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Review

An Overview of Augmented Reality

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Abstract: Modern society is increasingly permeated by realities parallel to the real one. The so-called virtual reality is now part of both current habits and many activities carried out during the day. Virtual reality (VR) is, in turn, related to the concept of augmented reality (AR). It represents a technology still in solid expansion but which was created and imagined several decades ago. This paper presents an overview of augmented reality, starting from its conception, passing through its main applications, and providing essential information. Part of the article will be devoted to hardware and software components used in AR systems. The last part of the paper highlights the limitations related to the design of these systems, the shortcomings in this area, and the possible future fields of application of this extraordinary technological innovation.

Keywords: augmented reality; virtual reality; Industry 4.0; vehicle maintenance

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1. Introduction

The term augmented reality (AR) was coined in 1992 by Boeing researcher Thomas Preston Caudell, who developed an AR application for industrial use to view some assembly diagrams. Today, there are several definitions of AR [1], although the most shared is that provided by Paul Milgram (Department of Industrial Engineering, University of Toronto) and Fumio Kishino (Department of Electronics, Information Systems, and Energy Engineering, Osaka University). They theorize the existence of different types of reality that create a continuum, which, starting from the real world, lead to a completely virtual world [2].

In their definition, the following environments are distinguished:

- Real Environment (RE): it is the environment in which we live and is governed by the laws of physics;
- Augmented Reality (AR): physical reality in which participants also see virtual elements;
- Augmented Virtuality (AV): it is a virtual reality in which the participants also see real elements;
- Virtual Reality (VR): represents a synthetic world in which the participant is completely immersed.

In Figure 1 we can see the schematic representation of the Reality–Virtuality Continuum [3].

AR's basic functionality consists of creating links, direct or triggered by user interaction with the device, between the real world and the information generated by a device or electronic information. This circumstance provides an interface to the user of an electronically enhanced physical world. AR is the technology that aims to digitally integrate and expand the physical environment or the user's world, in real time, by adding layers of digital information. This integration can be applied to various display technologies capable of overlaying or combining information (numbers, letters, symbols, audio, video, graphics) with the user's view of the real world.

AR can superimpose computer-generated information on real-world views, amplifying human perception and cognition in new and extraordinary ways. There are different types of technologies in which AR can be applied, each pursuing different objectives or applications, such as those mentioned below:

- marker-based AR;
- AR not based on markers;
- AR based on projections;
- AR based on overlaps.

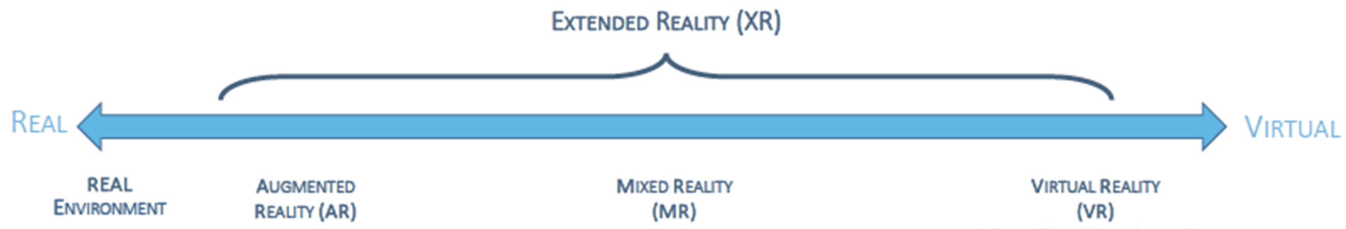

Figure 1. Reality–Virtuality Continuum schematic [1].

In particular, it is possible to analyze each of these different operating technologies or systems that exploit AR. Marker-based technology typically uses a camera coupled to a device marker as a real-world visual object; in this way, a unique and specific result will be displayed for the marker used. Applications that exploit this technology use simple, distinctive models as markers, such as QR codes, as these can be easily recognized and do not require particular processing skills for recognition. This technology is often called "image recognition".

On the other hand, markerless technology is the most commonly implemented technology in applications that use AR. In these cases, tools such as GPS, digital compass, speed meter, or accelerometer integrated into the electronic device are used to provide data based on its position. This application is also called "by location" or "geolocation". It is commonly used for address mapping and to find a specific address.

The applications that exploit the projection technique instead use real objects whose projection of artificial light from the real world is considered. Applications based on this type of technology allow human interaction by sending light onto a surface in the real world and then feeling the human contact with this projected light. Interaction with the user occurs when there is a difference between the expected projection and the actual projection. A user causes the latter. In this type of AR, failure to use a marker determines the need for greater computational power, helpful in processing virtual elements. Therefore, devices with greater processing power will be required to enjoy the experience of its operation fully.

Finally, the AR technology based on overlaps must be considered. This application partially or totally replaces the real-world view, superimposing an object with an enlarged view of the same object. In AR overlay, object recognition is vital because the application will not replace the original view with an augmented one if it cannot determine or recognize the object.

This work presents an overview of the main applications of AR, paying particular attention to its application to the industry of tomorrow. This technology can provide significant support in various fields of industry [4,5]; it is possible to think, for instance, of predictive maintenance in the automotive sector or the development of AR applications in the world of video games. A section of the article will be dedicated to hardware and software systems that support AR systems. Another chapter, as already mentioned, will be dedicated to the development of AR technologies in the context of Industry 4.0. Finally, the pros and cons determined by the introduction of these emerging technologies will be evaluated.

2. Applications in AR

2.1. A Brief History of AR

Although the definitions of AR, mixed reality, and VR date back to the 90s of the last century, the application and study of these technologies can already be found in the late 1950s. A first example is that of the 1957 Sensorama Simulator [6], developed by Morton Heiling. This simulator, slightly larger than an Arcade Cabinet in a game room, allowed the user to view 3D stereo images, enhanced by sensations such as vibrations, wind, feedback on the handlebars, stereo audio, and a specialized system for reproducing scents.

In 1966, Ivan Sutherland made the so-called "Sword of Damocles" (see Figure 2). The first helmet was equipped with lenses for AR. It made it possible to view images superimposed on the real world. It was developed to help helicopter pilots land at night by operating cameras with the movement of their heads. It took the name of Sword of Damocles as this mechanism, due to its excessive weight, was attached to the ceiling using a rotating arm that assisted the movement of the head [7–9].

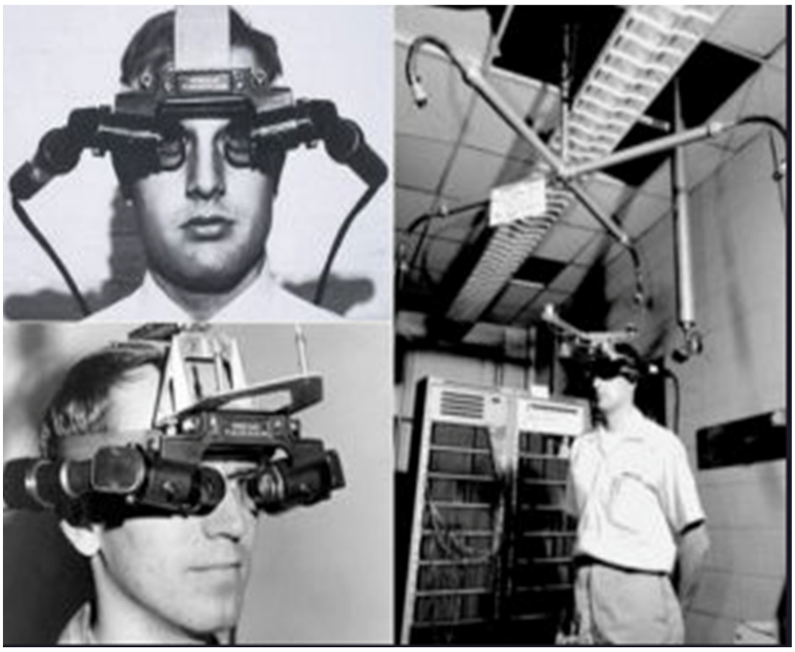

Figure 2. Configuration of the "Sword of Damocles" [7].

In the mid-1970s, Myron Krueger developed VideoPlace, an interactive AR laboratory. With this application, the user does not need to wear specific glasses as they interact with a video that shows some silhouettes created from other people's movements in other rooms. In 1992, Louis B. Rosenberg developed Virtual Fixtures, the first immersive AR system, guiding robotic arms. The main application of this device was for use in the US Air Force (USAF).

In 1993, S. Feiner, B. MacIntyre, and D. Seligmann created KARMA (Knowledge-based Augmented Reality for Maintenance Assistance). This first system uses AR and markers positioned on a printer to guide maintenance users by projecting a superimposed ghost image. In 1999, Hirokazu Kato of the Nara Institute of Science and Technology developed the first cross-platform open-source library called ARToolKit. It allows the recognition of square markers in real time [10].

With the advent of the new millennium and technology always in continuous development, giant steps have been made every year to develop new AR technologies. For instance, in this sense, think of all the things considered science fiction but that are now possible through new technologies such as AR and VR [11].

However, it should be noted that there is a substantial difference between VR and AR: the former replaces the natural environment with the digital one, projecting the user into this simulated environment using a computer; the second, on the other hand, projects digital objects into the natural environment using head-up devices, AR glasses, or commonly used devices such as smartphones or tablets, thus adding virtual information to the actual space [12,13].

AR consists of interfaces that allow interaction between users and digital content, such as 3D objects, superimposing them in real time on the physical environment that surrounds the user. For many years the use of AR has been limited to cases of academic laboratory use and for specific tasks on an experimental basis such as maintenance and repair; today, however, AR can be used in a wide range of applications.

The main objective of this technology is to provide the user with additional and valuable information. This great potential projects these new technologies into various applications, such as medical, military, driving assistance, entertainment, and many others [14,15].

2.2. Game Applications

In particular, AR attracted the attention of many users when the so-called Google Glass was developed in 2013 (Figure 3).

Figure 3. Google Glass [8].

These glasses represent an HMD (Head Mounted Display) device in the shape of glasses that allows you to view applications and web pages in AR. Microsoft has also tried to implement its version of 3D glasses using AR technology; thus, the so-called "HoloLens" (Figure 4) was born, an HMARD device that can be positioned on the head. However, AR systems are not limited to specific wearable devices but are also implemented on smartphones by improving algorithms [16,17]. In particular, in 2016, a game application called "Pokemon Go" was launched by Niantic and Nintendo, which made a boom in downloads in just one week. Another AR application exploited by the Nintendo Switch, a well-known Nintendo home console, is represented by the game "Mario Kart Home Circuit" (released on 16 October 2020).

This new game takes full advantage of this technology. The use of cameras and sensors allows mapping an AR circuit based on the surrounding environment, thus making the real and virtual GoKarts interact in real-time (Figure 5).

Figure 4. HoloLens [8].

Figure 5. Mario Kart Home Circuit.

2.3. Medical Applications

AR, combined with the IoT, exploiting the integration with WSN (Wireless Sensor Network) and WBAN (Wireless Body Area Network) networks, has improved various sectors such as healthcare, school education, entertainment, tourism, and the user's daily life in general.

For instance, in the medical field, applications that leverage the IoT aim to provide unique functions and services through the use and management of medical databases, such as the remote monitoring of patients, identification and prevention of critically ill patients, and of any pathologies and support for elderly patients who use an intelligent environment [18]. The use of AR in the medical sector allows for the diagnosis of pathology in a short time through the use of applications, including "EyeDecide", to facilitate blood sampling through the use of portable scanners that project the exact position of the veins, to facilitate surgical interventions through three-dimensional visualization of the part of the body to be operated on, and much more [18].

2.4. Other Applications

In the school environment, AR technologies can help students to understand some technical concepts better. For instance, through the use of simple smartphones equipped with AR applications, the entire structure of the human body or the molecular structure of a chemical agent, or even the structure of the solar system can be viewed in 3D [19].

In the commercial sector, technologies that exploit AR would be beneficial to more easily sell a specific product or to help the user during the purchase through the use of applications that allow viewing in 3D with the use of a camera; in this way, the chosen product could be seen in real time with different colors or any accessories before purchase [19]. In the tourism sector, IoT applications combined with AR could be used to provide various services relating to the status of flights and baggage, or for assistance during travel within an unknown city, through the use of applications that allow viewing interactive maps, buses, and metro lines, or allow travelers to automatically book a taxi based on their preferred location and preferences [20]. Nowadays, there are several fields in which these technologies are already taking hold. For example, AR is used in museums for guided tours or in general IoT applications used in private homes and smart cities [21,22].

3. AR Systems

3.1. Hardware and Software

The numerous applications of AR require specific software and hardware. Generally, however, the software used exploits the coordinates of the real world through cameras and tracking devices; the aim is to transfer this position information to an XML file, using the so-called ARML (Augmented Reality Markup Language). The functional blocks of ARML allow the fusion between real and virtual worlds by specifying the connection between them; this allows the incorporation of virtual objects in the real world. These objects are controlled based on the movements implemented by the user (Figure 6). Most of the hardware components used in AR applications are IoT devices that can be divided into:

- Input devices: these devices allow users to interact with AR systems. The AR interface acts as a mediator between these devices and the AR system. A typical example may be the interface used in the VOMAR application. The user can rearrange the furniture in his home using gestures that subsequently translate into commands in the application. Another example of an input device is gloves with built-in sensors, which can be used in various AR applications for drawing, gaming, and many more. The inputs can be of various types and nature: from gesticulating to blinking, touching to speaking [23,24].

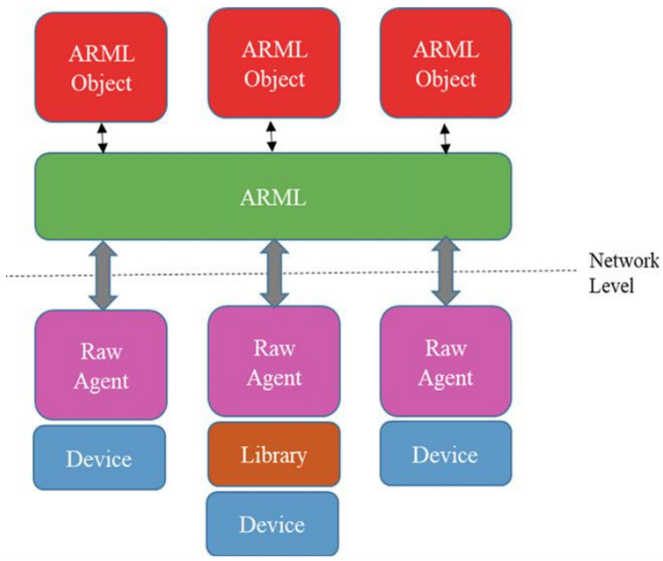

Figure 6. Functional blocks ARML [20].

- Sensors: these devices, useful in the tracking mechanisms, allow determining of the generic user's position or the generic object. This operation is essential for the visual recording of the physical environment and its digital information; in this way, it will allow a fusion of images of the physical world and the digital world. The composition of the scene is possible through the use of data traced by cameras or 3D models. The tracking devices and techniques are different (GPS, ultrasound, to name a few) and have different settings and ranges; they improve the tracking accuracy of the AR system.
- Display: these devices allow users to interact with the AR system. Examples are HMDs, monitors, and wearable devices (such as glasses, gloves, and clothing). HMD includes one or more cameras based on holography and optics (diffraction and reflection) techniques. These devices are typically placed on the user's forehead during use in a specific application (from videogames to the medical sector to the engineering field. Another device slightly different from the one just mentioned is the HUD (Head-Up Display). It is a very compact and lightweight device that provides additional information during any user's activity. Finally, Google Glass, Hololens, and smartphones also fall into this category [25,26].

The main feature of an AR system is that of offering a service in real time. This technology does not just improve the user experience. It also provides a great business opportunity for service providers and, therefore, for companies. The development of smartphones, sensors, high-end camera quality, tracking technology, and wireless networks allowed the implementation of AR applications even in mobile environments. However, there are some attributes to consider when designing an AR system and its related architecture. Such quality attributes are classified as common attributes and high priority. Considering the immersive property of AR, the attributes of high priority include latency in rendering and monitoring, the Quality of Service (QoS), or parameters such as the bitrate, packet loss, ping, management of multiple devices, reusability, and integration of new architectures with those already existing. On the other hand, low priority attributes include the reconfigurability, security, uptime of the system, fault tolerance, user preferences, and multiple hardware support.

As for the software part, the two most important players in the market, Apple and Google, have interpreted AR through their development platforms, ARKit and ARCore [27].

ARKit is an iOS app development kit. Apple unveiled ARKit at WWDC'17, and, almost immediately, it was available to developers around the world. ARKit's advanced features are limited to devices with A12 Bionic or higher chip variants. Currently, the A12 Bionic powers Apple's iPhone XR, iPhone XS, and iPhone XS Max, while the more robust A12X Bionic is available in the 11-inch iPad Pro and the third-generation 12.9-inch iPad Pro. AppStore presents applications built with ARKit in different categories: productivity, education, business, and, above all, games. The overall download of AR applications has exceeded more than 13 million times, and in 2020, the number of AR users has a value of around 1.7 billion.

ARCore is, on the other hand, a development kit for Android apps. When Apple launched ARKit, Google already had some experience with AR technology. Tango, a so-called AR platform from Google, lasted nearly four years from summer '14 to spring '18, but it has not enjoyed the amount of hype that ARKit has made. Eventually, Google wrapped up Tango and rolled out a completely new AR SDK. In March 2018, ARCore was officially released, and Tango was officially passed. However, the first stable version was only released in December of the same year.

One of the most popular applications for Android with ARCore is Google's Playground.

3.2. Design Limits

Systems that adopt AR make it possible to have contextual processing information. It is possible to design applications and systems based on context awareness, thus greatly simplifying their daily lives. However, there are some practical problems related to the design of such systems [28,29]:

- Interoperability: in AR, objects and devices should communicate with each other without problems, producing a significant result for users regardless of their heterogeneous nature; precisely for this reason, one of the leading design problems of an AR system is the interoperability between such devices. To overcome this problem, we should focus on semantic communication between objects and devices and between devices and devices so that they can interact without necessarily knowing their structure, thus working towards a common goal. This goal can be achieved using the semantic web, which can enrich the digital content and be viewed through the user interface [30,31]. The term "semantic web" was coined by Tim Bernes-Lee. With it, we mean the transformation of the World Wide Web into an environment where published documents, such as HTML pages, files, and images, are associated with metadata that specifies their semantic context suitable for automatic processing, such as querying and interpretation by search engines. It will thus be possible to carry out searches based on a specific keyword and the construction of networks of relationships and connections between the various documents, according to more elaborate mechanisms than the simple hypertext link currently used by the normal WWW [32].
- Security and trust: since each device is unknown to the other devices, it is necessary to implement mechanisms for verifying the object's authenticity through, for instance, certificates [33]. Another crucial point is the security of communication and the guarantee of information delivery. It is inadmissible that an untrusted device, a virus, or the loss of packets containing information compromise the correct functioning of the entire AR system. For this purpose, various encryption techniques (with symmetric and asymmetric keys) can be implemented through security algorithms such as AES (Advanced Encryption Standard), RSA, Diffie-Hellman, RC4 Double, Triple DES (Data Encryption Standard), and many others [34–36].
- Context sensitivity: communication between devices should be in real time, up-to-date, and relevant to the context of user requests. Consequently, applications must be designed in such a way as to be sensitive to the context and to correctly process and deliver the information relating to the latter in order to avoid possible conflicts between the various intelligent devices on the network.
- Minimal user intervention: another problem of AR applications is their dependence on the user and their intervention. Each IoT device should be self-sufficient and responsive. Its work should be invisible to the user, thus allowing them to have a much more autonomous system, even in any failures [37].
- Hardware problems: an IoT system uses a wide range of intelligent devices, from the least powerful, such as 8-bit devices, to the most powerful, such as 64-bit devices, which work in different environments and platforms, such as Atmel, Cortext, and Arduino. Therefore, one of the main objectives is the reduction in the energy consumption of these devices to make them more efficient. In this regard, various techniques can be used, such as the use of recharging mechanisms using kinetic energy for moving devices, using sunlight, and much more [38–40]. Two other main problems found at the hardware level are the device's failures and heaviness caused by its size. In particular, to overcome this last problem, thanks to technological advancement, we are already able to develop compact and low-weight devices, gradually guaranteeing greater portability.
- Software problems: given that AR applications can be run on hardware platforms with different computational characteristics, the software level's main problem is interoperability and compatibility. The operating system used to be versatile must be optimized in terms of code, size, and power. Examples of operating systems that can be practiced in the AR context are TynyOS, FreeRTOS, and OpenWSN. There are also specific browsers for AR, such as "Firefox Reality" launched by Mozilla, which allows the display of content through the use of viewers (HTC Vive or Google Daydream), and

various other devices that are still in the process of development. Therefore, it appears evident that it is necessary to develop appropriate toolkits capable of supporting different devices and applications running on multiple platforms and an interface capable of interacting as multiple interfaces where possible [41,42].

The IoT and the service network include sensor nodes, objects, RFID, and smart devices whose function is to interconnect objects around the user to provide continuous communications and contextual services. Through it, the user's life is more comfortable.

Furthermore, in order to have more services, advanced technologies are used, such as AR. Combined with an IoT system, it makes life and user actions even more accessible, making the system more autonomous and "user friendly". Indeed, the primary purpose of an IoT–AR system is to bridge the gap between the real world and digital world by interacting with the natural world in real time. The information-acquired context is the central pillar of these systems; therefore, context and management are critical processing features. All components of the entire system, from its architecture and the device's applications used by the user, must be context-sensitive and must be empowered to refer and deliver the various services based on the priorities of the moment. Another fundamental pillar in an IoT–AR system is the technologies of communication and gateway protocols, such as CoAP (Constrained Application Protocol) and MQTT (Message Queuing Telemetry Transport), as they are required to connect IoT–AR devices and use cases offline to the outside world via the Internet. All data relating to the user, preferences, and the surrounding environment are stored, managed, and processed in the cloud. Therefore, they are essential advanced and specific security algorithms for such applications. If, on the one hand, such systems have a high potential, on the other hand, they are weak in their structure as they are very complex to implement and require a high degree of interoperability with a number of devices. There are, in fact, various related design problems to them, such as scalability, context and data management, performance, control access, and security and privacy, which require additional developments and research.

Thus, suppose the system is already at the hardware level. In that case, there are in the market products that are already widely used by users, and there are still some challenges to the software design of such a complex system to face and some objectives to be achieved. Despite this, being that the development of such systems is already making great strides year by year and that AR and IoT applications are growing dramatically as they bring more and more innovations, technological advancement in this sense and the design of such systems appears to be promising. If it were possible to manage to overcome the various design problems, in the future, the whole real environment would become interconnected from houses to cities. There would no longer be the gap between the physical world and digital, thus allowing the user to interact with the data and have services with minimum effort and minimum intervention.

4. AR in Industry 4.0

AR is increasingly being described as one of the leading technologies of the 21st century and as one of the pillars of the new industrial revolution envisaged by Industry 4.0. Numerous articles in the literature outline some of the main specific applications of AR to develop its potential in numerous fields of the various industrial sectors. However, the current limitations of this technology are not particularly contemplated in the literature, especially in the case of its introduction into a natural work environment, where daily activities could be carried out by operators using AR-based approaches. However, this paper will examine this later.

The hardware and software needed to implement an AR application typically depend on the complexity of the virtual scene to be reproduced. In general, the minimum hardware required to run an AR application is composed of a camera that frames the outside world, a screen or a lens that is used to project a streaming video, and computational resources (PC, smartphone, or microcontrollers in general) necessary for the management of the video part and the detection of the objects present in the actual scene. Some application examples of the technologies proposed in Industry 4.0 are represented by analyzing big data, the Internet of Things (IoT), additive manufacturing, intelligent sensor networks, machine, and self-monitoring networks [43].

The application of AR technologies in Industry 4.0 has attracted the interest of many researchers in recent years. However, as presented in Figure 7, only in a very few cases is the integration of AR in Industry 4.0 applications treated [44]. Referring to the SCOPUS database and checking the number of articles having as single keywords "Augmented Reality" and "Industry 4.0", it is possible to find more than 2000 articles written each year for both topics (data obtained during the last five years). If, on the other hand, it is possible to search for both keywords jointly, the result that emerges is quite evident. There are no more than a hundred papers per year. This situation clarifies that although the sector is booming, much still needs to be improved and adapted for the widespread use of AR in Industry 4.0 [45,46].

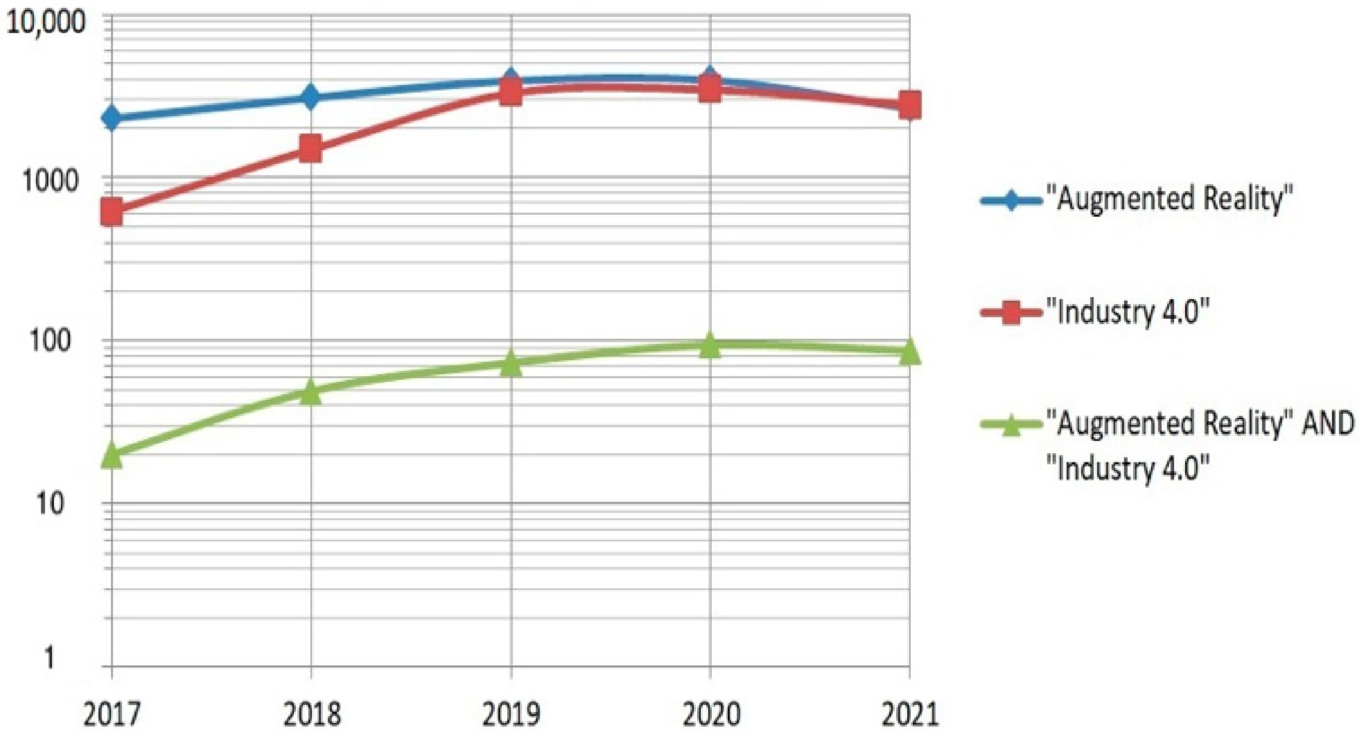

Figure 7. Trend of scientific articles published on Scopus in the last 5 years relating to the keywords "Augmented Reality", "Industry 4.0", and "Augmented Reality" AND "Industry 4.0".

Another interesting statistic can be obtained, again by checking the SCOPUS database, of the number of scientific articles that show the keyword "Augmented Reality" with another keyword that is indicated in the left column in Figure 8 (for example, "Design" or "Game" or even "Industry 4.0". The result obtained, visible in Figure 8, lends itself to numerous reflections.

This graph also allows us to analyze a scenario in which little has yet been analyzed in AR applications, such as Industry 4.0.

Although numerous scientific articles have now addressed the issues relating to the development of AR technologies, even today, numerous limitations still exist in the large-scale dissemination of them, especially in the industrial field. In particular, deepening the contents of some of the articles cited in the bibliography, numerous problems still need to be resolved so that these technologies are more widespread.

Specifically, ref [13] describes the current situation in relation to the spread of AR technologies. In particular, by making an overview of the research activities included in 96 relevant documents, published from 2011 to 2018, it is possible to observe how AR is not yet ready for industrial implementation in some areas, while it is in other sectors. In the same document, the authors present the state of the art, current challenges, and future directions of research in the field of AR technologies.

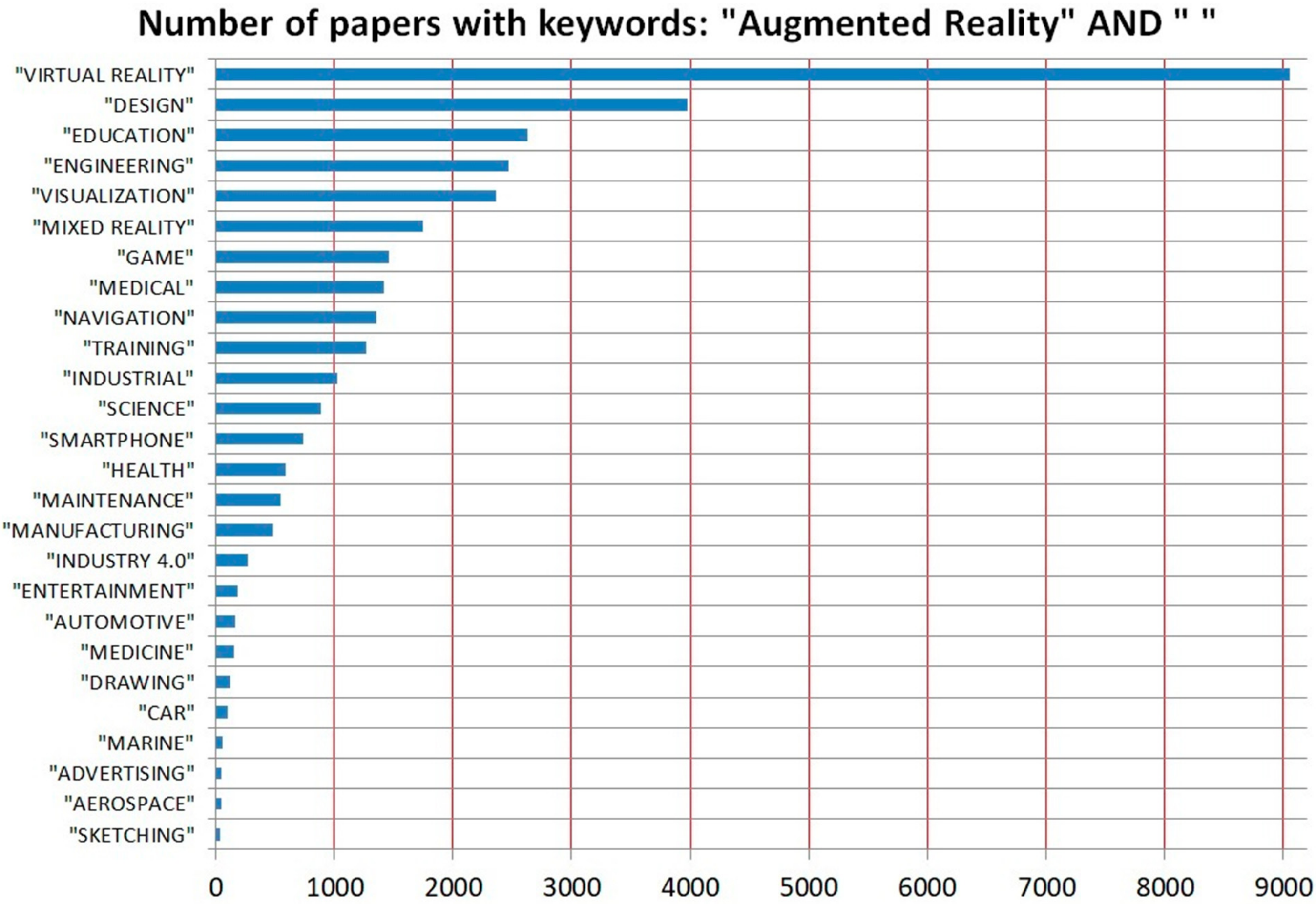

Figure 8. Trend of scientific articles published on Scopus in the last 5 years relating to the keyword "Augmented Reality" AND "X", where X represents one of the items shown in the left column.

In [23], the reasons why existing approaches have not established themselves outside the research context are presented. Next, solutions for three identified problem areas are reviewed. First, this article presents a theoretical method to create use cases for AR applications in the product design process based on a specific process model (Double Diamond design). The same authors then present the main properties of an AR device within a production environment, before finally trying to propose some resolutions to the central data integration problems.

In [25], the collaboration between human operators is analyzed with computational intelligence (CI) in real time through AR. Although digitization has been used in recent years to modernize modern industries, some manufacturing operations remain manual, and humans can perform them better than machines. This study conducts a systematic review of the recent literature on AR applications developed for intelligent manufacturing.

5. Conclusions

This article has presented an overview of AR and its main applications. It seems worthwhile, at this point, to describe some other existing limitations, which still determine a non-massive diffusion of these systems, as well as the possible future application scenarios for AR. AR is a well-established computer graphics technique in research applications. As already mentioned previously, several improvements in both software and hardware should be introduced before it is widely introduced in the industries of tomorrow. The artificial vision module represents the main limitations identified during the conceptualization of some AR applications; it cannot always provide results in real time. These modules suffer from great extension due to the volume of the input data; in particular, when it increases, the computation time increases exponentially. Therefore, it appears evident that the hardware must be equipped with particular performing and capacious elements, possibly also resorting to clusters of computers operating simultaneously.

AR technology can find applications in various industrial areas. An emerging problem in the field of industry is the wide range of AR-compatible devices. The properties of these devices vary greatly, and the requirements for industrial use are different from those for consumer products. Aspects such as ergonomics, weight, and brightness must be considered according to the target environment and the specific use scenario in order to be able to make a good choice on which AR device is best suited to the specific use case.

Finally, integrating AR data into business workflows is an essential aspect. AR software is composed of different components, which excessively complicates the customization process within a company. However, this process is necessary to adapt the AR to the desired scenario and data integration. A modular software architecture could be a possible solution to increase the efficiency of personalization. This goal would reduce the costs of AR software within a company's IT infrastructure.

Despite having exposed some of the limitations present in the diffusion of technologies in AR, numerous applications appear to rely heavily on these technologies in the future. First of all, the industrial sector, that of the so-called Industry 4.0. In this context, AR applications may provide for the use of so-called predictive or preventive maintenance. It can introduce many advantages both from an economic point of view and efficiency. The massive diffusion of preventive maintenance will allow avoiding annoying and unexpected machine stops due to sudden technical or structural problems, which, on the contrary, can be foreseen and planned for in due time. In this direction, the automotive sector, in general, appears to be the one in which this emerging technology can find widespread diffusion.

Unlike virtual reality, augmented reality is designed for constant use on the move, which gradually replaces the smartphone. No one will ever be willing to use these technologies in tandem, e.g., such as cyborgs. For this reason, many companies are proceeding in the opposite direction: they are not creating bulky AR viewers. However, they are instead marketing devices similar in all respects to a regular pair of glasses but equipped with some initial smart functions [47].

In this sense, Facebook's Rayban Stories are limited to taking photos, shooting videos, having integrated earphones, and little else. Amazon's Echo Frames are designed above all to communicate with Alexa; again, Snapchat's Spectacles are the first glasses that integrate real augmented reality functionality [48,49].

Therefore, the future world could become more and more similar to what the digital artist Keiichi Matsuda imagined: streets that digitally signal the passage of cars, buses that indicate when our stop has arrived, supermarket shelves that indicate where this is. Alternatively, as John Hanke, founder of Niantic Labs, said: "AR is where the real Metaverse will happen" [50].

From this point of view, the real metaverse would no longer be an environment that limits our movements, alienates us from the physical world, and forces us to interact with avatars but our usual digitally enriched world. Some companies are also experimenting with AR fashion garments (for example, a leather jacket that is displayed in flame by anyone wearing an AR headset) or its applications for smart working (during a remote meeting, it would be possible, for example, to view a colleague's hologram instead of seeing their face on a computer screen). This also poses several problems regarding privacy, surveillance, data collection, tracking of all our behavior, constant availability, and more. All themes should be explored one by one.

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