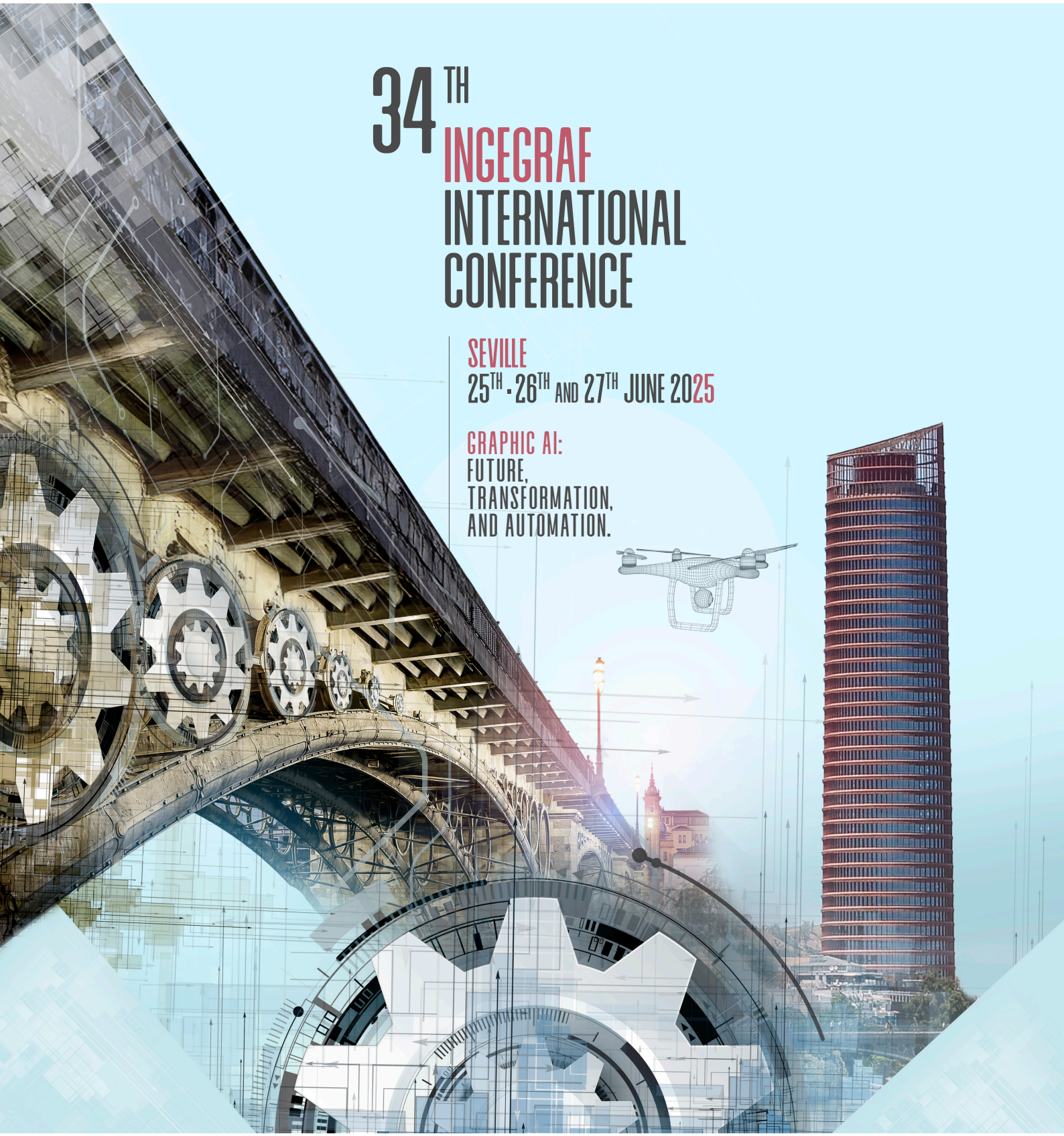
ABSTRACT BOOK



34TH INGEGRAF INTERNATIONAL CONFERENCE

SEVILLE
25TH - 26TH AND 27TH JUNE 2025

GRAPHIC AI:
FUTURE,
TRANSFORMATION,
AND AUTOMATION.

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Preface

The International Conference in Graphical Engineering has been annually supported by INGEGRAF (*Asociación Española de Ingeniería Gráfica*: https://ingegraf.es/, accessed June 2025) since 1988.

Its 34th edition has been hosted at the *Escuela Técnica Superior de Ingeniería* of the *Universidad de Sevilla* on June 25th, 26th and 27th, 2025, under the theme, Graphic AI: Future, Transformation, and Automation.

The congress has covered topics from various perspectives within the field, focusing on the following areas:

Management of products and processes. CAD/CAM/CAE, PLM, Digital manufacturing, Eco-design, Collaborative engineering, Ergonomics and human factors, New materials, biomaterials and recycled materials, CAD-based virtual prototyping techniques, Additive manufacturing, Reverse engineering and Industry 4.0 manufacturing.

Digital tools and artificial intelligence. Digital transition, Digital Twins for Industrial Products, Render and animation, Automatic generation of graphic content, Graphic design, Simulation and computer graphics, Biomechanics 3D modelling, Medical prosthesis design and modelling, Virtual and augmented reality, Applied Artificial Intelligence and Research Methods and Design.

Methodologies and strategies based on graphical engineering. Open CAD Research and Innovation, Novel Computational approaches for 3D Geometry, Analysis and Design, Optimization methodologies, Algorithms for spatial placement based on CAD, Novel CAD strategies, Application of Graphical Methods and Tools to new domains.

Tools and methodologies for management and analysis of spatial data. Cartography, Digital Terrain Models, GIS, Geoinformation Data capture, Photogrammetry, Remote Sensing, Digital Image Processing, Civil engineering, BIM, Landscape integration of infrastructure, Shipbuilding, aerospace, and industrial construction, Urban planning and heritage management, Sustainable building and architecture.

Graphical engineering in superior education. Metric Geometry, Descriptive Geometry, Graphic design tools, 2D and 3D design modelling, High level modelling, Creativity and teaching innovation, New teaching environments, Project-based learning and Collaborative learning.

This book of abstracts compiles the scholarly contributions of the participants in the congress, demonstrating the continuing vitality and research interest that graphical engineering generates within the international scientific community. The collected works reflect the interdisciplinary nature of the field and its crucial role in addressing contemporary technological and societal challenges.

We extend our sincere appreciation to the main organizing institution (*Universidad de Sevilla*), as well as to the supporting and collaborating organizations (*Vicerrectorado de Investigación de la Universidad de Sevilla*, *Turismo de la provincia de la Diputación de Sevilla*, *Instituto Geográfico Nacional* and *Instituto de Estadística y Cartografía de Andalucía*) and companies (SketchUp, Prismacim, TeamBIMcivil and ARUS Andalucía Racing Team) for their generous support and sponsorship.

The organizing committee is deeply grateful to the members of all committees for their dedication, collaboration, and outstanding work. Special thanks are extended to all the reviewers for their selfless efforts in evaluating the submissions, which greatly contributed to the overall quality of the final papers presented at the conference.

Finally, we would like to express our sincere appreciation to everyone who participated in the 34th International Congress on Graphic Engineering (INGEGRAF 2025). Their active involvement and valuable contributions were instrumental in ensuring the success of this event..

June 2025 The Organizing Committe

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Management of Products and Processes

Engineering graphics applied to the assembly process of a single-cylinder high-pressure steam engine with a Corliss Valve Gear

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Keywords: Geometric Modelling, Assembly Process, Autodesk Inventor Professional, Single-Cylinder High-Pressure Steam Engine, Corliss Valve Gear

Abstract

This paper presents a detailed description of the assembly process for the different components of a historical invention, specifically a high-pressure single-cylinder steam engine with a Corliss valve gear designed by Arnold Throp, as published in the 'Model Engineer' magazine in 1982 and whose original plans were reproduced by Julius de Waal in 2018. This assembly process serves as a preliminary step towards explaining the operation of the invention. Autodesk Inventor Professional 2024 was employed to create a coherent and functional 3D CAD model that incorporates all components described in the reproduced plans. However, challenges arose due to missing dimensions in the available plans and certain inconsistencies, necessitating the formulation of hypotheses regarding the geometries of some elements and the estimation of their dimensions. Additionally, a series of dimensional, geometric, and kinematic constraints (degrees of freedom) were applied to ensure a proper assembly without component overlaps. Furthermore, a limitation was encountered when using Autodesk Inventor Professional for assembling the invention: the software does not take into account for the deformation of components made of elastomeric materials such as the drive belt. Finally, once the 3D CAD model was obtained, graphical documentation of the invention was produced (including assembly plans and detailed perspectives), and a simulation of the invention's operation was conducted, resulting in a virtual recreation of the steam engine. This has provided new insights that facilitate a more comprehensive understanding of the invention and its dissemination to the wider community.

Review of PLM integration in the models, methods, and artifacts of PMBoK

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Keywords: Project Management, Software Selection, Performance Domains

Abstract

Companies must manage their projects as efficiently as possible. The PMBoK (Project Management Body of Knowledge) has become a widely recognized reference framework for project management. This guide provides a knowledge framework that enables the management of the lifecycle of any project. However, project management often involves handling a large volume of information, which adds significant complexity to the project lifecycle. PLM (Product Lifecycle Management) systems emerge as a suitable option for designing and developing product-related projects. The use of PLM to support project management reduces the complexity of information management. These systems establish a common platform that enhances communication and collaboration across the organization.

The project manager must formulate and implement plans that guide a project throughout its lifecycle. The use of PLM systems to support project management activities in a meaningful and integrated way can contribute to organizational efficiency. The latest edition of the PMBoK guide, presented by the PMI (Project Management Institute), defines eight performance domains to consider in project execution. These domains represent a set of interrelated activities necessary to achieve the outcomes of any project. However, the guide does not address the use of PLM systems in its content.

In this context, the present study is carried out with the aim of contributing to the development of this knowledge. PLM systems should support project management activities while also integrating seamlessly with the current systems of the organization and environment. To achieve this, the integration of PLM solutions is proposed through the eight performance domains defined by PMBoK for project execution. The PMBoK guide provides a high-level classification of different models, methods, and artifacts across these eight domains. This classification serves as a cornerstone in this study for integrating various PLM solutions.

This work conducts a review of PLM solutions, methodologies, standards, and software. Additionally, it provides guidance for selecting a PLM system from the perspective of the project manager. Numerous commercial PLM solutions are identified, which may consist of complete packages or integrated solutions. The reviewed literature offers guidelines for the general evaluation of PLM options, as well as critical areas that a company must examine when selecting PLM software. The performance domains of the PMBoK are established as a key criterion for selecting PLM systems that best address and support the needs of projects.

3D EXPERIENCE, in the design and industrialization of aircraft aerostructures: a case study

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Keywords: Aerospace Industry, PLM, CAD, 3D EXPERIENCE

Abstract

The creation and evolution of CAD tools have always been closely linked with the aerospace industry. In this and other fields—particularly in manufacturing or production industries—CAD systems, originally developed solely to represent and manage design in a more automated manner, have gradually incorporated applications that oversee the remaining stages or phases of a product's lifecycle: manufacturing engineering, production, quality, and after-sales services (maintenance, repairs, and spare parts). These ecosystems of integrated applications, which exchange information increasingly efficiently, are known as PLM and are among the pillars of today's Industry 5.0.

As is evident, the driving force behind all these systems—the foundation that supplies the initial information for the other applications—is none other than a CAD tool. Until very recently, and almost exclusively for aerospace manufacturers, this tool had been CATIA, in its various versions and releases. The emergence of 3DExperience, which, while maintaining continuity with the path established by CATIA, represents a significant leap forward—particularly with its more collaborative working approach—is set to modify some of the paradigms of PLM environments.

Focusing on graphic engineering, this article reviews and draws conclusions from the aerospace industry's first experience applying 3DExperience to a complete aircraft. The subject is the Falcon 10X business jet, whose primary manufacturer is the French company Marcel Dassault. In particular, we will focus on the HTP and VTP that AIRBUS, within its Aerostructures division in Spain, designs, having completed the assembly of the first unit at the Tablada plant in Seville at the end of 2024, acting as Dassault's partner.

Using 3D EXPERIENCE in a concurrent engineering process: assembly of a turboprop engine

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Keywords: Collaborative Design, Concurrent Engineering, 3DExperience

Abstract

It is a fact that computer-aided design and manufacturing software, and technologies in the field of manufacturing, are advancing and seeking to be increasingly complete, tending towards collaborative, multidisciplinary and intuitive platforms in which the so-called concurrent engineering is practiced.

This type of platform offers the user the ability to define a complete manufacturing system in which to include more and more stages from different areas, being able to observe the interrelation of all of them and the consequences that the modification of one element may have on the others. Finally, being able to extract a series of analyses of the system, in search of an optimized process with which to save time, resources and therefore generate the maximum possible benefits.

Currently, 3DExperience has become the maximum reference for this type of platform, being capable of offering almost unlimited possibilities, and as we will illustrate in the specific case of this work: the ability to observe, understand and even be instructed in the complicated process of assembly of a turboprop engine.

The main objective of this work, which is summarized in this article, has been the definition and simulation of the industrial digital model for the assembly of the Garrett TPE 331-10R turboprop engine, through iterative modelling of the process, making use of the different tools that the 3DExperience platform offers, in particular:

- Define the assembly structure and its associated MBOM using Manufactured Item Definition.
- Sequence and divide the assembly into different phases and/or assembly stations using Process Planning.
- Define the resources necessary to correctly carry out the process, distribute the layout operations in the assembly plant and assign these to the different resources defined using Equipment Allocation.
- Generate trajectories associated with the different operations, in order to verify the viability of the assembly process and a subsequent simulation of it, through Assembly Evaluation.

Sustainable design using technical-functional and Socio-Collaborative Tools

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Keywords: Sustainable Design, Technical-Functional Tools, Socio-Collaborative Tools

Abstract

A number of tools have been developed over recent years to provide support during the design phase of environmentally friendly products. However, the current production and consumption models require addressing the design process of both product and service systems and not only considering environmental aspects but also economic and social issues. Thus, the use of different tools integrating the technical analysis of sustainability specifications and the application of collaborative strategies aligned with the needs of all stakeholders involved are required. This work proposes a combined use of functional and socio-collaborative tools to achieve more sustainable products and services.

Two types of tools are examined:

- Technical-functional tools: These tools focus on the sustainability assessment and the impacts analysis providing appropriate data to guide more informed and sustainable decision-making. Techniques like Life Cycle Assessment (LCA) and the LiDS wheel allows designers to obtain a set of sustainability indicators and to apply strategies to improve them.
- Social-collaborative tools: These tools emphasize the integration of diverse stakeholder perspectives in the design process involving not only experts but also users as primary sources of information. Approaches such as User-Centred Design (UCD) and co-design are highlighted, alongside techniques like observation, surveys, and interviews, which allows the introduction of concepts associated to the social innovation.

This approach has been implemented in a study case related with the design of a cultural service. The combination of technical-functional and social-collaborative tools offers a more comprehensive approach to sustainable design, because ensures a practical sustainability study and the involvement of different stakeholders.

This work contributes to the development of more sustainable and adaptable design practices that will be essential for future global challenges.

Assessing the sustainability of a childcare service in a rural area of Zaragoza (Spain)

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Keywords: Sustainability, Life Cycle, LCSA, Rural Environment

Abstract

Nowadays, research works associated with sustainable design should be not only focused on the analysis of product systems since, in a wide number of cases, the combination of products and services interconnected is required in order to provide value and utility to users and consumers. In addition, sustainability is a comprehensive concept that transcends environmental considerations, encompassing social and economic dimensions. Thus, a triple sustainability framework that underscores the importance of balancing environmental preservation, economic development and social well-being to achieve equitable and enduring outcomes should be applied.

On the other hand, rural depopulation represents an increasingly pressing challenge in Aragón, characterized by an aging population and a notable lack of services to facilitate work-life balance. As highlighted by the Observatorio de Dinamización Demográfica y Retención del Talento en Aragón (Observatory for Demographic Revitalization and Talent Retention in Aragón), deficiencies in childcare services, public transportation, and employment opportunities drive younger families to migrate to urban areas, placing the sustainability of rural communities at significant risk.

The objective of this work is to analyse the sustainability of the three main stages of the life cycle (creation, provision and dismantling) of a childcare service located in a municipality with a population of 2,900 inhabitants. The Life Cycle Sustainability Assessment (LCSA) methodology, which takes into account the environmental, economic and social dimensions, is employed. A set of sustainability indicators has been utilised and impacts along the stages of the life cycle have been obtained. Indicators of greenhouse emissions, execution costs and working times, have been selected to quantify sustainability in each dimension and carry out a comprehensive presentation of results. In addition, the sustainability triangle, assigning different weights to indicators according to the particular interests of the decision-makers, is elaborated to represent the global sustainability of the service development. The factors of greatest impact have been identified, which should allow the selection of different design alternatives that improve the sustainability of the proposed service.

Guidelines for the successful design of products with environmental certifications

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Keywords: Eco-Labels, Sustainable Design, Guidelines, Certification, Greenwashing

Abstract

With the increasing attention paid to sustainability and sustainable consumption, many products are redesigned to diminish their environmental footprint. This is also triggered by changes in legislation and the growing consumers' interest to what is supposed to be more environmentally friendly. As a consequence, more and more products are getting certified by governmental and other bodies; this is made evident, especially for food items, through the display of eco-labels. However, the proliferation of eco-labels has given rise to consumers' difficulties to distinguish them in terms of their relevance, actual contribution to sustainability and, especially, genuineness. In this regard, green marks disguised as eco-labels are also diffused and represent a conventional marketing strategy ascribable to greenwashing. On top of that, much literature challenges the effectiveness of eco-labels in capturing consumers' attention and increasing their willingness to pay for the benefit of sustainability. Recent studies have highlighted that many factors, including aspects ascribable to design, and visual behaviour towards eco-labels affect product evaluation and consumer behaviour. While it has emerged that the design of eco-labels and the exterior aspect of certified products play a role here, dedicated design studies are still lacking.

In this context, the objectives of this paper are manifold. A first aim is to collect from the literature and catalogue the factors influencing the effectiveness of eco-labels and other forms of sustainability- and environment-related communication. These factors include a) product categories, e.g., food items, consumer goods, durables; b) target customers, especially in terms of their sustainability awareness; c) environmental benefits claimed by eco-labels; d) the design of eco-labels and their arrangement on the product or its packaging. After having made order on the factors regarding eco-labels, certified products, and their design, an additional objective to pursue is to lay bare those aspects or combinations of possibly affecting factors that have not been studied so far. This serves to present the extant open issues related to the design of eco-labels and products that have to display environmental certifications. Eventually, the final objective is to use the available knowledge to develop design guidelines. These guidelines should support designers in making appropriate choices when designing products including eco-labels while willing to convey sustainability-related information in the most successful and effective way. As some understanding is still required when it comes to products including eco-labels, the guidelines point to those situations where new studies and findings are needed to steer the design process adequately. Overall, the original contribution of this paper can be synthesized into viewing the inclusion of eco-labels in products as an opportunity, but also as an issue to consider carefully, in design. One of ramifications of the paper is to solicit the design community to become protagonist in the research on eco-labels, as those have been treated so far exclusively through the lenses of consumer behaviour, and, in a few instances, cognitive psychology.

Analysis of consumer trends and attitudes towards repair of small household appliances in Spain from a product design approach

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Keywords: Repair, Small Household Appliance, Eco-Design, Circular Economy, Consumers

Abstract

Repair is one of the main strategies of Circular Economy to extend product lifetimes and reduce their environmental footprint. However, other trends such as recycling receive more attention. Repair is in decline, especially for products that use electricity, and a culture of replacing broken goods with new ones rather than repairing them is leading to an increase in electrical and electronic waste. There are many strategies to promote product repair. Regulations such as the EU 2024/1799 'Right to Repair' Directive. Other initiatives come from grassroots movements like the Repair Café International Foundation. Finally, there is a growing body of research into how product design and eco-design aspects can be used to incentivise self repair by consumers. The aim of this study is to explore the current repair landscape of common small household appliances in Spain through a semi-quantitative survey, mixing closed and some open-ended questions. An online survey was designed to determine whether repair is a common practice, consumers' past experiences, repair habits and their willingness to repair. Users are asked about their ownership of common small household appliances, their repair experience, their willingness to repair, and their views on the usefulness and convenience of various measures to encourage repair from a regulatory and product design perspective. Finally, users are asked about their gender and age. A qualitative analysis is done on open-ended questions, to obtain results from this type of data and to complement the other results from the survey. Based on the representative sample of more than 200 responses to the survey, most respondents hadn't repaired their products, most of them young users. The low price of a new product compared to repair is the main reason to not repair, while the most common factors that complicate the repair process are convenience factors. Environmental and economic issues drive repair intentions. Finally, measures from the EU's 'Right to Repair' Directive are well received by the public, and product disassembly and available information are chosen as product aspects that motivate repair. The results of the survey have enabled us to create different 'profiles' of consumers based on their gender, age, the appliances they own and previous repair experience. This will be useful for targeting repair promotion efforts and selecting the most effective strategies to promote repair through product design.

A more sustainable scooter approach using natural composite materials

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Keywords: Scooter, Natural Composites, Sustainability, Urban Mobility

Abstract

Electric scooters have become a key element of urban mobility in recent years, offering an efficient, sustainable and agile alternative for city transport. They are powered by electric motors powered by lithium-ion batteries, allowing them to reach speeds of between 20 and 40 km/h with a range of up to 40 km.

Factors such as increasing traffic congestion, the need to reduce carbon emissions and the support of legislation in many cities have accelerated the growth of their use and integration into the transport ecosystem.

In terms of structure, conventional electric scooters are mainly made of steel alloys, which makes them heavy products, detracting from their autonomy. This work proposes the use of natural composite materials to achieve a lighter solution, with a structural performance similar to current proposals. In this way, sustainable solutions will be achieved with a reduction in mass that not only facilitates their transport and manoeuvrability, but also reduces the energy demand of the motor, which contributes to lower electricity consumption and greater battery autonomy.

In addition, a manufacturing system using direct generation of 3D printing moulds is proposed. This technology allows to reduce costs, development times and environmental impact through the use of recyclable materials and energy efficient manufacturing processes.

The environmental impact of the different configurations (current and proposed) are analysed under different impact categories, so that it is possible to quantify different environmental aspects. The phases of the scooter's life cycle that are most sensitive to the proposed natural composite materials are also explored in depth. The Life Cycle Analysis (LCA) methodology will be used to carry out the whole environmental study.

Transforming Andalusia's industrial sector through Eco-Design: new timber construction systems for Multy-Storey Buildings

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Keywords: Eco-Design, Timber, Construction, Multy-Storey Buildings

Abstract

Construction, and in particular, that produced in the building sector, is a fundamental activity in the productive and economic sector of Europe. However, the sector is responsible for more than one third of greenhouse gas emissions in the European Union (EU). Buildings generate approximately 36% of greenhouse gas emissions and consume around 40% of the EU's energy consumption. In this regard, structural wood used in multi-family buildings is playing a significant role compared to conventional concrete, brick or steel systems. In Spain, this development is taking place mainly in regions such as Galicia, Catalonia, the Basque Country and the Balearic Islands, and is also beginning to make significant progress in Andalusia.

As part of the research, the Life Wood For Future project of the University of Granada, together with Forest Owners' Groups, proposes to combat rural depopulation through the use of poplar and pine wood, through construction designs that combine wood and concrete. The results obtained reduce the carbon footprint and incorporate off-site technologies that improve the quality of the finishes; however, the aim is to achieve a greater reduction in the use of concrete.

With this in mind, a building has been designed for Andalusia, with more than five floors, whose floor slab is composed of prefabricated hollow core slabs, using poplar and pine wood from the surrounding area. This type of hollow-core wood slabs are widely accepted in different European countries, since they have high strength properties and speed of assembly, similar to prefabricated hollow-core concrete slabs. However, the concrete ones weigh about 17 times more and emit up to 16 times more CO2. Compared to cross-laminated timber panels (CLT), the engineered hollow core slab has a lower environmental cost because its optimized cross-section uses less wood, even though it requires the addition of thermal and acoustic insulation material.

To obtain material data, Autodesk REVIT 2025 software was used to generate a complete 3D model of the entire construction, which made it possible to optimize the volume of wood used, as well as material waste. On the other hand, the material used has been quantified and classified, making an environmental inventory of the building.

The aim of this work is to encourage the transformation of the industrialized wood sector in Andalusia for the rural development of forest areas. Through the design provided, it can be achieved a construction system that does not use concrete, lightweight and high strength, which has an affordable cost compared to current construction systems, and meets the standards of fire resistance and sound insulation. In conclusion, this system could be part of the typologies that approach construction from the perspective of environmental sustainability.

Integration of graphic information with performance data to be used in built digital models

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Keywords: BIM, Digital Product Passport, Built Assets, Standards

Abstract

The European Union has defined a Digital Product Passport (DPP) in the new Construction Products Regulation to store data related with performance and environmental characteristics. The DPP is also part of the EU Ecodesign Regulation. The information to be stored in the DPP, including graphical data (geometry, colour, etc.), is yet to be defined. Construction products can be described in BIM (building information modelling) using IFC (industry foundation classes), with several limitations. In particular, many construction products do not have a geometry until they are placed onsite (e.g. ready-mix concrete) and others can be defined with just one parameter (e.g. thickness in a waterproofing sheet), reducing the required information to be stored.

The objective of this research is to analyse the approach used in the Spanish Standard UNE 41316:2020 to refer to geometric information, stored in separated files, may be applicable for the data format to the DPP and, in particular, to the format proposed CEN/TC 442 "Digitalization of construction products performance characteristics". It also describes the potential relation between the performance information which will be stored in the DPP, IFC and the potential use at asset level (buildings or infrastructures).

The research adopts a structured methodology to assess the digitalization of construction products' formats and the relation with graphic information, based on the analysis of international standards, software tools and BIM objects available in manufacturers' websites. In particular, IFC (ISO 16739-1) and the Smart CE concept (CWA 17316 and UNE 41316). The study analyses previous articles in the fields of product data structures and formats based on a search with relevant keywords. It also analyses the ongoing work in the BIM and DPP standardization committees at European level (CEN/TC 442 and CEN/CLC/JTC 24).

The desegregation of performance (or environmental) characteristics and graphic data, primarily three-dimensional geometry, results in a reduction in the necessary files and, consequently, facilitates the transfer and management of product data at the built level. It also allows different performance characteristics to be related to the same geometry, and vice versa. A standardized approach to tackle these relations will improve the use of DPP data with graphic data in BIM projects

Graphic data is required to design buildings and infrastructure, but it is usually not available (or not relevant) at the product stage, in the information from the manufacturer. A standardized approach to obtain this information, without creating a burden to manufacturers, should enhance the design, construction and maintenance stages of built assets. The definition of relations between digital tools, such as DPP, IFC, BIM software or the building digital logbook (DBL) will promote a more efficient construction.

A look at energy efficiency and sustainability in industrial agri-food projects through engineering graphics and Eco-Design

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Keywords: Eco-Design, Industrial Processes, Graphic Engineering, Building Information Modelling, Energy Efficiency

Abstract

Energy efficiency is becoming increasingly important in the agri-food sector due to several factors, such as rising energy costs, the need to comply with stricter environmental regulations, and the growing demand for sustainability.

Optimizing energy processes enables agribusinesses to reduce energy consumption, which lowers production costs. By being more efficient in using energy resources, these companies can offer their products at more competitive prices and improve their market positioning in a context where consumers increasingly value sustainability.

The case study focuses on improving energy efficiency in table olive dressing processes, on which an energy analysis of different industries in the sector has been carried out using Autodesk REVIT 2025, BIM (Building Information Modelling) modelling software, and its Insight energy performance simulation engine.

These industries are characterized by their seasonality throughout the year due to the fact that the raw material is harvested starting in September and continues until the end of November, this being the period when most energy is consumed. The process involves receiving the olives, washing, sizing, and splitting. Once split, the olives are preserved in brine and, depending on the style of production, are kept in cold storage rooms, shaded patios, or fermenters, and are seasoned and packaged in the following months.

For its analysis, a BIM has been generated, which contains detailed information on the geometry, materials, systems, and operating conditions of the building. Likewise, the model has been georeferenced to establish its climatic conditions, in addition to defining its topographic characteristics using the cartographic base of Andalusia. Based on this information, energy simulations have been carried out to study the thermal behaviour throughout the year, in order to identify areas for improvement and propose solutions.

Among the problems detected are temperature losses in cold rooms, which account for around 25% of electrical energy consumption. Likewise, the use of fossil fuels, such as diesel oil, in pasteurization processes, which require the production of hot water at high temperatures, has also been detected.

