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Shaping the future maintenance operations: reflections on the adoptions of Augmented Reality through problems and opportunities

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Abstract

Maintenance technicians play a fundamental role in ensuring the success of the system reliability, but several fatal accidents occur during the maintenance operations in Europe due to the nature of the job and to human errors. Augmented Reality (AR) technology could ease the execution of complex maintenance operations under specified conditions reducing the probability of failures, guiding through the task the technicians, updating in real-time the operators about the environmental and boundary conditions, reducing costs and time for service and maintenance, reducing documentation of work processes, increasing the level of safety and decreasing the human error probability.
This paper investigates possible applications of AR technologies for assisting the workers during the maintenance operations, identifies challenges for the use of this technology in maintenance applications, and discusses the actual level of feasibility of the technology and the possible improvements in terms of information and communication selection and reduction of human errors.

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1. Introduction

The rapid changing of new technologies is turning the working rules and the working environment. New potential solutions (e.g. the adoption of systems to empower the workers) are giving the opportunities to better face the existing and well-known maintenance and Occupational Safety and Health (OSH) issues. These new technologies encourage research in a domain of scientific development such as the application of smart and functional equipment in different industrial sectors. The goal is represented by the possible reduction in terms of OSH risks and human errors and by the improvement of the job effectiveness in terms of quality and time. Maintenance tasks are complex operations that require a relevant amount of information, specific procedures and techniques for each machine and equipment to learn. Moreover, new equipment and machines are projected and built every year by industrial companies, requiring new training sessions for technicians. The result is a time-consuming and expensive training process. Therefore, finding ways to more efficiently train and guide technicians to perform their jobs is vital to continue to maintain different types of equipment around the world [1].

Mixing virtual elements with the existing reality AR offers promising technologies to address the mentioned needs, monitoring working conditions as temperature, humidity, spatial position of other workers and providing information and suggestions to the operator in real time empowering the real world. Supplying digital information to the user's real time environment, it is possible to increase the cognitive knowledge [2] of the users and helps them to perceive and interact with the environment.
An AR system augments the real world vision with real-time, interactive, computer-generated objects that coexist in the same space as the real world [3]. For these characteristics AR enables symmetrical communication between two parties and the right information in the right place can be displayed thanks to the embedding of them on the real scene.

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The approach finds its roots in the Digital Twin concept defined as combination of IT applications in the real world using digital and virtual techniques. It was applied during the Apollo missions for the first time in the '60s to carefully evaluate and mirror what it would be happened in case of failures on the space vehicles; in the recent years NASA formalized this method [4] defining it as integration of physical phenomena, sensors, objects and simulations.
The transition to the industrial applications was facilitated and supported by the introduction in the industries of the Internet of Things (IoT) paradigm that is giving the access to a relevant amount of essential data necessary to interconnect machines, equipment and operators. But the IT infrastructures have to be able to support and store a lot of data [5].
The achievement of new objectives and better results with AR, it is of paramount importance to ensure a constant support in terms of input processing, storing and data managing with suitable systems technology. As The choice of a software architecture [6] and hardware architecture play a very important role in determining the longevity and re-usability of these products whilst reducing the gratuitous complexity [7].
Therefore, still some big challenges have to be faced in order to effectively get benefits from this opportunity and to prove its feasibility: the digitalization of product information and the management and the way and the technological devices used to provide and supply big data to the operators.

2. Opportunities and challenges of AR in maintenance operations

The actual fields of application of AR show how the maintenance-related sectors are among the most utilized for testing the power and the effectiveness of new technologies. The Fig 1. [8] shows the continuous increasing in wearable AR devices utilization and a forecast the two coming years.

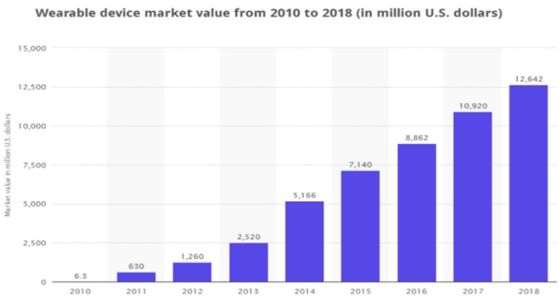

Fig. 1. The evolution trend of the wearable devices [8].

The reason lies on the nature of the maintenance: the involved technicians have always more information to remember on how to perform correctly and on time the tasks due to the introduction in every equipment of electronic components. It needs a relevant amount of time to learn all the required steps increasing the risk of human errors during the operation. Moreover, the increased turnover among the workers requires more training sessions forcing the companies to spend more resources and trying to find new solutions.

2.1. AR opportunities in maintenance operations

Maintenance activities are usually very costly in terms of time and often performed under pressure. Industries with very strict time schedules (e.g. railway and aircraft sectors), are looking for having better time management and reduction in the overall duration of these operations.
A great amount of time is spent searching for instructions, in order to reduce maintenance time, worker stress, and decreases overall job performance.
As suggested by Neumann [9], the 45% of an Aircraft Maintenance Technicians (AMTs) shift is spent on finding and reading instructional procedures for job tasks. Railway technicians are likely under-time pressure due to the fact that railway is a time-critical system and a lot of logistic operations have to be taken into account. Moreover, it is also affected by external variables as construction activities, removal of trucks etc.[10].
According to these issues, AR technologies have been recently tested in order to accelerate the procedures in various maintenance tasks assisting the optimization of the physical movements and helping to save time and energy.
Allowing the transfer of asset information directly to the workers in a real-time mode it is possible to make the management of assets along the networks easier resulting in an increased general efficiency of the system.
It also means a significant improvement and an errors probability reduction in performing several potentially unfamiliar tasks in a complex operation or in an harsh environment. In the study carried out by Henderson & Feiner [11], two kinds of assistances were tested in order to discover the most suitable one to adopt: first an assistance based on a traditional approach of maintenance (a set of baselines to be followed) and a second approach AR-related. The study showed that the technicians performing maintenance sequences under an AR condition were able to address tasks more quickly than when using baseline conditions. Furthermore, the instructions visualized in a AR platform are easier to manipulate than in a traditional baseline.
The support of AR in time saving is also extremely relevant for the knowledge acquisition and transition from skilled experts to new technicians.

2.2. AR challenges in maintenance operations

As discussed in the previous paragraphs due to the nature of the maintenance operations the involved personnel is constantly facing numerous challenges; therefore, an assistance is desirable even for the most experienced technicians for several reasons [12].
The information must be content specific and dynamic. The users should have real time information on request: recognition of objects and patterns in the real world, current location and direction. Moreover the system should track his progress and communicate it, driving the user through the different time steps.
The operation requirements arise several challenges that have to be properly managed to provide helps and not obstacles. The physical and cognitive needed requirements to perform a maintenance task could represent a critical step towards a successful maintenance task. Most of the times, for each task, simultaneous sub-operations are necessary. Only optimizing

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