultural Awareness in Design Education: Evidence from Interior Design. Global Journal of Human-Social Science Research, 13(12).

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FROM CO-WORKING TO MULTIDISCIPLINARY GROUP DYNAMICS IN AN INTERFACE DESIGN EXPERIENCE

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Abstract

This paper introduces a three-year collaboration experience between the Engineering Degree of Industrial Design and Product Development and the Engineering Degree of Informatics of the University of Zaragoza. The experience reflects the methodology evolution from the several project sections development by students of each specialization to the multidisciplinary work-group dynamics.

In order to progress at the multidisciplinary development of interfaces for smart phone applications (which is a complex task involving different disciplines and knowledge areas such as ergonomics, graphic design, perception theory or computer sciences, etc.), it was required to count with external experts coaching, observation and reviews of the working dynamics with enough perspective to be able to propose corrections in the working process.

With the teaching methodology adaptation presented in this paper we want to verify if much better products' development can be achieved. Moreover, it must be highlighted the importance of transversal competence teaching method and the creation of multidisciplinary collaboration networks.

1 Introduction

The changes i n the Euro pean Higher Education Area [1] (Sorbo nne Declaration of 19 98, European Ministry of Ed ucation 1999, Ministry of Education, Culture and Sports, 2003) a nd the ch anges in production system and labour market require the adaptation of teaching methodologies. They must serve not only to train specialized professionals in their area of expertise but also persons capable of working in multidisciplinary teams, of identifying needs and o pportunities of the m arket and of p roposing creative solutions to the problems and challenges of their professional future. To achieve such goal, the students should develop a set of kno wledge, competences [2,3,4], attitudes and values [5] throughout their studies at the University. At the same time, one of the most important challenges for teachers is to overcome the traditional teaching methodologies, introducing those with an experimental character [6,7,8], implementing effective teamwork experiences [9,10,11], multidisc iplinary work [12,13,14], interdisciplinary work [15], organizing deliveries as collaborative projects [16,17] and applying the methodology of learning by doing [18,19,20].

The new degrees in Computer Science Engineering and Engineering in Product Design and Development, to which the two subjects involved in the experience presented in this article belong: Human Computer Interaction (HCI) and Graphic Design and Communication (GD&C), in th eir teaching guides [21,22] and degree plans [23,24], define the specific and transversal skills that stude nts should develop. Teaching in these subjects counts with over five years of Module Project experience enrolled in t he

methodology of project-based learning [25,26,27,28], in which the different subjects involved apply a diverse knowledge within a single project during the semester. The experience presented below, although it draws on past experience, it differs from them by involving in a one-project subjects of different degrees, inviting students from different profiles to develop a project in multidisciplinary teams along the semester. This experience is carried out within the scope of two Teaching Innovation Projects: the first one entitled "IPODGyC - Collaboration Network between Computing and Graphic Design" (course 2013-14) and the second one, currently under development, called "Consolidation of the Collaboration Network Computing and Graphic Design and publication of research results" (course 2014-15). The main aim in both projects was to involve students of the two subjects in the development of a mobile interface. To progress at the multidisciplinary and co-working development of the applications [29] (which is a complex tasks involving different disciplines and knowledge areas such as ergonomics, graphic design, perception theory or computer sciences etc.), it was required to count with external experts couching, observation and reviews of the working dynamics with enough perspective to be able to propose corrections in the working process.

2   Methodology and development of the experience

The objective of the experience was to break the divisions between different degrees and to give to the students the possibility of the participation in the multidisciplinary approach towards the design projects of human-computer interfaces, allowing the establishment of joint projects as basis for a future joint entrepreneurship. For students of the subject of HCI, the goal was to enhance their knowledge of the communicative role that graphic elements of the interface must have, and to learn how they ought to design and develop those elements. And for the GD&C students the aim was to increase their knowledge on interaction between person and computer, in order to qualify them to design a proper graphic interface.

This experience should also serve for teaching of specific tools: in the case of HCI students the interface development techniques (for example UML language, software for rapid prototyping as Axure, etc.), and for students of GD&C the use of the development techniques characteristic for their specialty (for example Adobe Illustrator, Photoshop, InDesign) for the design of the brand and the graphics of the interface.

Throughout all courses of the experience, several cross theoretical conferences (HCI basis were given to GD&C students, and DG&C basis were given to HCI students) were performed in order to provide all of the students with the basic knowledge of other subject.

Previously to the teaching innovation projects, a pilot project was developed in the 2012-2013 academic year. The students of HCI and GD&C had to achieve together the "design of the prototype of an interactive support system for patients with polypharmacy". Each group separately conducted the research, previous analysis and the definition of target audience, students of HCI created the navigation map and the functional prototype of the application while students of GD&C performed imagotype design of the application and the layout the two most representative screens. Finally work of GD&C students have been presented to HCI students and evaluated by them.

In the following course (2013-2014), within the first innovation project, the creation and assignation of approx. 4 groups of GD&C students to each group of HCI students was introduced. A practical class in which students of both subjects met, exchanged contact details and established the rules of collaboration was performed. The part of research, analysis and definition of target audience was performed separately, with a later sharing of the results. HCI students conducted a navigation map and chose, with GD&C students, the two most significant displays and their usability, so the graphic layout could be performed. Finally, HCI students chose one of the design proposals of the GD&C students to apply in its prototype.

In the current year (2014-2015), students of both subjects shared practical classes in which they could work together creating real multidisciplinary teams. In the first session, students established the rules and objectives of the collaboration using an adaptation of the Weisbord survey [11]. A joint submission was required.

In each academic course the evaluation of students' works was performed following the official guidelines for each subject, with no modifications. For the assessment of the perception of the experience by the students, a final survey was conducted. This survey was structured into the following sections: profile of the respondent, assessment of the experience, objectives compliance, assessment of the acquisition of various competences and overall satisfaction with the work done.

The evolution of collaboration over the three years is presented in Table 1. The differences are the result of the implementation of the necessary modifications detected in the analysis of the surveys completed by the participants of the experience.