As a result of the study, it is proposed to improve thermal insulation in cold rooms, incorporate shading in facades more exposed to sunlight, replace diesel boilers with biomass boilers fed with waste generated in the industry itself, such as olive pits, and evaluate biomass gasification as a technology being adapted to the sector.

After the analysis carried out, the combination of the proposed measures could reduce energy consumption by up to 30%, which is equivalent to considerable annual economic savings, and would increase the commitment of these industries to the environment.

Conceptual design of a collaborative nesting system for shipbuilding

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Keywords: Shipbuilding, Collaborative Engineering, Multi-Agent System, Nesting, Sustainable Manufacturing

Abstract

The sheet metal nesting process in shipbuilding poses a challenge in terms of optimization and sustainability. Digitalizing this process through a collaborative system based on intelligent agents can significantly improve its efficiency. This study presents the conceptualization phase of such a system, identifying, describing, and linking actors and use cases within the shipyard ecosystem, aligning with the principles of collaborative engineering.

The first phase of the MAS-CommonKADS methodology is presented, focusing on the identification, description, and relationship of actors and use cases in the nesting process. The interaction of various agents, both human and software, within a collaborative environment is described, laying the groundwork for the multi-agent system's development in subsequent phases of the methodology.

The conceptualization of the case defines a structured framework for implementing the collaborative system, identifying roles, information flows, and interaction dynamics. A robust model is obtained, which can be further developed and materialized into software for use in shipyards. This establishes the foundation for improved decision-making, initially in the nesting process and, in the future, across other stages of the value chain.

The application of the conceptualization phase of the MAS-CommonKADS methodology structures a collaborative system where humans and intelligent agents optimize nesting in shipbuilding. This framework not only facilitates future software implementation but also drives digitalization and sustainability in the sector.

From UX to Design for Wellbeing: which research is needed to develop pleasing products

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Keywords: Design For Wellbeing, User Experience, Design Methods, Pleasure, Hedonism

Abstract

User Experience (UX) has been introduced in design to evaluate products for target users. Within design, the role of UX is to give user feedback to designers for the enhancement of their designs. Despite research on UX in design being extensive, there are few indications on how to achieve positive UX through designs. To ensure the outmost positive UX, designers should consider the domain of wellbeing, including design for wellbeing. Design methods swivelling on wellbeing should ultimately empower designers to develop products and environments that not only enhance hedonic aspects like pleasure and comfort but also significantly improve overall users' quality of life. It is evident that such methods do not exist yet, even if we consider niche domains.

By using UX as a springboard, the goal of this study is to explore the research needed to develop overall pleasing products, focusing on wellbeing. The first step in this direction is made thanks to this paper, whose objective is to provide the big picture and identify the main open issues in the research on design for wellbeing.

Through an initial mapping of the available literature, it emerges that the discussion on wellbeing reveals several issues, with the first being a matter of terminology. Some contributions present the term "well being" as two separate words, others use a dash in "well-being", and some simply write it as "wellbeing" in one word. This makes the task of gathering all relevant contributions difficult. Secondly, the term 'wellbeing' is often confused with 'wellness', which is a concept associated with hot springs, massages and spa treatments; while these may contribute to wellbeing to some extent, this is not the only focus of this research, besides being poorly linked to design. Additionally, the third issue pertains to the components and close domains of wellbeing. Wellbeing encompasses subdomains like design for pleasure and design for comfort. However, these two domains are more focused on specific hedonic aspects and cannot represent the whole wellbeing of people. The dispersed research in wellbeing across diverse applications and research fields, makes it difficult to pinpoint the key components and aspects that require testing for designers to successfully incorporate wellbeing into their design methods.

Beyond analysing contributions specifically targeting “design” and “wellbeing” contextually, we investigated cases where UX and user-centred design resulted in the creation of products that not only met users' needs but also enhanced their overall wellbeing.

The exploration of the literature, whose difficulties have been already highlighted, has allowed us to identify and classify key research contributions in design for wellbeing. This has led to define the necessary research approaches to establish effective design methods that contribute to create a holistically positive UX. This research has pinpointed crucial areas for future research, e.g., experimenting comfort-oriented studies in product design, and offer recommendations for integrating wellbeing principles into the design process, e.g., to consider biophilic design in unexplored areas. Eventually, the contribution of this paper is a roadmap for future studies to develop comprehensive design strategies that prioritize user wellbeing.

Semi-active Orthosis for the Treatment of Equinus Foot

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Keywords: Equinus Foot, Orthopedic, Rehabilitation, Semiactive Orthosis

Abstract

Orthopedics devices are experiencing significant innovation, especially orthoses. These devices, which provide external support to the neuromusculoskeletal system, have significantly improved thanks to new body parametrization methods, allowing for personalized orthoses. Although, these ergonomic advancements make orthopedics more accessible to a diverse range of users and facilitate their integration into daily routines. The primary goal remains to enhance their assistive functions during injury recovery.

Nowadays, there are various medical conditions in which immobilization of the affected zone is not the most effective long-term solution, among them are neuronal disorder affecting the extremities. Individuals with equinus foot do not have the ability to complete the stance or swing phase during gate due to insufficient strength to position the joint at 90 degrees. For equinus foot patients multiple devices are available that immobilize the ankle, restricting mobility and, consequently, causing the neuromuscular area required for that movement to become inactive, as it no longer needs to perform the swing function during gait. These are known as passive devices.

The development of the proposed device for this condition has required a extensive market and user study, as well as guidance and follow up from therapeutic professionals, which has allowed for the creation of the product aligned with the required needs. Both current market deficiencies and the mons innovative projects have been reviewed in order to provide a device that adapts to new knowledge while also proposing a feasible project for its introduction into the market.

Research is being conducted on active orthoses. These devices enable autonomous movement, meaning the user receives variable assistance provided through servo motors that have previously collected signals about the user's gait status. Implementations like these allow to continually maintain a neuromuscular activation of the affected area while providing automated personalized automatic assistance. The limitations of this method are the proper challenges of robotic devices, like lack of ergonomics and limited economic viability.

This article presents a new equinus orthosis technically and economically viable that combines the benefits of neuromuscular activation with an ergonomic structure realized through elastic mechanisms. The presented orthosis is considered semiactive, as it does not generate a proper movement assisted by driving elements, however it does provide customizable assistance in the development of the rehabilitation. The range of motion and the intensity of assistance will be proportional to the configuration set in the elastic components. The project aims to promote the activation of the neuromuscular area affected by equinus foot, offering and additional element in the rehabilitation provided by physiotherapists. These professionals will be able to adjust the device according to the patient´s progress.

The result of this research has been reflected in the filing of a patent application, with the aim of finding a business partner who can commercialize the product and improve the quality of life of individuals with this type of condition.

Ergonomic design considerations for next-generation Smart Walkers: enhancing mobility and safety ergonomic design aspects of walkies robotic walker development

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Keywords: Ergonomics, Smart Walker, Rollator, User-Centred Design, Design Modification

Abstract

The global ageing phenomenon significantly increases the risk of falls among older adults, highlighting the urgent need for innovation in mobility aids. Traditional unpowered walking aids, such as canes, crutches, wheelchairs, and rollators, have been widely used worldwide for years, but they have limitations. These passive devices often impose high musculoskeletal and cognitive demands. They are suitable only for individuals with mild walking impairments, as they require sufficient strength for independent use. They are ineffective for populations with moderate to severe walking disabilities. Smart walkers, integrating mechanical structures, electronic and control systems, and various sensors, offer enhanced physical support, navigational aids, biomechanical monitoring, and safety systems. It is among the most promising mobility aids for older adults and individuals with moderate to severe walking disabilities. However, most smart walkers remain at the research stage and lack essential ergonomic design considerations. Poor ergonomic design limits device effectiveness and may even harm users with varying degrees of physical weakness. This research contributes to the product and process management field by demonstrating how ergonomic design decisions impact the usability and effectiveness of assistive mobility devices. The present work describes the ergonomic design aspects of a walker, integrating user-centred design principles to enhance comfort, stability, and adaptability throughout the product development process. Ergonomic design is basic in developing rollators and robotic walkers, improving user comfort, functionality, and overall walking experience. This includes adjustable height settings, padded handles, and manoeuvrability. The ergonomic design of walkers plays a crucial role in optimising user comfort, reducing physical strain, and ensuring accessibility, contributing to an improved quality of life for individuals with mobility impairments. These aspects ensure proper support and reduce strain, enhancing comfort and usability. By applying ergonomic principles, this study highlights the importance of optimising key parameters such as handle positioning, frame adjustability, and user posture to minimise fatigue and maximise support. In addition, the design incorporates lightweight materials to enhance portability without compromising durability. This approach follows key ergonomics and human factors principles, ensuring that user needs, postural requirements, and ease of use are fully integrated into the product development process. The frame provides stability and support, while the folding mechanism allows easy storage and transport. Attention to detail in the design process ensures that WalkIES promotes proper posture and reduces strain on the user's body. The findings provide insights into how ergonomic improvements in mobility aids can be systematically incorporated into the product design and manufacturing cycle, ensuring user safety and production efficiency. Whether in indoor spaces or outdoor terrain, the ergonomic features of WalkIES adapt to diverse user needs, enhancing mobility and independence. However, ergonomic design is not limited to physical comfort alone. The braking system remains a challenge that must be addressed to ensure user safety and accident prevention.

Mechanical characterization of compression-molded discontinuous carbon fiber/epoxy composites

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Keywords: Short Fiber, Discontinuous Fiber, Carbon Fiber, Reinforced Plastics, Mechanical Properties

Abstract

This study investigates the elastic properties and failure response of forged carbon composites, manufactured by compression molding using randomly oriented short carbon fibers in a thermosetting resin matrix.

Compared with standard lay-up methods, this produces much simpler manufacturing processes yet maintaining similar properties, with the reduction in costs that less operator times carries. Also, unlike traditional discontinuous fiber composites produced from pre-impregnated tapes, this process directly incorporates dry carbon fibers with resin, offering greater flexibility in material formulation and manufacturing.

Test parts were molded under controlled conditions to achieve uniform fiber dispersion and minimal void content, following the recommendations offered in the different UNE-EN ISO normative followed in this article and molding processes described. Tensile and flexural tests were conducted to evaluate mechanical performance. Also, the energy absorption was compared against a wet lay-up test part to determine if its more suitable for scenarios where impact resistance is required.

The failure analysis indicates a matrix-dominated fracture mechanism, with limited fiber breakage, leading to variability in mechanical properties. However, the ability to mold intricate geometries with high carbon fiber volume fractions highlights the potential of forged carbon in lightweight structural applications. This study reveals the optimal properties of this material to obtain products with great mechanical properties maintaining an optimal balance with production costs, resistance and aesthetics.

These findings contribute to the understanding of forged carbon's mechanical behaviour, emphasizing its suitability for applications where weight reduction, manufacturability and complex three-dimensional structures are required. Also allows for rapid manufacture of short runs of very stiff and resistant pieces.

Moving to organic goods and materials to reduce global warming potential emissions

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Keywords: Organic Products, Life Cycle Assessment, Organic Food, Organic Textile, Environmental Impacts

Abstract

Climate change is a global challenge that requires coordinated efforts to prevent its devastating environmental, social, and economic negative impacts. The current globalised economic market and its impacts are interconnected with diverse raw materials and production methods sourced from all over the globe, leading to an increasing dispersion of responsibilities regarding their effects. Therefore, actions should be taken from each local context to obtain global effects. Shifting from conventional high environmental products to low socio-environmental products is a step towards reducing environmental impacts of human activities. In this respect, to understand how sustainable different production restrictions are, organic and conventional ones, the aim of this study is to compare the Global Warming Potential (GWP) of organic products from different categories with their conventional analogues. The research involves collecting data from literature reviews published between 2015 to 2024, as well as analysing Life Cycle Assessment (LCA) and environmental impact reports for certain fairtrade products. Two product categories have been analysed including food and textiles products. Through this comparative analysis the study aimed to quantify the organic products capability to mitigate climate change. Preliminary results indicate significant variation in the literature, with food products showing a reduction of 1.58% in GWP due to the use of organic production, while textiles show a reduction of 49.27%. The standard deviation varies from 17.46 for food products to 0.36 for textiles. This variability highlights the contradictions found in the literature. Furthermore, in certain products different authors have contradictory positions, such us in the coffee production where certain reduction of 30.75% and other increases of 1342% in organic production are identified. Organic land use yield is lower than conventional one, needing more production areas to obtain same product quantities. This is translated to more transport emissions, as well as lower profits, thus the specific research of calculating the impacts of organic products needs to be continued, to have a more uniform and realistic results in different products categories. Additionally, it is a clear fact that an economic investment would need to be performed due to the increased land use.

Optimising rheology and printability of a natural hydrogel for 3D Bioprinting

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Keywords: Bioprinting, Cell Viability, Characterisation, Printability

Abstract

3D bioprinting is a key technology in tissue engineering, but its applications are limited by the difficulty of finding bioinks with optimal printability and biocompatibility properties. This study aims to develop and characterise a hydrogel based on K-Carrageenan (KC) and Tragacanth Gum (TG) that combines good printability, structural stability and low cytotoxicity. The goal is to obtain a modular biomaterial that allows the printing of complex biomimetic structures without compromising its cellular compatibility.

Stock solutions of KC and TG were formulated at different concentrations to evaluate their individual rheological properties. Viscoelasticity tests were performed by determining the storage (G') and loss (G'') moduli as a function of temperature and shear rate. An optimal formulation was selected and mechanical extrusion, pressure and collapse tests were performed to evaluate its performance in 3D bioprinting. Finally, its feasibility in the printing of complex structures using three-dimensional scaffolds was analysed.

Rheological tests showed that KC provides a more elastic structure, while TG provides modulable viscous characteristics. The final formulation presented a pseudoplastic behaviour with a stable thermal transition in the physiological range (36.5-37°C), ensuring a homogeneous extrusion without structural collapse. Mechanical tests indicated that the hydrogel maintains its integrity after extrusion. In addition, the collapse test showed optimal reproducibility in grid printing and bioprinting of a biomimetic model.

A hydrogel based on KC and TG with excellent printability and mechanical stability properties has been developed, demonstrating its suitability for 3D bioprinting. Its rheological behaviour allows its viscosity to be modulated by the applied pressure, ensuring optimal conditions for the printing of complex structures. Furthermore, its low cytotoxicity positions it as a promising candidate for tissue engineering. Future research will explore its behaviour in advanced cell cultures and its integration with specific cells for biomedical applications.

Modelling and additive manufacturing of gelma-based bioinks applications in bioengineering

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Keywords: Bioprinting, 3D Design, Characterization, Hydrogel

Abstract

This study aims to develop and characterise a new bioink based on hybrid hydrogels for application in 3D bioprinting. The aim is to evaluate the viability of these materials in regenerative medicine, through the synthesis and optimisation of natural and synthetic hydrogels. In addition, the aim is to analyse their mechanical, rheological and printability behaviour in order to select the most suitable formulation for the creation of biomimetic three-dimensional structures.

The study was carried out by synthesising hydrogels from gelatin methacrylate (GelMA) and konjac, using photoinitiators such as LAP. The methodology included the characterisation of rheological properties by rheometry, evaluation of self-supporting capacity and determination of printability by 3D bioprinting with the BIO X bioprinter. Mechanical tests were also carried out to analyse the flow strength and Young's modulus of the hydrogels obtained.

The obtained hybrid hydrogels showed adequate printability and structural stability. It was observed that the combination of GelMA with konjac improved the mechanical properties and support capacity of the bioprinted structures. Rheological analysis revealed a pseudoplastic behaviour suitable for use in bioprinting, with a controlled viscosity that facilitated the deposition of successive layers without structural collapse. In terms of self-supporting capacity, hydrogels with higher GelMA concentration showed higher strength, while formulations with konjac showed better elasticity and adaptation to biological conditions.

The development of hybrid hydrogels based on GelMA and konjac has proven to be a promising alternative for 3D bioprinting, offering improvements in mechanical stability, printability and biological compatibility. The optimised formulation allows the fabrication of three-dimensional structures with properties adaptable to applications in regenerative medicine. The implementation of these materials in future research is recommended to evaluate their integration into functional tissue models and their potential for advanced therapies.

Use of finite elements to verify the aptitude of the Iberian falcata for combat

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Keywords: Iberian Peninsula, 3D Modelling, Sword Design, Archaeological Sites, Hand-To-Hand Combat

Abstract

Throughout of humanity history, war conflicts have been a constant. Since the Upper Palaeolithic, the weapons development used in combat has given rise, almost jointly, to the development and expansion of cities where fortifications prevailed as an emblematic building. It is precisely in the Age of Metals, where the development of swords significantly fuelled conflicts, with the falcata being one of the main bladed weapons associated with the populations of the southeast of Iberian Peninsula in pre-Roman times. In this research work, all falcata sections, 12 in total, found in archaeological sites, were modelled. Each sword was then subjected to finite element stress analysis to determine its suitability in combat. The results show that the displacement vs weight relationship is important in deciding whether the sword was used in the initial training of soldiers or in real combat. On the other hand, the excessive tension exerted, during combat, on the tip of each of the sword sections analysed, suggests that its design made it easy for it to be lost in hand-to-hand combat. In conclusion, the design of each section was of great importance for its effective use in combat, probably due to a strategic decision related to the enemy to be faced.

Design and implementation of a 3D-Printed outlet cover for an open turbine in irrigation systems

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Keywords: 3D Modelling, CAD, Additive Manufacturing, Sustainable Materials, Irrigation Systems

Abstract

This work presents the design and implementation of a custom outlet cover for an open turbine to optimize water utilization in an irrigation system after electricity generation. The objective was to develop a component that efficiently redirects the outgoing flow, ensuring proper irrigation while maintaining the turbine's functionality. The work focuses on the design methodology, from technical drawings to CAD modelling and the transition to a 3D-printed prototype manufactured with sustainable materials.

The development process began with 2D technical planning, followed by 3D CAD modelling to ensure proper adaptation to the turbine structure. The design process considered dimensional constraints and assembly requirements to ensure an efficient fit with the turbine casing. Once the model was finalized, it was manufactured using additive manufacturing based on 3D printing with a sustainable filament, chosen for its mechanical properties and environmental benefits. High-precision printing ensured dimensional accuracy and a watertight seal with the turbine.

The 3D-printed outlet cover was successfully integrated with the turbine and tested within a real irrigation system. The design effectively redirected water flow, maintaining adequate pressure while preventing leaks. The cover demonstrated mechanical durability and stability, confirming the feasibility of the selected material and manufacturing approach.

This study showcases a systematic workflow from technical drawings to functional 3D-printed components, emphasizing the role of graphical engineering in fluid system design. The integration of sustainable materials in additive manufacturing offers a practical and environmentally conscious approach to customized engineering solutions. The successful implementation of the outlet cover highlights its efficiency in irrigation applications while demonstrating the potential of 3D printing for tailored hydropower-related components.

Modelling and digital fabrication of the F50 SailGP catamaran using CATIA v5 and FDM technology

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Keywords: F50 SailGP, CATIA V5, Additive Manufacturing, Reverse Engineering, Digital Prototyping

Abstract

The primary aim of this study is to design, model, and fabricate a scaled prototype of the F50 SailGP racing catamaran using CATIA V5 software and the FDM (Fused Deposition Modelling) additive manufacturing technique. To address the limitations arising from the scarcity of detailed technical data, a reverse engineering methodology is implemented, enabling the precise recreation of the model. Additionally, the project seeks to establish a replicable workflow methodology for future professional environments and advance the technical understanding of the catamaran, materializing this knowledge through a physical prototype. The capabilities of additive manufacturing in the industrial field are also explored, emphasizing its potential in terms of sustainability and efficiency.

The methodology employed is divided into four main phases:

1. Data Collection and Processing: ImageJ software was used to extract numerical measurements, while CATIA's Sketch Tracer module was utilized for more complex geometries, both derived from reference images and aeronautical standards.

2. CAD Modelling: Using CATIA V5, individual components of the catamaran (internal structure, hull, sails, and auxiliary elements) were modelled and assembled into a complete model using the Generative Shape Design and Assembly Design modules.

3. Preparation for Printing: The models were scaled to 2% of the original size and optimized for 3D printing, with parameters such as layer height, infill density, and printing speed being defined.

4. Additive Manufacturing and Post-Processing: The Creality Ender-3 V3 SE printer was used alongside Creality Print 5.1 software for FDM fabrication. The parts were printed in PLA material, with post-processing adjustments made to joints and finishes to ensure the final prototype quality.

The project successfully developed both virtual and physical models of the F50 SailGP, integrating aspects of naval and aerospace engineering. The prototype was evaluated for geometric quality, structural stability, and dimensional accuracy, achieving a balance between detail and manufacturing efficiency. The FDM technique proved effective for reproducing complex components, enabling significant cost and time reductions compared to conventional methods. The methodology addressed the challenges posed by the lack of precise technical data, implementing innovative solutions to ensure an accurate representation of the model. Additionally, the efficiency and effectiveness of the printing process were analyzed, providing real values for manufacturing costs. Generative Shape Design was the most utilized CATIA V5 module, highlighting its utility in designing complex geometries.

This study provides a detailed exploration of the design and prototyping of the F50 SailGP, emphasizing its relevance in competitive sailing and its potential to inspire innovations in naval and aerospace design. The presented methodology is replicable for other complex models in fields such as aeronautical and industrial engineering, contributing to the transformation and automation of processes in digital manufacturing. Furthermore, the combination of CAD tools and additive manufacturing demonstrates its feasibility for advanced design projects, promoting the development of sustainable and efficient solutions. Finally, areas for improvement were identified, such as the aerodynamic optimization of the sails and the use of advanced materials in future iterations, paving the way for greater automation and performance in the design of complex structures.

Study of the lidinoid lattice structures as a substitute of expanded polystyrene foams in bicyclist helmets

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Keywords: Lidinoid, Foam, EPS, Helmet, 3D Printing

Abstract

Lidinoid structure is a triple periodic minimal surface structure (TPMS) that is defined by a mathematic function and creates a unit cell of a thin structure that can be repeated to fulfill the interior of part. The main parameters that define TPMS are the thickness of the wall, that defines the volume fraction and the length of the side of the unit cell using two different parameters. Therefore, a completely customizable structure could be created to obtain a specific density and mechanical properties. These structures cannot be created using traditional manufacturing technologies, so only additive manufacturing technologies are suitable for this purpose

In this article, it will be studied different parameters of these structures to obtain the mechanical properties under compression efforts. In particular, four different materials, 4 length cells and four volume fractions were tested according with the ASTM D1621/00 using a uniaxial INSTRON testing machine. The results obtained were the force and the displacement that were used to obtain the stress-strain curve. In addition, all the specimens were weighted to obtain the density and, as a result different other parameters were also calculated to obtain finally other curves. Specifically, specific stress-strain curve, energy absorption-strain curve, specific energy absorption-strain curve and efficiency-strain curve were calculated.

On the other hand, using a camera, the deformation and crash process of the different structures was obtained to determine the failure process and the evolution.

These results were used to compare these structures with different EPS foams with different densities that were previously be tested using the same ASTM regulation and procedure.

The analysis of the results indicated that the mechanical properties of TPMS structure were lower than the EPS foam ones with the same density. However, TPMS structures could be totally customizable to obtain a structure that could have different properties depending on the zone using different thickness and different lengths of the unit cell in the same structure. What is more, it is possible to create multi-material structures and evolutions of the properties using gradients or any other functions. Consequently, this would be useful in some specific applications, such as helmets, to optimize the mechanical properties of the different parts of the helmet depending on the zone of the brain that must be protected. This is due to the fact that mechanical properties of the different parts of skull vary as well as the damage tolerance of different zones of the brain.

Finally, using 3D scanner, a bicyclist helmet was scanned and 3D model obtained that was the basis to create an innovative helmet using Lidinoid structures that would be tested in the future.

Fabrication of an additive manufactured mold for the production of a drone engine cover using the infusion composites process

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Keywords: 3D Printing, Composites Materials, Fused Filament Fabrication, Infusion Composites, Infusion Moulds

Abstract

Metal moulds have historically been employed in the fabrication of composite components. The primary drawbacks associated with this method of mould fabrication include the substantial time investment required and the significant expense, which necessitates amortisation only when manufacturing large quantities of a component. As an alternative, we propose the utilisation of moulds additive manufactured fabricated by fused deposition modelling (FDM) technique. This technology has become increasingly popular in the field of rapid prototyping in the last years. The primary benefit of this technology is their accessibility, which facilitates their localised manufacturing in a significantly reduced timeframe. This renders them well-suited for the fabrication of moulds for composite components in limited production runs. Moreover, the utilisation of biodegradable materials derived from renewable sources during manufacturing processes enables the creation of moulds in a more sustainable manner. In this case study, the computer-aided design (CAD) process and manufacture of a mould using FDM for the production of a cover for a drone engine is presented. The design phases and requirements are outlined, and the challenges encountered during the process are discussed. In order to achieve this objective, a detailed analysis of the design specifications for the engine cover of a previously designed drone is conducted. The most appropriate material for 3D printing is selected, and an analysis is con-ducted to determine the ideal printing parameters for it. Subsequent to this, an initial design trial is per-formed, after which improvements are implemented to optimise the design. Modifications are made to ensure optimal demoulding of the final infused component. Furthermore, post-processing methodologies are employed to enhance the quality of the surface finish, taking into account the distinctive attributes of this additive manufacturing technology. The infusion process is conducted using sustainable materials such as flax and bio-epoxy resin. The final result of this process is the engine casing, which is composed of the aforementioned materials as part of the Sustainable Industrial Design of Textile Structures for Composites European project (SustDesignTex). The conclusions drawn from this study demonstrate that these types of moulds are a more accessible, feasible infusion method and represent a more sustainable option when compared with conventional moulds for infusion composites fabrication.

Optimization of printing parameters for a ceramic-adapted 3D Printer

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Keywords: Ceramic 3D Printing, Parametric Design, Printing Parameters, Experimental Analysis, Additive Manufacturing

Abstract

The objective of this study is to establish the appropriate parameters for achieving successful ceramic printing using a modified 3D printer adapted for ceramic material extrusion. The study focuses on identifying the key variables that influence print quality, such as material flow control, to optimize the ceramic printing process. Additionally, it highlights the advantages of using ceramic as a sustainable material due to its durability, recyclability, and low environmental impact.

A parametric design approach is applied to create a test part, considering geometric parameters such as height, base diameter, and the mathematical function governing diameter variation along the height. The resulting parts, despite sharing the same underlying code, exhibit significant visual differences due to variations in these parameters.

The 3D printer used in this study was not originally designed for ceramic printing but has been modified following the methodology proposed by researcher Eduardo Chamorro. This adaptation involves integrating a pneumatic extrusion system and a helical screw to regulate material flow.

An experimental analysis is performed to determine the optimal printing parameters required for obtaining a successful printed part. These parameters include nozzle diameter, printing speed, extrusion pressure, among others. All of them significantly affect material deposition.

After identifying the optimal printing parameters for ceramic extrusion, validation is conducted using a reference part. The analysis then extends to assessing how these parameters influence different geometries. The results indicate that factors such as extrusion pressure and nozzle diameter must be carefully adjusted to maintain consistency across various shapes. Additionally, findings suggest that ceramic printing benefits from controlled drying times to prevent deformation and cracking. The study further highlights the environmental advantages of ceramic additive manufacturing, as it minimizes material waste and enables the use of natural, non-toxic raw materials.

This study establishes a systematic approach for determining optimal printing parameters for ceramic-adapted 3D printers. The findings contribute to enhancing the precision and reliability of ceramic additive manufacturing, particularly in cases where printers have been modified for this purpose. By optimizing extrusion and printing settings, the research supports the development of sustainable manufacturing practices, leveraging ceramic's long lifespan and recyclability. The outcomes serve as a foundation for further advancements in ceramic-based 3D printing, enabling broader applications in fields such as architecture, biomedical engineering, and sustainable product design.

Advanced design of non-pneumatic wheels for wheelchairs: simulation and manufacturing with 3D Technologies

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Keywords: Non-Pneumatic Wheels, Wheelchairs, Cellular Structures, 3D Printing, Impact Absorption

Abstract

The conventional design of a wheelchair typically includes two fixed rear wheels positioned on the sides of the seat, aligned parallel to the structure, and two smaller front wheels with 360-degree swivel capability. During movement, terrain vibrations are transmitted to the user through the wheels, with a greater impact on the lower limbs due to the reduced impact absorption capacity of the front wheels. This vibration transmission can induce spasticity in users with certain neuromuscular conditions.

