Journal of The Gujarat Research Society

ISSN: 0374-8588
Volume 22 Issue 1, January 2020

An Examination of Augmented Reality Applications in The Field of Maintenance.

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ABSTRACT: For over 50 years, academic research has focused on Augmented Reality (AR) technology for assisting maintenance operations. Major advancements have been achieved in the past decade, and AR technology is coming closer to being used in business. The benefits and drawbacks of AR have been investigated and evaluated in terms of Key Performance Indicators (KPI) for industrial maintenance in this study. Unfortunately, there are still certain technological problems that prohibit AR from being used in industrial settings. The goal of this article is to demonstrate the present state of the art of AR in maintenance and the most important technical constraints using the findings of a comprehensive literature review. Filtering a huge number of articles down to 30 primary studies published between 1997 and 2017 was part of the study. The findings reveal a significant level of fragmentation across hardware, software, and AR solutions, resulting in a high level of difficulty in choosing and creating AR systems. The study's findings reveal the areas where AR technology is still in its infancy. Future research areas in industrial maintenance are also suggested, including hardware, tracking, and user-AR interface.

***KEYWORDS:** Augmented Reality, Building Management, Digital Engineering, Maintenance, Tracking*

INTRODUCTION

Augmented Reality refers to the use of virtual items to “enhance” the actual environment. The AR systems must have the following characteristics: the ability to integrate real and virtual things in a real environment; the ability to run interactively and in real time; and the ability to geometrically align virtual and real items in the actual world[1]. Tourism, entertainment, marketing, surgery, logistics, manufacturing, and maintenance are just a few of the areas where AR technology has been used. Its use in the area of maintenance has yielded a number of academic benefits. All activities aimed at restoring any functionality of a product throughout its lifetime are referred to as maintenance. When the product is industrial production equipment, the maintenance is generally referred to as industrial maintenance. Technical, administrative, and managerial measures may all be taken to restore a product's functionality[2]. AR research in maintenance have shown promising results in increasing human performance in doing technical maintenance jobs, improving maintenance operations administration, and assisting maintenance managers in making decisions. Despite the fact that AR technology has been available for more than 50 years, there are currently just a few instances of it being used in business. As a result, the purpose of this article is to describe the current status of AR in terms of technology, applications, and limits, with an emphasis on the maintenance environment. The authors conducted a Systematic Literature Review in order to accomplish so (SLR). SLR stands for a thorough literature review that guarantees the study's repeatability and scalability, as well as the objectivity of the findings. This method is very useful for research that is presently progressing rapidly[3]. A SLR method was utilized to assess the current state of the art for AR in maintenance. SLR's goal is to find, evaluate, synthesize, and analyze all papers pertinent to a certain area of study. The primary goal is to identify gaps in the literature and therefore offer evidence for future study areas. Planning, defining the scope, searching, evaluating, synthetizing, analyzing, and writing are the seven stages used to complete this SLR. Each stage has its own approach, which will be described in the subsections below. The stages of the SLR technique are described, as well as the results of each step (blue rectangles). In addition, owing of the topic's fast evolution, a manual search of Grey Documentation was conducted. It comprises information accessible on the Internet and produced by non-academic institutions such as businesses, governments, and local governments. Defining the scope results in the formulation of adequately answered research questions[4]. These were determined via an iterative process that included I initial brainstorming, (ii) literature search, and (iii) application of the PICOC (Population, Intervention, Comparison, Outcomes, and Context) framework. Different review and important articles on AR have been discovered as a consequence of I and ii. After that, the PICOC framework was used to identify the research's main ideas. Population, Intervention, Comparison, Outcomes, and Context are the components of PICOC. The population for this research is the industrial maintenance job performed by human operators. The intervention that is being explored is the use of Augmented Reality technology. Virtual Reality technology may be used for both training and operational environments, as well as conventional instructional techniques and remote maintenance assistance. The results of using these various techniques may be assessed in terms of KPIs linked to a certain maintenance job. The time it takes to execute an operation and the number of mistakes are two common key performance metrics. The impact would have an effect on human performance while doing a maintenance job, thus it is mostly economic and social in nature. Finally, for both training and operational operations, the Context comprises the industrial environment and the "customer environment." The Searching phase is going through each of the databases that have been identified individually. It was chosen in accordance with the study objectives and key ideas. To offer a more thorough initial screening, the Boolean operator "AND" is used. The collection is the outcome of this searching phase, which was updated on February 13th, 2017. Because this step was completed individually for each database, the total number of 723 documents includes duplicates[5]. The author analyzed and synthesized the 30 papers found via systematic research in order to address the research questions. It's important to note that the findings of this SLR study were impacted only by the 30 articles chosen. Other relevant research will be used to explain the findings and provide the reader a better grasp of the subject in