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REVIEW

Applications of augmented reality technology in design process

Aplicaciones de la tecnología de realidad aumentada en el proceso de diseño

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ABSTRACT

Introduction: design is a complex process that goes beyond creativity and sketch; it includes the integration of opinions, research on current technologies, evaluation of resources, and collaboration of people. Current three-dimensional effect maps do not fully express the designer's intentions; instead, virtual representation with augmented reality (AR) ensures significant improvements in the process. The objective was to characterize the application of AR technology in design process.
Methods: a total of 20 articles in Spanish and English were extracted from Scopus, Science and Springer; using as keywords: augmented reality, industrial design, product design, architectural design, being more than 50 % of the last five years.
Results: AR is a visualization tool that combines digitally created data with the real environment. AR environments within the design have three main characteristics, intuitive observation, informative visualization and immersive interaction. They focus on product visualization, usage simulation and ergonomic analysis, hybrid/augmented prototyping, industrial design assembly. The designer can view and interact with the prototype in a way that is realistic and also able to connect the virtual prototype with materialized designs.
Conclusions: augmented reality technology guarantees improvements in production time, use of resources, effectiveness and acceptance of the design; It allows you to view the model on a real scale, modify and adjust the virtual space at will, as well as great adaptability and the possibility of positive feedback.

Keywords: Augmented Reality; Industrial Design; Product Design Process; Architectural Design.

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RESUMEN

Introducción: El diseño es un proceso complejo que va más allá de la creatividad y el boceto; incluye la integración de opiniones, investigación sobre las tecnologías actuales, evaluación de recursos, colaboración de personas. Los actuales mapas de efectos tridimensionales no expresan plenamente las intenciones del diseñador; en cambio, la representación virtual con realidad aumentada (RA) asegura mejoras significativas en el proceso. El objetivo fue caracterizar la aplicación de la tecnología de RA en el proceso de diseño.
Métodos: un total de 20 artículos en español e inglés fueron extraídos de Scopus, Science y Springer; utilizando como palabras clave: realidad aumentada, diseño industrial, diseño de producto, diseño de arquitectura, siendo más del 50 % de los últimos cinco años.
Resultados: la RA es una herramienta de visualización que combina datos creados digitalmente con el entorno real. Los entornos de RA dentro del diseño tienen tres características principales, observación intuitiva, visualización informativa e interacción inmersiva. Se centran en la visualización de productos, simulación de uso y el análisis ergonómico, creación de prototipos híbridos/aumentados, ensamblaje en diseño industrial. El diseñador puede ver e interactuar con el prototipo de una manera que sea realista y también capaz de conectar el prototipo virtual con diseños materializados.
Conclusiones: la tecnología de realidad aumentada garantiza mejorías en cuánto a tiempo de producción, empleo de recursos, eficacia y aceptación del diseño; pues permite visualizar el modelo a escala real, modificar y ajustar el espacio virtual a voluntad, así como gran adaptabilidad y la posibilidad de retroalimentación positiva.

Palabras claves: Realidad Aumentada; Diseño Industrial; Diseño de Producto; Diseño de Arquitectura.

INTRODUCTION

Design is a complex process that goes beyond creativity and sketching; it includes the integration of opinions and particularities of the target market, research on current technologies, and evaluation of available manufacturing resources and requires the collaboration of a group of people, usually with different backgrounds, to achieve the desired result.[1]

In representing their ideas, designers use tools and methods such as hand sketching, digital sketching

hand sketches, digital sketches, computer models, and physical mock-ups. However, the tools and methods traditionally used by industrial designers are only sometimes sufficient to convey the full spectrum of user interaction offered through the design of a new product.[2] The designer's interaction with the three-dimensional (3D) model is generally restricted to two-dimensional (2D) interfaces such as the mouse and monitor.[3]

As technology advances, contemporary visualization techniques offer new capabilities to project sketched products more realistically than the use of PC monitors.[1] In addition, the scientific community posits that manufacturing processes need to become more responsive and systematic to be efficient and economically competitive.[4]

