INNOVATION POTENTIAL OF AUGMENTED TECHNOLOGIES IN INDUSTRIAL CONTEXT

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Abstract: *The goal of this paper is to provide a resource that can be used by the Augmented Reality research community and practitioners to understand the most recent potentials for application of the innovative Augmented Reality technology in various industry. Firstly, it is described mainly the role of the Augmented Reality in logistics and maintenance. Secondly, the paper provides an overview of research papers in the period 2008-2018 in the field of Augmented Reality for facilitating and supporting industrial applications.*

By efforts of research, review and classification the author outlines both opportunities and challenges for spreading the Augmented Reality applications in smart manufacturing environments that will provide the baseline for further discussion and research in this direction.

Presenting this survey the author aims at creating an active community that further discusses the future development of Augmented Reality particularly in Supply Chain Management. Future steps will be taken in research workshops and online community work.

Keywords: AUGMENTED REALITY, INNOVATION, INDUSTRIAL CONTEXT, MANUFACTURING

1. Introduction

With the constant development of new technology – digitalization and integration with all sorts of internet platforms, various cloud services and artificial intelligence with machine learning, the ever-brewing competition and rivalry drives many companies to reconsider the management of their Supply Chains and invest in better, more innovative ones. Even if their goal is not to aim for the top places, taking the time to arrange their raw materials, manufacturers, distributors and even logistics details, in the best way possible, can really save the company from a lot of financial and material losses.[1]

Digital manufacturing consists of different steps which not only create the digital data, but also steps that compress the content so that it is easily and more quickly distributed and delivered, steps that ensure the quality of the content.

Digital logistics nowadays is replacing the old way of distributing physical goods that carried the same digital information by implementing virtual distribution using different platforms and cloud technologies that can be accessed on demand.

Many innovative technologies are appearing and companies are taking advantage of integrating them into their current Supply Chain Management (SCM) systems, or altogether replacing them for better, faster and more reasonable ones.

In this paper, we will look into the innovation of the Augmented Reality technology in industry that more and more companies are either implementing or integrating to secure their future on the market or as the top leading companies in their respective fields.

2. Background on Augmented Reality

Famous companies who have introduced AR to their commerce webstores are eBay, which has focused on car enthusiasts for now, who are said to be able to see how different auto equipment would look like on their personal vehicles; IKEA has allowed its customers to use their own smartphones or tablets while browsing furniture to help them visualize them in their own homes using only the phone's camera and IKEA's application. DHL have been using virtual reality glasses to speed up the warehouse picking up process, which help ensure that the proper product is being picked up and thus minimize losses by eliminating human error and at the same time shortening the time for checking the products with a slower device.

Augmented Reality (AR) is a novel human–machine interaction that overlays virtual computer-generated information on a real world environment. It has found good potential applications in many fields, such as military training, surgery, entertainment, maintenance, assembly, product design and other manufacturing operations in the last ten years. This research aims to provide a survey of developed and demonstrated AR applications in manufacturing activities. The intention of this survey is to provide researchers and engineers, who use or plan to use AR as a tool in manufacturing or in Supply Chain Management (SCM), a useful insight on the state-of-the-art AR applications and developments.[2]

Various solutions based on Augmented Reality have been proposed by the research community. Particularly in maintenance operations Augmented Reality tools have offered new perspectives and have promised dramatic improvements. On the other hand, Augmented Reality is an extremely demanding technology and at present it is still affected by serious flaws that undermine its implementations in the industrial context.[3]

AR technology is particularly suited for maintenance industry, as it can be easily implemented in several processes. AR can enhance the user's view of the surrounding scene with different content that include visual animations, sounds, written instructions or static images. Using AR can potentially reduce the numbers of errors during maintenance tasks. In fact, AR provides information that is generally not easily available or whose retrieval is relatively demanding. In general, many processes in manufacturing, aviation and automobile industry have to deal with assembly tasks. During

maintenance operations, mechanics have to deal with a large amount of different parts that represents a large proportion of search time: standard manuals or handbooks can lead inexperienced operators to frustration and poor performance.[3]

Training specialized workers is an expensive voice in any kind of industry. In the case of aviation, it takes up to 2000 hours for inspectors to be completely trained. AR can remove restrictions of time and location, leading to a much faster transfer of knowledge and a better understanding of the maintenance processes. Hence, from an economical point of view, industry can use AR to lower processes' operational costs and thus sustain their growth and innovation.