certain instances. It was discovered that building a table that could correlate the papers in order to identify patterns and common characteristics of the many research was required in this stage. The author chose to create a table with 30 articles as columns and the key features of an AR system as rows: field of application, maintenance operation, hardware, development platform, tracking solution, interaction technique, and authoring solution. These key features were chosen based on the articles and the writers' knowledge of the subject[6]. It's fairly uncommon, for example, to see sections devoted to hardware, tracking, and interaction techniques in AR research. Furthermore, the writers of AR studies typically describe the application area and development process of the AR system they are testing or creating, as well as the maintenance operation considered and how the AR processes were created. The following sub-sections will give definitions for each feature. Because of the disparity in terminologies and the significant fragmentation of devices and tools used by the writers of the article under consideration, an attempt was made to develop more complete categories for each of the table's characteristics. The categories are broken down into sub-sections below[7]. The industry and/or technical environment in which the use of AR has been explored is referred to as the field of application. An AR system's area of use has been classified into six distinct groups. It's not surprising if the fields recognized by the application aren't all at the same degree of information or have various granularities. In reality, the selection procedure is based on an examination of the papers chosen for the SLR, as well as the statements gathered and kept throughout them. Another factor to consider is that airplane maintenance is a subset of mechanical maintenance, although this is not entirely accurate. We may readily envision that the criteria for dependability and availability of a mechanical system placed on a train and one integrated on an airplane are quite different. Because these groups have distinct needs for AR systems and maintenance, AR standards are often justified by the application area. Please note that these were the most often cited categories in the filtered list of articles found[8]. The author of each article that involves the creation of an AR system specified one or more maintenance activities that the developed technology can enable. A summary of the 30 papers identified is provided, divided by the following characteristics: field of application, maintenance operation, hardware, development platform, tracking solution, interaction method, and authoring solution, in order to describe the state of the art of AR applications in maintenance. Using the approach outlined before. It is a typical figure of the area of application covered in the 30 articles, and it is used as a case study in each of them. Aviation, industrial plants, and automobiles were all identified as the top three fields of interest for AR in maintenance. The mechanical field takes up the most space on the graph. It may be justified by the fact that it covers the automobile, railway, and military industries, as well as certain unclassified general mechanical maintenance activities. In reality, it is quite typical for an AR application created by a research team in an academic setting to be evaluated using the assemblies and items in their own lab. They verified their tool using five distinct mechanical assemblies in their study on marker-less object recognition and AR for assisting disassembly processes, without defining the area of application. Even if the program is evaluated using a mock-up or in a lab, the author typically offers insight into what the application was designed for. For example, without giving any test on the particular situation, recommends using his camera &IMU based rapid posture estimator" to improve training in a real-world setting. The aviation industry is the first area of application, as you read clockwise around the pie-chart. Several factors contribute to the aviation industry's significant interest in augmented reality technology. Human mistakes' effect on maintenance operations is necessary for increasing air-transportation safety. Traditional training methods do not apply to the modern technologies on board airplanes. AR must support the abilities needed for dealing with today's sophisticated systems and avionics. Following instructions in a manual or handbook to complete a difficult assembly job may lead to frustration and poor results. Furthermore, an aircraft maintenance inspector requires about 2000 hours of training, and his or her skills and expertise are not readily transferrable to another maintainer[9]. More broadly, there is a need to improve aircraft maintenance performance owing to the continuous requirement to ensure

ISSN: 0374-8588
Volume 22 Issue 1, January 2020

safe operation at a low cost. The second slice of the pie-chart shows the proportion of plant maintenance applications referenced or illustrated throughout the 30 articles, going clockwise. The upkeep of facilities/buildings/infrastructure that offer a living or working environment falls under this category. Because buildings are planned and built to endure for many years, the Operations and Maintenance phase of the lifespan will undoubtedly be the longest. Damage prevention and maintenance for subterranean infrastructure may be made easier using AR. An excavation project, for example, has a "high risk of unintentionally harming existing underground utilities," resulting in mostly financial damage and, less often, accidental fatalities. Service and maintenance are inherently mobile operations, necessitating mobile assistance. Furthermore, his goal was to empower industrial maintenance by enabling any maintenance professional to do plant maintenance. The localization of the objective to be maintained seems to be particularly important in the facility maintenance area. It is required in order to increase the efficiency of O&M. The first focused his study on indoor navigation using natural landmarks. The latter created an AR application that combines facility management data from the Computerized Maintenance Management System (CMMS) and the Building Automation System into one application (BAS). In his experiments, he was able to save on average 51% of the time it took to identify the target[10].