The use of wheels with enhanced suspension capabilities, such as non-pneumatic tires (NPT), emerges as a viable alternative to conventional models. This study presents a comparative analysis of different NPT configurations from a structural perspective, aiming to develop a practical and efficient solution that provides a feasible alternative to traditional pneumatic wheels in terms of durability, mechanical properties, and ergonomic benefits.

Specifically, the study proposes the design and implementation of a non-pneumatic wheel based on cellular structures for the front wheel assembly of a conventional wheelchair. This approach seeks to improve user comfort and mobility by reducing vibrations from uneven terrain without requiring additional damping systems.

The research is conducted through the development and application of 3D printing technologies to manufacture cellular structures using thermoplastic polyurethane (TPU) and polylactic acid (PLA). Using computer-aided design (CAD) tools and finite element simulations, key parameters such as lateral stress resistance, impact absorption, and structural stability have been evaluated. The rigidity of the structure has been optimized based on thickness, inclination, and the number of spokes, ensuring a balance between manoeuvrability, impact absorption, and stability.

The final design consists of a rigid PLA rim combined with a TPU-based flexible tire and spoke system, achieving effective shock absorption without compromising structural strength. The proposed solution not only enhances the user experience by providing a more comfortable and secure ride but also minimizes manufacturing and maintenance costs.

Comparison of photosensitive resins and filaments for additive 3D Printing of orthopedic devices

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Keywords: 3D Printing, Additive Manufacturing, Orthopedic Devices, Thermoplastic Filaments, SLA Resins

Abstract

This study compares the mechanical properties of photosensitive resins and thermoplastic filaments for the manufacturing of orthopedic devices using additive 3D printing. A mechanical characterization was conducted on different materials, including ABS, PETG, PLA, carbon fiber-reinforced PLA (PLA-CF), and SLA resin, employing Fused Deposition Modelling (FDM) and Stereolithography (SLA) techniques. Tensile tests were performed according to standardized norms to evaluate strength and elongation properties, analysing the influence of material type, printing parameters, and layer thickness.

The results indicate that PLA exhibits the highest mechanical strength (≈50 MPa), outperforming PLA-CF (≈40 MPa), ABS, and PETG (≈35 MPa). In contrast, SLA resin showed the lowest tensile strength (<20 MPa), highlighting a significant difference in performance between filament-based and resin-based materials. While PETG and PLA-CF demonstrated superior elongation, especially with a 0.2 mm extrusion diameter, SLA resin exhibited limited deformation capabilities. Printing orientation had a minor impact on mechanical properties, with slight variations in tensile strength and elongation.

The findings suggest that thermoplastic filaments, particularly PLA and its composites, offer superior mechanical properties compared to SLA resins for load-bearing orthopedic applications. However, SLA resins provide advantages in surface finish and intricate detailing, which may be beneficial for specific medical applications. The study highlights the trade-offs between these two additive manufacturing approaches, contributing to the selection of optimal materials for customized orthopedic device fabrication.

Study of dimensional tolerances in additive manufacturing using commercial equipment

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Keywords: Additive Manufacturing, FDM, Laser Scan, 3D Printing, Dimensional Tolerances

Abstract

In 1981, Hideo Komada built the first prototype of a machine that manufactured parts layer by layer using resin solidified by ultraviolet light, thus creating stereolithographic printing (SLA). Taking advantage of the expiration of patents from the 1980s, Adrian Bowyer launched the REP RAP Project in 2005, an open-source initiative aimed at enabling a printer to manufacture another printer, thereby developing prototypes of Fused Deposition Modelling (FDM) technology. As a result, over the past 20 years, additive manufacturing has gained widespread popularity. Additionally, the rise of low-cost CAD design tools and laser scanners has facilitated fast and cost-effective design and prototyping of parts.

The main objective of this research is to present a method for determining the dimensional tolerances of manufactured parts throughout the design, manufacturing, and verification cycle. This method will be applied to parts fabricated using basic geometric primitives.

The experiment was conducted in four main stages. First, basic geometric primitives were modelled using CAD software and converted into STL format. Second, the models were further processed into GCODE format and manufactured using two Cartesian FDM 3D printers from different years (2017 and 2023). The material selected for manufacturing was PETG due to its versatility in 3D printing, offering good mechanical and chemical resistance while maintaining ease of printing. Third, a verification process was conducted, which included manual measurements using a digital caliper. Additionally, point clouds of the printed objects were generated using Quad-camera Infrared Structured Light technology with Single-frame Accuracy, achieving a precision of 0.05 mm. These point clouds were analysed with a Python-based tool to determine the part dimensions. The analysis techniques included Principal Component Analysis (PCA) to determine the main axes. Mathematical operations from geometry, such as projections using dot products, norms, and distances, were employed for measurements. In the fourth stage, the point clouds were converted into a mesh model, allowing the process of additive manufacturing and verification to be repeated.

This method enables both manual and digital acquisition of dimensional data for each part, allowing for the analysis of dimensional tolerances throughout the entire FDM manufacturing cycle. The machines used in the experiment produced manufacturing dimensional tolerances, according to ISO 286-1, corresponding to IT11 for the 2023 printer and IT12 for the 2017 printer.

The selected method is considered suitable for evaluating the manufacturing tolerances of Cartesian FDM printers at each stage of the production cycle. A notable improvement in printer quality over time is observed based on the comparison of manufacturing tolerances. These tolerances allow for industrial applications in precision parts made from PETG.

This evaluation method for manufacturing tolerances can be extended to other types of 3D printers, materials, and dimensional measurement methods. Additionally, it could be used to assess geometric tolerances.

Design and manufacture of a device for the transport of biological material in 3D Bioprinting

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Keywords: Bioprinting, Cellular Transport, Biomedical Engineering, Device, 3D Modelling

Abstract

Efficient transport of cells and biomaterials is a challenge in 3D bioprinting and regenerative medicine. This study presents the design and fabrication of an innovative device for the transport of biological material, guaranteeing optimal conditions of cell viability during the process. The aim is to develop a functional, portable and controlled solution that allows cells to be kept in suspension at the right temperature and conditions until their use in bioprinting.

The device was designed using 3D modelling and additive manufacturing with PLA as the base material. Electronic elements such as temperature and humidity sensors, thermal regulation systems and an autonomous power supply system using a rechargeable battery were incorporated. Functional tests were carried out in the laboratory to validate thermal stability and cell preservation at different time intervals

Tests showed that the device maintains the temperature in a controlled range (36-37°C), suitable for cell preservation. In addition, cell viability tests confirmed that the internal environment of the device prevents dehydration and maintains the stability of the culture medium. The PLA-printed structure proved to be mechanically strong, ensuring safe and contamination-free transport.

The developed device represents an efficient solution for the transport of cells in 3D bioprinting, ensuring the stability of biological conditions during the process. Its modular design and the integration of sensors allow for future improvements in connectivity and remote monitoring. This advance facilitates the implementation of bioprinting techniques in clinical and research environments, optimising the performance of bioinks and the success of tissue regeneration.

Automotive Wheel Rim Prototyping using Reverse Engineering and Computer-Aided Design within the Industry 4.0 Context

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Keywords: Automotive Wheel Rim, Industry 4.0, Reverse Engineering, CAD, Additive Manufacturing, Topology Optimization, Finite Element Analysis, ECE R124, Lightweighting

Abstract

This study explores the feasibility of designing and prototyping a customized automotive wheel rim by leveraging a suite of Industry 4.0 tools, including reverse engineering (RE), computer-aided design (CAD), finite element analysis (FEA), and topology optimization (TO). Commencing with a commercial wheel rim (Rota Wheels GRA 18"), a high-fidelity digital replica was acquired using structured light 3D scanning. Subsequently, a reverse engineering process was employed to generate a parametric base CAD model, from which a novel redesign was proposed. The structural integrity of both the baseline and redesigned models was computationally evaluated using FEA under loading conditions stipulated by the ECE R124 homologation regulation, comparing common aluminum (SAE 356) and advanced titanium (Ti6Al4V) alloys. Finally, topology optimization was applied to explore further lightweighting potential, and additive manufacturing (AM) process considerations were conceptually simulated. The integrated digital workflow demonstrated significant potential as a pathway for the rapid customization and performance enhancement of complex automotive components, although experimental validation and thorough economic analysis regarding advanced material selection and AM implementation remain essential next steps.

Augmented reality for machinery layout optimisation in olive oil mills: an innovative approach

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Keywords: Engineering Graphics, CAD, Augmented Reality, Industrial Design, Spatial Optimisation

Abstract

Efficient machinery layout planning in industrial environments is a key challenge in optimising production processes. In the olive oil sector, the arrangement of equipment within oil mills has traditionally relied on CAD tools and two-dimensional representations, which can lead to difficulties in spatial interpretation and increased installation errors. The integration of augmented reality (AR) into this process introduces new possibilities for improving planning accuracy and reducing operational costs by allowing interactive visualisation of three-dimensional models in real environments.

One of the main difficulties in industrial design is ensuring that machinery is optimally positioned to minimise interference and optimise workflow. Conventional methods require advanced knowledge of 3D modelling and rely heavily on the expertise of technical staff to interpret complex layouts. This creates barriers to decision-making, as operators and managers without CAD training may struggle to assess the feasibility of specific configurations. Augmented reality overcomes these limitations by superimposing digital models onto the physical workspace, enabling real-time evaluation of different layouts and early identification of potential issues before installation.

To address these challenges, this study presents the development of an AR-based application for machinery layout planning in olive oil mills. The system was designed using Unity, incorporating interactive spatial planning methodologies. These methodologies were programmed with geometric constraints that consider key spatial parameters, including clearance zones, operational safety distances, and workflow efficiency. The application allows users to position, move, and adjust machinery layouts in real time, significantly improving pre-installation planning accuracy. To assess the impact of AR on machinery placement, a study was conducted comparing traditional layout planning with AR-based methods. Three-dimensional models of various types of machinery were developed and tested in industrial environments. Operators and technical personnel were provided with AR-based simulations, allowing them to visualise and interact with proposed equipment arrangements in real-time.

The results indicate that AR significantly enhances spatial planning and decision-making in the olive oil sector. The ability to interact with 3D models within a real-world setting enables operators to detect installation errors before physical modifications are made, reducing costs associated with machinery relocation and improving overall efficiency. Moreover, AR democratises industrial design by making layout planning more accessible to professionals without prior experience in CAD software. Unlike commercial CAD tools, which require extensive technical expertise, this application enables users to physically explore virtual models, bridging the gap between conceptual design and final implementation.

Beyond operational benefits, the adoption of AR in industrial design presents new opportunities for innovation in the management of production spaces. The ability to integrate interactive simulations fosters collaboration among stakeholders, promoting a more dynamic and adaptable approach to decision-making. These findings suggest that AR is not only a practical tool for optimising industrial layouts but also a transformational technology that redefines how companies conceptualise and manage their infrastructure.

In this study, augmented reality emerges as an innovative solution for the planning and arrangement of machinery in olive oil mills, offering significant improvements in efficiency, accuracy, and accessibility.

Construction 4.0 and 3D-Printed Housing: innovation for seismic zones

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Keywords: Construction 4.0, 3D Construction, Printed Housing, Seismic Resistance, Sustainability

Abstract

The provision of housing in Chile and worldwide faces an unmet demand due to high costs, prolonged construction times, location constraints, significant environmental impact, and habitability issues resulting from standardized designs. In this context, Construction 4.0 and 3D printing technology emerge as innovative alternatives with the potential to enhance productivity and sustainability in the sector. However, their implementation in seismic zones and diverse geographical contexts has not been widely explored.

This study aims to design and construct a full-scale prototype of a 3D-printed house, called Casa Semilla, integrating Construction 4.0 principles with seismic-resistant criteria, low environmental impact, and high interior quality. The design considers adaptability to different climates and sizes, as well as an expressive and welcoming architectural form that combines straight and curved lines.

The methodology included parametric programming for the design and wall printing, along with the development of optimized cementitious mixes with a lower ecological footprint and reduced carbon emissions. The prototype was executed in collaboration with industry partners, allowing for the validation of the system's technical and construction feasibility within the framework of digitalized, automated, and sustainable processes aligned with Construction 4.0.

The results show that the developed 3D-printed construction system consists of the architectural design of housing units with cementitious double-wall structures, filled with thermal insulation and reinforced with reinforced concrete in pillars, foundations, and upper beams. The structure is complemented by upper metal beams and a lightweight metal roof with an inclined surface. Additionally, it incorporates large double-glazed windows and complementary elements such as terraces and planters also 3D-printed. The architectural envelope was designed with energy efficiency criteria, considering thermal insulation, solar protection, and strategic orientation to optimize natural lighting.

It is concluded that the proposed and built solution differs from conventional construction systems mainly in its execution and design processes, which have been specifically optimized for Construction 4.0 and 3D printing in seismic contexts. This approach allows for reduced construction time, optimized resources, minimized waste, and improved project management, while also generating a novel aesthetic and more comfortable living spaces. Compared to traditional housing, which requires assembling multiple components through slower and more resource-intensive processes, Casa Semilla represents a viable and sustainable alternative within the paradigm of Construction 4.0, leveraging automation, digitalization, and innovative materials for greater efficiency and resilience.

Design of an evolving cot convertible into a Montessori bed

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Keywords: Convertible and Evolving Furniture, Finite Element Method, Creative Design, Ergonomics, Sustainability

Abstract

This paper focuses on the development a new model of an evolving and convertible cot that transforms into a Montessori bed at ground level, aiming to enhance the functionality and sustainability of children's furniture. The project is based on a comprehensive review of current trends, market, and competitor analysis, as well as the associated manufacturing and marketing processes.

This study presents an innovative and sustainable model developed using tools such as SolidWorks, which facilitates the design and analysis through the Finite Element Method (FEM), thereby assessing the strength and stability of the structure and ensuring its suitability for everyday use.

The cot design takes into account specific technical and legal requirements, including safety standards, test methods, and the selection of appropriate materials and tools for woodworking.

The evolving cot features telescopic legs that allow height adjustment. Additionally, it includes a folding side to enable co-sleeping and a lower section that can function as a rocker or be fitted with wheels for easier mobility.

The decision to make the cot convertible into a Montessori bed at ground level is based on the numerous advantages of this type of furniture. This approach prioritizes the child's needs by adapting the design to their height and fostering autonomy, which contributes to their development, well-being, and happiness. Engaging in activities from an early age stimulates cognitive growth and enhances motivation. These pieces of furniture are designed to promote interaction, the development of new skills, and self-correction.

To achieve an ergonomic design, anthropometric measurements were considered, ensuring a well-founded range of dimensions. Data from the Andalusian Health Service, based on WHO growth standards, were consulted. According to the collected data, the cot's length is set at 120 cm in the standard cot position and extends to 140 cm in its maxi cot and infant bed configuration, while its width remains constant at 80 cm.

Parents have the flexibility to use either the Montessori bed or the elevated bed according to their preferences. As a result, its use is estimated to extend into pre-adolescence.

The outcome of this study is an evolving cot characterized by its adaptability and ability to grow with the child. Its convertible nature extends the product's lifespan, thereby reducing resource waste and promoting sustainability.

Digital tools and artificial intelligence

Reframing urban morphology for AI. Integrating qualitative datasets for specialized Artificial Intelligence

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Keywords: Customized GPT-4o, Morphological Glossary, Urban Form, Qualitative Dataset, AI-Driven Research Framework

Abstract

Hagazy M. and Saleh A. M. trace AI's origins in architecture to the late 1930s, evolving from modular approaches to computational design and machine learning. However, its integration into urban morphology remains underexplored, hindered by the lack of specialized databases. Current AI tools rely on broad, unstructured datasets, yielding generalized responses that overlook urban morphology's theoretical typological discourse, shaped by scholars like Muratori, Caniggia, and Conzen. Fragmented and lacking coherence, AI applications in this field demand excessive energy to run extensive servers. Moreover, sharing sensitive datasets with private servers raises structural security concerns. This research advocates for specialized AI tools to enhance sustainability, security, and efficiency in addressing urban morphological challenges.

Many universities are developing specialized AI datasets to enhance research analysis across various disciplines. Following this motivation, the study introduces a customized GPT-4o language model tailored to typo-morphological theories, explicitly examining how AI interprets theoretical terminologies. Trained on a curated dataset focused on typo-morphology, this specialized model generates a structured glossary of morphological terms. To refine typological definitions, the study draws on three seminal works on urban form—The Image of the City by Kevin Lynch (1960), Townscape by Gordon Cullen (1961), and The Death and Life of Great American Cities by Jane Jacobs (1961). Each of these books has played a pivotal role in shaping the typological approach: Lynch's mental maps introduced paths, edges, landmarks, neighbourhoods, and nodes; Cullen's concept of serial vision explored the city's visual experience; and Jacobs emphasized safety as a key element of good urban design. Introduced in the 1960s, these concepts transformed city analysis and urban planning.

However, AI struggles to fully grasp this lexicon due to a lack of precise definitions, limiting its ability to analyse urban form comprehensively. By leveraging this glossary, the model analyses prompts related to these concepts, drawing from a comprehensive collection of sources to provide well-informed, concise responses. It systematically compares definitions across different sources, grouping similar ones under a unified category. Through this refined glossary, the study not only evaluates AI's ability to interpret urban forms concepts but also identifies gaps between the existing definitions and the responses of the customized GPT-4o model. Ultimately, this framework strengthens AI's foundational knowledge, improving both the contextual accuracy of responses and computational efficiency in urban morphology research.

This targeted data organization enhances research efficiency by minimizing unnecessary data processing and improving the precision of AI-generated outputs. By bridging traditional typo-morphological theories with emerging AI methodologies, the study contributes to AI's systematic and meaningful integration into urban morphology, advancing theoretical understanding and practical applications.

Innovation in personalized Ambient Assisted Living technologies for older adults: from wearable devices to integrated care ecosystems

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Keywords: Digital Ecosystem, Assistive IoT Systems, Wearable Technology, Smart Healthcare, Interoperability

Abstract

The development of wearable devices in the healthcare sector has significantly transformed the monitoring of physiological parameters. Beyond individual monitoring, the current trend is shifting towards the development of integrated care ecosystems, where wearable devices, fixed sensors, digital platforms, cloud services, AI, and healthcare professionals collaborate to enhance the efficiency of care. These ecosystems require high levels of interoperability and digitalization of services, ensuring that data from multiple sources can be processed in real time to optimize healthcare delivery. This study explores how wearables can evolve from individual devices into interconnected nodes within a digital care ecosystem. The proposed model integrates assistive devices, fixed sensors in the home environment, smart insoles, mobile apps, and cloud services to create a distributed system capable of detecting risk situations and enabling proactive intervention. This research is part of MyGait, a project focused on developing a health ecosystem based on wearable technology, such as smart insoles. The technological ecosystem was developed following a methodological process based on the Cosica IoT system design methodology, complemented by user-centred design, service design, and Lean Design Thinking strategies to optimize system functionality and ensure that user needs are met across various scenarios. The system was developed from both a product and service design perspective as well as a technological standpoint. Key aspects were identified during the process to ensure the effective design of such ecosystems. Interoperability was recognized as a fundamental aspect to ensure efficient communication among devices, using common technological standards and cloud-based platforms. This approach enables real-time monitoring and service adaptation based on user needs. The resulting ecosystem consists of a primary wearable device—a customizable bracelet or pendant—complemented by secondary wearables and sensors that add specific functionalities based on individual user needs. This system is capable of detecting risk situations and automatically initiating emergency calls when necessary. Furthermore, its modular and adaptable design allows seamless integration into different environments without compromising user autonomy or emotional well-being. Additionally, the system's ability to integrate with existing healthcare infrastructures facilitates remote patient monitoring, reducing hospital burden while enabling more personalized care. The collected data can be utilized to adjust therapies, prevent complications, and improve patients' quality of life. The results demonstrate the feasibility and scalability potential of the proposed integrated care model, supported by its ability to integrate with existing healthcare systems and its acceptance among users. This approach has the potential to transform healthcare by enabling older adults to remain in their homes safely and independently, contributing to greater autonomy and well-being. When designed from a user-centered perspective, the digitalization of healthcare services not only enhances system efficiency but also improves care quality and ensures long-term sustainability. Future research should focus on conducting longitudinal studies to assess the long-term impact of the ecosystem and further optimize its technological components and user interaction.

Development of a Digital Twin for industrial engineering: connecting sensors and actuators to AR/VR applications

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Keywords: Digital Twin, Augmented Reality, Virtual Reality, Sensors, Actuators

Abstract

The integration of Digital Twin and Augmented Reality technology into industrial engineering presents groundbreaking opportunities for process optimization, monitoring, and control. This initiative focuses on leveraging advanced technologies, including BIM modelling, sensor and actuator networks, and AR visualization, to enhance operational efficiency in industrial facilities. By establishing connections between physical systems, company servers, and AR applications, this project exemplifies the potential of digital transformation in manufacturing and facility management. The DiTwinAR project (Digital Twin and Augmented Reality) consists of several phases, beginning with data acquisition through terrestrial and aerial laser scanning to create a three-dimensional model of the industrial facility. These scans are processed into coordinated point clouds, providing the foundation for detailed Building Information Modelling (BIM) representations. The BIM model includes comprehensive geometric data and property sets (pSets), serving as the backbone for the integration of real-time data from sensors and actuators. To enable intelligent process automation, the project emphasizes analysing and implementing various sensors and actuators. Sensors will monitor critical parameters such as temperature, motion, and operational statuses, while actuators will respond by executing physical actions like adjusting machinery (overhead crane) or opening/closing industrial gates. Notably, existing components, such as a Vesta-113N alarm panel and industrial cranes, are assessed for compatibility and upgraded with APIs, relays, or encoders to enable connectivity. The resulting system ensures a seamless flow of data between physical components and the central server. One of the project's distinguishing features is its focus on intuitive data visualization through an AR/VR application. This app allows operators to overlay BIM models with live data from sensors and actuators using tablets or smartphones. Features include real-time monitoring, control commands, and geopositioning within the facility. The use of fiducial markers and 3D controls enables efficient navigation and interaction with the digital twin. Additionally, the platform incorporates solutions such as IFC importers for integrating BIM models into AR environments. These tools streamline the visualization of spatial and process data, enabling operators to make informed decisions without extensive technical expertise. For achieving the goals of the project, it is necessary to fulfill all the phases that need to be developed, in order to follow a logical and efficient workflow. Those steps are accompanied by their corresponding deliverables, which are: 1. 3D data files from laser scanning (Deliverable D1). 2. Processed and coordinated point clouds (D2). 3. A detailed BIM model with property classifications (D3). 4. Technological specifications for sensor and actuator connections (D4). 5. An AR/VR app for visualizing BIM data and control signals (D5). The DiTwinAR project exemplifies the transformative potential of digital twin technology in industrial engineering. By connecting physical systems to digital representations and AR interfaces, this initiative sets a benchmark for intelligent facility management. Future work includes refining sensor-actuator interactions, enhancing AR functionalities, and scaling the solution to other industrial domains. The successful implementation of DiTwinAR will streamline operations and foster innovation and adaptability in industrial ecosystems.

Designing Digital Twins for smart climate control in pig farming: applying IoT and LoRa technology to modernize farm facilities

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Keywords: Smart, Digitalization, Pig, Farm, Automation

Abstract

This work presents the development of a digital twin based on IoT and LoRa for intelligent climate management in pig farms. The objective is to modernize existing facilities to optimize energy efficiency, improve animal welfare, and promote sustainability. To achieve this, a digital model has been designed to accurately replicate the ventilation system, integrating sensors and an intuitive interface for remote control and monitoring.

The development is based on the climate control infrastructure of OSMOEUROPA (www.osmoeuropa.com), a company with over 25 years of experience and thousands of operational installations, making them ideal candidates for digitalization. The chosen cloud platform is Microsoft Azure due to its scalability and security, utilizing services such as IoT Hub for secure and bidirectional device communication, Functions for control logic execution and data processing, and Web Apps for deploying the web interface, enabling remote access from any internet-connected device.

The project methodology was structured into five phases. First, the digital twin model was designed. Second, sensors were integrated to capture environmental variables. Third, an interface was developed for real-time visualization, remote control, and historical data access. Fourth, alerts were implemented for incidents and malfunctions. Finally, the system was evaluated under real conditions.

The benefits of the system are divided into two categories. Among the qualitative benefits, the system provides greater precision in climate management, optimizing ventilation and temperature control. It also enables real-time remote access, facilitating immediate supervision and control. Another key advantage is the historical data logging, which allows for trend analysis and data-driven decision-making. Additionally, the system supports early fault detection through alerts, preventing costly breakdowns. Regarding the quantitative benefits, the system is expected to reduce energy consumption through optimized management. It is also anticipated to improve animal welfare by reducing stress and disease. Lastly, productivity is expected to increase by accelerating growth rates and optimizing feed conversion.

In conclusion, this work demonstrates the feasibility of modernizing pig farms through digital twins by integrating OSMOEUROPA's infrastructure with Microsoft Azure. Significant improvements in energy efficiency, animal welfare, and productivity are expected, facilitating the digital transformation of the livestock sector.

Autocad automation through python scripting

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Keywords: AutoCAD; Python; Automation; Computer Aided Design; Applied Programming

Abstract

he primary objective of this work is to explore the automation of AutoCAD workflows using Python scripting, with a focus on the different Python libraries available for such tasks. The article aims to provide a comprehensive analysis of four prominent Python modules—pyautocad, ezdxf, win32com, and pyautogui—assessing their strengths and weaknesses in the context of AutoCAD automation. Additionally, this work seeks to offer a clear understanding of the practical applications and trade-offs involved in each tool's usage, guiding users in selecting the most suitable approach for their automation needs.

The study reviews the four Python libraries, emphasizing their features, ease of use, and compatibility with AutoCAD. pyautocad is evaluated for its direct integration with AutoCAD's COM interface, making it ideal for automating basic tasks within the AutoCAD environment. ezdxf is examined for its ability to create, modify, and parse DXF files, providing an alternative to direct interaction with the AutoCAD interface. win32com is analysed for its broader scope in automating AutoCAD through Windows COM technology, offering advanced scripting capabilities. Lastly, pyautogui is considered for its screen automation features, which allow simulating keyboard and mouse actions to control AutoCAD indirectly. To evaluate the performance of these libraries, a Python script was developed for the simple task of prefixing layer names in an AutoCAD drawing, testing each library's effectiveness in accomplishing this task.

The findings indicate that each Python library offers distinct advantages depending on the automation requirements. pyautocad provides a straightforward solution for automating AutoCAD commands and tasks within the application, but it may be limited in handling complex drawing manipulations. ezdxf proves to be highly effective for tasks involving the creation and editing of DXF files, though it lacks direct interaction with the AutoCAD GUI. win32com offers a more robust and flexible solution for advanced automation, enabling full control of the AutoCAD environment, but requires a steeper learning curve. pyautogui, while versatile for automating the GUI, is generally slower and less reliable for complex or precise automation tasks compared to the other tools. A comparative analysis of versatility, ease of implementation, and documentation support is provided.

The automation of AutoCAD through Python scripting presents significant opportunities for improving workflow efficiency, reducing manual errors, and enhancing productivity. The choice of Python module depends largely on the specific task and user preferences. pyautocad is ideal for users looking for simplicity and direct interaction with AutoCAD, while ezdxf is best suited for file-based manipulations. win32com stands out for more complex, customizable tasks, while pyautogui serves as a quick and flexible solution for basic GUI automation. Ultimately, the work provides valuable insights that will assist engineers and developers in selecting the right tool for their AutoCAD automation projects, based on the trade-offs between functionality and ease of use.

Advanced analysis of Sashimono: a traditional Japanese woodworking technique

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Keywords: Mechanical Engineering, Joints, CAD, FEA, 3D Printing

Abstract

Sashimono is a traditional Japanese woodworking craft renowned for its intricate joinery, created without nails, screws, or adhesives. This technique highlights precision craftsmanship and the inherent qualities of wood to form durable and visually harmonious connections. Central to its philosophy is sustainability, achieving functionality with minimal environmental impact while emphasizing the beauty of natural materials.

The origins of sashimono can be traced back to ancient Japan (1603–1868). During this time, sashimonoshi (woodworking artisans) developed and perfected these techniques to meet the growing demand for refined furniture, storage boxes, and architectural elements. Sashimono embodies simplicity, balance, and practicality, combining functionality with elegance.

