International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249 – 8958, Volume-9 Issue-1, October 2019

Augmented Reality (AR) Application in Manufacturing Encompassing Quality Control and Maintenance

Amelessodji Kokougan Etonam, Giulio Di Gravio, Patrick W. Kuloba, Jackson G. Njiri.

***Abstract*: Augmented Reality (AR) systems present a technological platform that allows a harmonious integration of the real and virtual worlds, structured with endless capabilities in its application. With the rise of information technology, AR has made a significant contribution to industrial applications, namely: medicine, aviation, manufacturing, etc. This paper aims to provide dipper insightful on AR technology by investigating the current state-of-the-art of AR technology usage in the manufacturing industry encompassing quality control and maintenance. It describes how AR technology has been integrated into quality control and maintenance, current and available AR devices in use, and future research direction.**

***Keywords*: Augmented Reality (AR), Manufacturing, Quality Control, Maintenance, AR Glasses.**

I. INTRODUCTION

Innovation has become an essential feature of the manufacturing industry and aims at improving quality, controlling pollution, and eliminating wastes. Revolution in the industries is rampant and is characterized by the digital revolution and the use of widespread application of the internet, intelligent components, robots, and technologies. Several technologies such as Machine learning (ML), Artificial Intelligent (AI), Cloud technologies Recently, the manufacturing industry is experiencing rapid growth around the globe. In this industry, quality control and Maintenance play an integral role in the product. Quality control is a vital stage in the production process, and it directly affects the overhead cost. The production of defectives unites reduce the profit margin and increase the overall production cost. Defective products detected by the customer may cause twice the cost of producing the original product. Similarly, maintenance is a critical aspect in that, the quality of the product depends on the health state of the machines within the production line. Technological, Internet of Things (IoT), Virtual Reality (VR), to name a few, are technologies that are being used to support manufacturing activities include production quality control and maintenance in various industries. For a thorough acquainted with AR technology, this work presents an overview of recent and supportive technologies, potential applications, development platforms, and future trends of AR systems. The other part of the paper is structured into four segments. Section 2. Introduces technologies that support AR systems, devices being used, and focuses on the contribution of information tech in AR. section 3. Identifies the application areas of AR, its integration into manufacturing encompassing quality control and maintenance. section 4. focuses on the analysis of the AR system in manufacturing. Finally, section 5 concludes and provides directions we believe AR research might take.

Revised Manuscript Received on October 20, 2019.

* Correspondence Author

Amelessodji Kokougan Etonam *, Department of Mechanical Engineering, Pan African University Institute of Basic Sciences, Technology, and Innovation, Nairobi, Kenya. Email: eamgan@gmail.com

Giulio Di Gravio, Department of Mechanical and Aerospace Engineering, University of Rome, La Sapienza, Italy. Email: giulio.digravio@uniroma1.it

Patrick W. Kuloba, Department of Mechanical Engineering, JKUAT University, Nairobi, Kenya. Email: kulobap@ymail.com

Jackson G. Njiri, Department of Mechatronics Engineering, JKUAT University, Nairobi, Kenya. Email: jackgithu@eng.jkuat.ac.ke

II. AUGMENTED REALITY (AR)

A. Definition and brief history of AR

Though this paper concerns Augmented Reality, it's convenient to differentiate between VR, AR, and MR. Virtual Reality (VR) is a technology that allows the user to take part in a simulated reality experience, while Augmented Reality (AR), is a technology that places digital objects on real surroundings. Mixed Reality (MR) is similar to AR but allows users to interact with digital objects placed in a real environment which according to Milgram is a superset of AR applications in the real-virtual spectrums between contrasting real and virtual environments [1].

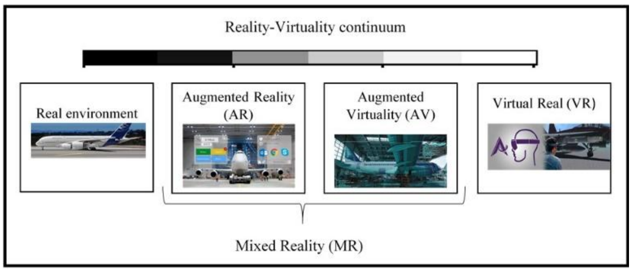

Figure 1. Paul Milgram's Reality-Virtuality (RV) continuum.

Augmented Reality (AR) has deferent definitions according to the authors, and this is to avoid limiting the perception of the concept, we wish to suggest a definition of AR as a technology/system based on real-time Data Visualization.

