Augmented Reality in Industrial Applications: Technologies and Challenges

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Abstract

When it comes to Industry 4.0, Augmented Reality (AR) is regularly referenced as the up and coming interface innovation for communication and collaboration between humans and machines. Innovative technological advances have removed some of the central technological limitations in recent years and AR applications with restricted functionality are presently abundant and can be downloaded as applications onto most mobile devices. Although it is a key technology development, that promises to change many industries, their utilization is restricted generally to entertainment and marketing applications. The use of augmented reality in industrial applications (IAR), is simply beginning to wind up progressively. We can understand Augmented Reality technology as an intuitive interface that allows us to see through the real and the digital world. Over the direct comparison of real-world objects with virtual planning data, planning errors in production environments can be detected faster and more efficiently. The available literature of the areas above mentioned will be reviewed in this paper, in order to analyze the underlying challenges and the existing technologies involving IAR, in particular in assembly and picking activities.

Keywords
Augmented Reality, Industrial Augmented Reality, Industry 4.0, Cognitive Manufacturing, Cyber-Physical Systems

1. Introduction

When it comes to Industry 4.0, Augmented Reality (AR) is regularly referenced as the up and coming interface innovation for communication and collaboration between humans and machines (Langfinger et al. 2017). Besides the use of Computer Aided Design (CAD), utilized to accelerate and advance the development process, virtual and mixed reality technologies are being added to the industries (Nolle and Klinker 2006). These technologies were additionally created to support human beings, since it is notable that, the significance of human beings as the most noteworthy and most valuable production factor is, these days, undisputable. Human beings are portrayed by flexibility, creativity and high problem-solving potential (Reinhart and Patron 2003). Described as a variation of Virtual Reality (VR) (Pathomaree and Charoenseang 2005), AR can bolster the human visual sense (Reif and Günthner 2009). To follow the purpose of the user to see the virtual information/models (computer graphics, text, sound, etc.) as existing in real-time, AR endeavors to coordinate that data into de physical environment as existing in real-time (Yuan et al. 2008). This combination can be multisensory and might incorporate the improvement of a picture with virtual comments, the detection and intensification of sounds, or the utilization of haptic feedback to build touch sensing (Reinhart and Patron 2003). AR has numerous conceivable fields of application in industrial environments. Some investigation projects use AR applications for development, production and service. Assembly, maintenance and production planning are additionally frequently referenced (Reif et al. 2010). The available literature of the areas above mentioned will be reviewed in this paper, in order to analyze the underlying challenges and the existing technologies involving IAR.

2. Augmented Reality and Industry 4.0

Since the beginning of the Industrial Revolution, we can state that industrial productivity has faced dramatic increments due to technological advances. As in the present day, we are amidst a change that is fueled by nine primary technology advances (Autonomous Robots, Simulation, Horizontal and Vertical System Integration, the Industrial

IoT, Cybersecurity, the Cloud, Additive Manufacturing, Augmented Reality and Big Data and Analytics), a change that we know as being the fourth wave of technological progression: the ascent of new digital technology known as Industry 4.0 (Rüßmann et al. 2015). Different technological developments made Industry 4.0 rise up. This new paradigm faces the challenge of being exceptionally computerized and financially savvy, just as producing custom products in a large-scale manufacturing condition, and can possibly change the role of traditional assembly lines by altering the manner in which goods are produced and services are offered (Santos et al. 2018). Among the distinctive Industry 4.0 innovations, this paper focuses on augmented reality, whose application in the industrial field has prompted the concept of industrial augmented reality (IAR). IAR can be characterized as the application of AR so as to support an industrial process (Fraga-Lamas et al. 2018).

According to Azuma we characterize AR as a mix of the real and virtual world with 3D registration and that is intuitive in real time (Azuma 1997). AR and VR, being an available innovative computer graphics interfaces, can change essentially the manner in which technical information is displayed to the user. Indeed, in the past, paper-based information was fundamentally in printed structure and was hardly upheld by static tables, images, and drawings (Gattullo et al. 2019). AR applications can possibly enhance user experience of applications in which users must access and interface with data that has a direct spatial connection to their immediate environment (Paelke 2014). An AR system needs to ceaselessly perform real time estimation of its position and orientation in 3D with respect to the real world, which is an undertaking known as tracking. Detecting planar fiducial markers placed around the environment using a video camera is a typical method to achieve this (Lima et al. 2017).