Augmented Reality (AR) is a visualization tool that combines digitally created data with the real environment.[2] It is defined as a direct or indirect view of a physically real environment, parts of which are enriched with additional digital information relevant to the object being viewed, mainly in textual or pictorial form.[5] It has been in development since the 1960s; however, recent developments have made the technology accessible and in demand in commercial and research fields.[2]

Current three-dimensional effect maps cannot fully express the designer's intentions; instead, virtual representation with AR can take the digital three-dimensional model as the core of the design idea, display the work perfectly in the form of a multidimensional model, zoom and rotate the product through the software, and deepen the relevant personnel's understanding of the product design.[6]

The AR environment within industrial design has three main characteristics: intuitive observation, informative visualization, and immersive interaction.[7] It is a key technology that allows the designer to immerse themselves in a virtual environment where geometry is projected, and they can interact with it and examine it on a realistic scale in isolation or alongside other product designs.[1]

In view of the above, the present literature review was conducted with the objective of characterizing the application of AR technology in the design process.

METHODS

A literature review type study was carried out, where articles in Spanish and English were selected from the Scopus, Science, and Springer databases, carried out in different contexts, with variable typology, using as keywords: augmented reality, industrial design, product design, architectural design. Twenty articles were selected, from which the information of interest was extracted in order to synthesize and order it for the preparation of this research.

DEVELOPMENT

According to the current definition of the concept of industrial design in academic circles, industrial design should include not only the design of form and function of traditional industrial products but also human-machine design.[6]

Product design is a central activity in manufacturing, where solution requirements are projected directly onto products. Decisions made at this level are crucial and affect the cost and success of the entire product.[1]

Product development requires collaboration between multiple employees and organizations, each with unique complementary experiences and capabilities. The primary goal of collaborative design is to reduce time-to-market and comparative costs of new products while maintaining product production reliability and reducing the impact on the environment.[8]

Prototyping is one of the most critical activities in new product development. It determines a large portion of resource deployment in development and influences the success of a design project. Disadvantages of physical prototyping include manufacturing time and cost, which often increase with fidelity and material requirements.[9]

Several research studies have shown that virtual prototypes can be used effectively to validate design solutions in the early phase of product design.[9]

According to Azuma et al., AR must satisfy three conditions to be effective: a combination of reality and virtuality, real-time operation and interaction, and a 3D real world.[10] It can be of great help because of its ability to simulate, assist, and improve your processes before they take place.[11]

Examples of AR can be seen in sectors such as advertising, architecture and construction, museums and tourism, medicine, mechanics and repair, social networking, entertainment, military, and shipping. Research on the use of AR in industrial design activities focuses on product visualization, use of simulation and ergonomic analysis, virtual design environments, hybrid/augmented prototyping, assembly in industrial design, and collaboration across design disciplines.[2]

Why it can be applied

AR is considered a real-virtual link technology, so its applicability in different design sectors guarantees better results in terms of time, cost, and efficiency, as well as educational applicability.

The literature indicates that in computer-aided design solutions need more intuition and facilities such as real-time evaluation of any perspective. At the same time, AR provides greater efficiency and effectiveness for the user.[12] In 2D and 3D design, the user is limited by poor interaction with hardware elements such as the mouse and monitor, unlike in real-time projection.

One of the most critical challenges for the designer in the interior design process is the problem of working on a reduced representation of something that is elsewhere and often larger.[13] At all stages of design, especially in drawing and modeling. However, with AR technology, designers' ideas remain flexible and locked into two-dimensional computer screens without gaining real insight into them and interacting with all the components of the products.[14]

Many of the errors in interior design are due to the reduced adaptability of traditional working models, which require, in part, professional expertise; this is an advantage of AR-assisted modeling.