Sashimono offers a variety of advantages, making it a timeless woodworking method:

- Durability: Its precision joinery eliminates reliance on fasteners or adhesives, ensuring long-lasting structures.
- Aesthetic Appeal: The joints are crafted to seamlessly blend with the design, elevating the overall beauty of the piece.
- Sustainability: The exclusive use of wood minimizes waste and environmental impact.
- Flexibility: Wooden joints adapt to environmental stresses, such as humidity and temperature changes, without losing structural integrity.
- Sashimono includes a wide array of joints, each tailored to specific applications:
- Kumiko (格子): A latticework joint used in decorative panels and partitions.
- Kanawa-tsugi (金輪継ぎ): A traditional scarf joint for extending beams with structural alignment.
- Ari-gata (蟻形): A dovetail joint designed for stable, interlocking corners.
- Kigumi (木組み): Framework joints for assembling large architectural structures.
- Shikuchi (仕口): A tenon-and-mortise system for structural stability.
- Kakushi-Kanawa-Tsugi (隠し金輪継ぎ): A concealed scarf joint that provides seamless and hidden connections.
- Kawai Tsugite: A modern, complex joint characterized by interlocking geometric patterns, showcasing the evolution of traditional craftsmanship.

The geometry of sashimono joints is meticulously designed to maximize contact areas between wooden components. This ensures stability through friction while evenly distributing loads across the joint. Symmetry, particularly bilateral symmetry, plays a significant role in achieving structural balance and aesthetic harmony. While most joints feature symmetrical designs, some are asymmetrical to address specific structural needs or load distributions.

Sashimono techniques remain highly relevant in contemporary design and engineering. They are particularly valuable in sustainable architecture, furniture design, and eco-conscious construction. Its principles inspire modern prefabricated modular systems, offering efficient, resource-conscious

solutions and align with growing trends in minimalism and environmental sustainability, making them ideal for residential and industrial contexts.

This article focuses on the tensional analysis of sashimono joints through finite element methods (FEM). To achieve the research objectives, several sashimono joint typologies were modeled and 3D-printed using PLA material. These physical models were subjected to both simulated and real-world stresses to evaluate their mechanical behavior, load distribution, and adaptability.

By bridging traditional craftsmanship with advanced analytical tools and 3D printing technology, this study explores how sashimono techniques can inspire innovative solutions for modern engineering and design challenges. The results aim to demonstrate the enduring relevance of these ancient woodworking methods in today's technologically driven world.

Custom geometrical reconstruction of human corneal surfaces based on NURBS curve optimization by an evolutionary algorithm: a preliminary study

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Keywords: Evolutionary Modelling, CAD, NURBS Optimization

Abstract

Recent advances in surface reconstruction from 3D point cloud data have significantly improved available techniques used for generating accurate digital models of physical objects. Among these, new methods have been proposed for generating NURBS (Non-Uniform Rational B-Splines) surfaces from 3D imaging data using machine learning algorithms. This study introduces a novel approach to the three-dimensional modal reconstruction of the human corneal surface using an evolutionary algorithm-based method.

The proposed workflow employs an evolutionary algorithm to optimize the zonal reconstruction of the anterior and posterior corneal surfaces, ensuring precise alignment and smoothness of the resulting geometry. Genetic algorithms are particularly effective for optimizing NURBS curves with Galapagos software, making them well-suited for tasks such as minimizing approximation errors relative to reference points, enhancing curve smoothness, or achieving specific configurations in applications like parametric design, engineering, or manufacturing. The process begins with an initial population of NURBS curves, which are generated with randomized configurations of control points, weights, and parameters. To enhance convergence, curves can be based on an initial baseline design.

All data used in this study was obtained from the IBERIA BIOBANK database (Universidad Miguel Hernández de Elche, OFTARED–Instituto de Salud Carlos III). The spatial point cloud data was integrated into a parametric workflow using Grasshopper software. The inclusion of an evolutionary algorithm introduces a significant layer of optimization to generate NURBS surfaces. This method adapts to the topographic data, iteratively refining the corneal model based on fitness criteria. The evolutionary algorithm operates over multiple generations, evaluating, selecting, and reproducing new NURBS curves. The process continues until a stopping criterion is reached, such as a maximum number of generations or a predefined error threshold.

This study presents a novel framework for corneal modelling using an evolutionary algorithm-based method integrated with Galapagos software. By combining parametric design and advanced optimization techniques, this methodology establishes a foundation for innovative diagnostic applications in ophthalmology. The potential benefits include improved understanding and management of corneal diseases, contributing to advancements in clinical practices.

Digital Twins models applied to CXL treatments of corneas affected with keratoconus

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Keywords: Corneal Biomechanics; Finite Elements; Patient-Specific Models; Corneal Ectasia

Abstract

Keratoconus is a disorder of the cornea structure due to a combination of genetic, environmental and hormonal factors that results in a progressive thinning and bulging of the cornea that in initial phases can be treated with cross-linking (CXL) techniques to make the cornea stronger. CXL is based in the application of riboflavin on the cornea and the exposure to UV-A light incrementing the joints between corneal collagen fibres and the reinforcement of the corneal tissue.

The evolution of the treatment effectivity can be analysed with the development of in-silico patient specific cornea models that consider the influence of the CXL treatment. For this purpose, a variation of the parameters that define the stiffness contribution of the collagen fibres in hyperelastic materials can be considered.

The development of computational corneal models opens the possibility to analyse the local effect of CXL techniques with the development of sectorized in-silico patient specific model where different materials can be considered in different zones optimizing the riboflavin use and the effectiveness of the treatment. The possibility to vary the stiffness in the thickness can also contribute to simulate with more accuracy the real effects of CXL techniques.

Computational models can contribute to create a digital twin of corneas with CXL treatment facilitating follow-up and evolution after treatment of these ones.

Discrepancies in corneal material parameter estimation: comparing tensile and inflation tests in biomechanical modelling

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Keywords: Corneal Biomechanics, Holzapfel Model, Hyperlastic Material, Parameters Estimation

Abstract

Estimating corneal material parameters using tensile and inflation tests leads to significant discrepancies, preventing direct comparability. This study examines the causes of these differences, including variations in testing conditions, optimization strategies, and applied pressure or tension rates. Tensile tests, which apply uniaxial loading, yield higher stress-strain responses, while inflation tests capture biaxial behaviour under physiological conditions, leading to inconsistencies in parameter estimation.

The Holzapfel-Gasser-Ogden (HGO) model, widely used for corneal biomechanics, defines the cornea's isotropic stiffness through c_1, while its anisotropic fiber behaviour is governed by k_1 and k_2, representing non-linear fiber stiffening. However, due to differences in mechanical response between test types, these parameters vary significantly, with k_2 values in inflation tests typically being much higher than in tensile tests.

Our findings confirm that parameters obtained from both tests are not interchangeable, highlighting the need for a unified methodology that integrates both approaches to improve the accuracy and standardization of corneal biomechanical models.

Integrating 3D Printing parameters into technical drawings: a framework for seamless additive manufacturing

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Keywords: 3D Printing, Additive Manufacturing, Technical Drawing, 3D Modelling, Dimensioning Rules

Abstract

3D printing, or additive manufacturing, has emerged as a transformative fabrication technology, enabling rapid prototyping, customized production, and complex geometries that are difficult or impossible to achieve with traditional manufacturing methods. Its applications span across industries such as aerospace, healthcare, automotive, and consumer goods, offering cost-effective and efficient production solutions. However, despite its growing adoption, the integration of 3D printing parameters into technical drawings remains an underexplored area, creating a disconnect between digital design and manufacturing execution.

The implementation of 3D printing data into technical drawings is essential for streamlining the transition from digital models to physical components. While traditional technical drawings incorporate complex fabrication parameters such as tolerances, surface finishes, and material specifications, they do not yet fully integrate the necessary data for seamless 3D printing execution. This research proposes a framework for embedding essential 3D printing parameters directly into technical drawings to bridge this gap.

Key parameters required for 3D printing include layer height, printing speed, infill density, support structures, extrusion temperature, bed adhesion methods, and cooling settings. These factors significantly impact the final part's mechanical properties, dimensional accuracy, and overall print quality. To implement these parameters effectively, a standardized annotation system must be developed, akin to existing conventions for machining and casting processes. This system would define a structured approach to encoding 3D printing information within CAD-generated technical drawings, ensuring consistency across various software and manufacturing environments.

Implementation would follow methodologies used for incorporating complex fabrication data in traditional manufacturing. Just as geometric dimensioning and tolerancing (GD&T) allows precise communication of design intent in CNC machining, a dedicated 3D printing data layer within technical drawings would provide explicit instructions for additive manufacturing. This could be achieved through an extended metadata section or specialized symbols that represent print settings, allowing engineers and machine operators to interpret and execute prints without requiring additional process sheets.

Standardization efforts, such as integrating these annotations into widely used CAD formats like STEP and IGES, would further enhance interoperability. By embedding 3D printing parameters within technical drawings, manufacturers could reduce errors, streamline workflows, and improve repeatability in additive manufacturing. This approach would support a more efficient transition from design to production, reinforcing the role of 3D printing in high-precision applications and mass customization.

Procedure for solid modelling and Morpho-Geometric analysis of a crystalline lens using 3D Scanning and Digitization Techniques

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Keywords: 3D Scanning, Morpho-Geometric Analysis, Structured Light, Crystalline Lens, Parametric Modelling

Abstract

This study aims to obtain a parametric three-dimensional (3D) model of the human crystalline lens using 3D scanning and digital modelling techniques. Several different scanning technologies were tested, in order to determine which is the most suitable when it comes to processing the generated point cloud and later creating the solid parametrizable model for morpho-geometric analysis. The results obtained contribute to the methodological and technical advancement in the fields of medicine and ocular research.

The study was conducted in the 3D scanning laboratory of the Industrial Design and Scientific Calculation Service (SEDIC) of the Technical University of Cartagena, using five scanners employing different technologies (structured light, laser, and infrared). Samples, including a lentil for initial testing and a human crystalline lens, were scanned under controlled lighting and temperature conditions. The point clouds obtained were processed with specialized software to generate digital meshes (Geomagic), being later transformed into solid models using CAD modelling techniques (Rhinoceros). Geometric and physical parameters of the models were evaluated (SolidWorks), to establish their quality and applicability in the healthcare field.

Significant differences were found in the precision and resolution of the models generated by each scanner. Structured blue light-based scanners, such as the Artec Spider, demonstrated a higher ability to capture fine details of the crystalline lens compared to infrared or white light technologies. The generated models allowed for precise measurements of geometric parameters, such as volume and areas, which are essential for clinical and research applications. Additionally, the advantages and limitations of each technology were documented based on the characteristics of the scanned object.

Results suggest that 3D scanning technologies based on structured blue light are the most suitable for the digitization and modelling of the human crystalline lens, due to their higher resolution and ability to handle small and complex objects. The developed methodological approach not only enables the generation of precise solid models but also establishes a replicable procedure for future studies. These results have potential applications in medicine, such as the design of personalized lenses and the optimization of ophthalmological treatments.

Design and development of an affordable, ergonomic bionic hand for improved daily functionality

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Keywords: Medical Prosthetic, Prosthetic Hand; Control Mode; 3D Printing

Abstract

A hand loss or severe impairment can significantly affect the quality of life by limiting essential daily activities and professional tasks. Current solutions, such as traditional prostheses, face challenges in terms of cost, accessibility, and functionality. This study proposes an innovative prototype by designing and developing a bionic hand prosthesis. The design combines ergonomic principles, intuitive control, and sustainable manufacturing methods to create a user-friendly design. The device will improve not only the life conditions of users with upper limb disabilities but also their performance in everyday activities such as picking up a bottle, writing, opening the door, etc. Many people face challenges related to self-perception, confidence, and social integration, as prosthetic devices can sometimes reinforce feelings of difference rather than restore normality. This project tackles that challenge by developing a bionic hand that balances functionality with an ergonomic, lifelike appearance. By reducing stigma and enhancing acceptance, the prosthesis aims to improve both the physical and emotional well-being of users, ultimately enhancing their quality of life. Therefore, the primary goal of this project is to design and develop a functional bionic hand that combines ergonomic design, lightweight construction, and advanced sensor technologies to replicate essential hand functions. By emphasising affordability and usability, the prototype aims to offer an accessible alternative to conventional prostheses while maintaining high performance and adaptability to individual needs. The design process employed a digital workflow, relying on CAD tools to precisely model the hand's geometry and simulate mechanical performance. Nonetheless, it has been necessary to consider a wide range of factors that directly influence its usefulness and effectiveness. For instance, the materials used should be biocompatible, cost-effective, eco-friendly and consistent. This framework employs additive manufacturing using lightweight, durable materials to produce the prototype, balancing robustness with comfort. The design aims to be aesthetically appealing and free of negative connotations, which could positively influence users' willingness to adopt these devices. Furthermore, this research also explores control strategies independent of electromyography (EMG), addressing the limitations of traditional prostheses in terms of accessibility and cost. Advanced sensors, including force sensors and inertial measurement units (IMUs), were integrated to enable precise control of the prosthesis. Force sensors in key areas provide grip strength feedback, while IMUs track orientation and movement. The control system processes the inputs, facilitating intuitive operation without reliance on electromyography. This study has provided valuable insights into the development of a novel bionic hand prosthesis designed to address accessibility, affordability, and functionality. By eliminating EMG-based control systems, the prototype broadens its applicability to a broader range of users, including those with minimal residual muscle activity. This approach promises to improve users' quality of life and reduce the cost of prosthetics, potentially democratising access to these solutions for populations in developing countries. The ergonomic design, advanced sensor integration, and eco-friendly manufacturing techniques position this device as a practical and sustainable solution for individuals needing hand prostheses.

Design, modelling, and optimization of a biomechanical finger for a pediatric prosthetic hand

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Keywords: Prosthetic Hand, Finger Design, DFAM

Abstract

This work presents the process of redesigning the biomechanical finger of the prosthetic hand named 'HandBot-Kid'. The project was initiated with the objective of developing a prosthetic hand for adolescents, with the aim of improving the functionality of existing commercial solutions. To address these needs, the initial finger design was developed to integrate a four-bar mechanism. The selection of this mechanism was driven by its capacity to emulate flexion-extension movements with a degree of naturalness and similarity to those of a real finger.

The initial design satisfied the operating conditions, but the main problems were weight and size. This work was initiated to satisfy these weight and size conditions by redesigning the finger. To reduce the size, work was undertaken to optimise the design of the bar mechanism, improving the internal joints and integrating the mechanism itself into the finger design. Weight was reduced by using additive manufacturing techniques to provide a more compact solution to the finger and mechanism design. The initial design of the finger was developed in machined aluminium parts; however, the redesign of the finger using additive manufacturing processes will also result in weight reduction. This is due to the fact that the polymers utilised in additive manufacturing possess a higher strength-to-weight ratio than aluminium, due to their significantly lower density.

The redesign process and the implementation of additive manufacturing techniques have facilitated the optimisation of the manufacturing process of the parts. The initial concept was developed by conventional manufacturing processes using computer numerical control (CNC) machinery for the aluminium parts. For this new concept, methodologies such as design for: additive manufacturing (DFAM) and for assembly DFA have been implemented. The primary objective of this methodologies is the optimisation of the manufacturing process of the parts in terms of cost and time. The DFAM methodology has been implemented in this work to improve the manufacturing process of the parts, aiming to reduce printing times. The incorporation of the DFA concept ensures that downstream assembly processes are integrated into the finger redesign process, aiming to streamline and simplify the assembly of the components.

The results obtained in this work imply a new finger design that optimises weight and size while maintaining the same operating mechanism. The incorporation of DFAM and DFA methodologies into the additive manufacturing processes leads to an optimisation of the finger manufacturing process. This optimisation is reflected in the reduction of the manufacturing and assembly times of the parts.

Enhanced Virtual Reality reconstruction: deep learning approaches for realistic architectural space representation

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Keywords: Computer Vision, Deep Learning, Virtual Reality, Architectural Simulation

Abstract

The integration of deep learning methods in the development of virtual reality (VR) simulations is revolutionizing the creation and programming of virtual environments by introducing reconstruction methodologies that offer unprecedented opportunities to enhance the realism, interactivity, and adaptability of immersive experiences. Advances in computational power and the evolution of deep neural networks, such as Neural Radiance Fields (NeRF) and the Gaussian Splatting methodology, have enabled the efficient reconstruction of complex architectural spaces through continuous, volumetric representations. These representations allow for realistic rendering from any viewpoint and include detailed information about ambient lighting conditions.

This study specifically explores the use of NeRF methodology to generate volumetric representations of three-dimensional environments, starting from two-dimensional images derived from photographic captures and video frames. This approach reconstructs the geometric and visual properties of the acquired scene with high fidelity. The NeRF methodology is complemented by Gaussian Splatting, which leverages volumetric Gaussian distributions to describe the visual and perceptual properties of scene components, effectively preserving the specular and reflective behaviour of materials.

As a case study, San Antonio Square, located in the city centre of Cádiz, in southern Spain, has been selected. This quadrangular space meets the necessary requirements for a comprehensive assessment of the tools to be tested. It is an open area, yet fully enclosed by buildings and a church, which serves as its main architectural element. Moreover, all the surrounding buildings possess significant architectural value, with the Aramburu House standing out. Data acquisition is carried out at different moments of the day.

The results demonstrate that the combined application of NeRF and Gaussian Splatting facilitates the reconstruction of architectural spaces with a higher level of visual detail compared to conventional techniques while reducing the computational burden for real-time rendering. The resulting simulations exhibit accurate rendering of the physical properties of environments, such as lighting and materials, significantly enhancing user immersion and interaction. Additionally, optimization for VR hardware ensured a seamless, lag-free experience, even in complex scenarios.

Towards a flexible VR-Based product evaluation system: a customizable approach for designers

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Keywords: Virtual Reality, Product Evaluation, Heatmap, Eye-Tracking

Abstract

In recent years, Virtual Reality (VR) has become a powerful tool for product evaluation, driven by technological advancements that have lowered costs while improving device quality. This technology enables the visualization of high-fidelity virtual prototypes within synthetic and controlled Virtual Environments (VEs), which offer flexibility in adjusting and contribute to optimizing time and costs in the design process. However, some researchers have pointed out perceptual differences between real products and their virtual counterparts, which could affect the reliability of user feedback and lead to design errors. Nevertheless, recent studies have shown that incorporating tactile experiences during the evaluation process can significantly reduce these discrepancies, sometimes eliminating them entirely. Traditionally, designers have relied on self-report techniques to gather user opinions about a product. While useful, these methods provide only superficial insights and fail to leverage the full potential of VR. In response, recent research has been exploring the use of eye-tracking (ET) during product evaluation, as well as analysing user trajectories when assessing larger products. This approach helps explain collected data, such as identifying Areas of Interest (AOIs) that were not observed. Understanding user trajectories in VR product evaluation is crucial, particularly when assessing medium to large-sized objects that require physical movement for a complete inspection. Unlike traditional 2D interfaces or constrained 3D experiences, VR allows users to navigate freely within a virtual space, simulating real-world interactions more accurately. By analysing movement patterns, researchers can gain insight into how the user approaches and engages with a product, revealing potential usability issues or design flaws that might otherwise go unnoticed. Furthermore, trajectory analysis can help identify behavioural patterns that correlate with decision-making processes. For instance, prolonged exploration of specific areas might indicate design ambiguities, while avoidance of certain sections could suggest ergonomic or visibility concerns. By combining trajectory data with ET metrics, a more comprehensive understanding of user interaction can be achieved, enhancing the accuracy and reliability of virtual prototype evaluations. Despite its potential, integrating these advanced evaluation techniques into the design workflow remains a challenge. Many industrial designers lack training in VR technologies and development, such as programming or the use of game engines (e.g., Unity). This creates a barrier to adopting these tools, particularly in small design studios where resources and expertise are limited. Addressing this gap requires accessible methodologies that simplify the implementation of VR-based evaluations without demanding extensive technical knowledge. In this context, this article proposes a simple and accessible methodology for setting up a product evaluation environment, covering everything from its configuration to data collection and analysis. The approach includes gathering ET metrics (dwell time, number of visits to each area of interest, first area of interest visited) and analysing user trajectories (path visualization on a top-down view of the environment and heatmap generation). By providing a structured framework for leveraging VR in product assessment, this study aims to bridge the gap between industrial design and emerging virtual evaluation techniques, ultimately improving the efficiency and reliability of prototype testing.

Assessing the current use of isolated buildings in Andalusia through AI techniques

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Keywords: Gazetteer, Rural Houses, Ruins, Cadastre, Cartography

Abstract

The Andalusian Gazeeteer (in Spanish, Nomenclátor Geográfico de Andalucia, NGA) is a toponymic geodatabase created in 2007 following international standards, containing information on over 245,000 geographical place names with more than 320,000 locations. These names originate primarily from the official basic cartography at a 1:10,000 scale provided by the Andalusian Institute of Statistics and Cartography (in Spanish, Instituto de Estadística y Cartografía de Andalucía, IECA), as well as other geographic databases that have been incorporated over time, such as locations from the Cadastre or for instance springs and water sources from individual projects. The NGA offers the most comprehensive collection of georeferenced Andalusian place names available to the regional government. It is accessible to the public, the academic community, and specialised technicians through free and interoperable services.

In recent years, a comparison with the Basic Geographical Nomenclature of Spain revealed that many isolated buildings in rural environments have experienced a degradation in their use since their initial acquisition. Specifically, cases were identified where buildings have become dilapidated due to abandonment, completely disappeared, or been demolished and replaced by new constructions, which may also offer a different name. This study focuses on a sample of such entities located in the province of Huelva, extracted from the NGA in November 2024. The dataset consists of 49,134 records classified as Rural Buildings (48,117 records) and Rural Buildings that have disappeared or are in ruins (1,101 records).

The methodology was developed within a GIS and Python environment, employing various artificial intelligence techniques to attempt to automate the detection of buildings in a state of ruin or disappearance. The extracted dataset was enriched with clip raster image around the buildings obtained from the National Aerial Orthophotography Plan (in Spanish, Plan Nacional de Ortofotografía Aérea, PNOA), including both the most current and historical images, through Web Map Services. Using Deep Learning with Neural Networks, specialized software for identifying objects in aerial or other images and an AI-powered tool to describe and interpret images, the temporal change of the buildings was classified and studied. In addition to this, the existence or absence of these buildings was verified in the downloadable versions of the Spanish Cadastre and/or the Andalusian Cartographic Base downloaded in February 2025.

Spatial data analysis towards achieving an Artificial Access Consciousness using Knowledge Graphs, Large Language Models, and Graph-Driven Reasoning

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Keywords: Spatial Data Analysis, Knowledge Graphs, Large Language Models, Graph-Driven Reasoning

Abstract

Artificial Access Consciousness (AAC), regarded as one of the primary challenges in cutting-edge AI research, aims to enable artificial systems to interact effectively with physical environments by accessing and processing spatial information to guide behaviour and decision-making, similar to human cognitive functions. This research project examines the integration of spatial data analysis with Knowledge Graphs (KG), Large Language Models (LLM), and Graph-Constrained Reasoning (GCR). The proposed methodology combines the inductive and deductive reasoning capabilities of LLMs with structured knowledge in KGs to enhance reasoning accuracy and minimize errors, providing a possible pathway toward achieving AAC.

Spatial data analysis, fundamental for interpreting and interacting with physical environments, plays a pivotal role in engineering, construction, and agriculture. In engineering, AAC enhanced by spatial data analysis can improve infrastructure design by analysing spatial constraints and optimizing material allocation. In construction, it enhances site monitoring and safety management through real-time interpretation of spatial data. In agriculture, AAC enables precision farming by integrating geospatial data with weather patterns and soil conditions to optimize crop yields. The tools proposed in this methodology enable addressing this complex challenge.

Exploring Large Language Models for CAD automation: a case study with CATIA scripting

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Keywords: Large Language Models, Generative AI, CAD Automation, CATIA Scripting, 3D Modelling

Abstract

Generative AI has emerged as a mature technology poised to enhance efficiency in various fields traditionally considered exclusive to human expertise. Computer-Aided Design (CAD) is one such domain that could benefit from this technological evolution. This study explores the potential of Large Language Models (LLMs) in generating code for creating 3D models through text prompts, specifically in CATIA using its scripting module.

A series of modelling challenges were defined with increasing levels of complexity. LLMs were prompted to generate scripting code capable of constructing corresponding 3D models in CATIA. The generated scripts were tested, and their outputs were analysed based on accuracy, completeness, and the need for manual intervention.

The experiments revealed that while LLMs can generate functional code for 3D modelling tasks, manual review and refinement are often required to ensure correctness and usability. The study also highlighted limitations in model comprehension of geometric constraints and parametric design principles.

This research highlights the potential of integrating reinforcement learning techniques into CAD scripting. By controlling 3D modelling through scripts, it is possible to design automated processes that adjust parametric models dynamically. Reinforcement learning algorithms can be incorporated to optimize design parameters, enabling more efficient and adaptive CAD workflows. Future work could explore how AI-driven optimization strategies can enhance geometric modelling and automate complex design decisions.

Integration of Artificial Intelligence and Open-Source tools for intelligent natural language queries on IFC models: an accessible and collaborative solution

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Keywords: BIM, Artificial Intelligence, OpenBIM, Open-Source

Abstract

To maximize the potential of Building Information Modelling (BIM) projects and to ensure effective collaboration between multidisciplinary teams, efficient information management is essential. This paper presents a solution integrating open-source openBIM tools with advanced artificial intelligence to perform intelligent queries on IFC model data. The solution is implemented as a plugin for Blender and Bonsai (formerly known as BlenderBIM) and utilizes the IfcOpenShell library to process and extract model data, including class attributes and property sets. The data is organized in a structured JSON file to facilitate user queries.

The proposed workflow begins with users formulating natural language queries in a text box within Blender. These queries, along with the extracted model data, are processed by an advanced AI system, such as Gemini, which can interpret natural language and analyse complex data. The AI retrieves the relevant GUIDs that match the specified criteria, enabling the application to visually highlight the corresponding elements of the BIM model in the 3D environment, changing their colour for easy identification.

This solution emphasizes the use of open-source tools, ensuring accessibility, adaptability, and flexibility for both developers and end users. By utilizing Blender, Bonsai, and IfcOpenShell, the workflow promotes interoperability and allows the creation of custom applications tailored to the specific needs of the construction industry. Additionally, the natural language query capability makes BIM model information more accessible, enabling both technical and non-technical users to interact with models intuitively. This enhances decision-making efficiency and fosters interdisciplinary collaboration.

Integration of Artificial Intelligence tools in architectural design and construction planning processes. Case study of a single-family house in Ecuador

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Keywords: Building Design, BIM, Costs Planning, LLM, AI

Abstract

The advent of artificial intelligence (AI) in the construction sector is transforming design and planning processes, thereby enabling the optimisation of complex tasks through algorithms that automate decision-making and predict results. Among the most recent innovations, large language models (LLMs) merit particular attention. These AI models, trained on large amounts of data, can generate content, answer questions, and undertake complex analysis through natural language processing. These capabilities render them well-suited tools for integration with design technologies such as Building Information Modelling (BIM), thereby improving the interaction between users and automated systems.

On the other hand, BIM has proven to be a key methodology for centralizing construction project information in three-dimensional digital models, improving accuracy, efficiency, and regulatory compliance. Nevertheless, the effective integration of AI and BIM remains challenging, particularly in contexts that require adaptation to stringent local regulations. Recent research highlights the potential of combined AI-BIM technologies to automate structural designs and streamline regulatory validation. This approach, complemented by advanced real-time simulation methodologies, has the capacity to transform traditional construction workflows, rendering them more efficient and sustainable. This study aims to analyse the potential of AI to support building design and construction planning in BIM environments. It explores the impact of AI on process automation, resource optimisation, and regulatory compliance, and it enriches user learning and understanding in the implementation of BIM technology.

The methodological approach adopted in this study is centred on the enhancement of a BIM model, starting from a basic building design. The model will be tested through specific queries to AI tools to validate its compliance with local construction regulations. Subsequently, the building model in IFC format, with the support of AI tools, will generate a preliminary time and cost plan. This data will be integrated into a 4D construction simulation within the BIM environment, thereby providing a real-time depiction of the construction process. The Revit 2024 tool will be used for BIM modelling, and ChatGPT-4 will serve as an advanced AI assistant to guide the modelling and design of various structures, with the objective of maximizing process efficiency. Finally, the planning simulation will be conducted using Navisworks. The case study is focused on a single-family house in Ecuador.

It is concluded that AI is an excellent ally in design as a support to BIM. Moreover, it is key for aiding decision-making in construction planning and cost estimation. Additionally, it facilitates regulatory compliance certification, paving the way for intelligent and efficient building design.

Future research endeavours should focus on the advancement of integration with AI and BIM, aiming to automate regulatory compliance through interconnected global and local databases, adaptable to the specific regulations of each region. Lastly, the use of advanced language models (LLMs) can revolutionize interaction in BIM environments, facilitating professional training, real-time problem-solving, and data-driven decision-making, contributing to a smarter, more collaborative, and sustainable construction industry.