The main factor retarding the full deployment of the new technology has been until now the human one, because the gap between technology and human resources culture has grown, not reduced. [4]

3. *Application of AR technologies*

The goals of our study is to investigate the following research questions:

RQ1: What is the state of the art of the scientific literature on the innovation potential of Augmented Reality in manufacturing in journal articles from 2008 to 2018, as well as

RQ2: Is AR the future of Supply Chain?

To address these questions, we performed a systematic study of scientific publications on Augmented Reality in manufacturing.

It is acknowledged that AR technologies are well applicable in many different industries like Automotive, Aeronautics and Aviation, Robotics and Automation, Software, Construction industry, Transportation, Marine, Dentistry, Electronics, as well as Education. In Figure 1 the distribution of typical industrial fields of AR application are graphically represented.

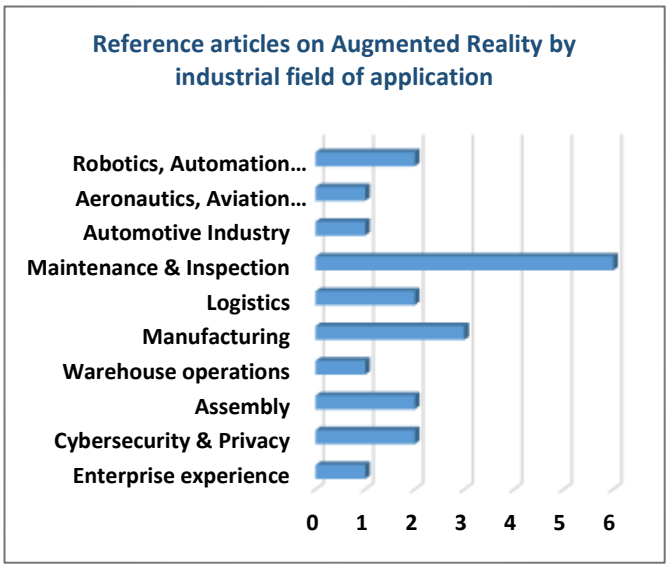

Fig. 1 *Distribution of reference articles on AR by industrial field of application*

Table 1 summarizes the articles being reviewed on Augmented Reality per year of publication and facet type.

Table 1: *Referenced articles on Augmented Reality per year of publication* and facet type

Facet type	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Research method	1		1	1	1	1
Implement ation field	1					1
Industry type						
Facet type	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Research method	1	1	1	2	2	
Implement ation field	1	1	1	4	2	
Industry type	1			2		

Figure 2 depicts the distribution of articles on AR both by year of publication and facet type.

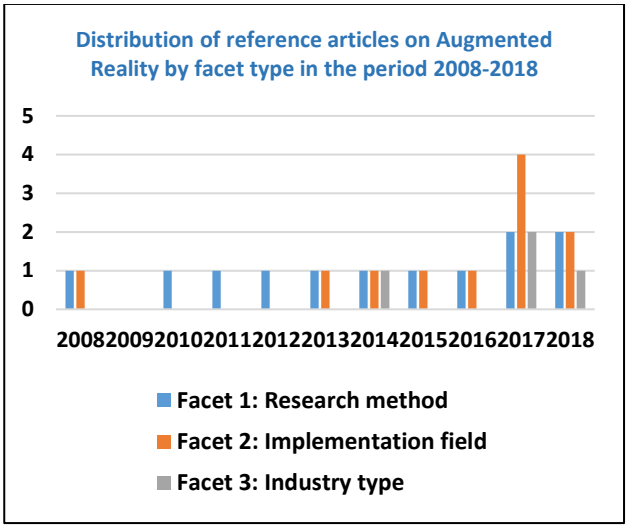

Fig. 2 *Distribution of the number of reference articles on AR per year of publication and facet type*

4. *Main advantages and disadvantages of AR systems in Industry*

AR technology is extremely flexible and, particularly in maintenance industry, it can be easily implemented in several processes. Thanks to the additional knowledge provided by AR, the number of errors during maintenance tasks can be greatly reduced. In fact AR provides information that is generally not easily available or whose retrieval is relatively demanding. In general many processes in manufacturing, aviation and automobile industry have to deal with complex assembly tasks, which execution involves a large amount of different parts. In these situations standard manuals or handbooks can lead inexperienced operators to frustration and poor performance.

From an economical point of view, industries can use AR to lower processes' operational costs and thus sustain their growth and innovation: training specialized workers is an expensive voice in any kind of industry.

In the case of aviation, it takes up to 2000 hours to fully train a maintenance inspector. AR can remove restrictions of time and location, leading to a much faster transfer of

knowledge and a better understanding of the maintenance processes.

Main disadvantages of AR systems

Even though AR is a promising technology, it still presents some disadvantages that may jeopardize its actual implementation in real maintenance applications. In fact, a bulky, relative low resolution prototype with fixed focus cameras or a small field of view HMD can become an actual occlusion to work execution, and so seriously influence the perception of the AR technology and the advantages introduced. Another important aspect that should be considered is the weight of the hardware: the average weight of high-end HMD is 700 grams, while normal reading glasses weight around 100 grams. When the process that we want to improve takes more than one hour, the user may get tired and perform the work poorly: it thus become very important to take breaks between steps of the process, unavoidably resulting in important delays. To avoid wearing a heavy HMD, we may use an LCD screen, but this would diminish the quality of AR experience and would force the user to wear a helmet or a belt holding the cameras so that they could keep objects of interest inside their field of view: such a solution is very uncomfortable and would hardly be accepted by operators. Also the range of movement plays an important role in the development of AR applications: since HMDs are usually not wireless, the displacement of the user is limited by the extension of the wire. Another characteristic that is limiting the spread of the technology to new markets is the cost, because high ranges vision glasses are between 500 to 5000 dollars, depending on resolution, transfer speed and comfort for the user. To open the technology and make it more attractive to public, these hardware limitations must be surpassed: companies like Microvision, Vuzix or Lumus are already working and improving current AR systems, trying to overcome the flaws that are slowing down the spreading of AR.[3]

A different kind of problem is given by the computational cost of AR applications: the amount of polygons that can be drawn at 25 frames per second on a single frame is limited by the computing hardware of an AR system. Usually a 3D CAD model with more than 100000 polygons already represents an interesting challenge.

Even if hardware is continuously improving, especially thanks to the availability of extremely performing parallel CPUs, this still constitute a limit when the AR application has to deal with complex environments or has to draw several detailed objects.

Research on how to take advantage of Augmented Reality applications and technologies in the domain of manufacturing has brought forward a great number of concepts, prototypes, and working systems. Although comprehensive surveys have taken into account the state of the art, the design space of industrial augmented reality keeps diversifying. Within our classification framework we collected and classified relevant publications in terms of implementation area facet as shown in Table 4. This facilitates initial research activities as well as the identification of research opportunities [5]. Thus, we lay the groundwork, but forthcoming workshops and discussions shall address the refinement.

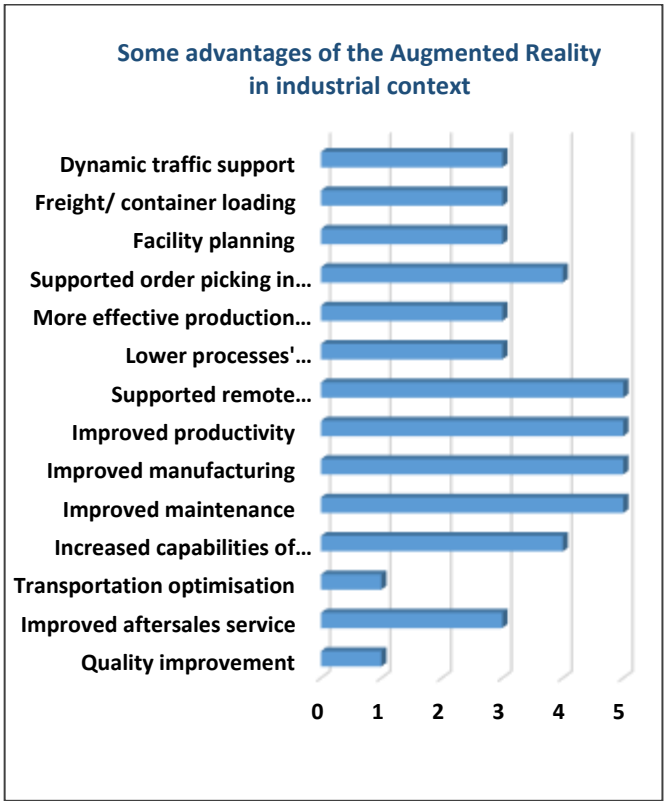

Fig. 3 *Advantages of Augmented Reality in an industrial context*

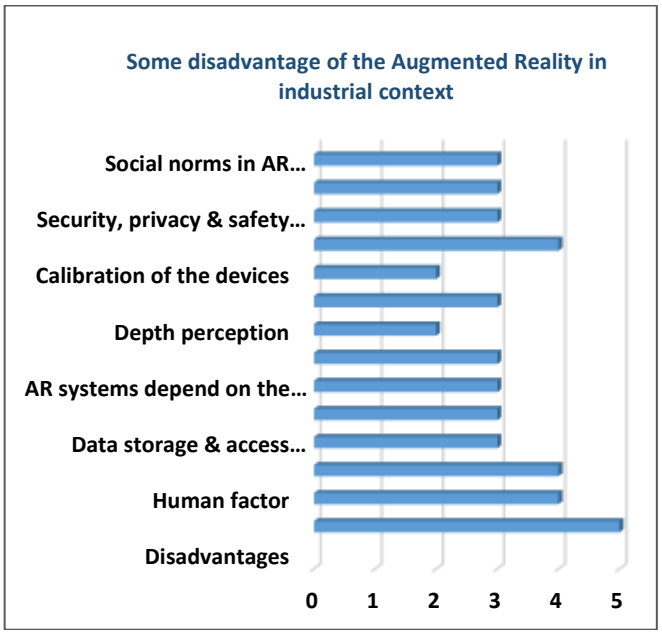

Fig. 4 *Disadvantages of Augmented Reality in an industrial context*

In Figure 3-4 are summarized the main advantages and disadvantages of the AR in an industrial context.

5. Is Augmented Reality the future of Supply Chain

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As defined in the industry report on Augmented Reality by DHL, Augmented Reality refers to the layering of computer simulation models over the physical layout of current surroundings. In a sense, this is the hallmark of virtual reality, but AR refers to using this information to improve the efficiency of today's processes as they relate to the supply chain.

Most common forms of Augmented Reality involve some sort of glass, visual display for a wearer to use in the process of increasing productivity and performance. For example, smart glasses in the warehouse are considered a form of Augmented Reality Supply Chain, explains SupplyChainDigest. The wearer is able to overlay a computer simulated image into the physical space.

By 2017, Augmented Reality is estimated to have a value of just over $6 billion. Evidently, this trend is growing at one of the fastest paces in the market, 100 percent annually. One of the largest sectors we will see grow is in the "Industrial" sector, meaning application for both an Augmented Reality Supply Chain to include manufacturing, distribution, and logistics [4].

Augmented Reality is currently being used to provide a sense of scene recognition during order picking processes. Most traditional order picking processes involve paper-pen picking or picking through voice-automated systems. However, this continues to result in inefficiencies.

At any time, employees in a given warehouse must typically perform multiple actions in order to successfully pick an order. For example, the picker must locate the correct product, scan the product, and deliver the product to the loading dock. However, scene recognition and Augmented Reality allowed a camera-operated system to autonomously identify where a product is located if it is the correct product, and how to move to the next product at a faster pace. All of this information is displayed to the user of the Augmented Reality-enabled device.

On the consumer-end, Volkswagen has created a vehicle that can display the current speed, status updates, and other information on the windshield of the vehicle for improving the safety of the driver. Yet, truck drivers spend up to 60 percent of their time away from facilities locating the correct order in the truck, not driving, explains Karolina Maziliauskaite (Maziliauskaite, 2015). This is unacceptable. AR could be used to help a driver rapidly identify exactly where the shipment is located within the truck, cutting the amount of time spent not driving drastically. The applications of augmented reality in the future of the supply chain are limited only by the imagination. Since AR allows a non-tangible aspect of business to take place on top of the physical parts of business, AR will dramatically change how consumers and businesses view typical processes within the standard supply chain, thus creating an augmented reality supply chain.

For example, the process of item repair and reverse logistics (aftersales services) could be made much simpler. AR could be used to help an entry-level tech immediately identified incorrect circuits and problems within a given product. On the other hand, Augmented Reality could be applied to a video stream from the consumer of a current product's condition. This video could be applied to the AR aspect on the business-end or customer service-end of the Augmented Reality Supply Chain to immediately identified what is wrong with the product. As a result, the consumer does not lose any time in bringing the product into the store, the Supply Chain partner does not lose any time in analyzing the problems with the product, and the consumer is able to obtain a repair or replacement at a faster pace. The level of consumer service is increased, which helps to propel the entire supply chain forward.

AR is not without its faults. These brief descriptions of AR rely on some sort of power source, and wearing a battery pack on the head is simply impractical. As explained by Roland Martin (2015) [8], the biggest challenge to the widespread use of AR is low battery life. The solution to this problem must rely on using technology and innovation to define a new way of getting power to the systems rapidly and efficiently, without imposing a burden on the employees. Ultimately, Augmented Reality may be used to figure out a way to create a smaller, more durable battery to power AR-enabled devices. Essentially, the applications of AR are continuing to expand.

Consumers are demanding more from the modern Supply Chain, and the level of competition between different Supply Chain service providers is growing. However, AR will be one of the defining forces of the modern supply chain in 2016, where the augmented reality supply chain will start to shape. Once, the use of radio frequency-driven headset seemed like the best solution to supply chain management and the use of technology. However, the use of technology is taking on a new level through augmented reality, and it will only continue to grow as society becomes more apt and reliant on advanced technologies. [6]

With this overview on the recently available scientific articles on the Augmented Reality applications in an industrial context web try to give contribution to understand better the present and future technological impact on SCM processes.

A new wave of Artificial Intelligence applications can approach and solve many problems of Planning and Control of Supply Chain, in the past approached only through off line mathematical models combined with inter-functional team work. [4]

We can conclude that Augmented Reality is a promising driver for industrial applications and it is a breakthrough technology that could considerably ease execution of complex operations.

6. Conclusion

The work to be done at research and implementation levels is enormous to assure a full exploitation of the AR technological potential for SCM. The main factor retarding the full deployment of the new technology has been until now the human one, because the gap between technology and human resources culture has grown, not reduced. Demonstration

systems, prototype systems and productive systems are still required. [4]

AR is a breakthrough technology, but at present it is still affected by serious problems that jeopardize its implementation in industrial environments. In this article we have presented the main advantages that AR can offer to industrial processes, with particular attention to maintenance operations. AR could seriously improve human performances, and this can lead to great benefits not only from an economical perspective: a better maintenance on a car or an airplane does not only mean cheaper costs, but also higher reliability and thus, less failures and subsequent accidents. [3]

Main flaws that are heavily hindering AR spread in the industrial background were detailed: valid solutions to these flaws are needed to make AR a more competitive technology. Better materials, faster algorithms, smaller hardware are demanded and the research community must take charge of this need and offer valid solutions.

How to get to the most relevant information with the least effort from databases, and how to minimise information presentation are still open research questions.

AR systems will depend heavily on the available types of content. Scientific and industrial applications are usually based on specialised content, but presenting commercial content to the common user will remain a challenge if AR is not applied in everyday life. [7]

Our research investigation gives us the opportunity to identify broader lessons and key challenges to inform the research and practitioners about the potential use of AR technologies in industrial context with focus also on the whole Supply Chain. The study highlights important security and privacy challenges that emerging AR technologies will raise. [9]

Supply chains will continue to evolve and become more integrated with the information technologies. It can be said that it is a concurrent evolution, and with the evolution of the IT, the evolution of the SCM will also take place and leading companies will make sure that they do not get behind, so they are more and more applying in their operations disruptive technologies like the Augmented Reality.

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