On the other hand, AR supports geometric representation on a realistic scale in the field of view of the end user's real environment. Therefore, the product designer can see and interact with the new product design in a way that is realistic and also able to connect the virtual prototype with materialized designs (e.g., previous versions of the same product).[1]

It has more advantages than the traditional sand table model. It can realize the design of the full-scale model of the design space. Users can walk through, modify, and adjust the virtual space at will to make it more effective. Humanization and fidelity greatly improve and enhance the overall control and design level of the interior space.[6]

In this regard, the ability to perform real-time comparison with other models, or even follow instructions or perform the process under real-time, non-face-to-face instruction from an experienced professional, ensures the popularity of this technology within the design field.

Among the main benefits cited is the combination of virtual and real objects in the natural environment, real-time interaction environment, creation of an immersive environment, multimedia, and multisensory visualization, portability, ease of use, attention-grabbing, interactivity, providing a sense of existence, conceptual learning, real observation, and perception, sensory-motor, and feedback.[13] The authors consider it necessary to point out the fact that the very adaptability of AR to different scenarios, as well as the possibilities of choosing among the available devices the most suitable for the intended purpose, guarantee better design results.

AR can produce faster and more accurate task completion, reduced cognitive load, and a greater communication base in peer-to-peer collaborations.[15] The importance of using AR technology lies in transferring designers' ideas and perceptions from the two-dimensional environment of computer screens to the physical environment of the real world so that effective judgments can be made about the success of the design and the degree of its integration.[14]

The use of AR in conjunction with aided design can solve some of the problems related to errors in measurements, an adaptation of designs to the final environment, and prototype previewing, and brings some advantages at the industrial and training level since, with the use of AR, the testing of full-scale designs, in reality, is possible to some extent, allowing more visual feedback to be obtained than in the computer-aided design program.[16]

An important advantage of this technology is the possibility of locating, extracting, and reusing engineering information from previous projects and suggesting expert knowledge to designers. This improves the performance of new products, guarantees a positive feedback process, and ensures improvements in aspects such as manufacturing, maintenance, reliability, and ergonomics.[7]

One of the main advantages of AR in Industry 4.0 is its ability to improve efficiency and productivity. It can be used to provide real-time feedback, allowing workers to identify and correct errors, thereby reducing the error rate.[17] The design can be evaluated by faculty or senior designers in a more intuitive and comprehensive way.[1]

Both feedback and the use of guides and previous projects make AR a viable option for industrial, informational, and architectural design due to the characteristics demanded by the activity, in which the user's knowledge and experience are integrated, as well as his or her ability to adapt a product to the needs of a potential buyer-user.

Other authors[15] find that AR improves the efficiency of engineering design by facilitating communication between stakeholders, facilitating visualization processes, and reducing design and construction time. The author attributes singular importance to the role of teamwork and communication in the product design process. AR ensures a safe way to foster a complete understanding of the parties involved and improve the process outcomes, as well as the time it takes to achieve them.

Min Ki Park et al.[10] indicate that among the main advantages of interactive design evaluation with AR is that it saves time and costs needed in product development because evaluations are performed in advance in the design phase without producing a physical prototype. It is possible to exhibit several designs of a product similar to real ones without space limitations. It provides a more intuitive and flexible environment than a design evaluation using a digital display.

It ensures that the company responds quickly to market demand, generates digital prototypes in a virtual manufacturing environment, and predicts and evaluates them. In the industrial design of virtual reality technology, the integration of design, engineering analysis, and manufacturing is realized. The construction of a three-dimensional virtual digital model can provide people with a real experience, modify and operate it in the sense of immersion, and better realize human-computer interaction. In the industrial design of AR technology, it can better reduce design modification, save design costs, and improve design accuracy.[6]

Mixed reality, also applied in various design sectors, utilizes the facilities of virtual and augmented environments, enabling more complete and realistic user experiences. The maturity and affordability of this technology provide the opportunity to synchronize digital and physical elements in real time, allowing virtual information to be clarified in the physical world.[9]

Applications

In the design and conceptualization stage, AR technology helps to evaluate different ideas, compare alternatives, and choose the best ones based on their presence in the real environment. Thus, it provides the designer with numerous technical drawings supported by augmented technical drawings.[14]

In augmented prototyping, AR has been found to be a valuable tool for bridging the gap between low-quality mock-ups that need more details. In this regard, Verlinden et al.[2] have coined the term AR prototyping to describe the process of enhancing physical prototypes with virtual details. It is worth mentioning that one of the limitations due to the characteristics of the physical layout is the time required for its realization, which makes the process an obstacle to the promptness of the design.