DISCUSSION

The "mechanical field" is the third most popular application area. It encompasses mechanical component maintenance in a variety of industries, including automotive, rail, and military. It's worth noting that repair and maintenance expenses account for 40% of the overall lifetime costs of vehicle ownership in the automobile sector. It has been claimed that hard manuals cause maintenance activities to be delayed. Because the operator does not need to read the paper instructions while using HMD, his or her attention may be concentrated on the job at hand. By switching attention between the item to maintain and the instructions, AR may "reduce eye and head movements, improving spatial awareness and therefore increasing productivity." These ideas are applicable to a wide range of applications. Moving on to the next slice of the pie-chart, we can see that consumer technology was referenced 17% of the time in this SLR's 30 articles. Many examples in the literature show how maintenance tasks may be applied to "consumer technology" like printers and laptops. The articles cited in this SLR make no mention of the need for AR to keep consumer technology up to date. The authors believe that AR in consumer technology is mostly used to show the possibilities of AR systems, which are frequently repeatable in other areas of maintenance. AR may assist with disassembly procedures by dismounting a computer blower. Data from non-expert AR maintainers. As a result, he contemplated a notebook maintenance method. His findings indicate that utilizing AR-based instructions rather than paper-based instructions reduces both mistakes and time. Even though he identifies the auto-motive and aircraft maintenance industries as the ones in need of cost maintenance reductions, he uses AR to apply it to notebook and printer repair operations. His research colleagues anticipated a 40% decrease in travel time and a 30% cost reduction for maintenance operations. Continuing clockwise, 8% of the research mentioned nuclear power plants as a potential use for AR in maintenance. Nuclear facilities are more complicated and need greater dependability than other industrial facilities, similar to the relationship between aircraft and automobiles. Because nuclear power plant maintenance is costly and complicated, a large amount of procedural paperwork is generated. It's critical to keep their downtime and safety to a minimum. These ideas have already been proven to anticipate the nuclear industry's growing maintenance problem. He said that owing to the strict maintenance schedule, even the most experienced workers may make mistakes, resulting in increased time and costs. Nuclear power plant maintenance must be improved not only because of their complexity, but also because of the existence of radioactive surroundings. In his case study, he dealt with the accessibility of the LHC (Large Hadron Collider) collimators, which had altered owing to the installation of additional equipment after the design. We found apps that mention the use of augmented reality (AR) for remote maintenance. The cooperation between an expert and a maintainer who are physically separated is referred to as remote maintenance. It's also known as "collaborative maintenance" or "remote help" by authors. Several articles discuss the use of augmented reality to improve remote maintenance. Traditional "on-the-phone" remote help cannot keep up with today's technological sophistication. He also stated that, although VR can help with maintenance training, AR may help with real-time knowledge transmission from expert to technician. AR is 10% quicker than phone support for collaborative maintenance. Machine tool manufacturers are particularly interested in using AR for remote maintenance. Machine tool manufacturers, who are represented in the initiative, find it ex- passive to help their customers. Furthermore, since each unit is unique, specific maintenance methods are needed. Improving remote help may result in higher customer satisfaction as well as lower maintenance costs. The automotive sector is also aware of the issue of distant cooperation. In-vehicle sensors now provide for remote access to diagnostic and maintenance information. A new collaborative approach may help car manufacturers, mechanics, roadside assistance providers, and customers alike. It's also worth noting that remote AR has additional uses throughout a product's life cycle. For example, suggests a collaborative design system that combines augmented reality and telepresence technology.