Unlocking AI's creative potential in Climate-Responsive architectural design

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Keywords: Generative AI, Climate-Responsive Architecture, Climate Change, AI-Enhanced Creative Processes, Technosphere

Abstract

Architectural design has traditionally relied on precedents and typologies to generate new ideas. The emergence of artificial intelligence introduces a new variable, enabling novel creative processes where architects collaborate with algorithms. AI represents a fundamental shift, as it can generate entirely new images based on its vast training data. Unlike human imagination, AI operates without historical biases and processes enormous datasets, making it a powerful tool for reinforcing architectural ideation. This study tests AI's creative advantages in an academic environment. Rather than editing AI-generated results to fit architectural conventions, we explore a new design space where its potential unfolds freely. To move beyond conventional typologies and anthropocentric design, we must disable "architectural automation" and operate in an unknown field devoid of disciplinary references. How can we design for an entity not traditionally bound by architectural principles? This research investigates generative AI as a speculative tool for resilient architectural solutions to climate change. Climate change is a diffuse entity, making conventional architectural methodologies insufficient. Following Timothy Morton's concept of hyperobjects—vast, distributed entities beyond immediate human comprehension—we frame climate change as a hyperobject. Since hyperobjects are perceived only through their consequences, designing resilient architecture requires speculative approaches where AI can deploy its full potential. Furthermore, our goal is to use AI to generate resilient architectural forms functioning as symbiotic hybrids at the boundaries of the Technosphere, a term expanded by geologist Peter K. Haff as "a manmade set of large-scale networked technologies that enable rapid resource extraction" and its interactions with the natural spheres (Lithosphere, Atmosphere, Biosphere, Hydrosphere, and Cryosphere).This study examines scenarios such as injecting CO_2 into underground reservoirs or creating artificial materials like plastic stones—strategies lacking formal materialization or architectural equivalents. AI formalizes these ideas into unprecedented architectural solutions that integrate with planetary systems. The study employs generative AI models trained to synthesize morphological and material patterns from multiple scientific fields, including atmospheric chemistry, geomorphology, and biological adaptation. AI's ability to process vast datasets enables speculative design beyond predefined architectural norms. The project utilizes deep learning techniques to extract formal solutions from non-architectural sources. A case study was conducted with architecture students who applied these principles to design climate shelters. Their projects explored AI-generated forms integrating environmental adaptation strategies while challenging conventional typologies. The generative outputs reveal spatial and material configurations that defy conventional classification. These speculative structures demonstrate resilience by adapting to their environmental context, optimizing morphology for energy efficiency, structural integrity, and climate responsiveness. AI-derived forms exhibit strong coherence with natural patterns, suggesting a new design mode that is neither purely biomimetic nor technologically deterministic but an emergent synthesis of both. This study demonstrates that AI can anticipate solutions beyond technical imagination, expanding architectural intervention into previously inaccessible domains. By freeing design from typological constraints and embracing non-anthropocentric paradigms, AI fosters architectural forms deeply integrated with planetary systems. This shift toward artificial natures is crucial for developing adaptive infrastructures in an uncertain climatic future.

Artificial Intelligence as a tool for translating abstract languages into architecture

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Keywords: Generative AI, Architectural Design, Abstraction, Spatial Configurations, Transdisciplinary

Abstract

Throughout history, architectural design has relied on human intuition and both manual and digital representation tools to develop spatial concepts. The emergence of generative AI has introduced a new paradigm, allowing architects to integrate transdisciplinary inputs into their design processes in unprecedented ways. This study explores how generative AI serves as a translator of abstract languages into architectural form, transforming external influences into spatial configurations. Rather than replacing human creativity, AI expands the architect's conceptual framework, broadening the scope of design possibilities.

This research examines how generative AI expands the architect's creative capacity by facilitating new formal and conceptual relationships unattainable through traditional methods. Unlike previous approaches where architects interpreted external disciplines, AI offers a non-linear and computational reinterpretation, processing large datasets and generating multiple design iterations beyond human limitations. This study investigates how AI-driven processes translate abstract compositions into architectural geometries while preserving their conceptual essence. Additionally, it explores the extent to which AI fosters novel spatial organizations and how architects maintain conceptual control while leveraging AI's computational power. By doing so, the study highlights the potential of AI as a design tool that enhances creative exploration rather than imposing predefined solutions.

Conducted in an academic setting, this study engages architecture students in an experiment where generative AI is used to transform Suprematist paintings into spatial forms. The process begins with a formal analysis of key compositional principles—balance, dynamism, and spatial tension—extracted from the paintings. These elements are then input into AI algorithms that generate volumetric configurations reflecting the extracted logic. The students iteratively refine and curate the generated outputs, ensuring they retain the essence of the original painting while adapting to architectural parameters. This methodological approach aligns with Lyotard's notion that translating sensory structures across mediums preserves traces of their origin, fostering transformation rather than mere replication.

The findings indicate that generative AI introduces unexpected spatial solutions that enrich the design process. While rooted in Suprematist abstraction, the generated forms acquire new materiality and three-dimensional logic, producing outcomes beyond what conventional manual methods could achieve. Additionally, the iterative interaction between architect and AI fosters a feedback loop where human judgment remains crucial in filtering and directing computational outputs, ensuring coherence with the design intent.

The study shows that generative AI serves as a catalyst for design experimentation, allowing architects to explore uncharted formal territories. By translating abstract visual languages into spatial configurations, AI enhances interdisciplinary integration and redefines creative workflows. This research highlights AI's role in architectural education, emphasizing its potential to challenge conventional design approaches and foster new architectural expressions.

AI for automated processes in CAD: from the origins to the latest trends in the area and how to apply it in the CAD lessons

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Keywords: Artificial Intelligence, Computer Aided Design, Generative Design, Projects Based Learning, 3D Printing

Abstract

According to the RAE (Royal Academy of the Spanish Language), Artificial Intelligence (AI) is defined as follows: "Part of computer science that studies and develops systems that imitate human intelligence to perform tasks that naturally require it, such as natural language processing, pattern recognition or machine learning." Nowadays the artificial intelligence has changed the game, and specifically the education world. In addition, the different applications of the new technologies have change dramatically the classroom aspect, from the blackboard to the digital classroom and from the physical presence to the digital classrooms. The graphic design teachers need to be aware of the innovative AI trends. On the one hand, because the students are asking for them, and on the other hand because there are serious advantages in the CAD software that include AI technology. A groundbreaking current trend consist in AI integrated into the CAD software, in order to improve and automate various aspects of Assisted Design. Here, a review of both fields, CAD and AI, is presented. There is a description of the knowledge area, and developments of both fields over time are depicted and compared. Finally, the advantages of AI application in CAD is analysed. Those include the improvements of typical software, such as design automation, a performance optimization, a design assistance, a predictive analytics, an advanced simulation and a smart interface. Besides, there is a bigger improvement in the field; there is a new flashy software that is known as Generative Design. This new field is also defined and analysed, purposing new Generative Design software for the CAD lessons and placing them in the engineering students PBL process.

Generative Artificial Intelligence applied to the parametric drawing of floor plans. Origins, evolution and current state

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Keywords: Design, Generation, Automatic, Planimetry, Graph Theory

Abstract

The emergence of Artificial Intelligence in different professional fields has accelerated so much in recent years that it has become an indispensable tool for any professional, or teacher, who does not want to become obsolete. In this sense, the celebration of this congress is a magnificent opportunity for teachers, researchers and professionals, both experts and those who come to it in search of the necessary continuous training, to share experiences and knowledge. This presentation is addressed to both groups, which addresses one of the most controversial issues of Artificial Intelligence. Is this new technology capable of generating solutions in areas that are considered exclusive to human creation? In this sense, this discussion has been, and continues to be, particularly controversial in the field of building projects, in which the different professionals in the sector (engineers, architects...) are usually reluctant to consider this possibility.

A critical journey is proposed, starting at the origins of this technology, at surprisingly early dates, and with the presence of pioneering researchers in several Spanish universities, to the current programs that offer solutions in this field, although with their own particular characteristics within AI. Knowing these particularities to approach these new tools, both for those who use them and for those who intend to access them, will significantly enrich your user experience.

The theoretical origins of this question date back to the 1960s, and to the works of Nicholas Negroponte and Christopher Alexander, both professors at the Massachusetts Institute of Technology, where these ideas began to develop, based largely on the theoretical approaches that Alexander presents in his renowned books, Notes on the Synthesis of Form (1964) or A Patter Language (1977). In the 1970s, a feeling of optimism was generated regarding the potential that the union between the initial approaches, based mainly on Graph Theory, and the possibilities that the emerging computer technology, particularly in CAD, would make possible.

The Faculty of Computer Science of the Polytechnic University of Madrid joined this line of research very early, and in fact in 1971 organized the SEMINAR ON AUTOMATIC COMPOSITION OF ARCHITECTURAL SPACES, which was attended by mathematicians, engineers, university professors in the area of drawing... and even Christopher Alexander himself. This seed gave rise to several doctoral theses at the University of Seville, which even created software (expert system) capable of generating architectural spaces in plan.

In the 1980s, initial expectations were not met, mainly due to the restrictions of computers at the time, but the advance of CAD programs, and especially those based on parametric drawing, was a great boost, which was even greater at the beginning of this century with the development of BIM systems. Currently the challenge that this technology faces is its incorporation into the recent advances in Neural Networks and Machine Learning. Circumstances that will be analysed with practical examples of the main programs that are currently dedicated to these functions ARCHITECTURES, FINCH, PLANFINDER.

Remote identification of biofouling on submerged surfaces: image analysis and deep learning-based approaches

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Keywords: Biofouling, Remote Monitoring, Automatic Detection, Underwater Conservation, Deep Learning

Abstract

Biofouling, the phenomenon involving the growth and accumulation of marine organisms on submerged surfaces, poses a significant challenge for the conservation of underwater structures and historical artifacts. Its presence can accelerate material degradation and complicate potential restoration efforts, especially in cases where direct recovery from the marine environment is not feasible. In this context, the early identification of biofouling is crucial for developing targeted intervention strategies and minimizing long-term damage. This study aims to lay the groundwork for creating a training dataset for a deep learning-based segmentation network. Images of submerged specimens were captured in both the visible spectrum and under UV illumination, which reveals biofouling often invisible to the naked eye. Using semi-automatic thresholding methods, segmentation masks were generated from UV images to approximate biofouling regions. RGB, HSV,Lab, and YCbCr color spaces were systematically compared to determine the most stable and reliable color model for segmentation. Results identified the HSV space as offering the most consistent thresholding performance across the dataset. These segmentation masks provide a foundation for training deep learning models aimed at automatically detecting biofouling in visible-light images, where manual annotation is challenging.

Blockchain, AI and Data Visualization: history and evolution of design in digital archives

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Keywords: Blockchain, Artificial Intelligence, Digital Archives, Communication Design

Abstract

Digitalization has radically transformed the way information is preserved and made accessible, profoundly influencing historical research and the promotion of design and communication culture. Emerging technologies such as blockchain and artificial intelligence (AI) are redefining the concept of digital archives, ensuring authenticity, transparency, and more efficient data management. The objective is to harness these innovations to improve preservation, security, and accessibility of sources, enhancing corporate cultural heritage and making it available to a global audience.

Blockchain, developed to ensure immutable and decentralized records, has been implemented in the realm of digital preservation as a tool for certifying and protecting archival content. A significant example comes from Riva, a historic company in the recreational boating industry associated with Museimpresa, which utilized blockchain to link digital certificates to its historical images. Through notarization, a DIGEST was generated to certify data integrity. Simultaneously, artificial intelligence has been adopted in archives to streamline organization, indexing, and data retrieval. A noteworthy example is the Archivio Storico Fondazione Fiera Milano, which digitized its historical archive and enhanced navigation through the application of both discriminative and generative AI. The integration of AI also enables the use of advanced data visualization techniques, facilitating the intuitive graphical representation of large volumes of information. By employing analysis algorithms and machine learning, connections, patterns, and trends within the data can be identified, providing new tools for interpreting the history of design and corporate communication. Integrating corporate archives into advanced platforms such as Google Arts & Culture offers immersive and interactive interfaces for experiencing cultural heritage.

The combined application of blockchain and AI has led to more secure, transparent, and efficient archive management. Blockchain ensures the integrity and authenticity of content, protecting digital sources from potential alterations. At the same time, AI simplifies document organization and analysis through automatic indexing, accelerating researchers' work and enabling more precise access to materials. A significant outcome is represented by data visualization, which offers new ways of exploring and presenting data. Researchers can dynamically visualize connections, enhancing their understanding of archival information and opening new perspectives for study.

The adoption of blockchain and artificial intelligence represents a significant step toward more inclusive, interactive, and secure digital archives. These technologies facilitate the preservation and accessibility of historical sources and enhance their value. However, they cannot replace the interventions of archivists in ensuring the proper management and cataloguing of records, from which AI can then extract and operate on data. The proposed cases demonstrate the effectiveness of these innovative solutions in preserving and promoting corporate tradition. The introduction of data visualization, in particular, further enriches the potential for analysing and utilizing archives, contributing to the creation of a dynamic and open digital ecosystem capable of connecting the past, present, and future of design culture.

An analysis of the temporal consistency of the user's opinion about product design attributes: a case study with household products

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Keywords: Product Evaluation, Product Design, Subjective Impressions, Semantic Differential, Test-Retest

Abstract

In an increasingly competitive market, where affective values have become a key aspect of differentiation, understanding user opinions is crucial to ensuring success in product design. Traditionally, designers have collected data on product assessment through various self-report questionnaires, such as the Semantic Differential technique by Osgood, a widely used method for evaluating product aesthetics and user affect. It consists of multiple semantic scales composed of bipolar adjectives describing the attributes of a given product, typically using Likert-type scales for data collection, and has been rigorously validated and is popular for understanding user opinions. However, some authors consider that users may not be too reliable in maintaining a consistent opinion over time, raising concerns about the stability of the collected data. Despite the importance of this issue, existing literature has paid little attention to the temporal consistency of responses obtained through self-report questionnaires during product evaluation, questioning whether these techniques provide stable results during the evaluation process. For this reason, this study presents two case studies in which a group of volunteers evaluated two types of products (i.e., chair and watering can) using the Semantic Differential technique in different sessions (one week apart). Additionally, data about confidence in the response for each attribute was collected to obtain more robust results. The main objective was to determine whether statistically significant differences exist between the different measurements to assess response stability and, consequently, the reliability of self-report methods over time. The results showed that some attributes were affected by the temporal factor for both products, with consistent findings across all watering can designs (durability and precision), suggesting that a user's opinion may evolve over time specifically for certain attributes (depending on the product typology). In this context, our results indicated that 75% of the evaluations remained consistent for the chair, while approximately 55% were consistent for watering cans. Furthermore, attributes related to Jordan's physio-pleasure category remained stable across experimental conditions, suggesting that, although self-report questionnaires might not be entirely reliable for assessing certain product features, they could still serve as a useful evaluation tool. However, a high level of confidence in the response indicates that the opinion is genuine at the moment of product evaluation, even though it can be flexible and subject to change based on external factors, such as the user's experience with the evaluated product.

Artificial Intelligence in museums: an overview of facial expression analysis techniques in Museum-Space-Visitor Interaction

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Keywords: Museum Visitor Emotions, AI Technology, Facial Expression Detection, Interactive Spaces

Abstract

With the rapid development of new technologies, recent advances in Artificial Intelligence are promoting the growth of the Cultural Heritage field and changing approaches to the design of museum spaces. In fact, the visitor experience in museums is evolving towards greater user involvement, creating new dynamic and interactive cultural contexts. The design of museum spaces and, in particular, the organization of visual, spatial and material elements are more oriented toward the needs and expectations of visitors, thus generating an impact on direct involvement and the quality of the visit. In this context, among the tools for capturing user engagement data, facial expression analysis enables the collection of implicit and explicit measures of user activation and emotional engagement in application fields ranging from neuromarketing to user experience. To support this analysis, Artificial Intelligence technology plays a key role through its ability to generate data and algorithms to "reshape" the creative process beyond traditional design methods and tools derived from the study of human perception. This paper proposes a review of the state of the art of the main digital technologies used in museum exhibitions and the identification and detailed study of integrated systems and methods used for facial emotion recognition during the enjoyment of museum works and spaces, through examples and case studies in the literature. In addition, the study proposes to provide guidelines for the design of museum spaces in line with current areas of research related to advanced visitor experience in the enjoyment of cultural heritage.

Digitisation and geometry of the arches of the New Bridge of Ronda: comparative morphological analysis with other historic bridges and aqueducts

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Keywords: Heritage Digitisation, Arch Geometry, Architectural Heritage, Historic Bridges, New Bridge of Ronda

Abstract

The presented work analyses the geometry of the arches of the New Bridge of Ronda, a structure of unique morphology built in the 18th century in Spain, and part of the group of historic stone bridges in the country. Using digitised plans of the bridge employed during its construction, as well as photographs, the aim is to obtain the proportions and classify the arches within the context of the types of arches used in stone bridges built in Spain. Additionally, a comparative analysis is made between the geometry shown in the plans of this bridge and the forms that the arches ultimately adopted and can still be observed today. All of this allows for determining whether the morphology of the New Bridge of Ronda corresponds to that of bridges or aqueducts, also constructed in stone.

In the conducted study, original plans of the construction of the New Bridge were used, along with photographs of the bridge, which were digitised and imported into the graphic design software AutoCAD. The proportions of the arches were measured and obtained, relating their height and span. Once these results were gathered, the arches of the New Bridge were classified according to the types of arches used in stone bridges in Spain, such as semicircular arches and skewed arches. Additionally, the dimensions of these arches, as reflected in the plans and photographs, were compared. Finally, the morphology of this bridge was analysed in relation to that which predominates in historic bridges and aqueducts in the country.

This work successfully classifies the arches of the New Bridge of Ronda, through the calculation of their geometric proportions, contrasting this geometry with the types of arches traditionally used in stone constructions. The design of these arches has been confirmed, as well as the possible discrepancies with the dimensions of the construction as it was ultimately carried out. The comparative analysis suggests that certain morphological characteristics of the New Bridge are similar to those of stone aqueducts, highlighting great versatility in its construction.

The use of digital resources, along with the analysis of heritage elements that have survived to this day, is an appropriate methodology that allows for the evaluation of the geometry of elements, and the accuracy of their construction in the built heritage. In the specific case of the New Bridge of Ronda, the usefulness of this procedure has been demonstrated in the comparative analysis of the designs, as reflected in historical plans, with the actual construction. Furthermore, the morphological uniqueness that characterises this bridge is emphasised, as it is very different from traditional stone bridges, while exhibiting certain similarities with features typical of aqueducts. This study encourages further research into other heritage engineering works

Methodologies and strategies based on graphical engineering

Flat patterns of general developable ruled surfaces in CeDG

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Keywords: Computer Extended Descriptive Geometry, Dynamic Geometry Software, Computer Graphic Parametric Modelling, Flat Patterns, CAD

Abstract

CeDG technology was developed to enable the construction of computational three-dimensional parametric models capable of addressing the spatial analysis challenges inherent to Descriptive Geometry (DG), surpassing the capabilities of conventional CAD tools. Any model created using CeDG consists of a set of interconnected graphic-mathematical objects, structured according to a specific construction sequence. This sequence establishes a one-to-one correspondence with the 3D model representing the spatial system under study. Previous research has demonstrated that CeDG enhances both accuracy and scope in generating flat patterns for radiated spatial surfaces, particularly for cones and cylinders, outperforming traditional CAD techniques. Notwithstanding, developable ruled surfaces also encompass other technically significant solutions, such as the developable helicoid, convolutes, and surfaces of constant slope. While these surfaces are well understood in DG, their manual implementation remains highly complex, particularly when the retraction edge is warped. Recently, new techniques have been developed to facilitate the computation of these surfaces using parametric CAD tools, such as Grasshopper within Rhinoceros. This study presents a preliminary analysis of the application of CeDG in the computation of these surfaces. The research focuses on generating two developable ruled surfaces with a warped retraction edge: first, the developable helicoid, and second, a convolute with both a planar and a warped directrix. This selection is justified by the fact that the retraction edge of the helicoid exhibits a constant-radius primary curvature, allowing it to be used as a supporting curve in the flat pattern process. In contrast, this characteristic is absent in the second case. The parametric 3D model of the helicoid and its flat pattern have been successfully resolved using standard CeDG techniques, yielding an exact solution. For the convolute, an initial technique has been developed to automate the flat pattern of the retraction edge through the discretization of n points, where n serves as an additional model parameter. This curve serves as a supporting structure for the generatrices and, consequently, for the flat pattern. Unlike the helicoid, the convolute's flat pattern is discrete; however, its precision can be increased as needed. Nonetheless, the discretization technique prevents the dynamic parametrization that typically characterizes CeDG. CeDG has proven effective in computing the flat patterns of developable ruled surfaces with a warped retraction edge, although dynamic parametrization remains limited. Further research is required to restore dynamic parametrization in these surfaces.

Influence of stems and metaphyseal cones on bone stress in revision total knee arthroplasty: a Voxel-Based finite element study

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Keywords: Voxel Models, Total Knee Arthroplasty, Modular Knee Prosthesis, Finite Element Analysis, Bone Stress

Abstract

The aim of this study is to assess different configurations with stems and metaphyseal cones of the Implantcast GmbH ACS® MB SC knee revision prosthesis on the distribution of internal bone stress in the femur and tibia by means of voxel modelling and finite element analysis.

CT scans from the Visible Human Project were processed with 3D Slicer and modVOX to create voxel models of femur and tibia. The components of the modular knee prosthesis (femoral component, insert, tibial tray, stems and metaphyseal cones) were modelled in Autodesk Inventor. A non-prosthetic knee model and four configurations were studied: primary TKA, adding stems, adding metaphyseal cones, and adding both stems and metaphyseal cones simultaneously. Virtual surgeries were performed in Autodesk AutoCAD and modVOX, to create bone-prosthesis voxel models. Finite element analyses were performed in Ansys and the bone stress distribution extracted for eight regions of interest along the femur and tibia. The bone stresses were compared between the study models and the model without prostheses. New 3D models (VTO3D) were created to facilitate the interpretation of the results by practitioners, using Python scripts to improve both the calculation and rendering of stress comparisons (reducing computing time by 99% compared to previous automation routines) and to enhance the user experience of the whole procedure.

The primary TKA prosthesis configuration presented the lowest bone stress variation post-surgery. Adding metaphyseal cones resulted in a higher decrease in bone tension in the regions near these components, femoral condyles and tibial plateau. Moreover, the presence of stems also reduced bone stress in those areas and in the diaphysis of both femur and tibia, and produced notable stress concentrations around their tips. Both stems and metaphyseal cones configurations induced higher stress shielding in the distal femur and proximal tibia than the prosthesis in its primary TKA configuration. The stress shielding was more noticeable when all the components were implanted together.

Primary total knee arthroplasty prostheses provide a stress distribution closer to the non-prosthetic knee model. In patients requiring additional fixation, such as those undergoing a revision total knee arthroplasty, the configuration using metaphyseal cones would be the best option. Stems, although providing excellent fixation, also produce a high stress concentration on their tips that may lead to pain or other discomfort in patients. Stress shielding patterns were observed in the distal femur and proximal tibia, especially when both stems and metaphyseal cones were implanted. This could lead to bone remodelling in these areas, losing bone density due to bone resorption.

Meshing strategies for CFD simulations of lubricated mechanical components in Open-Source Software

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Keywords: Gear; Rolling Element Bearing; OpenFOAM; Lubrication; Computational Fluid Dynamics

Abstract

The electrification wave is driving mechanical components to operate at increasingly higher rotational speeds, aligning with the efficiency peaks of electric motors. However, as rotational velocity rises, fluid interactions with rotating components become a dominant factor in power losses, significantly impacting overall system efficiency. These losses, commonly classified as load-independent losses, can be analysed either through extensive experimental campaigns or Computational Fluid Dynamics (CFD) simulations. The latter has proven to be a valuable design tool for studying the lubrication of Rolling Element Bearing (REB) and gearing system.

In recent years, a growing number of studies, along with multiple review papers, have explored the application of CFD in lubricated mechanical components. These studies have highlighted key factors influencing simulation accuracy and efficiency, including solver selection, imposed boundary conditions, and — perhaps most critically — the mesh quality. The meshing process plays a pivotal role in determining both the precision of results and the computational time required for simulations. However, mesh generation can be time-consuming and technically demanding. Nevertheless, dedicating time to high-quality meshing during the pre-processing phase is widely considered a valuable investment, as it can significantly reduce computational costs, particularly in simulations that may take weeks or even months to complete.

This paper provides a comprehensive review and technical discussion on meshing techniques and strategies for CFD simulations of lubricated mechanical components using open-source software such as OpenFOAM. Specifically, it summarizes methodologies for modelling cylindrical roller bearings, tapered roller bearings, ball bearings, spur gears, helical gears, and planetary gear systems, as well as bevel gear mechanisms. Moreover, based on the authors' expertise, the paper details mesh manipulation techniques for both rigid geometries with rotational and translational motion (e.g., REB) and computational domains with time-dependent topological changes (e.g., meshing gears). A detailed literature review is included, summarizing and analysing existing meshing strategies in open-source environment. Additionally, based on case studies from the literature, this paper presents original research findings on multiple lubricated mechanical systems. Given the goal of INGEGRAF, particular emphasis is placed on the generation and handling of computational meshes, starting from technical drawings or CAD models. The study explores how to impose complex kinematics to accurately simulate lubricant fluxes and related power losses, involving lubricants such as air, oil, and grease.

The originality of this work lies in its ability to synthesize and structure a crucial but often overlooked aspect of CFD literature: mesh generation and management for lubricated mechanical components. By providing a detailed and practical overview of meshing techniques, this paper aims to bridge the gap between theoretical advancements and real-world CFD applications, ultimately enhancing the efficiency and accuracy of simulations in tribological and electromechanical systems.

Topological optimisation of biodegradable plastic products for material reduction and surface area increase

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Keywords: Topological Optimisation, CAD, Eco-Design, Biodegradable Plastic, End Of Life

Abstract

This study presents a topological optimisation methodology for products composed of biodegradable plastics. Plastic pollution is a critical environmental issue characterized by the accumulation of plastic objects and particles in the Earth's environment, adversely affecting humans, wildlife, and their habitats. The problem has escalated since the invention of synthetic plastics which introduced durable materials resistant to natural degradation processes. Today, it is calculated that more than 8 million tonnes are released to the oceans annually, where the plastic waste is accumulating unlimitedly. This research is focused on the design of bio based and biodegradable products in marine environment, aiming a partial reduction of plastic waste accumulation. Biodegradation of plastics are susceptible of the amount of materials, as well as the superficial area in contact with the degradation environment. Since 50% of the plastic waste recollected in the ocean consists of marine industry equipment, the product selected for the research is therefore related to such industrial area: buoy, traps, lines, containers, etc. The major goal is to reduce the quantity of material required while increasing the surface area of the finished product, which allows for optimal biodegradation at the end of life. For this purpose, in first place the geometrical design is performed according to the product specifications and afterwards a topological optimisation is carried out, which is an advanced CAD design technique that allows material to be redistributed within a given domain to optimize structural and functional performance. Optimisation algorithms and computational simulations are used to identify critical regions where material can be reduced without compromising structural integrity. The study is accompanied by the quantification of the environmental benefits of the designed product, by using Life Cycle Assessment methodology (LCA). By means of LCA different scenarios are studied: production and end of life of the product manufactured by conventional petrochemical based plastic, as well as scenarios describing the production of the same product using bio based and biodegradable polymer. The results show that significant material reduction can be achieved, contributing to the product's sustainability and efficiency, while increasing surface area, thus improving its functionality and biodegradation potential. The effect in the biodegradation is being assessed in ongoing research. This novel approach provides a feasible option for the eco-design of more sustainable and circular products.

Estimation of tree canopy volume: comparison between traditional method and that obtained from projected shade

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Keywords: Scanner, HDS, Dendrometry, GNSS

Abstract

The study of tree measurements, known as dendrometry, is a fundamental technique for most operations carried out in the field. Specifically, the canopy volume data is one of the most important and its correct estimation entails promoting minimal contamination and variation in the environment. This study shows the importance of the method to be used to calculate the volume. A comparison of three methods will be carried out: the traditional one, the one calculated according to the shape of the tree crown and the laser scanner method. All techniques are currently valid; However, when carrying out the study, great differences were observed between them, which is the reason for this analysis. The method that provides the most reliable results in calculating the volume of the crown of a tree will be sought. Even if a clear conclusion is reached regarding the reliability of the methods, the optimal one will be the one that takes into account their operability in the field and the economic value of the different studies. All factors will be considered when making the decision, since the accuracy of the results and purchasing power come into play.