Attention exchanging between the instructional medium and the actual task can be lessened by using AR as a medium of instruction also, the use of AR, can enlarge human attention. The user’s field of view is converged with integrated computer graphics and attention can be drawn by arrows, tags, object highlighting, animations, etc. (Tang et al. 2003). AR can be shown relying upon the context, i.e. in reference to specific components or subassemblies, which cannot be achieved by paper-based work guidelines or multimedia information systems. The context-related perception of information decreases search time in assembly or in upstream activities, adding to that, secondary operations, such as reading information, can be diminished or joined with other value-producing activities (Reinhart and Patron 2003). The access to data in industrial manufacturing is fundamental for laborers, as in work steps must be portrayed, spatial information on areas and items must be given and admonitions must be understood effectively and on time by workers. With AR, data is shown situation-dependent in a user’s field of view (Tumler et al. 2008). Making full use of individual's visual and spatial aptitudes to navigate in 3D, AR along these lines, establishes a particularly promising new user interface paradigm (Echtler et al. 2004). The AR system generates the required augmentation information, rendering an image, and the information is joined with the user’s perspective of the real world and is displayed. To do so, an AR system must be composed by sensors, the AR software and a proper display. The sensors decide the current position and orientation of the user in the real world, regularly referred to as the “pose”, the sensors and corresponding software are referred to as the tracking system (or tracker), as referenced previously, on the grounds that they track the user’s movement (Paelke 2014).

With an end goal to help industrial processes, an assortment of AR-based applications was made in the past, some of them will be referenced in the following chapters. These applications spread all parts of the industrial product process: design, production and planning and service and maintenance. Be that as it may, just a few of them really figured out how to develop from demonstrator applications or models into important and set up arrangements (Pentenrieder et al. 2007).

3. Augmented Reality to Support Picking Activities

We can define order picking as collecting of goods out of a readied scope of items according to the client orders, all things considered, it is the last procedure venture before the merchandise are conveyed to the customers. Subsequently, zero deformity picking is one vital goal of order picking (Reif et al. 2010). There is a requirement for exceptionally efficient and instinctive approaches to exhibit information, with regards to supra-adaptative logistics applications, (Schwerdtfeger and Klinker 2008). Because of the high assortment of products in order picking applications, machines typically cannot supplant human being with his adaptability and fine motor skills (Reif et al. 2010). In the present day, 75% of warehouses are operated manually with the greater part of the expenses brought about by the process of order picking, having this information in mind, manual order picking, gives great chances to use AR technology. This is on the grounds that, the use for information transmission is of exceptional interest in this procedure and it is the most well-known arrangement of an order picking system (Elbert and Sarnow 2019). Laborers need to adjust to new working conditions and situations rapidly, frequently, and with minimal training, for that they should be provided with the correct information at the right time (Schwerdtfeger and Klinker 2008). Flexibility is required because the product range and the variety of items increments, while the extent of orders is diminishing. The idea is to ideally bolster laborers by technical devices amid their task fulfillment (Reif et al. 2010). As explained before, when it comes to order picking, workers gather sets of items from an assortment in a warehouse as indicated by a work request. They then convey them to the following station in a definitely planned material flow process, AR can help with this procedure as illustrated in Figure 1 (Schwerdtfeger and Klinker 2008). Production and logistic systems, similarly as the specialists inside these systems, need to end up continuously versatile to fulfill the customers' needs (Reif et al. 2010).

A variety of strategies exist for order picking in warehouses. Lately there has been some developments in researches for picking activities using the help of AR, such has the research conducted by Elbert and Sarnow that, based on the available literature as well as empirical data, proposed designs for the user interfaces for three primal levels of order picking support to make the measure of accessible data controllable (Elbert and Sarnow 2019).

In present day stockrooms, worker support based on a standard paper list is regularly supplanted by Mobile Data Terminal (MDT), Pick-by-voice (PbV) or Pick-by-Light (PbL) systems (Reif et al. 2010), also the picking time-effectiveness is affected by the picking information system through overseeing how rapidly an worker acquires picking data, searches for information and confirms the picked items (Fager et al. 2019). PbV bolsters the worker helping him with all directions through the computer's speech output, the problem is that these systems face challenges in loud industrial conditions. PbL offers the worker visual guide by introducing small lamps on every capacity compartment. PbL systems have the issue that the showcases and lamps have to be elaborately incorporated into the rack development and are, in this manner, over the top expensive and unbendable towards rebuilding (Reif et al. 2010).