Though it is difficult to know the exact date where AR was coined, one of the first examples of AR used back in 1968 was by a Harvard Professor who invented the first Head Mounted Display (HMD) a device that is worn on the head and comprises of an inbuilt display optic which may be on one or both eyes allowing to immerse the user in a visually simulated 3D environment. Surprisingly, the innovation remained relatively unexplored until the early 1990s and only garnered interest after Thomas Caudell, and David Mizell made the first AR systems by using an HMD. Navab explains and consequently coins the technological techniques used in digitally transmitting real-world objects, through an overlay of computer-generated data framework whose registration can help compute positional variables, as 'Augmented Reality' [1]. In the years that followed, researchers developed prototypes that simulated the possible industrial applications of AR technology. Interest in the technology has grown considerably attracting scientific and scholarly research. Advancements and adaptation of AR have been registered in various fields, such as Military, Medicine, Aviation, Engineering, Manufacturing to name a few, due to the revolution of mobile phones and a portable computer, the development of AR software like ARToolkit and hardware have contributed to the progress of the technology. In 2013, Volkswagen uses augmented reality through MARTA app as their car manuals. MARTA app is used on the iPad and can assist users in viewing the internal workings of the vehicle and allow the service mechanics to know what they are exactly dealing with. The MARTA application also shows sequential instructions to help mechanics with the projects they are working on. MARTA also helps with replacing parts, and can even be as specific as, which direction the parts should be facing. The app can be used for more cosmetic projects as well, including seeing how different color paint jobs can look on your vehicle. In 2014, Google Glass was revealed and was made available for consumers. The Google Glass wasn't that successful as developers hoped it would be, but it did show the potential of what wearable augmented reality could be. The next iteration of wearable augmented reality occurred in 2016 with the introduction of HoloLens by Microsoft and seemed to be everything that the Google Glass wanted to be. The research was conducted at Iowa State University, and it had been found that the HoloLens condition-issued faster completion times than all other conditions. HoloLens users also had lower error rates than those who used the non-AR conditions. Despite the performance benefits of the HoloLens AR instructions, users of this condition reported lower net promoter scores that users of the Tablet AR instructions. The qualitative data showed that some users thought the HoloLens device was uncomfortable and that the tracking was not always exact. Although the user feedback favored the Tablet AR condition, the HoloLens condition resulted in significantly faster assembly times [3]. In 2017, Unity 3D embraces Extended Reality (XR) was incepted to support both AR/VR. XR refers to all real-and-virtual combined environments and human-machine interactions generated by computer technology and wearables. And in 2019 Microsoft announces the HoloLens 2. [4].

B. Augmented Reality supportive technologies

The use of AR requires the application of high technologies which also is one of the factors that hinder the advancement and application of the technology over the years. But thanks to the evolution of information tech, hardware, and software become more available, affordable, and have the AR usage a bit easier. Also, it is substantive to highlight that the key components are required to make the AR system remain the same. In this section, each supportive technology will be pointed out and will be described as well as hardware/devices. Display, tracking methods, AR software, and development platform are the most technologies that are being used to support AR systems.

B.1. Display

The commonly used displays in AR include Spatial, head-mounted, and handheld displays. The head-mounted displays (HMD) are worn on the head hence enabling the user to have an aerial view of the real and virtual environment. HMD Is divided into two classes: Video see-through and optical see-through both pose distinctive mechanisms of displaying text [5] hence affecting how the user perceives them.

