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Application of augmented reality in automotive industry

Denis Gonzalez-Argote[1], Adrián Alejandro Vitón-Castillo[2], Javier Gonzalez-Argote[3,*]

[1]Universidad Argentina de la Empresa, Facultad de Ingeniería y Ciencias Exactas, Carrera de Ingeniería Informática. Ciudad Autónoma de Buenos Aires, Argentina.
[2]Universidad de Ciencias Médicas de Pinar del Río. Facultad de Ciencias médicas "Dr. Ernesto Che Guevara de la Serna". Pinar del Río, Cuba.
[3]Fundación Salud, Ciencia y Tecnología. Ciudad Autónoma de Buenos Aires, Argentina.

Abstract

Introduction: Augmented reality is defined as a direct or indirect vision of a physically real environment, parts of which they are enriched with additional digital information relevant to the object that is being looked at. In the field of engineering design, there is a wide range of industries that use this technology, such as automotive, aircraft manufacturing, electronics, engineering; so that it has gained popularity in assembly, maintenance and inspection tasks. The objective was to characterize the use of augmented reality in the automotive industry.
Methods: a total of 20 articles in Spanish and English were reviewed, from Scopus, Science and Dialnet; Using as keywords: augmented reality, automotive industry, manufacturing, being more than 50 % of the last five years.
Result: its main advantage is considered its potential as an interactive and intuitive interface. It promises to provide the correct information to the human operator at the right time and place. If it is considered an ideal environment in which the RA is applied safely, in adequate balance between automated processes and human control over them; The level of production and its quality will be positively affected.
Conclusions: Augmented reality is applied in areas of the automotive industry such as logistics design, assembly, maintenance, evaluation, diagnosis, repair, inspection, quality control, instruction and marketing; in order to guarantee better work performance, productivity and efficiency, mainly mediated by portable devices. Its degree of acceptance, although growing, is not yet clear.

Keywords: Augmented reality, automotive industry, manufacturing.

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1. Introduction

In many industries the implementation of modern technologies brings success in the global marketplace, drives a company's innovation and can even reduce production costs by maximizing profits. [1-9]
In the early 1990s the first public demonstrations of augmented reality (AR) began to take place at exhibitions and the prospects were quite promising for some of the industry observers who began their own experiments. [10-17]

AR 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. [18-23]
In recent years, many automakers have developed a strong interest in AR, mainly due to its accessibility and potential to generate innovative solutions. [1] Companies such as Volvo, Ford or Hyundai, use the technology to increase their efficiency in the design phase, processes, as well as in marketing or sales. [24-32]

*Corresponding author. Email: jargote@saludcyt.ar

According to Cohen et al, [4] up to 43% of manufacturing companies say that the use of AR in manufacturing will become standard in the next few years. [33-38] It is ranked by the European Union as one of the main technologies that will drive the development of smart factories.
Applications of AR range from industrial activities to everyday life activities, in various domains, such as manufacturing, robotics, healthcare, education, military, entertainment, etc. [39-47] In the field of engineering design, there is a wide range of industries using this technology, such as automotive, aircraft manufacturing, electronics, engineering, furniture manufacturing, etc. [48-53]
Automotive companies have introduced AR technology into manufacturing environments for assembly, maintenance and inspection tasks. They can benefit from providing informational-type operator assistance, complementing other technologies and telepresence systems. [54-61]
As technologies become more and more widespread in the industrial sector, the role of the logistics employee is changing. He or she will be integrated into existing processes as a controlling and monitoring actor. In contrast to machines, in the digital environment, humans are attributed with higher cognitive competencies. [62-65]
Even knowing all the potential advantages, market-ready AR tools are still scarce and as a consequence their real benefit in industrial contexts is not clearly demonstrated. [66-69]

A literature review was conducted with the objective of characterizing the use of augmented reality in the automotive industry.

2. Methods

A literature review was carried out where articles in Spanish and English from the Scopus, Science and Dialnet databases were analyzed in different contexts, using as keywords: augmented reality, automotive industry, manufacturing. The information of interest was extracted from the 20 selected articles in order to synthesize and order it for the preparation of this research.