Generative design of the swingarm of a motorbike

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Keywords: Computer-Aided Design, Generative Design, Finite Element Analysis, Additive Manufacturing, Swingarm

Abstract

This study explores the application of generative design for the development of a swingarm for a MotoStudent competition motorcycle. Generative design is an advanced, algorithm-driven design exploration process, sometimes enabled by artificial intelligence, used to generate a series of design solutions that meet a set of constraints. The generative design process involved: creating and assembling the bodies that represent the geometry to be preserved in the final design, the bodies that represent the geometry to be excluded from the final design, and the body that represents the initial geometry of the final design; specifying the boundary conditions (constraints, loads, manufacturing details, and materials); and performing different studies. Following this process, it has been possible to create two innovative, efficient, and non-intuitive swingarm designs in a fast and automatic way: one for additive manufacturing in AlSi10Mg aluminum and another for additive manufacturing in Ti 6Al-4V titanium.

Analysing public bus transport networks using graphical visualization techniques based on graph theory

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Keywords: Graphical Visualization, Graph Theory, Transport Networks, Complex Problems, Sustainable Transport

Abstract

The Agenda 2030 sets the world roadmap towards a better future, promoting prosperity while protecting the planet, by identifying the sustainable development goals. World leaders came together to establish policies and directives in their respective countries in order to successfully achieve them. In order to deal with climate change and sustainability, Europe is implementing some policies to reduce global warming, for example by limiting the emission to 55% by 2030. In this context, road transport is considered key to achieving this goal, as it generates a large amount of pollutant emissions. A lot of effort is put on designing and deploying more efficient, attractive and sustainable public road transport systems. However, selecting optimal strategies that combine sustainability, efficiency, passenger comfort and profitability is a complex task, and tools to assist in decision-making are required. Graph Theory is well-known for its ability to model relationships between objects and to graphically represent the connections among them. In fact, it is widely used in the representation of real-world complex problems. In this work, a methodology based on graph theory is proposed as a tool to graphically analyse public bus transport networks. Specifically, the complete public bus network of Barcelona is modelled as a directed graph by considering the bus stops as nodes and the connection between them as edges. This representation allows us to extract useful information about nodes (degree, clustering coefficient, etc.) and edges (emissions, velocity, flow passengers, etc.), for instance, relevance of specific bus stops in terms of connectivity or areas within the transport network with a higher number of passengers.

As a result, a graphical visualization tool for analysing bus networks is proposed in this work. Specifically, different graphics are generated, each representing the bus network according to a selected descriptive parameter. It should be noted the use of colour codes, which allow differentiating the ranges of values of each parameter. This provides a quick and easy visualization of how the parameters vary across the bus network, making it possible to characterize it.

For future work, we plan to include weights in the graph so an in-depth analysis of the transport network graph can be done, representing features also of the travelled segments. Links can be weighted with different aspects depending on varying driving conditions, such as terrain slope, speed, passenger flow, pollution, travel time, etc. In this way, very specific information about the network can be obtained, like the geographical distribution of pollutant emissions, allowing to identify areas of the city that should be improved in terms of sustainability.

A graphical method for determining the optimal position of the RTG carriage for dismantling by lowering optimal centroid

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Keywords: Centroid, CAD, RTG Crane, Efficiency, Collapse Mechanism

Abstract

Rubber Tyred Gantry (RTG) cranes are essential in the port and container handling industry. These mobile cranes, mounted on tires, allow for efficient and flexible handling of containers in storage yards, maximizing space and optimizing loads and unloads. A fundamental aspect in the design and operation of these cranes is the determination of their centroid.

The centroid is the point where the entire mass of an object is considered to be concentrated. In the context of an RTG crane, the centroid is crucial to ensuring stability and safety during its operation. The correct location of the centroid ensures that the crane can move and lift loads without the risk of tipping or imbalance.

Once the cranes have reached the end of their useful life, they are dismantled for scrapping. The dimensions, weight, and morphology complicate this process. One of the most innovative methods is the so-called collapse pseudomechanism, consisting of lowering RTGs by longitudinal folding. It involves locating the points where, with controlled cutting operations, RTGs are transformed into pseudomechanisms and, by defining the point of application of the force and its value, the cranes can be lowered safely. To allow folding, and prior to cutting operations, the four corners of the carriage and the upper crossbars must be fixed by welding.

For the point of application of the force, it is essential that the load is applied in a point where it is evenly distributed between the four supports. In this regard, for example, for a 900 T and 30 m high RTG, it is proposed that the pulling force be distributed at two points 22.5 kN each at the ends of the posts, so that the effort is transmitted to the rear posts through the upper crossbars. Additionally, it is important that the pulling angle is as horizontal as possible to avoid transmitting vertical loads to the crane, so it is proposed to pull at a distance of 55 m from the base.

The weight of the carriage and its position is essential to determine the position of the RTG's centroid, which will determine the pulling force and angle.

The objective of this study is to determine, through graphical methods, the optimal position where the carriage should be fixed to minimize the pulling distance while still allowing controlled lowering.

Graphical techniques applied to the evaluation of animal movement

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Keywords: Graphics Techniques, Topographic Factors, Animal Movement, Slope, 3D LiDAR

Abstract

This study aims to determine whether topographic factors influence the natural trajectories animals follow during their daily movements. Factors such as slope, terrain roughness, and altitude are hypothesized to play a significant role in route selection. By focusing on these elements, we seek to understand how animals make decisions regarding their movement in the absence of external pressures, such as predators or artificial barriers. Therefore, the determination and analysis of topographic factors potentially influencing wildlife movements is essential to characterize the pathways or trails chosen by the animals.

The study employed graphical techniques developed by Valderrama-Zafra et al. (2024) to define animal trajectories with precision. High-resolution satellite imagery and visual criteria were used to map animal movement transects, providing an alternative to GNSS collar tracking. GNSS collars are limited by battery life, resulting in insufficient point density to accurately capture topographic attributes at a fine scale.

Once natural trajectories were defined, a comparative analysis was designed to assess the impact of topographic factors. These factors (slope, terrain roughness, and altitude) were extracted using geomatics techniques in a GIS environment with high-resolution 3D LiDAR datasets. Alternative routes based on topographic parameters were generated and compared to the natural trajectories to evaluate the degree of alignment. External influences, such as predators or natural and artificial barriers, were excluded from the analysis to focus solely on topographic factors.

The graphical methodology effectively defined animal trajectories, providing the spatial resolution needed to derive topographic attributes. Preliminary analysis revealed significant correlations between natural routes and alternative paths influenced by topographic factors. Slope and terrain roughness showed the strongest associations, suggesting these factors heavily influence route selection. High-resolution 3D LiDAR data was instrumental in quantifying these features and validating their impact on movement decisions.

Topographic factors, particularly slope and terrain roughness, play a critical role in the natural trajectories selected by animals. The use of graphical methodologies offers a reliable alternative to GNSS tracking, addressing limitations related to point density and battery constraints. This approach provides new insights into animal decision-making processes and lays the groundwork for future studies exploring the relationship between movement ecology and landscape features.

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CAD Parametric Geometry Models: a useful tool for biomechanics and mechanobiology

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Keywords: Parametric Geometry, Endothelial Cell Monolayer, Finger Flexor Pulley System

Abstract

In the study of a biological system, the variability of geometries is substantial due to inherent biological variations and evolutionary constraints. This study analyses two distinct biological systems at two different scales: the cellular level (micrometres) and the organ level (centimetres). The objective of this study is to elucidate the correlation between the geometric characteristics of these biological systems and their biomechanics. To this end, simplified parametric geometries have been developed with the commercial CAD software SolidWorks. These geometries will subsequently be simulated using the Finite Element (ABAQUS).

In the organ scale, we analyse the finger flexor pulley system in the arm, which is key in rock climbing. In this sport, climbers need to grip the rock, and this system supports a significant percentage of the body weight, sometimes even all of it. Injuries of this system account for approximately 30% of all injuries associated with rock climbing. We propose a parametric geometry in the organ scale that will allow for the rapid construction of a finger flexor pulley system in different finger positions and with different geometries of phalanges, tendons, and pulleys. This can be achieved simply by assigning values to the model input parameters. Then, the geometries are analysed by finite element simulation which helps to identify the areas of the system which are most susceptible to injury.

At the cellular level, the biomechanics of the endothelial cell monolayer (EM) is examined. EM lines the interior of blood vessels. Abnormalities in the EM are associated with various pathologies, including atherosclerosis. A wide range of blood vessel geometries exist in the human body, with diameters varying from 8 μm in small capillaries to over 1 cm in arteries and veins. Furthermore, cells' shape and size can vary from one vessel to another. In light of this vast spectrum of vessel diameters and cell sizes and shapes, we propose a simplified parametric geometry of the EM and its surrounding substrate. This geometry facilitates the rapid generation of a wide range of blood vessel geometries, encompassing different diameters and cell shapes and sizes. The geometries obtained are also analysed using finite element calculations. This analysis enables the understanding of the cause of biomechanical abnormalities in the EM, which could result in different pathologies.

In summary, the use of CAD parametric geometries serves as a valuable instrument in the biomechanical analysis of a biological system. These geometries facilitate the generation of a vast array of configurations inherent to these systems in a relatively brief time period.

Impact of femoral stem positioning on bone stress and clinical outcomes in total hip arthroplasty: a Voxel-Based finite element study

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Keywords: Voxel Models, Total Hip Arthroplasty, Hip Prosthesis, Finite Element Analysis, Bone Stress

Abstract

Given the increasing number of total hip arthroplasties (THA) performed annually and the importance of implant longevity, this study evaluates the influence of femoral stem positioning on bone stress and clinical outcomes using finite element analysis and a prospective patient study.

Bone voxel models were created with modVOX software and virtual surgeries (Furlong Evolution stems) were performed by using Autodesk AutoCAD and modVOX. Finite element analysis was performed using CT data, simulating different stem orientations (neutral, mild varus, and mild valgus). Bone stress was analysed using Ansys software. In addition, 3D models of the bone stress difference were created to facilitate clinical interpretation by practitioners. A multicentre, observational, and prospective study was conducted involving 475 patients undergoing THA. Preoperative data, including anthropometric measurements and functional scores (Harris Hip Score and WOMAC), were collected. Statistical analysis was performed to examine relationships between implant positioning and clinical variables.

The finite element analysis showed small variations in bone stress between different stem positions. Mild varus resulted in increased femoral neck stress, while mild valgus increased stress in the femoral diaphysis. However, no significant differences were observed in bone stress between positions. Clinically, patients showed significant improvement in both the Harris Hip Score and WOMAC scores postoperatively, with no significant differences between implant positions. Although mild varus and valgus orientations altered bone stress distribution, the differences were not clinically significant and did not lead to detectable changes in recovery or implant failure rates.

This study suggests that mild deviations in femoral stem positioning in THA have minimal impact on bone stress and clinical outcomes, indicating that slight misalignments may not be a major concern for implant longevity or patient recovery. These findings may inform future surgical guidelines and prosthesis design, emphasizing the importance of other factors in THA success.

Tools and methodologies for management and analysis of spatial data

Machine Learning-Based classification of public works using user positioning data from GNSS correction services

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Keywords: Cartography, GNSS, Machine Learning, Geospatial Data

Abstract

According to a previous study by the authors, the user positioning data from GNSS Correction Services can serve as an unconventional source for cartographic updates. These data contain service information such as the user geographical coordinates, date, and duration. This analysis aims to automate the area identification of newly constructed civil works using regional data from the Spanish Andalusian Positioning Network service (RAP: www.juntadeandalucia.es/institutodeestadisticaycartografia/rap/nodos, accessed February 2025) between 2008 and 2020.

To achieve this, the methodology was developed in a QGIS and Python environment, following a two-step process. The first step was focused on vector data, where user positions were filtered and clustered, removing outliers and selecting relevant activity areas under study. In this initial analysis, convex hulls were generated from point clusters over time, enabling the delineation of these potential construction zones. These hulls were characterised using a geometric index to preliminarily distinguish between polygonal works, linear works, and other activities. Additionally, sinuosity measures were applied to discard areas with an insufficient number of inner points or negligible perimeter values. Subsequently, the skeleton or centreline was calculated to analyse the characteristics of the hull areas. Temporal parameters such as the start and end dates of inner connections, as well as the coordinates of the bounding box, were incorporated into these geometric parameters.

The second step involved exporting this shapefile table as a CSV file for processing in a Python environment using a supervised Machine Learning (ML) approach to test the automatic classification of work types. Initially, a training dataset was categorised into four classes: unidentified, linear works, polygonal works, and activities outside the scope of public works. This classification was manually validated by cross-referencing hulls with geospatial layers from the Andalusian Spatial Reference Data (DERA: www.juntadeandalucia.es/institutodeestadisticaycartografia/dega/datos-espaciales-de-referencia-de-andalucia-dera, accessed February 2025), which include roads, railways, industrial areas, airports, and ponds. These newly constructed elements were confirmed using both the most recent and historical orthophotos from the National Plan for Aerial Orthophotography (PNOA: https://pnoa.ign.es/, accessed February 2025).

Based on this characterised dataset, several ML classification algorithms were evaluated, including K-Nearest Neighbours (KNN), Decision Trees, Naïve Bayes, and Support Vector Machines, along with the use of dummy variables. Decision Trees achieved the highest performance, with an average accuracy of 75% across the four categories. These results highlight the potential of integrating unconventional sources in cartographic updates and the use of artificial intelligence to accelerate the time detection of new construction works that impact geospatial databases, particularly in basic cartography. However, this methodology is prone to false positives, which could be mitigated through automated change verification using AI techniques using PNOA updates or freely available satellite imagery such as Sentinel-1.

Use of LiDAR maps for the analysis of differential movements in buildings

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Keywords: LiDAR Map, Point Cloud, Building, Differential Movement, Foundation

Abstract

The Spanish National Plan for Aerial Orthophotography (PNOA) has implemented the PNOA-LiDAR project, aimed at capturing three-dimensional information of the Spanish territory using airborne LiDAR (Light Detection and Ranging) sensors. This optical remote sensing technique employs laser light to measure distances with high precision, achieving a resolution of 5 points per square meter and a root mean square error (RMSE) in height measurement of less than 10 cm in its ongoing third coverage. This level of precision could enable the analysis of elevations and differential settlements in buildings associated with foundation failures or changes in ground conditions when they exceed the LiDAR margin of error. This communication presents a case study of a newly built detached single-family house, constructed on a 20.20-meter thick soil fill poured for the levelling of the plot, located along the axis of a valley. After its construction, the building experienced an accumulated differential settlement of 285 mm, coinciding in direction and sense with the maximum slope of the natural terrain profile. This differential settlement, measured in the house using topographic levelling with a self-levelling laser, has been compared with measurements obtained from the LiDAR point cloud map. The results show variable deviations, in all cases less than 30%, with the virtual model reflecting the trend, direction, sense, and approximate magnitude of the movement experienced in the house. This analysis confirms the potential of LiDAR for the study of building and civil engineering damages associated with differential foundation movements and its application for such studies on an urban scale. Furthermore, the integration of LiDAR data with other geospatial technologies, such as Geographic Information Systems (GIS), and the availability of open source software for point visualization and processing facilitate the analysis of the causes of an incident originating in the ground or foundation, the analysis of associated damages, angular distortions or rotations of the building, and the analysis of possible measures for repairing causes and damages.

From photogrammetric fieldwork to 3D GIS modelling: The Defensive Wall of Seville as a representative case study (Jardines del Valle sector)

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Keywords: Photogrammetry; Architectural Heritage; Point Clouds; 3D Modelling; Level Of Detail (LOD)

Abstract

This work reflects on the advantages provided by Geographic Information Systems (GIS) in the semi-automatic construction of three-dimensional models for the management of architectural heritage information. For this purpose, a methodology has been developed that allows the generation of 3D-GIS models from a high density point cloud obtained by photogrammetry. The applied procedures have been based on a set of work phases that have allowed the classification, modelling and publication of the processed information. This research has selected as a case study a representative segment of the Almohad wall of Seville, belonging to the sector of the Jardines del Valle. This heritage element is part of the buildings belonging to the Master Plan for the Immovable Historical Heritage of Seville (PD-PHiM) and is characterized by being an archaeological asset of great extension and high complexity. The results obtained have generated a model that significantly increases the level of detail (Level of Detail, LOD) of the case study with respect to previous works carried out within the framework of the PD-PHiM. Similarly, the data tables relating to the property have been linked to the 3D model generated. All this has contributed to highlight the great potential of the strategies developed in those tasks related to the data management of heritage buildings.

GIS-AHP-Based Study for Selecting the Best Location for a Power Plant in the Province of Huelva (Spain)

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Keywords: Geographic Information System, Multicriteria Decision, Site Selection, Power Plant

Abstract

Due to the way life is conceived in modern society, access to a continuous and secure electricity supply has become an essential aspect of quality of life, both in urban and rural areas. Electricity generation is one of the fundamental pillars for a country's development, making power plants and associated infrastructure critical assets. This relevance, along with the evolution of the sector and the plans to renew the oldest plants, highlights the need to identify suitable areas for placing new infrastructure that can meet the growing energy demand of the population. In this context, the use of Geographic Information Systems (GIS) emerges as a key tool for optimizing the location of new power generation plants. GIS allows for an in-depth analysis that integrates geographical and spatial variables, considering the characteristics of the land and facilitating informed decision-making in the site selection process. Thanks to the capabilities of GIS, it is possible to accurately evaluate the advantages and limitations of each area, weighing factors such as accessibility, resource availability, and proximity to existing infrastructure. This document will focus on a multicriteria study using the Analytical Hierarchy Process (AHP) method for locating a power generation plant in the province of Huelva (Spain). This analysis will primarily rely on geographic information provided by GIS, which will help identify the most promising areas for installation. After determining the best locations from a geospatial perspective, a technical reanalysis will follow, evaluating additional factors such as available electrical infrastructure, logistics capabilities, and transportation conditions—critical aspects that directly impact the construction and operational costs of the plant. The use of GIS tools and support software for data visualization and processing will facilitate the creation of a detailed map of the most suitable areas for infrastructure installation. Throughout the document, the results obtained through this approach will be presented, emphasizing the importance of GIS not only to identify the best zones geographically but also to optimize the selection process based on technical and logistical variables that affect the success of the project. This integrated approach allows for not only obtaining an accurate view of the territory but also making strategic decisions that ensure efficient, sustainable energy development adapted to society's needs.

Automated detection and geolocation of banana trees based on deep learning from Very-High-Resolution RGB UAV images

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Keywords: UAV RGB Images, Banana Tree Detection, Deep Learning, YOLO, Plantation Management

Abstract

The main objective of this study is to test the latest version of the YOLO series single-stage detectors (i.e., YOLOv11) for automatic localization and height estimation of banana trees (Musa paradisiaca L.) in large plantations from RGB UAV images. The recently launched YOLOV11 was designed to enhance small object detection and improve accuracy while maintaining the real-time inference speed.

The two banana plantations used in this study were located in Ecuador, totaling around 800 hectares. One of them was used as a training and validation area for the YOLOv11s model, with a total of 14.6 hectares. The other plantation, with around 344 hectares, was reserved for testing and accuracy assessment. Very high-resolution RGB images were taken in both plantations using a Phantom 4 drone with RTK positioning. The flight height above ground was 120 m, while images presented a longitudinal and transverse overlap of 80% and 60%, respectively. These flight parameters were selected because they meet the usual operating conditions in Ecuador.

The training of the YOLOv11s model was carried out in a 2 x Intel(R) Xeon Gold 5220 CPU and an NVIDIA GeForce RTX 3090 GPU with 24 GB RAM. The system operated under Python 3.12.7 and PyTorch version 2.5.1 for deep learning tasks optimized by CUDA 12.3 to leverage GPU processing capabilities. The labeling of the banana plants was performed semi-manually on the orthoimage using the open-source package Label Studio, while the open-source framework Slicing Aided Hyper Inference (SAHI) was used to apply the trained model to detect banana plants on the test dataset. Note that SAHI was designed to detect and localize objects that are relatively small in an image, including inference and fine-tuning capabilities. Regarding testing phase, up to thirteen evenly distributed plots with areas ranging from 2053 m2 to 20786 m2 within the test plantation were used as field reference. In this regard, all banana trees within these plots were manually digitized on-screen in QGIS environment.

The results obtained can be qualified as very good. Precision metric, i.e. the ratio between correctly detected banana plants and the total number of banana plants detected by the model, took average values of 89%, which implies a low rate of false positives or overdetection. Recall metric, which measures the ratio of correctly detected banana plants to the actual number of banana plants in the reference data, yielded average values of 85%, thus achieving a low rate of false negatives or underdetection. Finally, F1-score metric showed an impressive value of 87%. This outstanding model performance was based on the notable capability of YOLOv11s to learn and extract banana plant features such as the flag leaf of the banana plant and the radial arrangement of the adult leaves. In this sense, the trained model has proven to be a formidable solution to address complex visual recognition challenges in very-high-resolution RGB UAV images. This approach could also be applied to the management of other species aimed at wood production that have great economic importance in Ecuador. (e.g. teak or balsa plantations).

Critical comparison between professional scanner and 3D Scanning mobile application

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Keywords: Architectural Heritage, 3D Scanning, Photogrammetry, Virtualization, CLoudCompare

Abstract

This study compares two 3D scanning techniques used for the digitisation of a composite order sandstone capital from the 1929 Ibero-American Exposition in Seville. The primary objective of this research is to evaluate the effectiveness of these scanning methods in documenting complex heritage objects, focusing on factors such as scanning time, data accuracy, texture quality, usability, and cost-effectiveness.

The first method employed was the EinScan Pro 2X Plus, a handheld structured-light scanner initially designed for industrial applications. The second method used was Scaniverse on an iPhone 15, a user-friendly application ideal for heritage digitisation, which enables 3D scans to be captured without prior technical expertise. The results from both scanning techniques were analysed and compared using CloudCompare, an open-source software for point cloud processing. This allowed for a comprehensive evaluation of geometric accuracy, texture fidelity, and resolution between the two methods. Although the results from the handheld scanner are more precise at the millimetre level, the results from the mobile device are optimal for heritage dissemination and documentation and the texture quality is superior.

The study highlights the trade-offs between precision and accessibility, demonstrating that while smartphone-based tools provide flexible and portable solutions, handheld scanners offer superior accuracy and detail, particularly in controlled environments. Ultimately, this research contributes to the advancement of efficient, accessible, and cost-effective methods for the digital preservation of cultural heritage.

Tree volume calculation through in-field photogrammetry for estimating growth evolution

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Keywords: Photogrammetry, Point Clouds, Volume, Precision Agriculture

Abstract

In the context of sustainable agriculture, optimising the management of resources such as water, soil and nutrients is essential for achieving the goals set by the European Commission's Farm to Fork Strategy. A crucial aspect of this optimisation is the precise assessment of tree growth dynamics to support efficient fertilisation strategies. Vegetative development can be quantified through biometric parameters, including tree height, canopy dimensions, and overall volume. These key features of tree growth can be monitored at different phenological stages using remote sensing techniques. In particular, photogrammetry enables the generation of high-resolution 3D models that facilitate precise and automated measurements of these parameters, avoiding the use of other expensive devices and their sometimes complex joint calibration, since it allows working in local coordinates. This cost-effective and non-destructive technique reconstructs 3D models from point clouds derived from red, green and blue (RGB) images, thereby providing precise measurements to assess the evolution of tree growth. This study aimed to develop and validate a non-destructive method for estimating avocado tree canopy volume and assessing their evolution over one year using in-field photogrammetry. By processing point clouds derived from high-resolution RGB images, this approach seeks to provide a robust and precise alternative to conventional manual measurements, enhancing accuracy and efficiency in canopy monitoring, and providing much more biometric parameters than those that can be obtained by hand. For this study, a colour camera (Canon EOS 600D) was used to capture images of avocado trees for photogrammetric reconstruction. Data collection was carried out in an experimental avocado orchard at IVIA in Moncada (Valencia, Spain), where six avocado trees were monitored during different phenological stages from March 2023 to April 2024. Images were manually captured, with between 50 and 60 pictures per tree from various perspectives by shooting in two complete circles around the tree at different heights to ensure a high-quality 3D photogrammetric reconstruction. The 3D reconstructions were performed using Agisoft Metashape (Agisoft LLC, St Petersburg, Russia), generating point clouds in local coordinates. The 3D model processing was carried out using Matlab R2023b (Mathworks, Natick, Mass) and CloudCompared v2.14 (2024). Manual measurements of key biometric parameters, such as trunk height, diameter and canopy height were taken as reference values. The data obtained from the photogrammetric reconstructions were compared to manual measurements to evaluate accuracy and reliability using statistical analysis. Preliminary results showed a certain correlation between photogrammetric estimates and manual measurements for canopy volume across all phenological stages. The evolution of the biometric parameters across different growth stages was effectively captured, particularly with regard to tree volume estimation. These findings highlight the potential of photogrammetry as a cost-effective and efficient tool for monitoring tree growth over time, thereby providing valuable data for precision agriculture applications.

San Esteban Church: new perspectives through 3D Modelling

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Keywords: Photogrammetry, Orthophoto, Survey, Heritage, Geometric Analysis

Abstract

Intervention on any architectural property requires exhaustive prior documentation. Often this documentation comes from different sources, sometimes offering unconnected or contradictory data. In these cases, it becomes necessary a review, structuring and expansion of such documentation. The use of fragmented 3D models in LOD (Level Of Details) and LUAS (Logical Units of Analysis), is a useful systematization or methodology for the geometric analysis of heritage elements, as well as for the validation of the existing documentation. This paper applies this methodology to the analysis of the Church of San Esteban (14th century), located in the historic center of the city of Seville (Spain). The urban layout of the surrounding area makes the traditional survey of the church very difficult, so there are significant discrepancies between the existing planimetries. The study focuses on the specific case of the main doorway ensemble of the temple; where a recent survey using scanning and photogrammetry has allowed the real vision of its dimensions and construction details, establishing a starting point for future actions. The results show differences between the current geometry and the one described in the historical plans of the building.

Preserving the legacy: SfM-Based photogrammetric reconstruction of the industrial olive oil heritage at Hacienda de Quinto

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Keywords: Photogrammetry, Heritage, Olive, Press, Mill

Abstract

Olive oil production has shaped Andalusia's agricultural and economic landscape for centuries, with historical infrastructures—such as traditional mills and presses—playing a central role in defining the region's cultural identity. Despite their significance, many of these industrial heritage sites face deterioration due to abandonment, environmental factors, and ongoing modernization efforts. The digital preservation of these structures is therefore essential for historical conservation, academic research, and public engagement. This study examines the use of photogrammetry-based 3D modelling to recover, document, and analyse key elements of the industrial olive oil heritage at the Hacienda de Quinto, specifically focusing on a truncated conical mill (Molino troncocónico) and a beam-and-quintal press (Prensa de viga y quintal). The methodology employed Structure from Motion (SfM) photogrammetry with Agisoft Metashape, using two different cameras—a Nikon D3300 (24 MP, DSLR) and a Fujifilm Finepix S5800 (8 MP, compact)—to assess the impact of image quality on reconstruction accuracy. A systematic image acquisition strategy was implemented, ensuring a minimum of 60% overlap between photographs for accurate alignment, followed by point cloud generation, mesh creation, and texture mapping. All processing was carried out on a high-performance computing server (32 GB RAM, multi-core architecture) to accommodate the computational demands of high-resolution 3D modelling.

Results indicate that the Nikon D3300 outperformed the Fujifilm Finepix S5800, producing higher-density point clouds, more accurate meshes, and requiring fewer images. The beam-and-quintal press posed additional challenges due to poor lighting conditions and geometric occlusions, which were mitigated through the use of artificial lighting and manual marker placement. Processing times varied: the truncated conical mill model required approximately 5 hours, whereas the more complex beam-and-quintal press model took up to 12 hours, primarily due to its intricate geometry and larger dataset size.

The final models were successfully exported in digital formats (3D PDFs, Sketchfab) and prepared for 3D printing, increasing accessibility for research, conservation, and educational purposes. This study demonstrates that photogrammetry is a cost-effective, non-invasive alternative to traditional laser scanning, providing a scalable solution for digitally preserving Andalusia's industrial olive oil heritage. The findings underscore the importance of high-resolution image capture and computational efficiency to achieve optimal reconstruction results. Future work should prioritize automating photogrammetry workflows, enhancing real-time rendering, and integrating AI-driven feature extraction for advanced digital documentation and heritage visualization. In doing so, this research contributes to the broader digital conservation of historical agricultural infrastructures, ensuring that Andalusia's rich olive oil heritage remains accessible for generations to come.