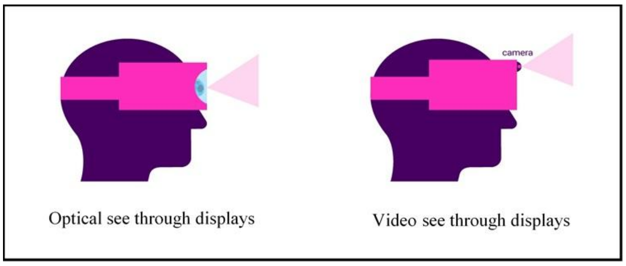

Figure 2. Optical – Video see-through displays

With video-see-through (VST), two cameras are used [5] whereby a digital video image is captured in the real world and is transferred in real-time to the graphics processors. At that point, the graphics processor combines the audiovisual images feed with visual content and parades it on the screen. With VST one can control the contrast, and the light intensity of the virtual elements and the physical world since the video processing takes place before displaying content to the user. [6] some notable drawbacks of VST include; Low resolution of reality, eye offset, and a narrow field-view which is caused by the position of the camera. On the other hand, optical see-through (OST) uses optical elements to function. These elements must be partly transmissive and partly reflective so to integrate both the real world and virtual elements. The half-silvered mirrors enable the user to directly see the surroundings since the mirror lets enough light from the real world to pass through. Concurrently, through a display element positioned in front or sideways the mirror projects computer created images. Unlike VSTs, optical see-through displays the world in a natural resolution. Also, they can function even when there is no power. However, with VSTs the user doesn't have control over the brightness and contrast of virtual and real-world components. Hand-held displays (HHDs) are AR systems that can be held on the hand by the user, such as smartphones and tablets PCs. The obvious advantage of HHDs is that they are portable. VST techniques are used in hand-held displays. With the ever-evolving technology of smartphones, the widespread and use of AR technology becomes diverse and more accessible [7].

Nowadays, a significant number of people on the planet use smartphones apart from them being affordable they are also equipped with convenient sensors like the Cameras and Global Position Systems (GPS) hence, they are an excellent platform for AR. However, high power retention ability can be a drawback in using a smartphone. Additionally, they have a small display. Compared to smartphones, tablet PCs are more powerful; however, they are more expensive.

Unlike HHDs and HMDs, spatial displays are not attached to the user's body [8]. This makes it possible for many users to use AR technology simultaneously. Spatial display use projectors, video- see-through or optical- see-through approaches to display information to mounted objects. Video see-through displays are also known as screen-based displays. They display mix videos and merge images on a monitor; hence, the field-view is dictated by the monitor's dimensions. They are the most cost-effective AR displays that can be used if the system doesn't need to be moved since they do not need a lot of equipment. Spatial optical see-through show imageries that are aligned in the natural surroundings. Also, just like video- see-through, OST does not support mobile applications. Projector- based displays, projects images onto a front physical object.

B.2. Tracking

GPS, Ultrasonic, mechanical, electromagnetic motion tracking and inertia are the main tracking based technologies used in AR. There advantages and disadvantages are outlined in [9]. Each tracking system used depends on the kind of system being developed. Also, they have different altitudes of accuracy.

Inertial

For an AR system to place the projected image accurately on the screen, the 'computer must be able to compute the precise motion and position of the person's head attached to the headset. [10]. An Inertial Measurement Unit (IMU) aids the process. To implements, the task the IMU uses an accelerometer, gyroscope, and a magnetometer. The accelerometer gauges the varying capacitance hence measuring acceleration, as shown in figure 3.

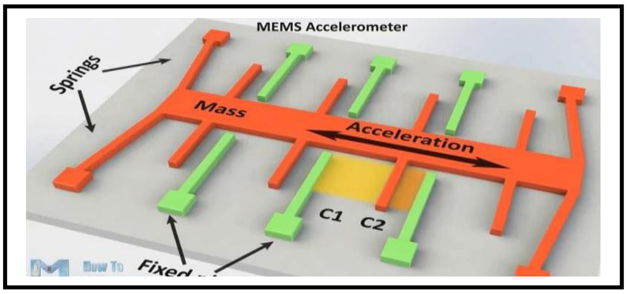

Figure 3. accelerometer microstructure

The gyroscope has a mass that attaches to spring. It only moves in one particular direction hence fixing the outer plates. Therefore, once acceleration from a specific direction is felt, the mass will change position, and the capacitance will change. The change will be measured and will correspond to a particular rate of acceleration. A gyroscope measures the angular velocity in units when a mass is moving in a precise direction. And when an external angular rate is applied as shown with the arrow in green.

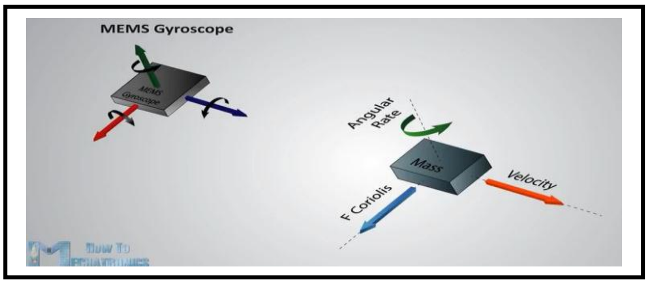

Figure 4. gyroscope showing the angular rate

As shown with the arrow in blue, a force occurs which causes the mass to have a perpendicular movement. This movement causes a change in capacitance, which is measured and matches with a specific angular rate. The microstructure is shown in figure 5.