	2012-2013	2013-2014	2014-2015
Aim of the project	"Design of the prototype of an interactive support system for patients with polypharmacy"	"Design of a prototype system for the organization of visits in a city "	"Design of the interface of an application for selection and reservation of restaurant based on user preferences "
Students participating in the experience	-HCI- 19 groups (53 students) -GD&C- 32 groups (68 students) Control group -HCI- 18 groups (53 students)	-HCI- 13 groups (38 students) -GD&C- 38 groups (77 students) Control group -HCI- 16 groups (46 students)	6 multidisciplinary groups -HCI-12 students -GD&C-24 students Control group -HCI- 16 groups (46 students) -GD&C- 27 groups of 58 students
Tasks assigned to each group	HCI-market research, definition of the target group, navigation map, application prototyping. GD&C- market research, definition of the target group, graphic design of the brand and representative interfaces	GD&C and HCI -market research, definition of the target group, separately but sharing the results. HCI- navigation map, application prototyping. GD&C- graphic design of the brand and representative interfaces HCI- application of graphic design in the prototype.	Joint development of the project, in which students assigned the tasks related to application development and graphic design of the interfaces.
Joint sessions	-	1	3
Final Project submission	Separate deliveries	Separate deliveries	Joint delivery

Table 1: Evolution of collaboration throughout the three courses

The sharing of the project, from its purpose, to the results, which means more joint sessions (as showed in Table 1), can facilitate the transit from "group" to "team". Beginning the process together, directing all work towards a common goal, requires a compromise in the structure of the work and liability among the participants, not only with a sense of the work, but also with the process itself becoming more effective and as efficient as possible. All this allows a return on the resources and can generate greater creative possibilities of mobilization of "collective intelligence" something qualitatively different from the me re addition of ideas and to be connected to the real experience of the world of work and organizations.

Some transversal skills objectives were directly related to the ones of the proposed exercise, such as getting familiar with new technologies and the most common tools; a cquiring analysis and s ynthesis capacities, accompanied by the development of critical and self-critical spirit; achieving the abilities to work individually and in groups; working being part of mu ltidisciplinary teams; and promoting the concern for quality.

3   Results

The results presented in this section derive from surveys conducted by 64 students of GD&C and 28 students of HCI during 2013-2014. The number of students is slightly lower than the students participating in the experience (Table 1) since a small number of them did not complete the survey, still the research sample is representative for the students participation in the experience. A Likert scale, from 1 to 7, was used to mark the different questions.

**Assessment of the fulfillment of the objectives to be achieved through experience**
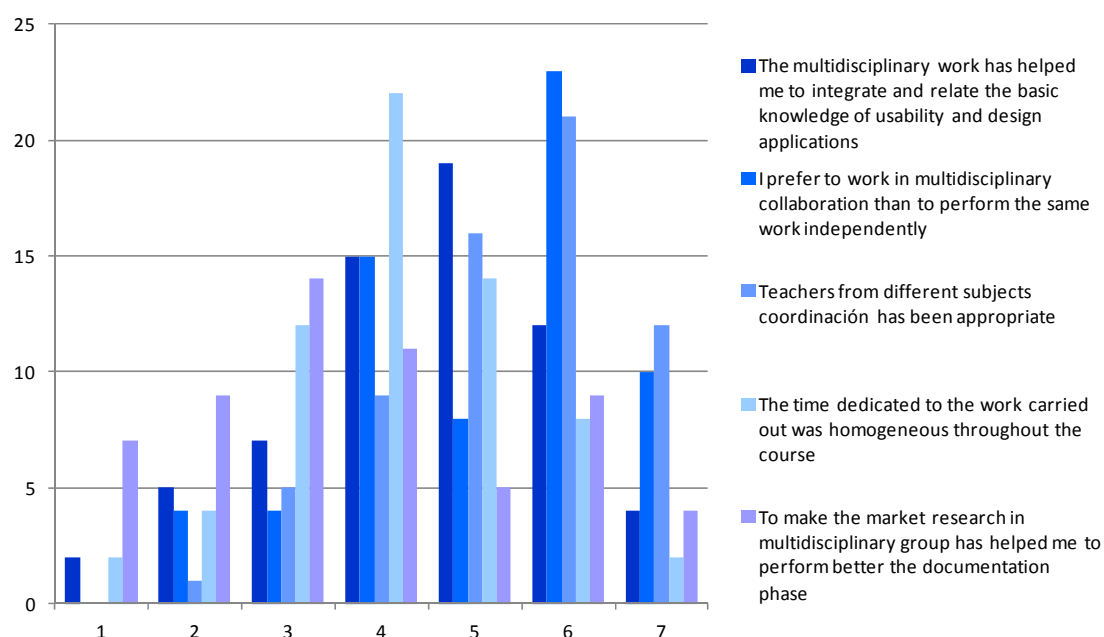
Fig. 1 Evaluation of the fulfillment of the objectives to be achieved through experience by GD&C students.
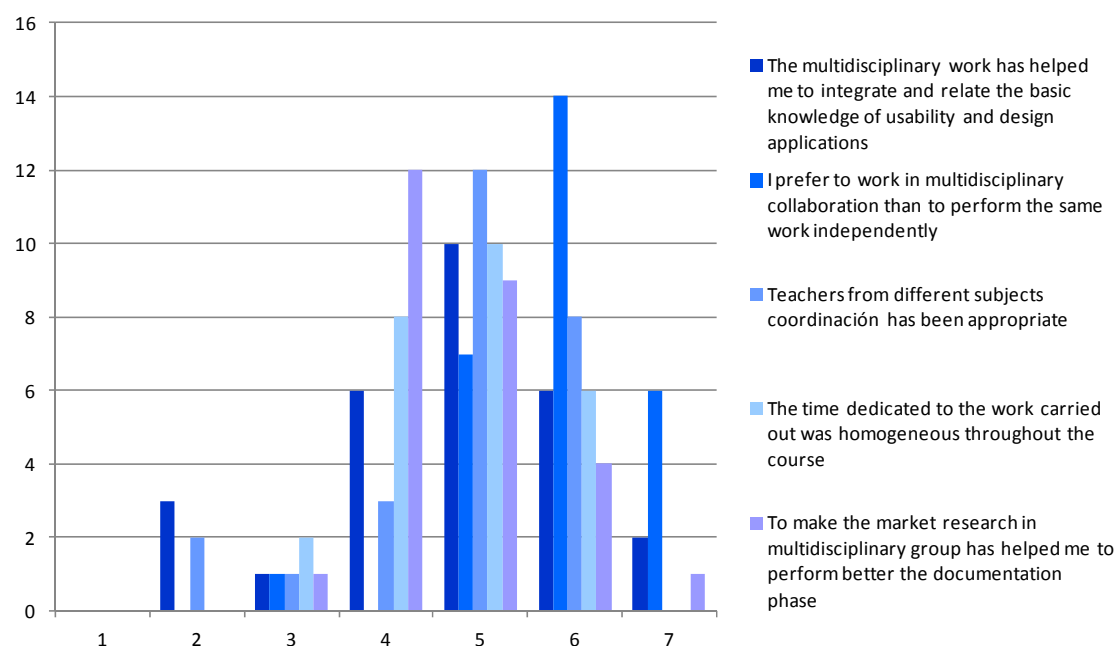

Fig. 2 Evaluation of the fulfillment of the objectives to be achieved through the experience of the students of HCI .

Students have evaluated positively the fulfillment of the o bjectives to achieve through the experience assigning an average mark of 5 in c ase of HCI students and 4.58 in case of GD&C stu dents (Fig. 1 and Fig. 2) GD&C students stan d out as most accomplished the fact that teachers from different sub jects coordination has been appropriate scored with 5.36 points and HCI point out that students prefer to work in multidisciplinary collaboration than to perfor m the same work independently assessing this objective with 5.86 points.

Assessment of the acquisition of the different competences
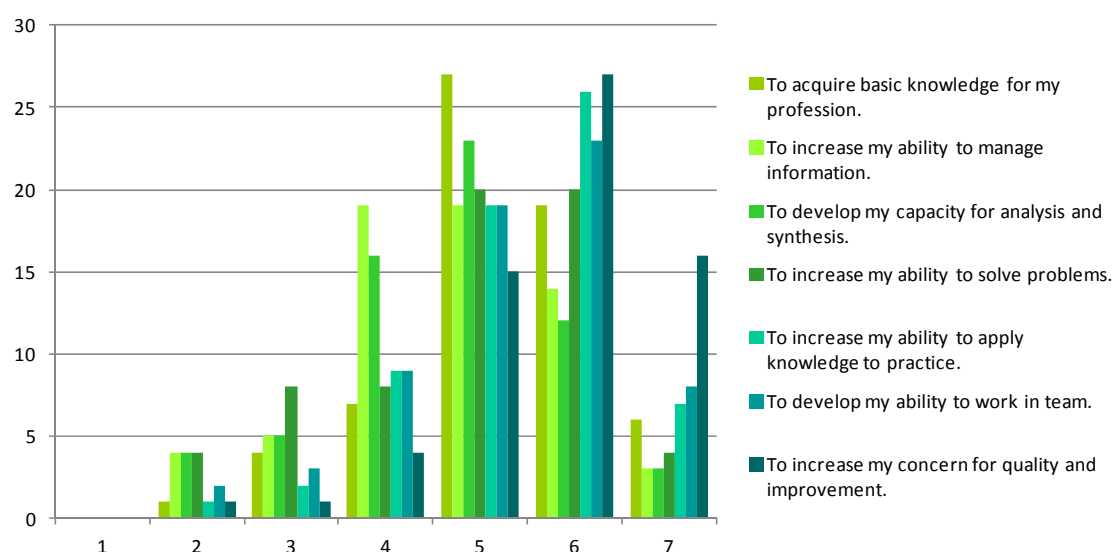
Fig. 3 Evaluation of the acquisition of different competences by the students of GD&C
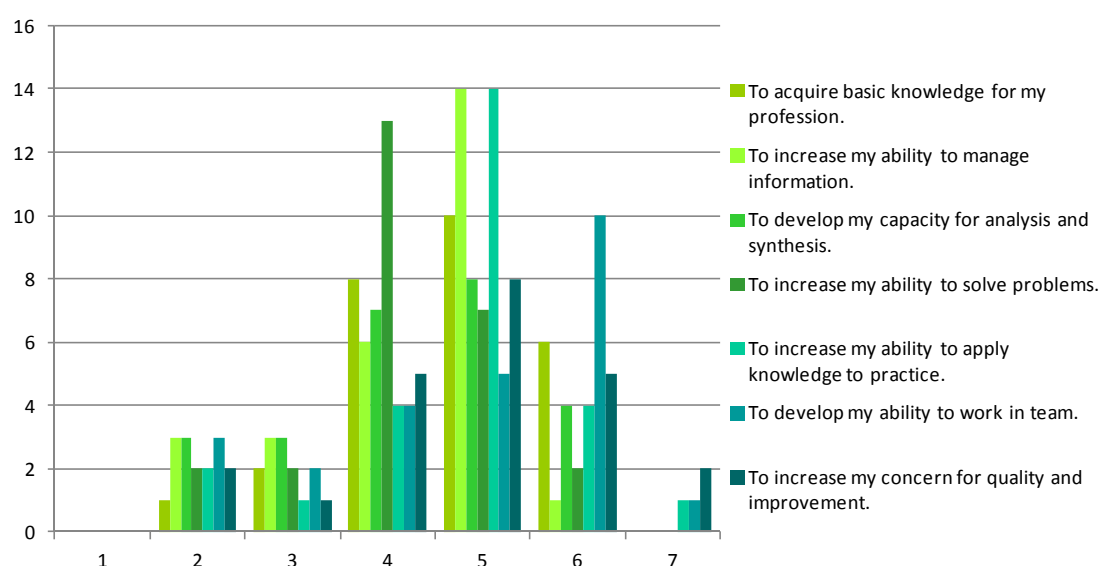
Fig. 4 Evaluation of the acquisition of different competences by the students of HCI

The results pr esented in Figure 3 and 4 show that students of b oth subjects perceive that the experience has enabled them to acquire different skills.

Both GD&C and HCI students indicated that the experience has helped them to develop the most is "to increase my concern for qua lity and improvement", valued by students of GD&C with 5.78 points and students of HCI with 4.83 points. In an assessment of the HCI students the next better scored competence was "to develop the ability to work in team" valued with 4.80 points and in the case of GD&C students "the ability to apply knowledge to practice" scored with 5.38 points. The assessment of the acquisition of all the competences exceeds the average, in the case of HCI students with a score of 4.54 points and in the case of GD&C students with 5.12 points.

Overall satisfaction with the work performed
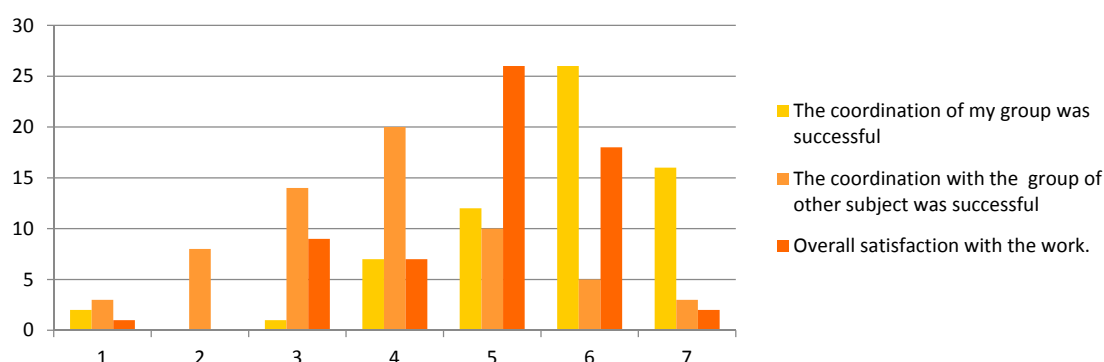
Fig. 5 Assessment of overall satisfaction with the work done by GD&C students
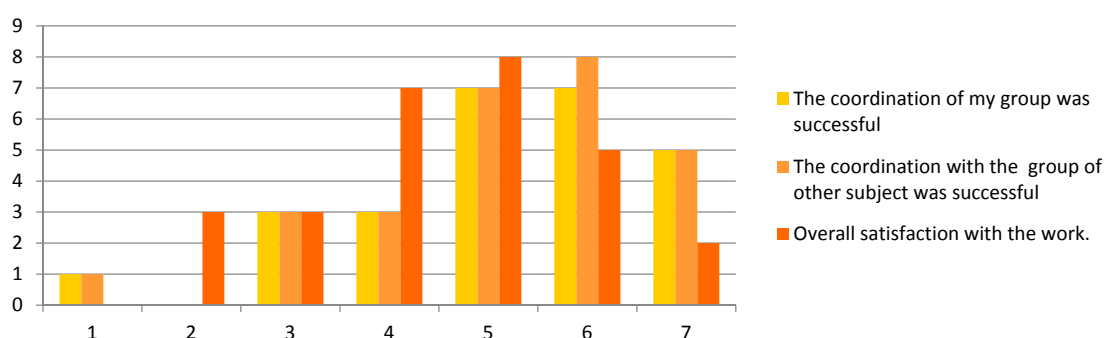
Fig. 6 Assessment of overall satisfaction with the work done by HCI students

The level of the satisfaction (Fig. 5 and Fig. 6) with the coordination of the same profile group as well as within the multidisciplinary and overall satisfaction was positively evaluated. In the case of HCI students with an average of 4.95 points and in the case of GD&C students with 4.79 points. GD&C students indicated the coordination with the students of other subject as problematic by allocating a score of 3.84 points. Although this value exceeds the average, improvement must be done in this field. Overall satisfaction was valued with 4.89 points in the case of GD&C students and 4.54 in the case of HCI ones.

Academic results

The final note for the practical part of the experience does not reveal significant differences, which could be attributed to the difference in teaching method in multidisciplinary groups and those doing the work in groups within their own degree (control groups). The average note of the practice part of the subject of HCI students was 7.23 versus average grade of 5.54 of the whole subject. The average rating of the practical part of the GD&C students was 7.5 against average grade of the entire course of 7.9.

Examples of the students' final works

Figures 7 and 8 present some screenshots of the works done by the students. The examples of Figure 7 show two prototypes of an interactive support system for patients that have to be on medication for a long time (course 2012-13). The screenshots shown in Figure 8 correspond with two different prototypes of a mobile application for the visits organization in a given city.

Fig. 7 Prototype design examples of an interactive support system for patients with polypharmacy
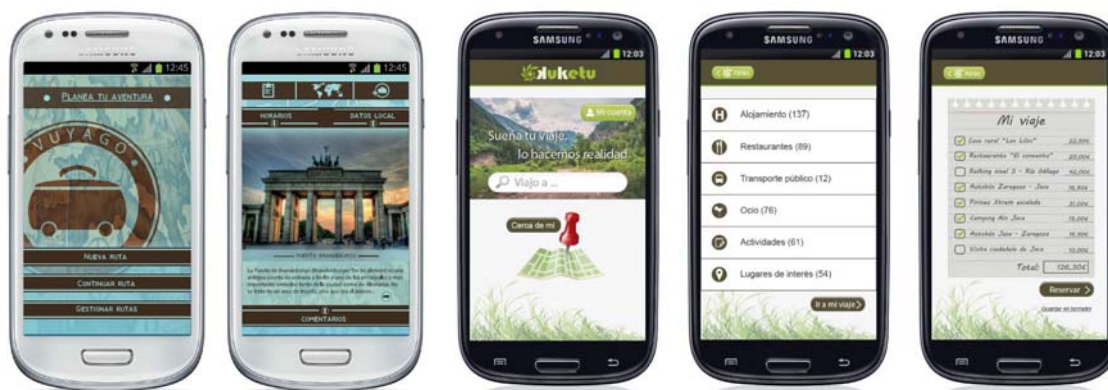
Fig. 8 Prototype design examples of a system for visits organization in a city

4 Conclusions

The assessment of the e xperience shows that the i ntroduction of col laborative work between different degrees is needed and that it motivates students. The overall satisfaction in the case of both sub jects rise above average. The experience has achieved its objectives. However in the next course there will be an attempt to improve these results, narrowing multidisciplinary collaboration.

It must be a dmitted that th is work dynamics requires great organizational and teaching effort. Making students work in multidisciplinary teams also requires the readiness and willingness of the teache rs to work in this ki nd of teams, to meet commi tments and adapt the vie wpoint and t he objectives of othe r subjects where a t eacher is not s pecialized at. At the same time schedules and academic calendar characterized by inflexibility does not help to find many opportunities to work together between different degrees.

However, the transversal and specific skills developed by the students and th e establishment of a network of con tacts with this experience, that could i nfluence in the students' employability in th e future, motivate us to go on with the effort and to share the r esults since it could be applied to other fields and degrees. The results support the increasing interest of the students themselves; improving employability can not be verified because the participants have not completed their studies yet.

References

[1]   R. Redondo, J.Sánchez. *Las directrices del Espacio Europeo de Educación Superior en el marco legislativo del sistema universitario español.* Aula abierta, 35,1 (2007) pp 35-48. (in Spanish)

[2]   J. Vanderweerd, C.Cambier, M. Romainville, P. Perrenou d, F. Desbrosse, A. Dugdale, P. Gustin. *Competency Frameworks: Which Format for Which Target?* Journal of Veterinnary Medical Education 41, 1, (2014) pp 27-36.

[3]   ANECA (2012). Guía de Apo yo para la elaboración de la Memoria p ara la solic itud de verificación de títulos oficiales (grado y máster). (in Spanish)

http://www.aneca.es/Programas/VERIFICA/Verificacion-de-Grado-y-Master/Protocolos-de-evaluacion-y-documentos-de-ayuda accessed 01 May 2015.

[4]   ICE, 2008; Instituto de Ciencias de la Educación de la Universidad de Zaragoza. Competencias genéricas y transversales de los titulados universitarios. Publicaciones ICE, 2008. (in Spanish)

[5]   A. Conchado, J. Carot. *Puntos fuertes y débiles en la formación por competencias según los graduados universitarios españoles.* REDU: Revista de Docencia Universitaria, 11,1 (2013) pp 429-446. (in Spanish)

[6]   M. Zabalza. Editorial: Formar Ingenieros para el siglo XXI, Revista de la Red Estatal de Docencia Universitaria, 11, special issue (2013) pp 9-12. (in Spanish)

[7]   I, Herrero, C. García, E.   González, L. Molina, E. Pérez, C. Urdial es. *Aprendizaje cooperativo en el ámbito de la ingeniería : una experiencia de iniciación al Trabajo en Grupo.* Revista de la Red Estatal de Docencia Universitaria, 11, special issue (2013) pp 221-251. (in Spanish)

[8]   E. Manchado, L. Berges. *Una experiencia de PBL en Grado de Ingeniería de Diseño Industrial, adaptando el método de sistemas de retículas de Diseño Gráfico.* Revista de la Red Estatal de Docencia Universitaria, 11, special issue (2013) pp 19-46 (in Spanish)

[9]   Dolan, S.L. y Martín, I. (200 0). Los 10 mandamientos para la dirección de personas. Barcelona: Gestión 2000. (in Spanish)

[10]   Lewicki, R.J et al. (1999). Desarrollo organizacional. México: Limusa. (in Spanish)

[11]   Weisbord (2010). Organizational Diagnosis: Six places to look for trouble with or without a theory. In Coghlan, D. y Shani, A. B. (Eds.) F undamentals of Organization Development. Four-Volume Set. VOLUME II: PILLARS OF   ORGANIZATION DEVELOPMENT Part III: Diagnosing.

[12]   J. Dyer. Multidisciplinary, interdisciplinary, and transdisciplinary educational models and nursing education. Nursing Education Perspectives 24,4 (2003) pp 186-188.

[13]   S. Hoeman. Rehabilitation nursing: process and application. 2 nd .ed. St. Lou is: MOSBY; 1996.

[14]   H. Garner. Teamwork models and experience in education. Allyn & Bacon 1995.

[15]   L. Diller. *Fostering the interdisciplinary team, fostering research in a society in transition.* Archives of Physical Medicine and Rehabilitation 71,5 (1990) pp 275.

[16]   S. Augustin. *The Burnout Phenomenon: A Comparative Study of Student Attitudes Toward Collaborative Learning and Sustainability.* Journal of Interior Design 39,1 (2014) pp 9-18.

[17]   R. Nimnual, S. Suksaku lchai. *Work in Progress - Collaborative Learning for Packaging Design Using KM and VR.* IEEE Frontiers in Education Conference.1-3 (2008) pp 1431-1432

[18]   K. Temmen, T. Walther. 'L earning by doing' Improving academic skills, IEEE Global Engineering Education Conference, Berlin, Marz 13th – 15th 2013, pp 118-122.

[19]   A. Garcia. Le arning by Doing. Experiments and Instrum ents in th e History of Sci ence Teaching, AMBIX 60,3, (2013) pp 301-302.

[20]   B. Penzenstadler, M. Maha ux, P. He ymans. University Meets Industry: Calling in Real Stakeholders, IEEE Conference on Soft ware Engineering Education and T raining, May 19th – 21th 2013, San Francisco, pp 1-10.

[21]   Interacción persona ordenador – Guía docente. (in Spanish) http://titulaciones.unizar.es/asignaturas/30217/contexto13.html accessed 01 May 2015.

[22]   Diseño gráfico y comunicación - Guía docente. (in Spanish) http://titulaciones.unizar.es/asignaturas/25814/contexto13.html accessed 01 May 2015.

[23]   Titulación - Grado en Ingeniería en Diseño Industrial y Desarrollo de Producto (in Spanish) http://titulaciones.unizar.es/ing-dis-industrial/ accessed 01 May 2015.

[24]   Titulación - Grado en Ingeniería Informática (in Spanish) http://titulaciones.unizar.es/ing-informatica/ accessed 01 May 2015

[25]   E. Manchado, I. Lopez. *Coordinación por módulos de asignaturas en el Grado de Ingeniería de Diseño Industrial y Desarrollo de Producto de la Universidad de Zaragoza.* REDU Revista de Docencia Universitaria.10,3 (2012) pp 195-207 (in Spanish)

[26]   I. Lopéz, E. M anchado. Aprendizaje Modular: Integración de conocimientos en proyectos de ingeniería de dise ño. XXI Congreso Universitario de Innovación Educativa en la s Enseñanzas Técnicas, June 10th – 12th , 2013 Valencia (in Spanish)

[27]   J. Agudo,I. López, A. Pardin a, B. Sánchez-Valverde, J. Sierra. XV Congreso Internacional de Ingeniería de Proyectos, July 6th – 8th , 2011 Huesca pp 2435-2449 (in Spanish)

[28]   M. Romainville. *Esquisse d'une didactique universitaire.* Revue francophone de gestion. La Sorbonne, CIDEGEF, special issue (2004) pp 5-24

[29]   E. Mercovich. Pone ncia sobre diseño de i nterfaces y usabilidad: como hacer pr oductos más útiles, eficientes y seductores, (1999) (in Spanish) http://www.gaiasur.com.ar/infoteca/siggraph99/diseno-de-interfaces-y-usabilidad.html accessed 01 May 2015.

Framework to develop ABET outcomes

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Article Information

Abstract

This paper presents the steps followed at the Escuela Técnica Superior de Ingenieros Industriales (ETSII) in the Universidad Politécnica de Madrid (UPM) to progressively implement an outcomes assessment framework. The implantation of this framework provides a big set of key performance indicators (KPi) where faculty can develop methodologies or strategies to assess the ABET outcomes. This assessment is understood as the complete process to guide and guarantee that graduates, when they finish their studies, have acquired the knowledge, abilities and skills established in the educational program. This is a process linked to the whole program (and not to a single course or activity). The previous steps to develop the framework will be presented in this work. Not all the outcomes have been developed with the same deep because the work still hasn't finished but it is unique in our university. The process has took more than two years and provide for all outcome a definition, Kpis, year to assess, methodologies, etc. The framework is in a continuous development stage and suggestions and improvements from teachers are included.

1 Introduction

Accreditation is one of the goals of our universities. There are two accreditations focussed on engineering programs: Euro Ace and AB ET. In 2010 the Escuel a Técnica Superior of Ingenieros Industriales from the Universidad Politécnica de Madrid obtained the Abet accreditation.

ABET, Inc., formerly the Accreditation Board for Engineering and Technology, is a non-profit organization that accredits postsecondary year programs in applied science, computing, engineering, and technology [1]. Accreditation is intended to certify the quality of these programs. ABET provides specialized, programmatic accreditation that evaluates an individual program of study, rather than evaluating an institution as a whole. The institution must design a strategy to ensure and enhance skill acquisition processes.

It has been a lready proved by several authors at differe nt universities that this model improves th e engineering environment [2] [3]. McGourty et al. [4] focus on different assessment approaches considering twelve different methods and their application to engineering education. J. M. Williams [5] described the use of engineering portfolios as an assessment vehicle. Nault and Hoey [6] argue how important it is to establish a culture of trust in an organization as a first step towards creating a sustainable assessment system.

Also, empirical methods can be used to develop a model of the engineering education process, Besterfiel-Sacre et al [2], Kaw et al. [6], Ste ward et al. [7] and Mitchell et al. [8] presente d innovative course-level assessment techniques. Finally, Howell et al. [9] suggest ed a pr ogram assessment process that links program objectives to course objectives an d educational activities. L. A. Sha y et al. [10] focus on th e important issue of impr oving the effici ency of the outcome assessment process (reducing the burden on already busy faculties) without sacrificing the quality of results.

To obtain an ABET accreditation, the educational programs requires a minimum curricula of at least one year of study in physical sciences and mathematics and some more ge neral education [1]. The students also need to finish a capstone project or design class during their education.

Another requirement is compulsory; the educational program must assure that all stu dents develop the outcomes listed below (designated with the letters from a a to k).

(a)	An ability to apply a knowledge of mathematics, science, and engineering
(b)	An ability to design and conduct experiments, as well as to analyze and interpret data
(c)	An ability to design a system, component, or process to meet desired needs within realistic constraints such as the economic, environmental, social, political, ethical, health and safety context and manufacturability, and sustainability
(d)	An ability to function in multidisciplinary teams
(e)	An ability to identify, formulate, and solve engineering problems
(f)	An understanding of professional and ethical responsibility
(g)	An ability to communicate effectively
(h)	The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
(i)	A recognition of the need for, and an ability to engage in life-long learning
(j)	A knowledge of contemporary issues
(k)	An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

Tab. 1 ABET Outcomes

Additionally, the Universidad Politécnica of Madrid (UPM) considers that 8 outcomes must be developed or reinforced in our students. These tree additional outcomes are described in table 2 and are designed with the letters from l to n.

(l)	The ability to work in a bilingual context (English-Spanish)
(m)	Organization and planning in a company context and in the context of other institutions, project organisations and human resources
(n)	Creativity
	Comunication (writing and speaking)
	Medioambiental care.
	Team work
	Lidership
	Problems solving
	Analisys and sinthesys
	TICS

Tab. 2. UPM outcomes

Outcomes defined by the Universidad Politecnica de Madrid are developed in a open website [2] where all faculty can obtain definitions, methods, strategies, rubrics and orientation about how they can developed these outcomes inside of their courses (fig.1). This website has been developed by a team of teachers during three years supported by 3 innovative teaching projects of the UPM. The website is in a continuous improvement feeding with the experiences of the faculty [11].

2   Procedure

The Escuela Tecnica Superior de Ingenieros Industriales received the ABET Accreditation in 2010 and started a deep change in its teaching methodology. An Outcomes Board were created to start with all this process. This Board is formed by teachers of the engineering programs, a representative of the Director of the College and a student representation.

The faculty in charge of develop this framework have designed a bottom-down approach. The first step was the definition of the outcome. All teachers should understand the same meaning for each outcome. Also some remarks or statements are included. In order to achieve the final goal, the outcome, a fragmentation in different stages were done for each outcome. Also the time when these stages should be obtained were defined during the degree and master studies. Activities to assess the outcomes were introduced and a proposal of outcomes performance indicators (KPIs).

Fig,1: UPM outcomes website

In a beginning stage, all this information was stored in a record document like the one shown in figure 2. At the same time severa l pilot projects started to assess the outcomes as it was described in our record documents. With the feedback from these projects we polished our indicators and the time to measure. Finally the Outcomes Board compiled all the feedback given by faculty about methods, activities and the facility to assess the outcomes with the suggested indicators. The evaluation of all these data lets to make a "photo" of the development of these outcomes in our students and help us to take decisions about future actions to improve our quality in the engineering program (fig.3).

Fig. 2. Outcome record document

Finally, a book with all the process, d efinitions, indicators and recommendations was published in November 2013. This book is also published in a pdf format for everyone [12]. Since t his moment some changes have been done and reviewed and have been included in the open ebook version.

This framework is supported with a continuous in formation program to facu lty and students. T hrough communications, meetings, confere nces, seminars… Faculty known how were the proc esses going on. Specialised workshops about teaching outcomes were performance by experts to teach the faculty methods, strategies and activities to develop competences during regular classes. As an example, Creativity has been one of the outcomes with more support from the Direction Board. A specific plan to develop this competence has been designed and perf ormed. This plan contained specific traini ng to teachers with two levels of expertise and special action to the students like internal contests or to sta blish a specific day for creativity activities [13].
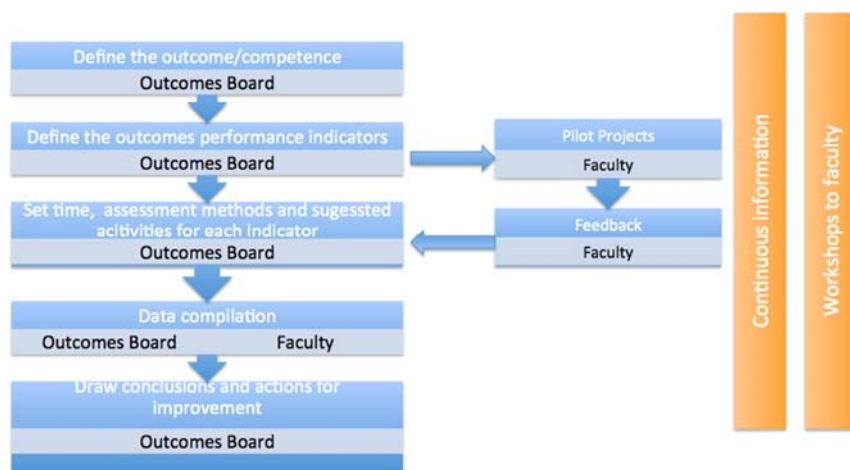
Fig. 3. Process followed and actors involved

3   Engineering Graphics outcomes

The engineering graphics subjects don't scape from this fr amework. Moreover the faculty have to teach the specific m atters relative to engineering graphics (Technical Drawing, Standardization, CAD,...) , they have to change the traditional teaching strategies to develop the ABET outcomes in their students. Mainly these methodologies are focused in the development of creativity as a fundamental component in the "An ability to identify, formulate, and solve engineering problems (e outcome)" and "An ability to design a system, component, or process to meet desired needs within realistic c onstraints such as the ec onomic, environmental, social, political, ethical, health and safety context and manufacturability, and sustainability (c outcome)" or directly in the Creativity UPM outcome.

These subjects start in the first semester of the grade. Students got some lessons about creativity (what's creativity, barriers of the creativity, methods and principles of creativity). To obtain the creativity first indicator (i.e, number of solutions), faculty developed a project with their students where they ask for all the different uses or improvements they can make in a device. This indicator measure a starting point to measure this group in the first stage of the grade. The number of solutions are in fig. 4. During the different subjects of the degree faculty will measure this indicator in order to measure the development of creativity.
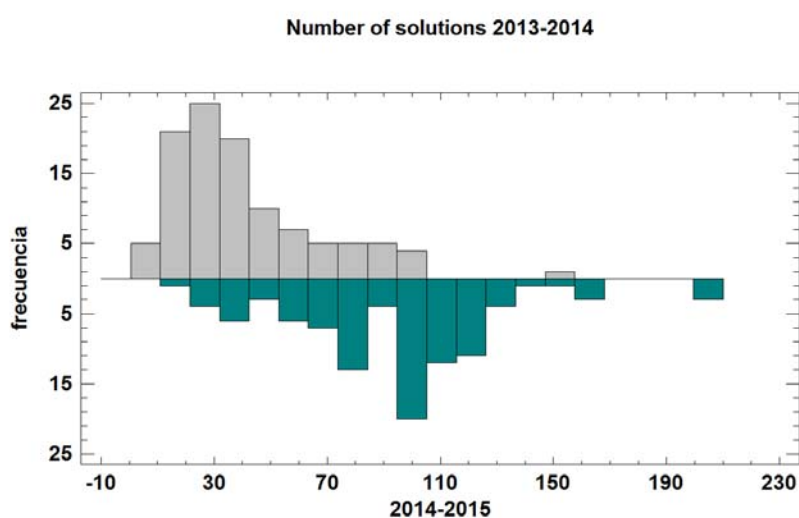
Fig. 4. Number of solution of students from different years.