A basic AR technique that overlays virtual arrows and text on top of the actual world It's worth noting that Yuan's study concentrated on the creation of a virtual interactive tool to enable AR rather than on the user experience. He utilized HHD to do maintenance on consumer electronics. He chose to put the job description at the bottom of the screen and offer a few buttons to help him move through the process. At each step, virtual animations are overplayed in the real world. A third example that demonstrates an attempt to deliver various levels of guidance. He suggested two levels of guidance in his research: a strong one that supports the user at every step, and a soft one that provides more top-level information and is intended for more experienced users. The capacity to give real-time feedback on the operation in the AR process. He may display warning messages to rectify the assembly process by looking at the location and orientation of the components. Finally, a somewhat different method. He created an augmented reality application to simulate assembly procedures during the component's early design phase. In his research, he considers the stiffness, forms, and contacting surfaces of both the actual component and the virtual prototype when estimating the forces involved in the assembly. The forces were computed in real time and then superimposed on the actual picture. The examples given are intended to show that, even for what seems to be a simple job, such as an assembly process, there are many kinds of information that the opera- tor may find useful. To offer the finest AR solution, an effort is needed to collect the needs of each assembly process. Despite the fact that these three types of maintenance operations are distinct, the AR applications created by the authors of the 30 articles all include dis/assembly processes. an introduction to the current state of the art in AR maintenance The major application fields as well as the procedures done have been outlined. More technical knowledge is needed to get a better understanding of the present AR technologies in use. In reality, the developer of an AR application for maintenance often needs to make a variety of decisions throughout the creation process. He or she must decide what device to use to overlay the digital contents on the actual environment, what programming platform to utilize, how the user interface will appear, what tracking technology to employ, and how the contents will be created. The sub-sections that follow will provide an overview of the most prevalent devices, development platforms, and solutions used by the authors throughout the 30 articles examined. Commercial HMDs make extensive use of this technology. Optical methods (both pupil and non-pupil forming) conclude that "there is no conventional optical combiner design that prevails because there is a compromise between having a big eye-box, a large Field of View (FOV), and enabling picture relocation." The apps that use Desktop PCs are shown in the third slice of the pie chart. The fact that this kind of device is used for various reasons throughout the 30 articles justifies their reasonably high utilization: remote maintenance applications on the expert side, static maintenance activities work bench, prototyping, and changing AR processes. When used to carry out maintenance tasks, such AR systems often involve the use of one or more cameras to capture the surroundings and activities. The gear detailed so far has both benefits and drawbacks. The use of SDK was only mentioned 14 percent of the time in the 30 articles. SDKs are becoming increasingly prevalent in recent years, since they often accompany new gadgets on the market e.g. HMD, HHD. SDKs alone are not enough to create an AR application; they must be incorporated in a larger software package built using a mid/low level programming language or game engine. 10% of the time, game engines have been mentioned. Unity3D and Unreal are the most often used game engines for creating AR apps. These are user-friendly platforms that enable the creation of applications with just a basic understanding of programming languages. Using them, however, will need the use of trained AR personnel. Other development platforms have been discussed in the articles as well. 3D modeling tools such as Rhinoceros, SolidWorks, Catia, and 3ds-MAX are used to create the contents of an AR application. The placement of markers must be carefully planned. The location and orientation of these marks on the actual item to be preserved are pre-registered on the AR system. Identifying the marker in this manner entails recognizing the item. The visibility of the marker, which may not always be in the camera's frame, is a limiting factor in marker-based tracking. In an industrial setting, for example, there are many things that may obstruct the marker's view people, tools, machineries, etc. This would result in the AR system's tracking failing.

CONCLUSION AND IMPLICATION

The answer to two research questions may be found in the outcomes of this SLR goal. The major areas of application and maintenance activities have been outlined using the SLR. The current technology used has been described, as well as a comparison of the 30 papers in this review. The major obstacles to AR implementation in maintenance have been addressed in response to the first question. Answering the second question, future AR directions and fields of study have been presented and highlighted. In general, AR technology is not yet developed enough to meet industrial robustness and reliability standards. HMDs must become more comfortable and powerful, tracking accuracy must be increased, and AR content-tools must be created. In response to the challenges to the SLR's validity and objectivity, the author developed a completely repeatable technique that is only subjective in the implementation of the quality standards. It's worth noting that the authors used the SLR technique on each database individually in this research, and only collated the documents chosen shortly before the synthesis and analysis stages. An alternative method would be to gather documentation from various databases immediately before to applying for the IC and EC. In fact, using the latter method, duplicates would be detected sooner in the research, reducing effort. The ultimate outcome will be unaffected.

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