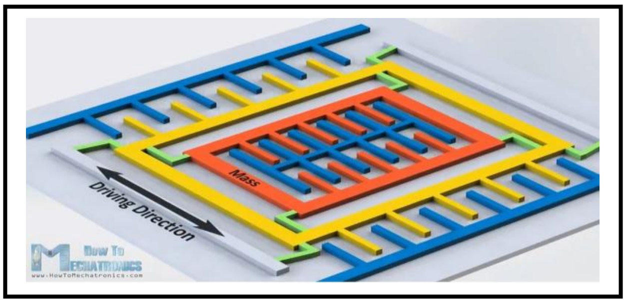

Figure 5. A microstructure of a gyroscope

The magnetometer measures the earth's magnetic field by using the magnet resistance effect [11]. The three elements measure the properties in 3 axes (X, Y& Z) When the signals are combined, they correct errors and produce measurements that are accurate to track the head movement and position.

GPS

With the latest AR application on navigation that uses GPS, the user doesn't need to follow a map on their smartphones; instead, they are guided by a virtual path on the camera preview.

Ultrasonic

Ultrasonic sensors are cost-effective, reliable in both detecting objects' presence and measuring the distance to the objects [12]. Figure 6 shows a microstructure. Unlike optical and laser distance sensors, ultrasonic sensors are unaffected by dust, smoke, fog, and steam. They are ideal for industrial use because they detect invisible objects at a far distance, they are independent of object surface and texture, and they are great for solid materials, rolled goods, bulk goods, and liquids. They are also independent of environmental noise, light, and temperatures. The only disadvantage of using them is that they can only detect objects that are within a distance of 13 meters.

Figure 6. Ultrasonic microstructure.

Electromagnetic sensors (EMS)

Electromagnetic motion tracking systems work by using a low frequency isotropic magnetic field generator (3D emitter) and one or several isotropic 3D magnetic sensors. The emitter and receiver sides need special 3D magnetic coils to generate and receive the signals of the magnetic field. The EMS measures the strength of the magnetic field using attenuation and the signal level in every axis. Subsequently, movement and orientation are defined. One disadvantage of using the sensor is that it does not measure the physical properties

Mechanical sensor

There are many types of Mechanical sensors that are used in measuring variables In AR, including velocity, position, force levels, pressure, acceleration, and flow. They sense changes in mechanical properties and are essential for positioning [13]. They play a considerable role in automation.

B.3. Software and development platform

Lately, there has been an integration of new technologies in AR. This has driven new software development in the field.AR developers have a large variety of AR software's to rely on, as discussed below.

AR visualization software

This software's enables consumers to explore their data and interact with it. It advances the involvement of the user and experience. When using the software, the user can change the color, upload content, balance the image, and add more details. This is of great benefit to business executives and data analysts among other users. The software enables the user to control and view their data in a unique way.

AR content management systems

This software enables the user to upload a lot of 3D raw content that serves as a basis for experiences in AR. It allows the user to manage their content or edit it within the system. Hence the user can make changes even after uploading the material; the user can add or remove color and also change textures on the products.

AR software development kit (SDKs)

SDK is an engine that influences the creation of AR experiences and apps. SDKs blends in digital information into the real world [14]. Since there are many SDKs, the features of the project to be done dictates which one to use. Each SDK has unique properties that enable AR developers to track, render, and recognize the app.

AR WYSIWYG editor software

This software enables users with no coding skills to customize their AR experiences. The users can edit their content by using dragging and dropping technique [15].

Industrial AR platforms

AR industrial software's are used in various industrial fields that include, marketing and sales to demonstrate products hence accelerating sales and creating virtual designs. Also used in promoting quality through incorporating AR in operations to ensure quality assurance, therefore, reducing defects. Besides, it is used to provide services, thus improving efficiency and accuracy.

AR training simulator software

This software empowers technicians to develop employee's customized training in different fields.

AR game engine software

This software allows game developers to develop AR game experiences. The engine often integrates with an AR SDK to enable the developer to design and test their games. With the software, the developer can edit and create 3 dimension characters that integrate with the real world [16]. Developers can also give behaviors to the characters.

Software Features of AR

Manage content – AR solutions should enable the user to manage all created content within the platform. The content can either be raw 3-dimensional content or content that has already been redesigned.

Enable editing – The software's should enable the user to edit the content that they upload on the platform. The user should be in a position to adjust the images, color, and add more details. Ability to Integrate with hardware's – AR experiences cannot be created without the integration of some hardware that includes mobile phones, glasses, and tablets, among others. Hence, the software to be used in AR development should have the capability of integrating with the hardware.