In user-centered design, first introduced by Norman and Draper in 1986, prototypes are used for iterative evaluation and validation against user objectives so that designers can better understand user needs.[9]

There is a current trend to allow users to interact directly with manufacturing information associated with manufacturing processes, with AR being the perfect medium to realize this interaction. 4 Virtual reality and AR technologies will facilitate design success in the apparel industry by providing rapid feedback to consumers to improve the performance of new products.[8]

In addition to the quality, performance, and price of a new product, with the application of AR, decision-making in its design has become an important factor for the customer. Therefore, in the product development phase, aesthetic design has become an essential process that is effectively evaluated without the need for actual physical prototyping, reflecting immediate feedback from evaluators.[10]

The author believes that user interaction with the product prior to manufacture ensures better results in terms of customization, conformity, and acceptance since involving the user early in the production or development process, whether material or computerized, ensures that the design results are based on personal requirements and interests. Among the advantages of AR, the literature praises its ability to work based on the adaptation of the user's interests.

Holographic projections are an innovative way of rendering geometry that allows the user to see the geometry in 3D and interact with it. However, existing approaches generally need more rendering quality or offer a limited field from which the user can accurately view the projection.[1]

Botta Design's mobile app, where users are allowed to "try on" different types of watches, is one example of visualizing user-product interaction. Another example is IKEA's printed paper catalog, enhanced with 3D models of the products to show assembly steps and visualize the products in the intended use environment.[2]

Min Ki Park et al.[10] indicate that interactive design evaluation with AR brings among its main advantages: time and cost savings needed in product development as evaluations are performed in advance in the design phase without producing a physical prototype. It is possible to exhibit several designs of a product similar to the real ones without space limitations. It provides a more intuitive and flexible environment than a design evaluation using a digital display.

In relation to the architectural sector, it is possible to create virtual mock-ups using AR that are placed in the desired location, either by markers or by taking advantage of the devices' sensors for projection. This allows user interaction with small models of buildings and monuments for study and testing for possible modifications.[16]

In light of the studies conducted so far, the application of AR in the field of architectural design can be grouped into architectural visualization and presentation, architectural design, preservation and restoration, building implementation and management, location-based information, and architectural education.[13] AR modeling sees among its main beneficiaries architectural designers, who, unlike previous models, can present results to their clients in less time and with better quality.

AR technology greatly expands the creative mode of graphic art design.

Graphic art design. By applying virtual roaming technology in architectural design, it can present a three-dimensional simulation of urban landscapes, residential landscapes, interior design, and historical buildings.[6]

Ben Guefrech, for his part,[18] posits that user participation in collaborative design sessions has always been a challenge. Despite research, finding a suitable way to implement co-design in the early stages of innovation remains problematic. In his study, he compares the results of conventional and AR-assisted collaborative design, with a notable increase in interactions in the latter, as well as increased sharing in meetings.

Masclet[19] proposes the use of AR environments in co-design sessions based on the fact that traditional methods are cumbersome and time-consuming, needing to be revised for the analysis of large industrial environments. It uses real-time "on-the-fly" coding of physical interactions in co-design sessions.

Patrick Bourdot et al.[7] presents a conceptual model to facilitate the collaborative part design and immersive product reviews, granting access to operators of construction history graphs, facilitating integrated haptic feedback and physical perception support of the components to be designed.

The author's experiences allow us to affirm that collaborative design, being a modality used mainly in the industrial and informational sector, sees AR as an adequate means to improve communications and the anterograde flow of information among those involved, as well as a real-time guide to direct the modeling effectively, adapting to almost all possible scenarios. An interesting example is the design of luminaires, a complicated task that requires both professional training and practical experience. Fully automated systems are not accepted by the manufacturing industry because they need more intuitive interaction and immediate feedback. Peng Gaoliang et al.[7] propose an AR model that allows a development process with spatial visualization and multiple views to aid in information representation and management.