3. Development

The wave of automation and digitalization in the production sector is referred to as the fourth industrial revolution or "Industry 4.0". [70-76] The vision of Industry 4.0 is to build cyber-physical production systems that connect the physical and digital worlds seamlessly to make manufacturing increasingly intelligent and thus increase adaptability, autonomy and flexibility. [77-84]
The main objectives of the Industry 4.0 era are higher levels of task efficiency and a rapid increase in productivity in work areas. Technologies used for these purposes include internet-based activities, wearable smart devices (glasses, watches, sensors), cyber-physical systems and AR. [85-89]

Although the positive impact of today's technological development in all spheres of everyday life can be assumed, its arrival in production processes can be described as controversial and heterogeneous. The acceptance by investors and producers determines the degree of its popularity.
Thanks to the state-of-the-art technology of our times, AR can be considered as a fully immersive environment, which allows the possibility of creating personal, realistic, unique and interactive experiences. It also provides users with the ability to interact with the virtual world and customize it according to their requirements. [90-92]
The automotive industry has experienced significant development mainly due to the adoption of new advanced technological improvements supported by AR such as virtual mock-up and prototyping, advanced manufacturing techniques based on sophisticated robotic systems, automated vehicle safety and user-friendly interfaces to enhance the driving and experience. [63,71]

Acceptance in the automotive industry

It contributes to automotive areas such as maintenance, repair, diagnostics, inspection and training. The increasing popularity of AR is mainly due to its potential as an interactive and intuitive interface. [1] One of its most important applications is to assist mechanics in their tasks. [22,53]

AR can be used for assembly operations in smart manufacturing, either in training or as a live guidance system for operators. In logistics, "vision picking" is a prominent concept using industrial AR to indicate pick locations and quantities. Other areas of logistics where AR can be used are general warehouse operations, quality assurance, maintenance. [54]
It allows users to obtain certain information they need about some aspects or procedures directly in the work environment and has the potential to enrich a person's sensory perception. [1] AR promises to provide the human operator with the right information at the right time and place. [7] See the above as one of the main benefits brought by the application of this technology, which can solve a lot of training and work practice problems.
Technicians can use AR-based systems to follow live instructions on methodology to be applied for vehicle diagnosis and repair, as well as measures to be taken in each case; this reduces the time needed for learning and mental effort. So even inexperienced people can work as mechanics following 2D, 3D instructions or through AR applications. [81]
Another way in which AR can have a big impact is face-to-face training. Modern production processes require more complex and numerous skills to operate. [3] It is more intuitive than handwritten instructions because it can show the instructed person directly how and where to perform the tasks in the training model. Thus, learning times are shortened because no mental transfer is needed and the instructed person can only see the instructions in front of his eyes. [11,93]

The AR training system can be useful for both job task training and job task orientation for novice technicians in a real work environment. [10,12] It is known that the main areas that have benefited from AR have been education and health, and research shows the superiority of the application of AR over other instructional modalities. On the other hand, the main limitation would be the computer requirements and the need for trained personnel for its use. AR also enables an efficient training modality for maintenance and assembly that accelerates the acquisition of new skills by technicians in maintenance procedures. [41,94]

Unfortunately, some failures cannot be easily predicted and in these cases maintenance requires an in-depth analysis of the problem and the presence of expert maintenance operators to perform the repair task. A possible advantage would be that local operators can try to fix the machine by communicating with remote experts using any multimedia and AR support, i.e. sending images, videos, chatting, talking through handheld devices. [12,95]

Although it represents a firm solution to many problems in the industrial endeavor, special attention must be paid to the fact that no technology surpasses the capacity and effectiveness of human practice, thus the authors emphasize the need for the application of AR and its dependence on experienced implementers to be effective hand in hand.

Technology in manufacturing makes it possible to visualize both the actual environment and the information displayed on the screen at the same time. [96] Visualization within the industry has increased lately due to advances in hardware and software. Improved data visualization on the shop floor provides support to cope with the increasing complexity of production and to monitor objects. It allows personnel to make decisions based on real-time data displayed in user-friendly interfaces. [13]

AR enables specific, real-scale visualization of important information. This can support visual imagination during the design process. Especially in the field of factory planning, errors and planning time can be reduced. This results in improved quality of work. [5] The author believes that all industrial processes that take place in digital environments will be favored by AR, the conflict of the issue begins in activities that, over time, have involved or required human presence or control for its proper development.