Drag and drop features – Some AR software is created to aid users with no coding techniques to create AR experiences. These tools allow users to insert objects into an already designed scene. This way, they become AR experiences.

Hindrances related to AR software

Cost- High cost involved in AR development is a significant drawback that hinders AR is becoming mainstream. It may be expensive in purchasing the hardware's, eg glasses to support AR technology but also, running the content with the appropriate software is costly. High expenses related to AR may make consumers hesitant in adopting AR in the future.

Accessibility- AR technology is not readily available to the public; this is due to the high cost related to AR development. As there are few people exposed to the AR technology, it is not easy for them to explore all the uses that AR offers.

III. AUGMENTED REALITY APPLICATION AREA

A. Field of Application

By field of application is meant the industry or a technological environment where the use of AR can be considered. The most current AR systems are applied to medicine, navigation, military, marketing, and maintenance, and repair, which mainly is discussed in section 4.

AR uses in the medical sector

Over the years, the latest technology in the medical sector has been adapted to promote quality service and efficiency while reducing risk.

AR Technology promises to revolutionize surgeries in the medical sector. With the use of AR 3D glasses, the surgeon can keep his head up while performing the task [17]. Also, the technology can scan the patient in real-time then shares the information with other doctors that might be helpful but not present in the surgery room. A growing number of hospitals will be adopting these new systems by 2020, pushing the boundaries of surgical reality as we know it. Also, AR helps in medical training since it can be used to study human autonomy interactively without a live person. It helps legally blind people to see better.

AR for navigation

With the exploration of AR technology in navigation, everybody can have an AR experience since navigation is used in everyday life. Recently, AR integration with GPS has made navigation more comfortable. Using a smartphone camera and an AR app for navigation, the user can follow a virtual route in real-time.

AR uses for military

As warfare evolves, the military has to keep up with technology. A smart helmet for the military is a work in progress still advancing. Military use a technology known as Tactical Augmented Reality (TAR). This technology will revolutionize how soldiers access information and conduct operations.

Moreover, TAR not only shows the military the exact position that the enemy is at but also the correct distance. With this, the soldier is not forced to look down to check the GPS location since the display is a head-mounted helmet. TAR allows the vision to be segmented into two so that the military can view the position of the enemy and at the same time view around the corner of over the wall; hence the soldier avoids a headshot. TAR also allows sharing of information among a military squad; thus, communication among them becomes more manageable. AR technology has also enhanced military training [18]. AR allows military trainees to perform military duties more tactically as they would in real warfare.

AR uses for marketing

Nowadays, furniture, clothing, and cosmetics industries caught on to the potential of AR because it creates strong competitive advantages. AR brings better visual recognition and emotional attachment. This increases the time of interaction with the product, increase product frequency, and the number of purchasing. [19, 20].

Figure 7. Shows an example of AR shopping.

Figure 7. AR shopping.

This AR app allows the customer to fit every suite or clothes he/she wants in a virtual world and feel it as worn in the real world by seeing the suite/cloth displaying upon his/her reflection on a screen.

B. Introduction of AR in Manufacturing

It is not easy to develop new products and produce massively without exploiting the appropriate computer-aided systems. Traditionally, manufacturing industries used Computer-aided manufacturing (CAM) systems to control automation production. To guaranty maximum enterprise profits, all manufacturing processes have to incorporate modern technology. The first applications motivating the use of AR were industrial such as Boeings wire bundle assembly needs and early maintenance and repairs. Augmented reality aided manufacturing (ARAM) embodies the application of AR technology in the manufacturing processes. Currently, enterprises are facing the pressure of producing innovative products without enough time to market. Also, due to the demand, product development processes have to be done in real-time, so to save time. On the other hand, environmental law on disposal has become tighter; hence, industries are obligated to recycle their products. Therefore, industrial processes have to be more systematic and organized to ensure minimum production cost and maximize profits while also keeping up with the competition. AR technology is seen as an efficient solution to keep up with the pressure in the manufacturing environment in various ways as discussed below.

IV. ANALYSIS OF THE AR SYSTEM IN MANUFACTURING

Data utilization is in any aspect of life, but the information is the most critical aspect. Data-driven technologies are making our life easier, faster, and more comfortable. In the manufacturing industry, when a machine breaks suddenly, it stresses the operator and often takes too long to identify and fix the problem, which leads to scrap. To often, we may need to transform to smart manufacturing. To improve productivity, it's enough to identify the area of waste and see which situations on the platform are causing loses in real-time to take preventive actions. That's where AR application in manufacturing found its use. [21]. By analyzing literature about AR system, their main current area of use in manufacturing are complex assembly, maintenance, and repair, Automation, and Quality Control.