A hologram is a design application that creates a platform for mixed-reality design and construction. Users include universities, multinational architectural firms, industrial designers, engineers, and artists. This application combines the designed travel configuration and the power of the designer to represent themselves in that space and at its scale and brings it to the same layer of representation.[13]

Other projects that use AR with conceptual design are those developed by different universities, such as ARCADE at the University of Singapore, which allows the creation and modification of designs by combining virtual or real elements. The AUGMENTABLE project at Iowa State University consists of a transparent screen with video capture devices for the recognition of color markers on users' hands.[16]

One of the industries in which the use of AR is quite common is the automotive sector, not only because of its advantages for the manufacturers' technical staff but also because of the opportunity for potential future users to check the chosen model with the desired characteristics by using AR, without the need for its express configuration to be available at that moment or for these same users to have the opportunity to view it at any instant.[16]

In the automotive industry, AR has been used to evaluate interior design by superimposing different car interiors, which are generally only available as 3D models in the early stages of development, on real body mock-ups.[4]

It is employed to find and solve problems with car assembly or parts in advance. Through the construction of a three-dimensional automobile model, designers can better experience the degree of comfort, the degree of driving simulation, the simulation of automobile interior faults, and improve the rationality and science of the design index.[6]

In contrast

Despite the established advantages, AR technology has yet to be widely applied in industrial environments. Some possible causes could be that the devices are often not suitable for production environments, battery run time, and the technology requires training and experience for its application.[12]

The author includes among possible disadvantages also limiting by the characteristics of portable devices that are not suitable for the design task in which they are intended to be applied, or the need for qualified personnel for their use and maintenance, as well as the digital support required for the use of AR.

It should also be noted that AR technology was born in developed or developing countries, so its use is not globalized, as the necessary digital support is one, if not the main, limitation in third-world countries.

Design education

To support effective product design, the stakeholders involved must have the required level of knowledge and a good perception of product design. This highlights the need for young engineers aspiring to be involved in manufacturing to have the right competencies to be able to perform well in an industrial environment. To achieve that goal, educational institutions must provide suitable learning environments that allow aspiring engineers to have sufficient experience and technical training in simulated environments before engaging with industrial cases.[1]

AR sees its main boom in the educational sector, one of the first scenarios in which its use became popular. Therefore, its applicability to the educational process of students in design careers guarantees independence and self-study as the main educational models in the 21st century; this technology provides an interactive and dynamic platform for teaching activities, mainly through distance learning.

Scientific-technological teachings can benefit from the possibility of explanations or the transmission of knowledge more clearly and simply, thanks to the possibility of seeing elaborate designs in a real environment without carrying out any prototype or final product manufacturing.[16]

Dimitris Mourtzisa et al.[8] propose a cloud-backed platform for the necessary data; users connect through mobile devices or head-mounted accessories so that students or the designated team can collaborate on the design of a new product in real-time, exchange meaningful information about the process without risk of losing the data, through vivid visualization during the whole procedure.

Hsinfu Huang,[20] applied AR technology to enhance the learning experience of product styling design students in a distance learning environment. The results showed that learning content directly affected the distance interaction, and perceived ease of use was an essential mediating variable. Students had positive attitudes toward the AR-assisted learning interface, and their feedback indicated that the 3D visualization stimulated their learning motivation and enhanced their behavioral intentions. (Hsinfu Huang, 2022)

The main limitations of the study include its bibliographic nature, the fact that no metric study of the literature was performed, and the criteria for selecting references due to their age.

CONCLUSIONS

Augmented reality technology in the design process guarantees improvements in terms of production time, use of resources, efficiency, and acceptance of the design since it allows visualizing the model at real scale, modifying and adjusting the virtual space at will, as well as great adaptability and the possibility of positive feedback.

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