Recent studies suggest that with employees starting to work with virtual reality tools (they were equipped with a tablet), the company found a significant 90% improvement in execution quality. Engineers who started working with virtual reality tools accelerated the speed of assembly of aircraft parts by 30 %. This means that, in the same time, a team can assemble 1.3 times the normal speed. [2]

By providing flexible real-time information, hands-free AR can offer a substantial efficiency benefit by decreasing the error rate during pick-up or assembly, and provides easy ways to communicate with experts on maintenance tasks. [4]

It can also help overcome personnel failure or absence, improve productivity through the hands-free option reduces the number of errors, as well as smoothing and speeding up processes by shortening machine downtime. [14]

Nowadays, human factors play a crucial role in industrial procedures, which depend most of the time on specialized personnel, operators dedicated to these inspection activities. In this context, distraction, fatigue and lack of training can result in errors that in turn can compromise the effectiveness of the task. [6]

In the case of quality inspections, it allows combining the information provided by an automated camera-based inspection system with the experience and skills of human workers. [7] The use of this technique is a promising approach to enable more efficient and flexible industrial quality inspection. AR is an effective enabler of real-time human collaboration with artificial intelligence. [7]

The use of AR in quality control processes can significantly increase task efficiency and reduce errors by keeping the worker focused on the task by providing visual feedback where needed. It can also reduce operating costs through increased spatial awareness and reduced error, time and cognitive workload. [6]

Existing internationalization, increasing pressure to innovate and individual customer demands are responsible for a great variety of vehicles. This and other aspects cause an increase in complexity in automotive manufacturing and lead to the continuous emergence of new challenges for intralogistics. [5]

Only well thought-out and innovative logistics planning guarantees a frictionless process in operational logistics. All this implies a high degree of flexibility and adaptability during the entire logistics planning process. One possibility for improving intralogistics processes can be the use of AR. [5]

The application of this technology in logistics planning will mean improvements in production processes, education and safety. In addition, there may also be a satisfaction of work processes due to a simplified presentation of information. [5]

For assembly processes, AR-based methods have been proposed to provide direct and accurate information to operators in order to reduce their mental workload and improve work efficiency. [8]

Although large assemblies often pose great challenges for workers, such processes are not included in semi-automation due to the payload limitations of collaborative robots. And is that, AR provides the perfect gear by providing manual guidance systems for worker adaptation and worker accompaniment. [15]

The author considers that the main cause of the delay in the application of technology in this area is the fact that errors in the assembly processes can result in human and material losses, depending on the characteristics of the industry in which it is applied; therefore, as long as the scientific evidence on the subject is poor, its degree of application will be affected following the principle of direct proportionality.

In addition to high-level decision making, a large number of studies attempt to extend the cognition capabilities of

AR-guided robots to improve their efficiency and ensure safety. By implementing perception systems, operator behavior can be monitored, so robots can adjust their trajectories and activities online. [15]
Panel assembly operations represent a delicate phase of the assembly process, during which body components are manually aligned while trying to respect clearance tolerances. Digital technologies currently driven by the Industry 4.0 approach, such as collaborative robots and AR, could help workers reduce the execution times of this "trial-and-error" procedure. On the one hand, human-robot collaboration can improve the efficiency of the assembly process by combining human dexterity and cognitive capabilities with robot repeatability and heavy load handling support; on the other hand, AR can provide interactive instructions to guide workers through the process. [16]
Extended reality, which includes AR, virtual and mixed reality, enables the creation of vehicle prototypes by automakers that can be easily adjusted and tested without the use of physical prototypes. As a result, it is possible to test a vehicle's aerodynamic performance, [17] fuel efficiency and other critical performance measures more thoroughly and accurately, which can save time and money. [9]
In addition to those already mentioned, other applications related to these areas can be mentioned: education - teaching/learning tools for students of automotive programs, [18] road safety - prevention of life-threatening situations, [19] logistics - increasing process efficiency, ergonomics - testing and validation of cooperative workplaces. Therefore, AR offers engaging ways through which one can interact with digital content, having the ability to enhance senses and understanding. [9]
If an ideal environment is considered in which AR is applied safely, in proper balance between automated processes and human control over them; the level of production and the quality of production will be positively affected.

For industry customers
This technology has recently been used as a *marketing* tool so that customers can interactively adjust their carts before placing their order. [1] Sales and *marketing* being other major areas where AR has rapidly gained popularity.
The benefits of augmented reality in automotive should be attributed to design, virtual prototyping, manufacturing, virtual assembly and training. [9] Virtual and augmented reality in automotive have the potential to reduce the number of screens inside the car and improve its design, production and maintenance, as well as the driver experience. [2]
AR ensures safer driving conditions, a novel information presentation for the automotive industry. It can provide real-time passenger routing information, traffic information, as well as traffic management data. It can also be used to evaluate safety issues such as crash prevention, road safety, among others. The driver can use these systems to feel more comfortable in the vehicle and increase attention while driving. [1]
Vehicle windshields can be used as navigation aids, representing a perfect medium for augmented displays. Companies have developed systems to display various information in the driver's field of vision, such as warnings when a pedestrian wants to cross the road, highlighting traffic signs and thus improving safety. [1]
The benefits of AR for the industry can come from driver training itself, ensuring a high level of knowledge of traffic laws that contributes to the prevention of accidents, thus fulfilling a social function. Its collateral use in accident prevention also seems to be a tempting option.

Applied accessories
The use of mobile devices makes it possible to apply AR directly in a factory, as the required information can be accessed at any time. An advantage of these devices, in addition to their ubiquitous nature, is that they can be used universally without being restricted to specific locations. In addition, mobile devices are small, lightweight, universally usable and characterized by high performance when employing AR. [5]
The author believes that the fact that one of the requirements of technology is the possession of mobile and portable devices makes it a concrete and accessible option, given the popularity of these technological devices.
Automotive companies are constantly striving to improve the human-machine interface, which is a key component of automotive development. They have tried to develop complex systems, integrating AR devices such as *Google Gass*, RGB-D sensors for 3D movements, systems involving sound experiences. All with dual purpose, enriching the driving experience and preventing accidents by increasing driver perception and attention. [1]
It is proposed that AR glasses help the employee with the operation processes, increase the speed and quality of work, provide both a safer environment for employees and more effective communication between workers and machines. [8] It remains to be analyzed the real cognitive impact and possible counterproductive consequences of the use of glasses and accessory devices in the industrial context, as well as their limitations.
Atici Ulusu et al, [8] in their study on the effects of AR glasses on the cognitive load of assembly operators in the automotive industry, found that there was a lower cognitive load for employees in the case of using AR glasses, so that the use of AR glasses can be considered as favorable if one values the fact that it improves communication, speed and quality of work.
Headmounted displays are well suited for industrial work, as they allow hands-free operation and provide information constantly in the field of view, thus minimizing the need for attention shifts. Popular accessories include *headmounted displays*, mobile AR systems, displays and spatial AR. [7]
In Romania, LINDE uses some applications with AR and virtual reality, among them: the LindeGO smart glasses and the FreezAR application for remote support in the different plants. When using the LindeGO smart glasses application, an instant live audio-visual link can be arranged with one

of Linde's experts, who can then view the plant live and try to solve the problem. The technician *on site* can immediately follow the information and instructions via the live audio-visual link. [2]

Intralogistics planning faces the problem of adapting planning data to the specific conditions in the assembly hall. Anke Rohacza, [20] proposes location-based tracking and mapping with handheld devices as a possible method to enable continuous AR use in large indoor areas.

Dalle Muraa, [16] proposes a model for the assembly workstation in which the station is equipped with a collaborative robot and AR capable of assisting and guiding the worker in panel assembly operations during car assembly. Among the advantages offered are: improvements in the separation and unloading error detection process with selection of the recovery procedure, step-by-step guidance, fast feedback, time saving in the panel assembly phase. It is valid to clarify that its application to production is quite limited according to the literature.

SOLDAMATIC Augmented Training is the world's first AR-powered welding training solution. It applies new technologies such as AR to enhance the learning process and uses real welding equipment to develop skills and muscle memory. Soldamatic can be used in the aerospace industry and in the automotive field for training. [2]

In contrast

The possible disadvantages are obvious: reduced productivity, an increase in rejected products and, therefore, higher costs. [3] Material and human damages would be other possible negatives of the fear in the opinion of the author.

In collaborative manufacturing systems, operators can work side-by-side with robots and share resources and even tasks at workstations in an unrestricted manner. However, in this barrier-free coexistence, confusion and challenges arise in terms of task assignment, interaction, adaptive control and safety that can lead to low acceptance of these partnerships. [15,97]

The use of technological advantages requires both qualified personnel and adequate technical and digital support for its correct operation. In addition, its application is extralimited to countries with a high degree of development.

Other reasons why AR has not yet become popular in industrial practice could be the low performance/cost ratio of the software and hardware technologies available on the market. Tracking technology always seems not to be accurate enough as required in industrial applications. Batteries do not allow prolonged use. [12,74]

Among the main limitations of the study are that it is of a bibliographic nature, only articles in Spanish and English were used, and the bibliography was filtered according to its age.

4. Conclusions

Augmented reality is applied in areas of the automotive industry such as logistics design, assembly, maintenance, evaluation, diagnosis, repair, inspection, quality control, training and marketing, in order to ensure better work performance, productivity and efficiency, mainly mediated by portable devices. Its degree of acceptance, although growing, is still unclear.

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