Assembling

In modern manufacturing, complicated assembling is inevitable. Whether you are assembling smartphones or aircraft engines, many components have to be put in a sequence as fast as possible. This can be a challenge because when stuck in the process, the person performing the task sometimes is forced to walk to a work station and have a look at a pdf or a video manual. With AR technology work is made easier and time is saved since the instructions needed for assembling the products are consolidated in AR glasses. Hence the worker can keep his hands on the work and doesn't need to walk in the work station to check on other instructions. With the use of HMD glasses, the developer uses the developing software that video streams instructions on assembling processes.

When 3D instructions are integrated with AR technology, students can learn to join techniques interactively. The method of disassembled mechanical parts is augmented in a video; other video effects such as animation could be incorporated to show a practical situation in the real world. All through the training sessions, students can view the actual assembling parts in their respective order. Necessary tools and technologies that aid in assembling are also displayed. Then, the system leads the student into a step by step assembling and disassembling processes. AR technology makes learning processes more appealing and practical. The figure below demonstrates the worker performing his assembly task.

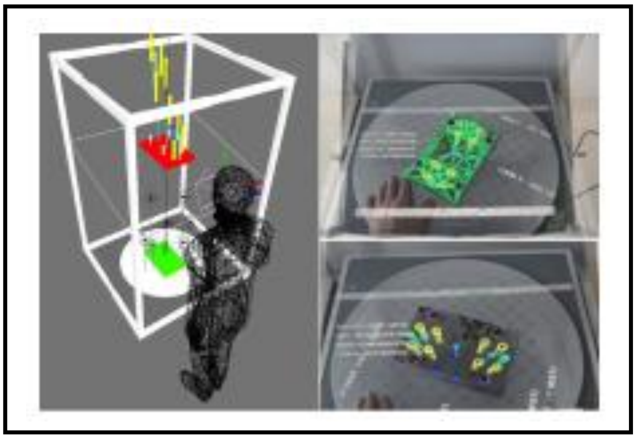

Figure 8. a worker performing his assembly task

There are three critical areas of applying certain features to utilize the AR assembling process to increase the user's comfort and improve quality in the assembling process.

1. Audio Support- When assembling machines, the developer may make mistakes due to vague vision. The audio support in the AR application can eliminate assembling errors. The audio may be recorded as short notes information inputs or beeps signals that rings upon detecting a mistake in the assembling process. The audio support is more helpful in assembling training sessions since the students are bound to make mistakes. It is better for them to correct the mistake in the first attempt other than re-doing the process.
2. Enhanced text – the quality of the information in the AR app determines the quality of the assembling process. Hence it is vital to strengthen the integration of text in the virtual assembling environment. Text is displayed in an interactive menu that enables the user to navigate additional information.
3. Interactivity – AR application used in the assembling process allows the user to interact with the 3D features in real-time. This gives the user comfort.

Maintenance

The first AR maintenance task is described by Feiner et al. [22]. In the past, when a machine failed in an industry, the user had to call a service technician but, using the power of (KARMA) knowledge-based AR and maintenance assistance system, the user is now able to perform that necessary service procedure by himself. Through scanning a machine with an AR display device, the user can detect the defect. Furthermore, the display can give directions to the user in real-time on how to repair the failure in the machine. An augmentation is displayed corresponding to the next repair step. The augmentation displayed on the glasses assists the worker in identifying the action to be taken. The technology may use highlights such as animation to guide the worker on the maintenance procedure. The technology can also visualize a defect in a machine before a task.

Reading long pdf and documents to carry out a sophisticated repair task, is time-consuming and tiresome. To ease this, Neumann et al. propose a maintenance AR application that would aid maintenance workers in an aircraft to test the circuitry [23]. This system gives guidance to the task, and also it detects the stages of the process and can detect unusual objects. Moreover, it can sense hidden objects, for example, something inside the dust. To examine a water supply system in the manufacturing industry, a voice-enabled AR is recommended. The user relates to the system using voice directives. The worker undertaking the task uses a PDA to aid the system to locate his position. The location activates an augmentation of the current view that interacts with the water systems. For example, the technician can vocally inquire for the valve's pressure. The system transfers the voice to the software managing the plant hence inspecting the status of the valve. This integration is beneficial to the technician since he will always have available information. Furthermore, AR systems can give the workers performing the maintenance task access to an expert. Sometimes a worker performing the maintenance task may encounter difficulties in detecting the problem whereas an expert might be helpful. The system can scan the problem in real-time and send graphics to the expert. The audio between the two is often augmented with a video feed. The worker needs to follow the instruction of the expert step by step in real-time.