According to Schwerdtfeger and Kinkler, we can measure the efficiency of the picking procedures in four interleaves tasks (Schwerdtfeger and Klinker 2008):

- The base time for getting the following request information;
- The dead time amid which that worker translates and comprehends the request as a 3D navigation and picking assignment;
- The way time during which the user physically moves to the chose item and
- The picking time to really grab the item

Mistakes in order picking can prompt high catch up expenses, so it is better to avoid them. In a typical order picking scenario, laborers are given printed-out pick arrangements of articles, describing their position in the stockroom, the sum to be collected, and short portrayals. It is possible to divide order picking process into two navigation phases: a) finding a way to the correct box and b) selecting of the correct box (Schwerdtfeger and Klinker 2008).

AR has the potential to offer to the user, visualization in parallel of data gathering with secondary employment. Consequently, there will be limited dead times and the periods for data pursuit can be decreased when the information is shown in the user's field of view (Reif et al. 2010). The Head-mounted display (HMD) is the most imperative equipment for PbV AR-based systems since it is the interface between the human and the technical system (Fager et al. 2019). Its undertaking is to show the important information to the order picker. It is important to take into consideration the perception of the essential information as well as ergonomics and the physiologic innocuousness of the device. The most noteworthy fact is that the laborer needs to wear the HMD during an 8 hours shift. Hence, the HMD ought to be light and ergonomically designed, yet in addition rough and with an 8 hours battery operation. Another basic fact for the usage of the HMD, is that the field of view must not be constrained because of reasons of labor safety (Reif et al. 2010). It is essential to include the laborers from the earliest starting point so as to accomplish a high user acceptance of new technologies (Rüßmann et al. 2015). Limited information is accessible with respect to the effective use of working environment HMD, particularly the choices of HMD types and user interface (UI) structures (Kim et al. 2019) although some researches have demonstrated a good performance, in terms of quality and time- efficiency, from HMD when compared to other order picking systems (Fager et al. 2019). Another vital hardware component is the tracking system, which is characterized by a variety of dissimilar elements, similar to degrees of freedom, accuracy, resolution, update rate and range. An AR system must be robust and safe in down to earth tasks, yet it likewise should have a superior performance than the system utilized previously with the goal that a short return on investments can be accomplished (Reif et al. 2010).

Order picking process can benefit from AR since it can relieve the worker to a striking degree, once the task load is significantly diminished contrasted with traditional picking support systems (Elbert and Sarnow 2019).

Figure 1. Two different types of visualization based on the AR algorithm to perform a picking process.Source: (Schwerdtfeger and Klinker 2008)

4. Augmented Reality to Support Assembly Activities

Assembly is one of the procedures whose performance can be enhanced drastically by IAR (Fraga-Lamas et al. 2018). Human capabilities are particularly essential in the territory of assembly (Reinhart and Patron 2003), since an assembly task illustrates the manners in which AR might guide and bolster a wide range of classes of human activity and sets a precedent for effectiveness (Tang et al. 2003). The effectivity of AR technology application may be influenced by the complexity of the visual highlights and of the product (Herrema and Oliver 2015). Nowadays, there is a series of assembly operations that are mechanized, but still a critical number of operations require human assemblers (Tang et al. 2003). Figure 2 demonstrates an example of an assembly workplace, with the human assembler using an AR device to help him execute the task (Paelke 2014). Having this in mind, there is a need to supply assembly workers with pertinent data at the right place, at the right time and with the appropriate quality, as efficiently as possible, this can be accomplished using AR technology (Reinhart and Patron, 2003). Automated assembly is best for undertakings that have all around characterized areas for acquiring and inserting parts, and for manufacturing processes of large-scale manufacturing (Tang et al. 2003).

With AR technology, the exchange of attention due to assembly data not being alongside the equipment, wouldn't be a problem, since the operator will be focused on the job that needs to be done without having to physically move to get the following arrangement of assembly directions (Yuan et al. 2008)

VR Technology is said to be used in the early period of the life-cycle of an assembly station, while AR is mostly used in the control and maintenance stage. In the assembly area, AR can be used by superimposing virtual arranging results onto the real assembly environment (Reinhart and Patron 2003), as shown in Figure 3 (Ong et al. 2008). Using AR in assembly, offers preferences wherever there is a huge extent of inquiry time, laborers need to ace much of the time changing work contents, or the assembly task is extremely complex and requires a lot of data (Reinhart and Patron 2003). It is important to determine 'when', 'what' and 'where' to show the virtual data in the augmented world, in utilizing AR for assembly guidance, which will require somewhere around a halfway comprehension of the encompassing scene. This will require adequate sensor methodology and translation that can speak with the AR systems and the applicable changes in the condition of the environment scene with which the user interacts (Yuan et al. 2008). To empower simple adjustment to various assignments, AR applications must be adaptably structured. It is essential not exclusively to think about the presentation and structuring of the information but to consider the whole arranging procedure, from the formation of the AR contents to the adjustment of the system to the assembly task (Reinhart and Patron 2003). The help of AR in an assembly work will build profitability and decrease mistakes because of the portrayal of the task appropriately enlisted with the workspace, also mistakes are more outlandish and the cognitive load of translating abstracted directions onto reality is reduced (Tang et al. 2003). Since humans have cognitive capacity, they are considered superior to automated systems in adapting to flexible, customized and elaborated procedures (Haslgrubler et al. 2018) although, one of the principle issues in manual assembly, is that master assemblers are difficult to prepare, especially for assembly procedures that require critical thinking abilities. It frequently takes a very long time for a beginner assembler to be an expert at assembling processes that have high intricacy (Tang et al. 2003).

Assemblers should be broadly educated, preferably on the job, to perform any kind of task so they have a more profound comprehension of the procedure all in all. For that, AR may significantly affect manufacturing industries by supporting human manual activities that might be required in customized conditions (Tang et al. 2003).

One of the latest ongoing endeavors of AR visual assembly guidance being proposed is a research based on real-time vibrotactile guidance method that also developed a Haptic Augmented Reality application with a low-cost configuration to evaluate the support of the proposed method in assembly tasks, the goal is that the method allows the user to concentrate on the task and avoid being dependent of the AR technology (Arbeláez et al. 2019).

Figure 2. Assembly workplace based on AR technology. Source: (Paelke 2014)

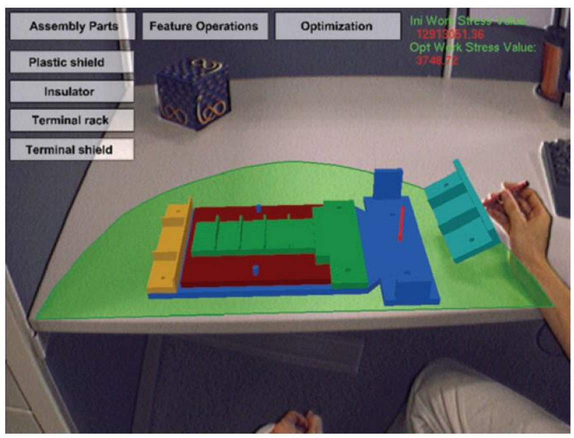

Figure 3. Visualization of the output of assembly layout using AR-based algorithm. Source (Ong et al. 2008)

5. Augmented Reality Challenges

The bad ergonomics of HMD and the issues with hardware are holding back a more comprehensive use of Augmented Reality in large scale manufacturing (Anastassova and Burkhardt 2009). Through the expanding interest for product assortments and customized designs, the present manufacturing plant arranging should be quick and adaptable while providing high quality. To accomplish this, planning errors should be decreased, which predominantly requires an exceptional and complete underlying planning information base (Pentenrieder et al. 2007). The utilization of AR technology is a conspicuous method to help convey the correct data to the right place at the right time. Service personnel force furnished with a wearable computer unit, can get the suitable data showed alongside or overlaid onto the object they are reviewing. Not exclusively would this be able to get rid of the requirement for a paper schematic, yet a far more richer data resource can be given by means of online access to committed information and media content. The guarantee is to expand effectiveness (fewer blunders) and efficiency (shorter time to finish the assignment) using context-sensitive, up-to-date, and media-rich information. AR technology and research has not yet achieved a dimension of development that takes into account a widespread deployment from scratch. The underlying application fields should be recognized cautiously with key people in trend-setter roles. These individuals should fill in as intently as conceivable with the researcher, know the application field well, and be generally acknowledged among their partners to serve as a point of multiplication for later spread. In the event that a project does not have such an individual who completely acknowledges the methodology and is ready to drive it to progress, the whole venture will most likely fall flat (Friedrich 2002). Every industry is exceptional in its own particular manner and the prerequisites of the business are not the same as one other. This distinction in prerequisites prompts another challenge that makes the need for specialization of technical answers for each industry (Yuvana et al. 2014).

It is essential to understand that most communications in an AR environment are as of now one-directional, i.e., real objects can influence the virtual objects, yet the virtual objects cannot generally influence the real ones (Pang et al. 2004). As applicable innovative technologies further enhance, it is normal that the HMDs will wind up smaller and lighter and never again be a physical and obstructive weight to the users. Wearable computing devices will likewise become smaller and, in the long run, getting to be oversized wrist watches (Ong et al. 2008).

An effective AR application in manufacturing and other fields ought to, in an ideal world, have the following hardware and software systems (Ong et al. 2008):

(1) The AR systems should be progressively precise, smaller, lighter, faster, simpler and less expensive. It ought to be exceptionally advantageous for the users;
(2) The systems should have efficient and suitable User Interfaces (UIs) that can be advantageously used to connect with the blended models in the manufacturing environment. The users can, without much of a stretch, work the virtual and real objects in the 3D manufacturing environments, for example utilizing their hands to uninhibitedly communicate with the things in their everyday life;
(3) A fast and stable Internet-based communitarian AR system for manufacturing activities will be perfect for meeting the very highly competitive business and manufacturing environment.

According to (Bilyk 2018), with regards to challenges related to the application of the AR technology, and in spite of the fact that the technology is experiencing expansive reception and public acknowledgment, all the investments are yet to satisfy for sure, that is because of the way that nobody had figured a distinct AR-related Business Model that will work long-term (besides, probably, gaming industry). Decision makers want to see the business esteem promptly once they have acquired a technology like AR on account of the mass changes that accompany it. Be that as it may, with AR this is not the case, instant results are improbable, however after some time the effect will be genuinely transformational (Ismail 2017). The majority of the AR-related arrangements that are springing up are integrated into the plan of actions that can be compelling with or without an AR solution. Then again, industrial companies have enough financial resources to help improvement in different fields. These sorts of applications can possibly set up an augmented reality technology as a practical helping apparatus that improves the general quality of the end product (Bilyk 2018).

There is likewise an absence of AR App Design & Development Standards, that are something of a widespread language for a software application, tying down its similarity and commitment to the general advancement of the technology. Implementation of technical standards is a question of time, and its adoption will connote the last phase of building up the technology as a real deal (Bilyk 2018). This is additionally obstructed by the hesitance of business leaders, and in fact workers, to change the usual methodology. Many are glad to work in an increasingly comfortable, conventional environment (Ismail 2017). That also raises the challenge of Security and Privacy Issues, because of irregularities in augmented reality programming, oversight and negligence, on the grounds that there is no actual regulation that assigns what is permitted and what is not in the AR environment. Developers of the technology must also have in mind the possibility of physical harm, once the technology drives attention away from reality which may cause a potentially dangerous situation (Bilyk 2018).

Masood and Egger, recently grouped the challenges that were reported during previous experiments conducted using AR technology, and demonstrated that the industrial environment causes new challenges contrasted with research facility situations. The major challenges were identified as being the following: hardware and software issues, weight, ergonomics issues, limited user acceptance, visual fatigue and concentration performance issues, data transfer, integration and security issues, content authoring, adaptive instructions, marker tracking reliability and cost (Masood and Egger 2019).

Having these challenges in mind, AR technology has proven its capabilities of extending user experience and making it progressively helpful, the solution of these challenges is a question of time.

6. Summary

Developments in the innovative territory of AR are uncommon. From one perspective, innovative work is still in its initial days. Then again, the academic and industry accomplices concur that there is colossal potential for the technology in a wide assortment of applications. Thus, different endeavors to bring innovative work and research and development of AR together have been made and AR is still at the highest priority on the rundown for potential developments.

Broad research has been done worldwide in addressing some of the critical issues in AR technology. Real-time tracking and computation are crucial since synchronization between the real and the virtual worlds must be accomplished in the briefest conceivable time interim.

AR applications are both hardware and software intensive. Exceptional gear, for example, HMD and accurate trackers are required. In spite of the fact that AR has discovered a decent number of uses in design and manufacturing, there are few in-depth studies that assess and evaluate human factors and interaction in AR system. The restricted comprehension of human factor issues is probably going to hinder widespread adaptation of AR systems beyond laboratory prototypes.

The future of IAR researches should focus on how to technically enhance the modern shop-floor and provide the operators with better instruments so as to help them to work optimally and settling on the correct choices.

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Biographies

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