Improving the greenhouse spring crop classification from Sentinel-2 time series in Almería (Spain)

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Keywords: Plastic Cover Greenhouse, Machine Learning, Deep Learning, Time Series, Sentinel-2

Abstract

Greenhouse cultivation has showed its efficiency in intensifying food production, so, this intensive agricultural system has been expanding rapidly in the last decades. Recently, two relevant paper related to the generation of global Plastic Covered Greenhouse (PCG) maps using commercial and freely available satellite imagery combined with artificial intelligence techniques have been published. Both studies agree in pointing out that, the total PCGs area of the world has reached to 1.3 million hectares accounting for 8 ‰ of the global cropland. One important reason for the widespread of PCGs is the role in the increase of both crop yield and quality. Local climatic conditions could be greatly improved for crops with an increased accumulated temperature and a decreased water evapotranspiration, which is significant especially for regions with adverse climatic situations. Moreover, the countries that currently have a large area of PCGs mainly include China, Spain, Italy and Vietnam.

This work aims to study the potential of Sentinel-2 time series for classifying the spring crops, which are grown beneath PCG in Almeria (Spain). In 2018, a paper entitled “Greenhouse Crop Identification from Multi-Temporal Multi-Sensor Satellite Imagery Using Object-Based Approach: A Case Study from Almeria (Spain)” was published in Remote Sensing by our team. The goal was the identification of crops in autumn and spring season in PCG located in the sea of plastic, Almeria. For that, in spring 2017, 1114 PCG were visited in order to control the crop that was being grown inside it. These crops were pepper, tomato, aubergine, cucumber and melon/watermelon. Using a Sentinel-2 time series compose of six images taken during the spring of 2017, an overall accuracy of 75.40% was attained by mean of Decision Tree approach. The melon/watermelon class was the best classified, with impressive Fβ values of around 94.6%. Note that the melon and watermelon crops cultivated under greenhouse in Almeria require full sun for proper growth, so the plastic sheet is usually maintained totally clean. This makes these horticultural crops easily detectable in the months of April or May, when they are in their maximum production stage, since they present high photosynthetic activity as compared to other contemporary crops. The other spring crops studied presented Fβ values of 76.76%, 75.05% and 41.53% for tomato, pepper and aubergine/cucumber, respectively.

Bearing in mind the aforementioned results, in the current work dozens of classifiers (e.g., efficient logistic regression, linear discriminant, support vector machine, ensemble or neural network) are tested using the old data taken in spring 2017. The goal is to find the best classifier dealing with Sentinel-2 time series to identify crops growing beneath PCG.

Benchmarking Artificial Intelligence methods to classify greenhouse crops in Almería from Sentinel-2 multi-temporal images: summer/autumn campaign 2016

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Keywords: Plastic Cover Greenhouse, Artificial Intelligence, Time Series, Sentinel-2, Crop Identification

Abstract

The growing importance of agriculture in managing sustainable natural resources highlights the need for development of practical methodologies for mapping and monitoring cropland. In this sense, it can be underscored an increasing amount of scientific literature mainly focused on cropland mapping using remote sensing techniques (satellite images, UAV, etc.), different classifiers (classical methods or machine learning based) and strategies (pixel-based or object-based (OBIA)), and single or multi-temporal data. In the case of outdoor croplands classification, several studies have provided robust workflows that ensure accurate results. The studies published by Aguilar et al. 2015, Nemmaoui et al. 2018 and Jiménez-Lao et al., 2023 have been the only works that have gone a step further by addressing the identification of horticultural crops under plastic covered greenhouses (PCG). This task is complex because the plastics used as covers in greenhouses are semi-transparent, so the spectral signature of the crop growing under the PCG affects the signal captured by the satellite sensor. This challenge has been addressed in by combining OBIA, decision tree classifier (DT) and multi-temporal satellite imagery (Landsat 8 (L8) and Sentinel 2 (S2)). Nemmaoui et al. 2018 used multi-temporal L8 and S2 time series to classify under PCG crops in two agronomic seasons: summer/autumn 2016 (eight images) and spring/summer 2017 (six images). The authors reported an overall accuracy (OA) of 74.04% and 72.96% for L8 and S2, respectively, in summer/autumn 2016, while similar figures of 73.79% and 74.42% were obtained in spring/summer 2017. In summer/autumn season, which is the focus of this study, pepper was the top-ranked crop, presenting an F1-score of 84%, while tomato achieved an F1-score of 70%. To build on the previous promising results, this study employed the same dataset as used in Nemmaoui et al. 2018 to evaluate various supervised classifiers. Beyond enhancing the outcomes, the goal is to identify and train the most effective classifier capable of classifying crops from other agricultural campaigns and at a larger scale. In this way, this work exhaustively tests multiple machine learning supervised classifiers to classify greenhouse crops, such as logistic regression, discriminant analysis, support vector machines, decision trees, Naïve Bayes, nearest neighbour, ensembles, and feedforward fully connected neural networks. The linear discriminant classifier provided the best results after applying 5-folds Bayesian optimization to set the hyperparameters δ and γ, showing an impressive average OA of 86% over a randomly selected holdout dataset not used for training. The top-ranked classified crop was pepper (F1-score = 95%), followed by tomato (F1-score = 84%), cucumber (F1-score = 78%), and aubergine (F1-score = 75%). These results significantly improved the results reported in, also highlighting that the accurate classification of different greenhouse crops can be primarily attributed to greenhouse management practices: For example, whitewash (suspension of calcium carbonate) is commonly applied to the greenhouse roof and walls during warmer periods (summer/early autumn to late autumn) to decrease air temperature inside the greenhouse.

Remote sensing of concrete slabs: a UAV-Based approach using fourier transform and PCA

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Keywords: Concrete Maintenance, Unmanned Aerial Vehicles, Image Processing, Principal Component Analysis, Probabilistic Hough Transform

Abstract

The prediction of pavement service life and the scheduling of maintenance activities are critical aspects of infrastructure management, as they involve significant economic investments. In airport pavement networks, precise service life estimation and efficient maintenance planning are essential due to the high safety and operational standards required for aircraft operations.

This study presents a multi-stage methodology for detecting deterioration in concrete slab units, leveraging advanced image processing techniques and remote sensing data. The first stage employs unmanned aerial vehicles (UAVs) to capture high-resolution orthomosaic images, establishing an accurate pixel-to-physical distance relationship. In the second stage, image segmentation is performed to isolate individual concrete slab units, utilizing the Probabilistic Hough Transform (PHT) for precise boundary delineation. Once each slab unit is identified, the Discrete Fourier Transform (DFT) is applied to filter out noise and non-relevant pixels. The remaining pixels, which likely correspond to cracks or surface defects, are then analysed using Principal Component Analysis (PCA) to assess their spatial dispersion and severity. If a significant level of dispersion is detected, the concrete slab is classified as deteriorated.

Experimental results demonstrate the effectiveness of this methodology in accurately identifying pavement deterioration, facilitating data-driven decision-making for maintenance prioritization. The proposed approach enhances the efficiency of pavement monitoring by providing an automated, scalable, and non-invasive solution for early damage detection. Future work will focus on integrating additional machine learning techniques to refine classification accuracy and expanding the methodology to other types of infrastructure.

Design for Human-Baboon conflict management: animal location using a sensor network ecosystem

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Keywords: Animal-Computer Interaction, Animal-Centred Design, Wildlife Conservation, Remote Sensing, Wireless Communication

Abstract

Human-wildlife conflict is a growing global challenge, exacerbated by urban expansion, habitat fragmentation, and resource competition (Schell et al., 2021). In South Africa's Cape Peninsula, chacma baboons (Papio ursinus) frequently invade urban areas in search of anthropogenic food sources (Chowdhury et al., 2020), resulting in property damage, health risks, and increased threats to their own safety (Kennedy Overton et al., 2024). This issue underscores the need for effective strategies to manage baboon presence and mitigate the impact of these interactions. Current conflict management strategies, including fencing, guarding, deterrents, and lethal control, have proven inconsistent and unsustainable (Fehlmann et al., 2021). Guarding, in particular, has been shown to be highly effective in reducing human-wildlife interactions and enjoys strong social acceptance. However, its high operational costs make it economically unsustainable in the long term, limiting its scalability. Given these limitations, technological tracking solutions, such as GPS collars, could provide an alternative by offering real-time data on animal movements and behaviour. However, their high energy consumption, size, and weight restrict their suitability for species such as baboons that require lightweight devices (He et al., 2023). This study aims to develop an alternative localisation system that supports the proactive management of guardians by enhancing energy efficiency and enabling continuous and responsible animal monitoring. To address these limitations, we propose a passive remote sensing system based on an Animal-Centred Design approach, which minimises the technological burden on baboons while optimising guardians' intervention. Our solution integrates low-power wireless communication technologies as remote sensors, employing a combination of LoRa (Long Range) and BLE (Bluetooth Low Energy) to infer the animals' location. The baboon wears a lightweight transmitting collar that emits signals detected by a network of receiving antennas installed on the rooftops of residential houses. This infrastructure enables real-time proximity data collection and processing, generating alerts when baboons approach urban areas. Beyond its non-invasive nature, this design facilitates proactive conflict management by alerting conservation guardian teams, allowing them to take preventive measures and notifying residents.

This approach offers multiple benefits. Energy consumption is significantly reduced, extending the device's autonomy and enabling long-term field deployment without frequent interventions. Additionally, the collar's optimised design aims to minimise interference with the baboon's natural behaviour while complying with ethical conservation requirements. Finally, the ability to generate early warnings supports a coordinated and efficient response, mitigating risks for both wildlife and local communities.

By integrating remote sensing and wireless communication technologies, this study presents an innovative, non-invasive solution for baboon monitoring and human-wildlife conflict management. The proposed system provides an alternative to conventional baboon tracking methods through a framework that prioritises both functionality and animal welfare. This system has the potential to complement the work of guardians, enhancing their ability to manage wildlife incursions more effectively. This work highlights the potential of Animal-Centred Design in developing scalable and effective wildlife monitoring technologies, demonstrating how well-structured design choices can lead to more responsible solutions for wildlife monitoring and mitigation.

Using LiDAR to model 3D tree structures and to estimate tree metrics in almond crops

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Keywords: Velodyne LiDAR, Woody Crops, Structural Metrics, Quantitative Structure Models

Abstract

This work describes an MLS LiDAR survey (Mobile LiDAR Scanning) carried out on a 4.6 ha almond crop at the Finca de La Reina plot, located on the left bank of the Vega del Guadalquivir, near the city of Córdoba (south of Spain). The main objective of this work is to obtain a high-density point cloud that allows the generation of a 3D model of tree structures. These models allow obtaining precise information on the structure, volume, biomass, and health status of trees, which is essential for decision-making in agricultural management.

Mobile scanning was performed using a Velodyne LiDAR sensor and with an adjusted point density, i.e. with a higher concentration of points in the most important areas for the structural analysis of the tree, such as the crowns, the upper branches, the trunks, and the base of the trees. The scanned area was 1.5 ha with planned trajectories to minimize areas without data. The LiDAR sensor was integrated with high-precision GNSS systems and inertial units (IMU) to obtain precise coordinates of each point (georeferencing). Point cloud processing began with the alignment of scan paths and the merging of multiple passes to generate consistent data. Filtering and cleaning were then performed to reduce or eliminate noise, and an initial classification was performed, which consisted of separating soil, vegetation, and artificial objects. Once the ground points have been removed, the algorithms can identify the characteristic shapes of the trees through the segmentation process using tools such as R (lidR package) or Python (PDAL). Finally, the data were processed and analysed with the Quantitative Structure Models (QSM) model to create geometric models that represent the complete architecture of a tree, from the trunk to the smallest branches, by combining cylindrical segments. It focuses on obtaining structural parameters such as height, diameter and branch distribution.

The structural metrics obtained using the QSM model in this work have been: total volume, trunk volume, branch volume, tree height, trunk length, branch length, total length, number of branches, maximum branch order, trunk area, branch area, total area, diameter at breast height, average crown diameter, maximum crown diameter, crown area, crown base height, crown length, crown proportion, and crown volume.

The use of the Velodyne sensor combined with QSM allowed for accurate tree-level segmentation, which is especially useful in tree crops with high heterogeneity such as olive groves or almonds. Furthermore, the methodology showed high efficiency in calculating key structural metrics for biomass estimation which is highly effective for different applications in agricultural management. In conclusion, this work is a first step to support research using LiDAR in woody crops.

Development of an application for visual exploration of Hyperspectral Images

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Keywords: Graphical User Interface; Image Exploration; Computer Vision; Hyperspectral Imaging

Abstract

Currently, there is no software, either commercial or open access, that meets the need for a preliminary and detailed visual analysis of images obtained from hyperspectral systems. Having a tool that allows for the initial exploration and evaluation of the collected data is essential, as it provides insight into how to approach the design of future experiments and their potential success. However, the available solutions are usually limited to basic viewers capable only of displaying monochromatic images (one band at a time) and, in some cases, a simple histogram, without offering the option for more in-depth analysis. This limitation makes it difficult to assess the quality or usefulness of the data before conducting an experiment. The objective of this work was to develop a graphical user interface (GUI) that enables the visualisation of images in various formats and facilitates advanced operations such as correction using reference values, image fusion, and processing of images from multiple cameras to generate a single high-quality hypercube, in addition to segmenting the images. This solution would offer a more flexible and suitable alternative for this preliminary analysis, overcoming the restrictions of commercial software, which is often tied to expensive and specific devices that cannot be purchased independently. The development of this GUI was carried out using the Visual Studio environment (version 17.2.6) and the C# programming language, along with the OpenCV image processing library (Emgu CV). This GUI allows users to open files in .BIL, .BSQ, .BIK, and .RAW formats, visualise images of objects in each band, and generate a graphical representation of all bands along a user-selected horizontal line. In the image of a specific band, the user can define a rectangular graphical window and select regions of interest (ROIs) to segment specific objects. Based on this selection, the tool allows for spectral analysis at the pixel, ROI, and horizontal line levels, displaying characteristic spectra of the selected areas along with basic statistics such as mean, standard deviation, maximum and minimum values, and the range of the ROI, as well as histogram graphs. This functionality provides valuable information for the preliminary analysis of the data. The GUI also allows for advanced corrections, such as adjustment using white and black reference images, the application of a median filter to reduce image noise, and a correction that adjusts the selected pixel values by subtracting the mean of the entire ROI, making the data comparable across bands or regions. This last correction facilitates the detection of spectral anomalies or defects in the image, enabling the generation of colour maps that highlight such anomalies. All settings can be manually adjusted by the user, including noise filter selection, graphical window size, image background colour, band to be visualised, ROI configuration, and the type of correction to apply. Therefore, this GUI provides an efficient solution for in-depth exploration of hyperspectral images, allowing for visualisation, correction, and segmentation while also facilitating defect detection and the extraction of key statistics to guide the design and development of future experiments.

Urban and transportation transformation in Seville: the legacy of the Expo'92 bridges and their projection into the AI era

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Keywords: Civil Engineering, Urban Transformation, Transportation Infrastructure, Artificial Intelligence, Expo'92

Abstract

Analyse the transformative impact of the five bridges built for the 1992 Universal Exposition on Seville's urban structure and transportation system. Specifically, this study aims to assess how these infrastructures improved connectivity, revitalized degraded areas, and catalysed the city's economic development. Additionally, it seeks to explore the potential offered by artificial intelligence to enhance this legacy within the current context of civil engineering, bridging innovations from the past with future technologies. A detailed analysis is conducted on the five bridges (Alamillo, Barqueta, Cartuja, Cristo de la Expiración, and Delicias) based on technical and historical documentation and specific undergraduate projects from students in the Civil Engineering Degree program at the ETSI of the University of Seville, supervised by one of the authors. The study covers their structural characteristics, innovative construction processes, and their impact on urban development. The methodology includes analysing construction systems used, such as the Barqueta Bridge, built on dry land along one riverbank and later rotated to its final position; the counterweight system of the inclined mast of the Alamillo Bridge; and the construction of the Cristo de la Expiración Bridge over the Chapina landfill and subsequent dredging beneath it, reconnecting the two separated parts of the Guadalquivir dock. Integration possibilities with AI technologies are evaluated through comparative analysis and projection of use cases, considering aspects like optimized design, automated construction, predictive maintenance, and intelligent traffic management. The five bridges significantly transformed Seville's urban structure, particularly by recovering the Guadalquivir dock and integrating the Isla de la Cartuja. The Alamillo Bridge, with its 142-meter inclined mast and harp-shaped cable-stayed system, became a symbol of the modern city. The Barqueta Bridge stood out for its innovative construction process and its 168-meter tied-arch structure. The Cartuja Footbridge added slenderness and simplicity, harmoniously blending with the surroundings of the Monastery. The Cristo de la Expiración Bridge helped recover the former Chapina Barrier, while the Delicias Bridge, with its bascule system, significantly improved port operations. These projects not only enhanced connectivity but also catalysed urban regeneration, creating new public spaces and boosting economic development in previously degraded areas. The construction of the Expo'92 bridges marked a milestone in Seville's urban transformation, setting precedents in innovation and design that are especially relevant for the current integration of AI in civil engineering. Lessons learned can be applied in four key areas: structural design optimization through data analysis and advanced simulations, automation of construction processes via robotics and intelligent logistics management, implementation of predictive maintenance systems based on real-time monitoring, and development of intelligent traffic management systems tailored to future urban mobility needs. This experience lays the foundation for a new era in urban infrastructure development, where the combination of traditional civil engineering and artificial intelligence will enable the creation of more efficient, sustainable, and connected cities.

Geostatistical approaches for the estimation and validation of air pollution forecasting maps

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Keywords: Geostatistical Maps, Air Pollution Forecasting, Leave One Out, LOO, ANNs

Abstract

Accurate air pollution prediction is essential for environmental monitoring and decision-making. This study evaluates the effectiveness of a geostatistical interpolation approach, Inverse Distance Weighting (IDW), as an alternative to Artificial Neural Networks (ANNs) for estimating pollutant concentrations and generating prediction maps with missing data. The proposed two-step methodology selects the optimal forecasting ANN model for each station, which is then used to generate pollutant predictions. A Leave-One-Out (LOO) validation approach is applied in the second stage, integrating IDW to interpolate missing predictions at excluded stations. The methodology was tested for SO_2 and PM_{10} concentrations prediction, yielding a mean correlation coefficient (R) of 0.7355 and a Mean Squared Error (MSE) of 733.74, which are slightly lower but comparable to those obtained with ANNs (R = 0.8541, MSE = 726.53) using a resampling procedure. These findings suggest that IDW can serve as a reliable alternative when historical data at a given station is unavailable, leveraging predictions from surrounding stations to maintain estimation accuracy. The proposed approach enhances the robustness of air pollution forecasting, ensuring continuity in environmental assessments even in the absence of ANN-based predictions.

Pedestrian Accessibility Characterization in a University Urban Environment for GIS Integration

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Keywords: Mobility, GIS, pedestrian, accessibility

Abstract

Cities face environmental challenges requiring effective mobility and urban planning. Mobility is crucial for connecting urban spaces and shaping city form. Málaga has expanded, particularly with its university campus development. Promoting sustainable mobility, especially pedestrian options, is essential for connecting these areas. Evaluating pedestrian environments necessitates an understanding of pedestrian behavior, which is influenced by sensory interactions with the city, other pedestrians, and the environment. Factors affecting pedestrian mobility are categorized into accessibility, safety, comfort, and attractiveness. Accessibility pertains to infrastructure, safety concerns traffic dynamics, comfort is subjective, and attractiveness relates to pedestrian engagement with surroundings. The Pedestrian Characterization in Mobility Environments (CPEM) method, developed by Talavera-García, Soria, and Valenzuela, quantifies these factors and assigns a quality level from one to five. Accessibility is gauged by pedestrian section width; safety is assessed via speed and traffic lanes; comfort considers noise and greenery; and attractiveness examines complexity. Using this methodology, evaluations were conducted for each faculty on the University of Málaga campus. Measurements included pedestrian passage width, obstacles, car lanes, and permitted speeds, along with the influence of bike lanes and metro tracks on safety perception. Measurements also assessed tree density, shade provision, ambient noise levels, and the presence of urban elements enhancing quality, such as benches and trash bins. Additionally, faculties were evaluated based on their interaction levels and complexity versus isolation. Some faculties, like the Faculty of Philosophy and the Faculty of Medicine, achieved high urban quality levels, while others, such as the Faculty of Fine Arts and the School of Computer Engineering, received lower scores....

Landscape restoration of the Murcian Huerta: integration of the Barraca as a prototype of minimal and sustainable housing

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Keywords: Huerta of Murcia, Landscape Integration, Heritage Management, Sustainable Building, Barraca

Abstract

The huerta of Murcia is a unique and singular area. It is a peri-urban landscape characteristic of the Mediterranean climate of the Iberian Peninsula, of great agricultural fertility. However, for several years now, various associations dedicated to the conservation of cultural heritage have been denouncing the lack of conservation of the huerta. At present, the built-up area is approximately double that legally permitted by the General Plan in force. These are constructions, many of them illegal, which are a far cry from the original model of the Murcian barraca, the original construction of the Murcian huerta. Therefore, it seems necessary to fight for the huerta, together with the integration of its constructions, so that it does not lose its identity, what it was, and what it should be able to be again. The aim of this paper is to defend the great interest of the huerta of Murcia, as a natural reserve of an increasingly scarce resource such as water. In addition, the aim is to highlight the value of the Murcian barraca as a traditional model of refuge and residence for the inhabitants of the huerta. In order for the barraca to be truly integrated into the landscape and urban planning of the Murcian huerta, urban planning measures are proposed that include legalisation and the implementation of an Integral Special Plan, as well as adapting the traditional barraca to the current regulations without losing the initial attributes of this building: minimal, self-built, self-sufficient housing, linked to an extension of agricultural land.

3D Indoor Evacuation Plans from point clouds for visually impaired people

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Keywords: 3D Modelling, 3D Printing, Indoor Navigation, Visually-Impaired People, Handheld Mobile Laser Scanning

Abstract

Evacuation plans are protective, and safety elements commonly found in any building, providing information about the user's situation and the shortest and safest route to exit. Evacuation plans also include self-protection elements such as fire extinguishers, hoses, or fire alarm buttons. To prevent individuals with visual disabilities from facing the risk of exclusion, evacuation plans should be accessible and interpretable for any group. This work aims to reduce the social exclusion risk for individuals with visual disabilities by creating a 3D indoor evacuation plan that accurately represents the reality of a building's floor. The proposed 3D plan is based on 3D LiDAR scanning data as a method to obtain the necessary precise 3D layouts.

As a case study, the second floor of the School of Industrial Engineering at the University of Vigo was used. The floor was scanned using a Handheld Mobile Laser Scanner Zeb Go, following a closed-loop procedure. The input point cloud was manually processed to remove outliers, using a Statistical Outlier Removal filter, and the ceiling, to create an open area for indoor visualization and hand access.

The processed point cloud was transformed into a mesh through triangulation. The mesh served as the foundation for generating the 3D printing model. The mesh was smoothed and refined to enhance the quality using smoothing techniques and point density adjustments. Subsequently, the model was simplified by removing elements such as closed doors that the evacuation route passes through, as well as furniture. Certain elements, such as stairs and complex areas, were improved through manual modelling. For the creation of the 3D evacuation route, the face corresponding to the floor of solid was selected, and a path of a width smaller than the doors was established, with right angles at direction changes. The route was extruded to a height of 1 mm.

The adaptation of the model for feasible printing involved editing to ensure realistic. One measure taken in this process was to increase the thickness of the model's walls and floor to provide greater rigidity. Additionally, considering the dimensions of the printing space and the case study, a 1:50 printing scale was selected to maintain the level of detail, and the decision was made to divide the model into various pieces. Tabs were designed to fit together like a puzzle for assembling the different parts. The printer used was an Ultimaker 2. In the end, 10 pieces were printed.

The results demonstrated that HMLS LiDAR data acquisition systems are fully valid tools for the creation of a 3D evacuation plan with the accuracy required for a tactile interpretable plan. 3D printing is key to the generation of three-dimensional plans, although the printing time may be too long to produce one single model. Future work will focus on assessing the addition of different textures and testing usability with impaired people.

Methodology for comparing the sustainability of different renewal models applied in retail spaces

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Keywords: Life Cycle Sustainability Assessment, Retail Space Renewal, Comparative Analysis, Aggregate Index

Abstract

Numerous research works are being carried out to obtain more sustainable buildings, but, in most cases, studies focus on the reduction of environmental impacts associated to residential buildings. This study outlines a methodology to evaluate and compare the sustainability of retail spaces applying the Life Cycle Sustainability Assessment (LCSA) framework, according to international construction sustainability standards, and analysing environmental, economic, and social impacts comprehensively.

Three distinct renewal models are considered: General Model (GM), Quick Renewal (QR), and Pop-Up (PU). Each model represents varying approaches to retail space renovation, ranging from complete redevelopment to minimal intervention. The objectives include determining the life cycle phases —creation, use, and end-of-life— of each renewal model and quantifying their impacts through selected indicators: Global Warming Potential (GWP) for environmental, Global Cost (GC) for economic and Labour Time (LT) for social dimensions.

This construction typology is developed within buildings whose life cycle is independent and of longer duration than that of the retail stores. Therefore, several renovation cycles of retail spaces are developed during the same life cycle of the building, with the duration of these cycles being different depending on the renovation model.

The life cycle of each model has been analysed in detail, determining the necessary stages in each phase (creation, use and end of life), different in number and duration in each model due to the specific features of each one of them.

The study uses standardized databases and software tools, such as CYPE "Arquímedes", CE3X and SIMAPRO, to gather and process inventory data across these phases, homogenising data collected in order to obtain comparable results for each phase and model analysed. Each renovation model has been assessed individually to obtain global data referred to the functional unit (usable m2), and comparatively, by weighting results over time and obtaining an aggregate index.

The results suggest that while the GM offers a complete brand-aligned renovation, it incurs the highest sustainability costs due to extensive material and energy requirements. QR, with its partial reuse of pre-existing elements, demonstrates moderate impacts but requires careful planning to optimize resource use. PU emerges as the least resource-intensive model, though its short lifespan and frequent updates may offset some sustainability gains.

The findings highlight the importance of strategic design and policy interventions in enhancing sustainability across the retail sector. This study provides a replicable framework for assessing and improving the sustainability of commercial spaces globally; fills the gap in comprehensive

methodologies for sustainability assessment of retail spaces and offers additional tools to apply a holistic approach to the analysis of other building typologies.

Reconstruction of a historical climatic dataset for Limón, Costa Rica (1886-1890): implications for energy simulation and architectural heritage analysis

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Keywords: Historical Climate Reconstruction, Energy Simulation, Architectural Heritage, UFCO Architecture, Restoration Scenarios

Abstract

This study presents the reconstruction of a historical climatic dataset for Limón, Costa Rica, dating from 1886 to 1890—a period marking the establishment of the United Fruit Company (UFCO) in the region. This work forms part of the research project "The United Fruit Company spaces in the Caribbean region of Costa Rica between 1890 and 1930: railroad infrastructure, agricultural enclaves and architectural forms." The dataset underpins energy simulations and performance analyses of historical buildings from the UFCO era, when the emergence of a distinctive "banana architecture" influenced the spatial and territorial development of Limón province. Although many original UFCO structures no longer exist, the architectural responses developed during this period continue to impact the evolution of local design and allow for restoration scenarios in existing historical buildings. Archival meteorological records—including monthly averages of temperature, humidity, precipitation, and solar radiation—were systematically compiled from historical sources. Advanced interpolation techniques and empirical modelling were then applied to convert these monthly averages into a continuous hourly dataset. The Hargreaves-Samani method was employed to estimate solar radiation based on temperature data, ensuring that both diurnal and seasonal variations were accurately represented. Additionally, statistical models simulated the natural fluctuations of atmospheric pressure and wind speed. The entire data processing workflow was implemented in Python within the Google Colab environment, utilizing libraries such as Pandas, NumPy, and SciPy. Following validation and quality checks, the dataset was transformed into the EnergyPlus Weather (EPW) format, ensuring compatibility with modern building simulation tools like DesignBuilder. Preliminary energy simulations using the reconstructed EPW dataset demonstrate its capacity to reliably replicate the climatic conditions of late 19th-century Limón. Digital reconstructions of historical buildings, developed through advanced modelling techniques, were analysed with this dataset, providing valuable insights into the thermal performance, energy efficiency, and bioclimatic potential of these structures. The results reveal that the climatic conditions during 1886–1890 significantly shaped the architectural responses of the era, fostering design strategies that continue to inform the adaptive reuse and restoration of the region's remaining historical buildings. Finally, the integration of historical meteorological data with interpolation and empirical modelling techniques has yielded a climatic dataset that supports precise energy simulation and enhances our understanding of historical building performance in tropical environments. This study illustrates that the UFCO architecture, while not a legacy in the traditional sense, fundamentally impacted the development of local architectural forms despite originating as a banana enclave. Furthermore, the methodology enables the formulation of restoration scenarios for existing historical buildings, offering a scientific basis for their conservation and adaptive reuse. This approach represents a replicable methodology for reconstructing climatic scenarios in periods with limited data, providing valuable perspectives for both academic research and practical engineering applications in heritage conservation.