Some maintenance procedures are complicated and need expert attention. Lipson et al. [24] recommend industries to use online product maintenance systems to fill the gaps of experts in the field. This avoids the extra cost of transporting the expert to the field to establish or repair the problem. Instead, the expert could simultaneously support many repairs in different locations. Through augmentation, the system can help field workers to perform repairs. This is valuable for manufacturing plants that need frequent maintenance. The system can also be used to train multiple trainees to carry out maintenance processes. The trainees from different locations are linked to one expert. Through an HMD they access augmentation in real-time and can interact with one another like a typical conference call. Besides reducing cost and saving time, these systems enable the trainees to learn from each other's errors.

Automation

With AR technology, more jobs are continuously being automated. AR technology has been implemented in robot programming. When creating a robotic device fit for realization real-time tasks, it is necessary to consider the issue of continual space so to keep the virtual and real scenes spatially aligned in one working space. For this purpose, two devices are used, Kinect and a software tool known as Skanect. Kinetic aids in obtaining the 3-dimensional scan of the physical environment and using the data to create a virtual one. Objects got from the scan assist in creating spatial connections from the computer to the robot base.

AR has integrated artificial intelligence to improve workers' skills and safety [25]. Smart helmets and robotic arms are an example of integration. Such technology makes information traditionally created for the control rooms available in helmets mounted on the worker's head, as shown in the figure below. This elevates the workers' skills, and he or she becomes useful in various departments that he did not have skills on. The Use of robots in the manufacturing environment increases industry productivity.

Figure 9. Smart helmet

Quality control

The cost of correcting defective products in different stages of production can be uneconomical. For example, fixing a defect detected by a customer can be as costly as producing two units of the same product [26]. Therefore, there is a need for industries to reduce product defects by employing quality control procedures. AR technology is an economical and efficient option for quality control in all stages of production within industries. AR apps can be used in the inspection stage, whereby the application shows graphical instructions that tutor the user on how to go about the inspection. The user carries on the check without taking off his eyes on the procedure. Therefore, this saves time and reduces errors that may occur. The smart eye is the new quality control AR device developed by Bosch's technologies. The worker can compare the finished product with the one in the AR device. The operator follows the inspection instructions in the audio walkthrough and approves or rejects the product by vocal command. The smart eye may take a photo of the defective product, which automatically sent to the central system for review. By using this device, inspection time is reduced by 80%, and errors are significantly reduced. Below is an image of an employee conducting inspection using the Smart eye device.

Figure 10. Smart eye device.

Recently Porsche assembling plant in Germany has adopted AR for quality control. The AR system here is used in the final stages of quality control before transporting the car to the customer. The assembling components and parts are thoroughly inspected for any quality issues. The elements are scanned and saved on a digital database; the workers have enabled to counter-check their placement through an AR display on the car in real-time. Hence, ensuring the vehicle as per the standard.

V. CONCLUSION AND FUTURE WORK

The objective of this paper was to provide a dipper insightful on AR technology by investigating the current state-of-the-art of AR technology usage in the manufacturing environment encompassing quality control, and maintenance. It also gives an overview of the potential benefits of adopting AR systems in the manufacturing industry that includes saving time, reducing cost, and reducing defective products. It's found out that AR technology has not fully embraced by many manufacturing industries due to the initial cost of purchasing the systems and also due to lack of research. As a new technology, AR developers should find ways to make technology more affordable to reach a broader market. Also, the developers of AR systems should involve the manufacturing industries to cater to their unique needs. Consequently, this paper recommends the application of concurrent engineering between AR developers with manufacturing partners to advance and mend their prototypes. In conclusion, this research has generally analyzed the benefits of using AR in the manufacturing industry, but the drawbacks have been scarcely studied.

ACKNOWLEDGMENT

This research was supported by the Pan African University Institute for Basic Sciences, Technology, and Innovation (PAUSTI). The authors would like to thank the reviewers for their valuable comments.