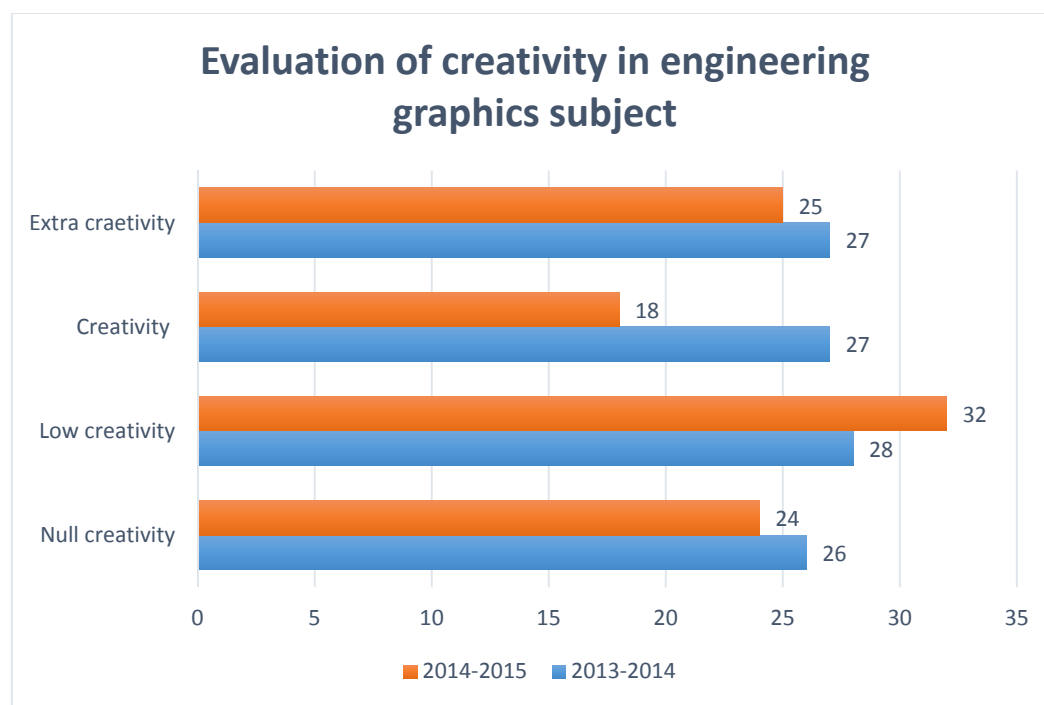Dividing the results in cuartils Faculty evaluate the projects in four levels as show in fig 5.

Fig 5. Evaluation of creativity

4 Conclusions

A framework to develop outcomes in the Escuela Técnica Superior of Ingenieros Industriales from the Universidad Politécnica de Madrid has been presented. This process is in a continuous improvement. Each year we evaluate three outcomes, assess three more and plan how we can improve these results. The next step is obtain a reaccreditation of ABET, ANECA (Spanish National Agency of University Quality Evaluation) systems and a new Euro-ACE (ENAEE) accreditation.

This framework helps to our Direction Board to move forward a quality system. The faculty are involved and have a strong knowledge about competences; and what it is more important, they understand that outcomes help our students to obtain an integral training; not only in technical contents but also skills and abilities to face their future with success.

References

[1] www.abet.org

[2] M. Besterfiel-Sacre, L. J. Shuman and H. Wolfe, Modeling undergraduate engineering outcomes, *International Journal of Engineering Education,* **18**(2), 2002, pp. 128-139.

[3] J. McGourty, L. Shuman, M. Besterfield-Sacre, C. Atman, R. Miller, B. Olds, G. Rogers and H. Wolfe, Preparing for ABEC EC 2000: Research-Based Assessment Methods and Processes, *International Journal of Engineering Education,* **18**(2), 2002, pp. 157-167.

[4] J. M. Williams, The engineering portfolio: communication, reflection, and student outcomes assessment, *International Journal of Engineering Education,* **18**(2), 2002, pp 199-207.

[5] E. Nault and J. Hoey, Trust: the missing ingredient in assessment, *International Journal of Engineering Education,* **18**(2), 2002, pp 117-127.

[6] A. Kaw, G. Besterfield and J. Eison, Assessment of web-enhanced courses in numerical methods, *International Journal of Engineering Education,* **21**(4), 2005, pp 712-722.

[7] B. Steward, S. Mickelson and T. Brumm, Continuous engineering course improvement through synergistic use of multiple assessment, *International Journal of Engineering Education,* 21(2), 2005, pp 277-287.

[8] G. Mitchell and J. Delaney, An assessment strategy to determine learning outcomes in a software engineering problem-based learning course, *International Journal of Engineering Education,* **20**(3), 2004, pp 494-502.

[9] L. Howell, G. Roach, D. Clark and J. Cox, Use of e xplicit instructional objectives to achieve program outcomes and facilitate assessment: a case study, *International Journal of Engineering Education,* **19**(6), 2003, pp 828-835.

[10] L. A. Shay, K. L. Huggins, J. R. S. Blair and B. L. Sh oop, Approaches to increasing the efficiency of an effective outcome assessment process, *International Journal of Engineering Education,* **24**(5), 2008, pp 884-892.

[11] http://innovacioneducativa.upm.es/competencias-genericas

[12] http://www.gig.etsii.upm.es/competencias/Folleto_Competencias_nov_2013_inter.pdf

[13] M. Luisa Martinez-Muneta, Mario Lopez de Avila, Gregorio Romero and Jesus Felez "Searching for the Most Creative Engin eer "*International Journal of Engineering Education,* **31**(1b), 2015, pp 35 4–360. ISSN 0949-149X

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