Graphical engineering in superior education

Functional dimensioning based on a 3D Nominal Model

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Keywords: ISO-GPS; Functional Dimensioning; Part Positioning; 3D Nominal Model

Abstract

A part definition drawing must accurately assume the functional requirements of the mechanical system to which it belongs to enable correct functional dimensioning. This dimensioning is essential for the methods office to define its production and for metrology to define its verification.

In this paper, we adopt a method that uses a 3D model of a mechanical system. It is therefore necessary to provide the nominal models of the components. Also relies on analysing the positioning of each part in the possible working states of the mechanical system.

The part functional dimensioning requires mastery of the ISO-GPS language (mainly UNE-EN ISO 1101:2017 and UNE-EN ISO 5459:2024) and a precise analysis of the operation and positioning of each component.

Analysis of how the mechanism works must be based on the tolerance stackups, applying the 'worst case' and statistical methods, depending on the number of components integrating the chain of dimensions

The positioning of each part depends on the identification and definition of the contact surfaces and on the order of the prevalence between them. This analysis of the part positioning will allow the definition of the necessary datum systems and the definition of the initial GPS specifications of dimension, tolerance zone and pattern (maximum or minimum material condition).

Both analyses should provide us with the ISO-GPS functional dimensions in the functional definition drawings according to ISO 16792:2021 and other GPS standards.

Application of multiple simultaneous methodologies in the realisation of CAD practices

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Keywords: CAD, Multiple Simultaneous Methodologies

Abstract

Innovation in the simultaneous application of new methodologies arises from the need to adapt to the different types of learning that students may have. This research evaluates the simultaneous application of multiple methodologies in the implementation of CAD practices. Specifically, it compares the performance of this practice with the traditional methodology of guided practice and, in the following year, the performance of the same with the implementation of other methodologies simultaneously. Specifically, it is applied to a computer-aided design practice in the creation of a mechanical assembly. The practice belongs to the subject of Engineering Graphics of the third year of the Degree in Mechanical Engineering taught at the Polytechnic School of Zamora belonging to the University of Salamanca. As a result of the statistical analysis of the results, the benefit that can be obtained from the simultaneous implementation of different methodologies at the same time is obtained. The study has been carried out on the basis of a comparison of the same practice without the application of simultaneous methodologies. The main objective is to improve the learning process through educational innovation based on experimentation in the classroom. The objective is achieved with a 35 % improvement compared to the results obtained in previous years. The research ratifies the different learning processes of the pupils, taking into account the limitations of the possible different knowledge bases of the pupils. The application of multiple simultaneous teaching methodologies gives the student the opportunity to choose as well as gives the teacher a glimpse of the possible specific needs of the student. This research concludes with the suitability of the application of simultaneous teaching methodologies in CAD practices for the improvement of the teaching-learning process.

Evaluating the integration of Artificial Intelligent tools in graphical engineering courses

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Keywords: Teaching Innovation, Artificial Intelligence, Autonomous Learning

Abstract

Artificial Intelligence (AI) tools are currently and consistently increasing their popularity not only in daily life tasks but also in professional environments. This novel reality is also relevant in the academic world, where undergraduates employ these tools to assist their learning process. The primary goal of the present work is to evaluate the best way to interact with the main AI tools available to the general public for use as assistants in the teaching-learning process. Among all the available tools, ChatGPT has become one of the most widely used due to its simple interface and the availability of a powerful free version. To assess the suitability of these tools in the field of technical drawing teaching, a question bank with different levels of complexity is created, covering content related to representation systems and applicable standards in the Graphic Expression subjects taught in engineering degrees. With the help of specially developed rubrics, an initial evaluation is carried out by the teaching team to obtain unbiased feedback. Subsequently, students solve the proposed bank exercises with the help of AI, recording all interactions made with it and providing a critical assessment of the AI's responses. With all this information, a detailed analysis is conducted to clarify which types of interactions yield the best results from a technical perspective. Based on this analysis, various recommendations are drafted to optimize the interaction between students and AI tools in the teaching-learning processes. Additionally, recommendations for the critical and responsible use of these tools are incorporated into the course content.

Application of Generative Artificial Intelligence in intersection design: a case study in road design

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Keywords: ChatGPT, Artificial Intelligence, Teaching Support, Syllabus Support, Civil Engineering

Abstract

In recent years, Artificial Intelligence (AI) has brought about a revolution in various fields, including engineering. In particular, tools have emerged that are able to generate both reasoned text and images from specific instructions provided by the user. These tools belong to the field of Generative Artificial Intelligence, and their integration opens up new possibilities, especially in the field of education.

However, it is essential to analyse how Generative AI behaves in the educational context to ensure that its use is appropriate and avoids possible errors, given that, in technical disciplines, a clear and precise explanation of concepts is essential for the training of future professionals, whose work may have direct implications for the safety of people and property.

This paper presents the design of a customised ChatGPT model to support the teaching of the subject 'Intersection Design', part of the Master's Degree in Civil Engineering at the University of Alicante. The objective is to provide a resource that facilitates the explanation of the fundamental concepts of intersection design, as well as the application of current regulations in the construction of road intersections. In particular, the model focuses on key aspects such as the calculation and representation of acceleration and deceleration lanes, turning radii and stopping distances, among other relevant regulatory elements.

The methodology employed consisted of customising a ChatGPT model to generate automated and accurate answers to frequently asked questions related to the subject, based on the theoretical and practical content of the course. Its effectiveness was evaluated by comparing the answers given by the model with the teacher's traditional explanations

The results obtained indicate that the progressive incorporation of generative AI tools in technical education is feasible and can enrich the learning process. Students showed a better understanding of fundamental concepts, especially in relation to the resolution of recurring problems in the syllabus. In addition, the model proved to be effective in clarifying doubts about the application of regulations and technical calculations, thus facilitating students' autonomous learning.

In conclusion, Generative AI can be a valuable tool in the teaching of technical subjects, contributing to the improvement of theoretical and practical understanding and offering additional support to teachers. The implementation of this type of technology could be extended to other disciplines within university degrees, providing a complementary resource that optimises the training of future professionals.

Learning to teaching industrial drawing: comparison with traditional methods

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Keywords: Engineering Graphics, CAD, Industrial Drawing, Augmented Reality, Agile Learning

Abstract

The study of different teaching methods in graphic engineering, particularly in 3D design and modelling, is key to develop the spatial visualization and geometric representation skills needed in this multidisciplinary field. The combination of Augmented Reality (AR) and active methodologies, such as Agile Learning, has emerged as an innovative alternative that allows students to interact with 3D models in a more dynamic and participatory way.

The objective of this study is to compare the effectiveness of Augmented Reality combined with Agile Learning versus traditional teaching methods in the training of engineering students in the subject of Industrial Drawing. The effects of both methodologies are analysed in terms of conceptual understanding, spatial skills.

The teaching of Industrial Drawing, which integrates knowledge of engineering, design and digital modelling, require effective teaching strategies and techniques that facilitate the representation and manipulation of three-dimensional objects. In this context, Augmented Reality allows visualizing mechanical parts in 3D, improving spatial perception and the interpretation of orthogonal views, cuts and sections. Complementarily, Agile Learning, based on iterative methodologies and teamwork, fosters autonomous learning, self-assessment and continuous improvement of the design process.

The results of the research consisted of assessing two teaching strategies: one based on AR and Agile Learning and the other following the traditional approach. Students participated in 3D modelling sessions, where they were provided access to AR tools for mechanical part manipulation. Pre- and post-session questionnaires were administered to assess the impact of each methodology on their understanding of object modelling and representation. In addition, an analysis of variance was applied to determine significant differences in the results.

In contrast, although the traditional method also generated improvements in student performance, these were less pronounced. Postsession questionnaires indicated that students perceived the traditional class as more passive and less participatory, which affected their motivation and engagement with the subject. On the other hand, students who worked with AR and Agile Learning rated the experience positively, highlighting the autonomy and flexibility offered by this approach.

These results highlight the importance of integrating immersive technologies and Agile methodologies in engineering education, as they enhance active learning, autonomous exploration and improved spatial representation. The combination of AR and Agile Learning is presented as an effective strategy for teaching Industrial Drawing, with direct implications for curriculum design in technical disciplines and the adoption of new technologies in educational environments.

An educational innovation project: learn to communicate with maps

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Keywords: Map, Cartography, Competences, Higher Education

Abstract

Under this title, we are carrying out an educational innovation project in the Department of Agroforestry Engineering (ETSIAAB-UPM). This project is closely related to the study of the competence associated with any engineering degree: the ability to transmit information, ideas, problems, and solutions with clarity and rigor. For this competence, the students of the Agro-environmental Engineering degree are required to know how to design maps as tools to understand and make decisions about natural resource management, risk and disaster assessment, or precision agriculture, among other topics. The main objective of this project is to know the degree of student's competence in communicating geospatial information through maps. Likewise, we are interested in knowing the main problems that students encounter when carrying out these maps to reinforce the concepts that are more difficult to understand for them.

The materials used have been obtained from four subjects, belonging to the degree from the first to the fourth year, and are respectively the following: Graphic Expression, Topography, Cartography and Photogrammetry, Geographic Information Systems, and Remote Sensing. The sequencing and participation of almost the same teachers in these subjects allow for monitoring of how students develop skills ranging from basic graphic representation to advanced communication of spatial data through maps. We based our research on class exercises, exams, and a survey in the last year where we asked students to show the map they are most proud of those they have made, explaining the reasons, and the concepts they have learned throughout their degree. To determine whether the described competencies have been achieved, we have relied mainly on the following characteristics of the maps: scale, symbology, metadata, aesthetics (proportion, position of the different elements, colour, etc.), and completeness.

The results obtained come from both the experience accumulated over the 14 years that we have been teaching these four subjects of the degree and from the educational project that we are carrying out. The main result identified is confusion regarding the concept of scale, both in the first year, where scale is applied to technical drawing and in the use of AutoCAD, and in higher courses, where maps are made with Geographic Information Systems software. Other weaknesses that we have found in our students are mainly aesthetic, related to the size of the different elements and the symbology used.

The main conclusion obtained is the need to reinforce the use of the concept of scale in analogical and digital formats, emphasizing the difficulties that students have in differentiating the scale of the original data, the scale of the display on the screen, and the scale of the print in both PDF and paper formats to have precise knowledge of the information represented. We also highlight the need for students to visualize and interpret maps from different sources to enhance their critical spirit and to know how certain information content could be included in a map.

NEB design: design of a teaching methodology to implement the New European Bauhaus in higher technical studies

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Keywords: Design Methodology, Creativity, Sustainability, Inclusion, Beautiful

Abstract

The New European Bauhaus (NEB) is a creative and interdisciplinary initiative that connects the European Green Pact with our living spaces and experiences. The initiative urges all Europeans to imagine and build together a sustainable and inclusive future that is beautiful to our eyes, mind and soul. By bridging different environments, spanning different disciplines and building on participation at all levels, the New European Bauhaus inspires a movement to facilitate and guide the transformation of our societies according to three inseparable values:

- Sustainability, from climate targets to circularity, zero pollution and biodiversity.
- Inclusion, from valuing diversity to ensuring accessibility and affordability.
- Aesthetics and quality of experience for people, through design and cultural benefits.

This manuscript proposes a methodological framework based on the principles and values of the New European Bauhaus, which serves as a reference in the teaching environment for learning the practice of design, in the classroom and outside it, and that can be implemented as part of the curriculum in higher technical careers.

The objective of the proposal is to reformulate the way to face any design project taking into account the principles and values of the NEB, and that students and future professionals acquire this methodological strategy when facing any real project, thus favouring our environment and society. In this context, it is intended to work on the main values of the New European Bauhaus, by addressing sustainability, for example, with the use of elements already in disuse, beauty in the design processes, and its inclusion in the design through methodologies such as Design Thinking and citizen participation.

The NEB initiative is, therefore, a current framework whose values are, moreover, essential in the practice of design. In this sense, it is essential that this current relevance is applied in the classroom and that it is transferred as an activator in the learning process of the design exercise as well. This study proposes to apply the approach of the New European Bauhaus within the framework of specific subjects, in optional subjects common to all technical degrees, or as a training module within key subjects.

To achieve these objectives, the proposed project methodology is based on the development of a teaching strategy that allows students participating in these subjects to learn about the NEB. This teaching strategy uses innovative teaching tools, such as a project validation tool from the NEB perspective and a specific classroom to work and develop all the principles and values. All this strategy would be implemented in a pilot course that would allow to analyse and learn if the knowledge and objectives of the project are being achieved. With these lessons learned, a training plan will be designed to be able to scale this project to other learning environments.

Relief interpretation with Twinmotion

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Keywords: Geospatial Thinking, Relief Interpretation, Twinmotion, Landforms

Abstract

Geospatial thinking allows us to visualize, analyse and understand geospatial concepts related to the Earth's surface such as locations, patterns, relationships and changes over time. Relief interpretation is part of geospatial thinking. By analysing relief forms, it is possible to study and understand the shapes and characteristics of the terrain such as mountains, valleys, plateaus and plains. In turn, relief interpretation helps to understand geological and geomorphological processes such as erosion, sedimentation, volcanic activity and plate tectonics, among others.

Tools such as Geographic Information Systems (GIS), spatial data infrastructures, images obtained with satellites and cartographies at different scales are used to represent relief forms. There are also applications such as Twinmotion, which allows a three-dimensional representation of the relief, in which the user can mould landforms from a flat surface, being able to add effects such as solar lighting, virtual flights and the inclusion of materials such as water, rocks, sand... The resulting terrain can be viewed in 3D in high immersion environments (virtual reality glasses), medium (multiprojectors) or low (computer, keyboard and monitor).

This research presents an activity with the Twinmotion application in the STEM field, in which engineering students carry out a workshop with this application consisting of drawing different landforms in 3D such as valleys, divides, hills, depressions and elevations. The students will carry out an interactive tour with the pedestrian and drone modes of the different landforms represented.

The impact of the activity on the ability to interpret the relief will be measured through pre-post measurements using the Topographic Map Assessment test, a standardized tool for measuring knowledge and skills related to the interpretation of topographic Maps.

Graphical Expression in engineering: implementation of pbl and 3D Printing as innovative pedagogical tools

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Keywords: Graphic Expression, PBL, CAD, 3D

Abstract

The first year of Graphic Expression course at Bilbao Engineering School (UPV/EHU) has undergone a significant pedagogical transformation in order to adapt to current educational and technological advances. This work focuses on consolidating project-based learning (PBL) and integrating new technologies such as 3D printing. The incorporation of these tools aims to transform the teaching-learning process, promoting a more interactive and creative experience that responds to the demands of the labour market.

The teaching team at the Bilbao School of Engineering has adopted a disruptive approach to address this issue. Through a comprehensive restructuring of the subject, methodologies have been implemented that increase the potential of the technological tool to facilitate the teaching of technical design. The combination of modern pedagogical models, such as problem-based learning and project-based learning, with advanced technologies, such as 3D printing, allows the challenges associated with this content to be effectively addressed.

This paper presents the results obtained by comparing two pedagogical methods: project-based learning (PBL) and problem-based learning (PBL). The performance of groups of students has been analysed who have used these methodologies and assess their impact on learning, motivation and student satisfaction.

On the other hand, teachers' perceptions regarding the impact of these teaching methods on the overall educational process has been explored. This includes examining how educators view the effectiveness of project-based learning (PBL) and problem-based learning (PBL) in enhancing student engagement, critical thinking, and problem-solving skills. Additionally, the study will assess the challenges teachers face when integrating these innovative methodologies and technologies, as well as the support they need to successfully implement them in the classroom. By understanding teachers' insights, the research aims to provide a comprehensive view of how these pedagogical approaches influence not only student outcomes but also the teaching experience itself.

Exploring the integration of BIM in Civil Engineering Education: a look at current practices in Spain

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Keywords: Civil Engineering, BIM

Abstract

BIM (Building Information Modelling) is a game-changing methodology in the AECO (Architecture, Engineering, Construction and Operation) sector, representing a significant leap forward over traditional design techniques by integrating digital representations of places' physical and functional characteristics. Its core focuses on how to collaboratively design, plan, and manage infrastructures around a digital representation of the asset, transforming the way the built environment is conceived and maintained. Also, the inclusion of data associated with the entire life cycle facilitates industrialization in construction, which allows us to optimize resources. BIM benefits are well-known, and its application is mandatory in Europe since the publication of the Directive 2014/24/EU of the European Parliament and of the Council of 26 February 2014 on public procurement, that established the need to use electronic systems in procurement processes for works, services and supplies as of September 2018. Spain, because of this action, created the BIM inter-ministerial commission, which developed the BIM road map for procurement processes and the current 2023 BIM plan, which made BIM mandatory for public projects from a specific budget. The integration of Building Information Modelling (BIM) into the workplace, coupled with its mandatory implementation, has significantly transformed and created new roles within civil engineering projects. This shift has introduced a new approach to work for graduates in the AEC sector across the world, although there are significant differences on how and when it is being applied among countries. In response to these evolving demands, universities have progressively incorporated BIM methodology into their curricula over recent years, aiming to equip students with advanced skills and prepare them as future professionals. This study seeks to provide an overview of the current state of BIM methodology instruction within Civil Engineering programs in Spain, encompassing both undergraduate and Master's levels, based on publicly available information. Accordingly, civil engineering schools across Spain will be examined to assess the integration of BIM into their academic programs. The syllabi of existing courses will be analysed for references to methodological concepts as well as technological and software platforms. Additionally, the study will seek whether BIM learning is concentrated in isolated subjects, integrated transversally throughout the program, or even complemented with postgraduate courses.

Integrating CeDG into Descriptive Geometry Education: effects on academic performance

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Keywords: Computer Extended Descriptive Geometry, Dynamic Geometry Software, Geogebra, Graphical Expression, Learning

Abstract

Descriptive Geometry (DG) is an essential component of engineering curricula due to its role in the two-dimensional representation of three-dimensional objects. Mastering DG requires advanced cognitive strategies and methodologies that develop spatial perception, logical-mathematical reasoning, and the ability to solve complex geometric problems. In engineering, DG focuses on teaching representation systems and analysing geometric surfaces and shapes commonly used in industrial applications. However, traditional paper-based methods present challenges, such as inaccuracies in drawing execution and limitations in precisely defining curves. To address these issues, CeDG was developed as a solution to enhance the precision of DG procedures. While reducing drafting errors was an important goal, the primary motivation behind the design of CeDG was twofold. First, the need for a computational three-dimensional parametric tool based on DG procedures, and second, the ability to exploit the capabilities of dynamic geometry tools to facilitate the comprehension of space. This is the first study concerned with the second goal. Objective: This study evaluates the implementation of CeDG for teaching DG, applied to the Bachelor's Degree in Electronic Engineering, Robotics, and Mechatronics (GIERM) during the 2022–23 and 2023–24 academic years. The approach is based on the integration of the Geogebra software tool into DG instruction. The study was conducted during the second four-month period (February to May) within the Graphical Expression course, a first-year subject in the GIERM program. The course was divided into four groups of approximately 24 students each. Students could choose between working with traditional paper-based drawing materials or using the dynamic geometry software Geogebra on a laptop. The course structure combined theoretical and practical sessions, where students completed exercises under instructor supervision, following structured timeframes and procedures. Additional reinforcement exercises were provided to strengthen learning outcomes and enhance technical skills. The findings are based on an analysis of academic performance over two consecutive academic years. The study examined both first-year students and the overall enrolled student body. The total number of passing students included those who successfully completed both the second midterm exam and the first official exam. Results from the second official exam were excluded, as it often includes students who do not attend classes regularly, such as those who are repeating the course. Analysis of academic data revealed that students who used CeDG outperformed those who relied on traditional paper-based methods, confirming the perceived increase in student interest due to the use of electronic tools. CeDG has demonstrated its effectiveness in enhancing the learning process for DG by improving precision, engagement, and overall academic performance. Although this is a preliminary study, its integration into engineering education represents a significant advancement in developing spatial reasoning skills.

"Smart Heartbeats". A student project developed within the framework of multidisciplinary teaching

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Keywords: Degree Project; Electronics; Biosensors; Electrocardiogram; 3D Modelling

Abstract

This project involves the creation of a system that integrates a digital finger heart rate monitor connected by Bluetooth to a model of a heart, whose movement is proportional to the beats recorded by the heart rate monitor. The corresponding electrocardiogram (ECG) is displayed in real time in a 1.9" LCD screen. The main tasks implemented in this project have been the measurement of the heart rate using a finger pulse sensor; the synchronisation a heart model that moves to the rhythm of the measured pulse; and the display of the corresponding ECG on an output device.

The components used to implement this system are: 1) a Main microcontroller in charge of processing the heart rate signals and controlling the peripherals. In this particular case, two versions have been tested, the standard and the mini (ESP32-C3), due to its greater adaptability for compact projects such as wrist mounting; 2) a Pulse sensor, device in charge of measuring the heart rate of a patient. In this particular project, the MAX30102 model has been used due to its ease of integration; 3) several Servomotors, which are responsible for controlling the movements of the heart model. The MG995 models were selected since their ideal adequation for their powerful motor, necessary for fluid and consistent movements; 4) an OLED screen, used to display the electrocardiogram in real time. The chosen model has 1.9" with a resolution of 170x320 pixels, based on the TFT-ST7789 controller, which guarantees a clear and precise display; 5) two Voltage Regulators to avoid problems in the system and ensure a stable supply of power to all the components. The first regulator converts from 8V to 6V, providing the necessary power for the servomotors, which require exactly 6V to operate correctly. The second regulator converts from 6V to 3.3V, guaranteeing a safe supply to the ESP32 and avoiding any risk of overheating or damage to the microcontroller; 6) two Rechargeable batteries model 18650, each with 3.7V. These batteries, when charged, can reach a voltage of approximately 4.2V. They are used as the main power source for the entire system; 7) a dedicated on/off Switch for easy and safe control of the system was added; and 8) Wiring and Connection elements necessary to link all electronic components and ensure signal transmission and power supply.

Previously to the implementation of the physical system, a prototype has been modelled using the Inventor Autodesk 2025 3D software. The 3D designs include the following custom parts later manufactured using a 3D printer with PLA filament: the servomotor supports, the wristband case, the display stand and the adjustable straps for the wristband.

The entire software for the system was mainly developed using an Arduino Integrated Development Environment (IDE) with programming in C++, for its execution on the ESP32 microcontroller.

Graphical Expression in Civil Engineering Degrees: content and methodologies

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Keywords: Graphical Expression, Teaching Experience, Civil Engineering, Drawing

Abstract

Universities are not only a part of society, but must also be an important actor in its changes and challenges. For this reason, universities have always modified their contents in order to be updated and to provide a good and useful education to their students. These changes are a common process in the study programme of all universities, what is probably new is the speed with which the digital transformation is changing the society, and this point is directly related to the field of Graphical Expression. This field has changed a lot in the last few years: software improvements with the capacity to make designs unimaginable a few years ago, virtual scenarios to show the information or projects, advances in cloud storage and new types of files to multiply interoperability, developing and managing projects in a digital way with the BIM methodology, and so on.

The subjects of Graphic Expression have to cope with all these changes and the Spanish Civil Engineering Universities are facing them in different ways. Different criteria and interpretations could emerge, all of them equally useful, and each drawing department has its own times. Are the contents of the different civil engineering schools homogeneous? Is the trend the same in the different schools? Are there really significant changes in the content of the subjects? This paper tries to give a summary of the current status of subjects related to drawing and graphical expression in civil engineering studies, to show how the different schools are managing the changes and to identify what are the bases of knowledge related to this area at this moment. In order to achieve this, the curricula of Spanish civil engineering schools have been studied in order to analyse their content, but also their methodology and the most relevant points according to the weight of each section in the study programme.

This paper belongs to a line of educational research started by this group at 2008, and it is a continuation of one paper presented at the same Congress in 2024.

Project-based learning for the design, modelling, calculation, augmented reality and physical model of a mining derrick structure

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Keywords: Design, Modelling, Calculation, Augmeted Reality, Teaching

Abstract

Project-based learning is a type of educational methodology that seeks to involve students in their own learning process through eminently practical projects. In the specific case of engineering, the trend is to introduce innovative practices where the engineer's creativity is a determining factor. Therefore, it is important to introduce in the classroom methodologies that encourage student creativity. With this in mind, a project has been proposed whose main objective is to encourage the active participation of students through collaborative work that allows personalized learning in the subject Theory and Calculation of Structures taught at the Polytechnic School of Mining and Energy Engineering of the University of Cantabria (Spain). This will be achieved through the integration of tasks of a very varied nature subject to continuous evaluation during the course.

The main objectives to be achieved with this project are the design and implementation of innovative learning activities and resources that encourage the active participation of students, as well as personalized learning strategies adapted to the profile and characteristics of the students.

The project consists of the following phases:

1. Bibliographic analysis of mining derricks.
2. Design of a derrick structure.
3. Parametric modelling, including specific training in CAD tools (using Autodesk software and three-dimensional modelling of the designed structure).
4. Structural analysis by performing the matrix analysis of the structure.
5. Representation through Augmented Reality, in this case Unity 3D that can be displayed on Android mobiles or tablets.
6. Construction of a reduced scale physical model of the derrick structure.
7. Public exhibition of the developed work and presentation of results.

The work will be organized in the form of a collaborative project, thus ensuring that learning is personalized, but not individual, giving students a realistic perception of the professional reality, posing a series of personal challenges such as: effective collaboration and conflict resolution; oral and written communication, leadership and management.

The competencies that the student will acquire during the project are the following:

1. Problem solving;
2. Critical and analytical thinking;
3. Personal responsibility, and
4. Professional ethics.

Likewise, the need to develop work under minimum quality standards, constant improvement in time management, adequate planning and prioritization of activities to be developed, adaptability

and flexibility in the face of changes will be encouraged. It is an autonomous and continuous learning, encouraging the search for new knowledge and promoting creativity and innovation.

The objective of this proposal is to alleviate the shortcomings that have been detected in the subject under consideration: the subject is fundamentally theoretical and the calculations necessary for the calculation of the structure are performed manually, without using any type of computer support. For this reason, this project-based learning methodology is conceived, with which a more practical conception of the subject is specifically pursued, in which students can develop a more critical thinking, advancing in problem solving and fostering their capacity for innovation, as well as their creativity.

Color characterization and cataloging of Historic Buildings in the Ensanche of San Sebastián: an educational and research experience

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Keywords: Architectural Heritage, Color Analysis, Graphic Expression, Urban Identity, Educational Innovation

Abstract

This research aims to analyse and catalog the characteristic colors of the historic buildings in the Ensanche of San Sebastián, integrating students from the courses Graphic Expression II and III, researchers from the School of Architecture of San Sebastián, and the company AIADEK. The study seeks to generate a scientifically based color guide that preserves the chromatic identity of the protected buildings in the area.

The study was conducted during the 2023-2024 academic year and consisted of several phases. Initially, students carried out elevation drawings of building blocks, identifying materials and chromatic characteristics. Simultaneously, the research team performed colorimetric measurements of the façades using specialized equipment. Subsequently, students used the collected data to design a catalog of façade colors, following a rigorous methodology that included historical analysis, color selection, and graphic design. A competition was held among the catalogs, with monetary awards for the best proposals. The winning designs contributed to the final version of the AIADEK color catalog.

The research provided a precise chromatic inventory of the Ensanche of San Sebastián, establishing a database of historically and aesthetically significant colors. The project enhanced students' technical skills in architectural drawing and color analysis while fostering collaboration with industry professionals. The competition structure increased student engagement and innovation, resulting in high-quality design proposals. The final color catalog serves as a practical tool for architects, urban planners, and building owners in the conservation and restoration of historic façades.

This initiative demonstrates the effectiveness of integrating research, education, and industry collaboration in architectural studies. By involving students in a real-world project, the study reinforced the importance of color in urban heritage conservation while developing their analytical and creative abilities. The methodology employed can serve as a model for future research-education-industry collaborations in the field of architectural preservation.

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