REFERENCES

1. P. Milgram and H. C. Jr, "Chapter 1 A Taxonomy of Real and Virtual World Display Integration."
2. N. Navab, "Projects in VR Developing Killer Apps for Industrial Augmented Reality," no. June, pp. 16–20, 2004.
3. M. Hoover, "An evaluation of the Microsoft HoloLens for a manufacturing-guided assembly task," 2018.
4. Augmented Reality (AR) / Virtual Reality (VR), 2019 (video file), Available from:< https://www.youtube.com/watch?v=J03dh-xBi4w> [12 may 2019]
5. Carmigniani, J., Furht, B., Anisetti, M., Ceravolo, P., Damiani, E., & Ivkovic, M. (2011). Augmented reality technologies, systems, and applications. *Multimedia tools and applications*, *51*(1), 341-377.
6. Rolland, J. P., & Fuchs, H. (2000). Optical versus video see-through head-mounted displays in medical visualization. *Presence: Teleoperators & Virtual Environments*, *9*(3), 287-309.
7. Wagner, D. (2007). *Handheld augmented reality*. na.
8. Bimber, O., & Raskar, R. (2005). *Spatial augmented reality: merging real and virtual worlds*. AK Peters/CRC Press
9. Yi-bo, L., Shao-peng, K., Zhi-hua, Q., & Qiong, Z. (2008, October). Development actuality and application of registration technology in augmented reality. In *2008 international symposium on computational intelligence and design* (Vol. 2, pp. 69-74). IEEE.
10. Grinberg, D., Sarusi, G., & Luria, E. (2015). *U.S. Patent No. 9,210,413*. Washington, DC: U.S. Patent and Trademark Office.
11. Lukin, M., & Walsworth, R. L. (2015). *U.S. Patent No. 8,947,080*. Washington, DC: U.S. Patent and Trademark Office.
12. Perkins, M. R., & Geng, W. (2013). *U.S. Patent No. 8,457,656*. Washington, DC: U.S. Patent and Trademark

Office.

13. Blank, T. B. (2015). *U.S. Patent Application No. 14/743,479*.
14. Amin, D., & Govilkar, S. (2015). Comparative study of augmented reality SDKs. *International Journal on Computational Science & Applications*, *5*(1), 11-26.
15. Hofmann, K. M., Van Der Klein, R. J., Van Der Lingen, R., & Van De Zandschulp, K. (2015). *U.S. Patent Application No. 14/239,230*.
16. Dobbins, M. K., Rondot, P., Shone, E. D., Yokell, M. R., Abshire, K. J., Harbor, A. R., ... & Barron, M. K. (2014). *U.S. Patent No. 8,624,924*. Washington, DC: U.S. Patent and Trademark Office.
17. Chen, X., Xu, L., Wang, Y., Wang, H., Wang, F., Zeng, X., ... & Egger, J. (2015). Development of a surgical navigation system based on augmented reality using an optical see-through head-mounted display. *Journal of biomedical informatics*, *55*, 124-131
18. Rublowsky, S. J., & Crye, C. C. (2017). *U.S. Patent No. 9,677,840*. Washington, DC: U.S. Patent and Trademark Office.
19. Meet the Industry 4.0 Application: ProManage AR (Augmented Reality), 2019 (video file), Available from:<https://www.youtube.com/watch?v=qw65E4pp__k> [8 July 2019]
20. Augmented Reality in Marketing [Efficiency of using], 2018 (video file), Available from:<https://www.youtube.com/watch?v=wiKaQNh5LDs> [8 July 2019]
21. Augmented Reality for Marketing & Branding, 2018 (video file), Available from:<https://www.youtube.com/watch?v=u8njnXc7ziY> [8 July 2019]
22. Feiner, S., Macintyre, B. and Seligmann, D., 1993. Knowledge-based augmented reality. Communications of the ACM, 36(7), pp.53-62
23. Neumann, U. and Majoros, A., 1998, March. Cognitive, performance, and systems issues for augmented reality applications in manufacturing and maintenance. In Virtual Reality Annual International Symposium, 1998. Proceedings., IEEE 1998 (pp. 4-11). IEEE
24. Lipson, H., Shpitalni, M., Kimura, F. and Goncharenko, I., 1998. Online product maintenance by web-based augmented reality.New Tools and Workflow for Product Development, pp.131-143.
25. Longo, F., Nicoletti, L., & Padovano, A. (2017). Smart operators in industry 4.0: A human-centered approach to enhance operators' capabilities and competencies within the new smart factory context. *Computers & industrial engineering*, *113*, 144-159.
26. Porter, M. E., & Heppelmann, J. E. (2015). How smart, connected products are transforming companies. *Harvard business review*, *93*(10), 96-114.

Retrieval Number: A1120109119/2019©BEIESP
DOI: 10.35940/ijeat.A1120.109119

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication