AR for Maintenance: A Review of Augmented Reality Tools and Platforms for Training and Maintenance Procedures

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ABSTRACT
Augmented reality (AR) is a widely accepted technology that can be exploited to provide mass-market users an effective and customizable support in a large spectrum of personal applications, by superimposing computer-generated hints to the real world. Mobile devices, such as smartphones and tablets, are playing a key role in the exponential growth of this kind of solutions. Maintenance, repair, and assembly have been considered as strategic fields for the application of the AR technology from the 1990s, but often only specialists using ad hoc hardware were involved in limited experimental tests. Nowadays, AR-based maintenance and repair procedures are available also for end-users on consumer electronics devices. This paper aims to explore use of this technology in maintenance and manufacturing industry, new trends in utilizing the technology, by also presenting the software framework to provide AR based maintenance solution

General Terms
Pattern Recognition, Marker based Augmented Reality

Keywords
Augmented Reality, Maintenance, Virtual reality

1. INTRODUCTION
Assembly of equipment and maintenance of industrial machinery are complex tasks that require substantial resources both for training and for operations. In this context, one of the most challenging problems is how to make those processes more efficient and robust. An effective approach is to rely on a set of emerging technologies, such as Augmented Reality, that are currently reaching maturity in many industrial domains. [1]

The term Augmented Reality (AR) refers to a bundle of technologies that allow the overlay of additional layers of digital information onto the objects and processes in the real world. These layers of information are contextually accessible in real time by means of suitable computing and visualization devices. Devices for AR not only include PCs, laptops, smart phones, tablets but also new generation wearable devices such as a variety of AR glasses (e.g. the bespoke Google Glass). A property of AR systems is to make hidden information visible and accessible whereas it is normally inaccessible and opaque to human senses.

Benefits of AR-based documentation for maintenance are well depicted in [1] and [2], where it is outlined how AR technology can reduce costs up to 25 percent and improve performances up to 30 percent. Moreover, although over the past decades AR-based applications for maintenance were used only by technical specialists, current solutions promise to profoundly change the way end-users will perform many of their daily tasks. For instance, traditional paper-based owner's manuals for ordinary car maintenance, furniture building instructions and installation manuals of electrical appliances could be soon replaced by AR-based applications on mobile devices. The number of people possibly involved in using AR-based applications is potentially huge and the social impact cannot be neglected.

The goal of implementing the AR based maintenance solution presented in this paper is twofold. On the one hand, it allows making better use of information already available in relation to the maintenance of the assets; on the other hand, it exploits the potential of Augmented Reality technology for improving the performance in training and operations, so as to achieve levels of effectiveness and efficiency never experienced before.

According to the above mentioned goals, the companies who provide maintenance solutions need to adopt tools adequate to: 1) ensure the improvement in efficiency and learning performance of the maintenance personnel 2) help reduce the maintenance costs of the machines 3) maximize/increase safety and minimize human error 4) provide an extensive and more effective support to the customer. In this context, the goal of the proposed maintenance solution is to provide end users with a set of tools, based on cutting edge Augmented Reality technologies, ubiquitous and connected to enterprise backend, to support maintenance operations of material assets, machinery, plants or anything else, in the field. For this purpose we have analyzed some existing projects and systems which have used AR in maintenance operation.

2. METHODOLOGY FOR REVIEW
The idea to convey maintenance instructions to technicians by using AR-based systems is not new. Early examples, which can be dated back to the 1990s, are well surveyed in [3] and [4]. AR-systems are usually classified based on different parameters, including tracking technology, human-system interaction method, data management strategy, etc. A rather common categorization, which is used in this paper, considers the visualization device. Predictably, a key role is played by wearable technologies [5]. In particular, since from the early experiments by Feiner et al. [6] with a head-worn AR prototype designed to support end-users in performing simple maintenance procedures on a laser printer, a number of head mounted display (HMD)-based solutions were developed.

Table 1 given below summarises such maintenance projects which have got benefit by using AR.

Table 1.AR based maintenance projects

Sr. No.	Ref .No.	Name of Project	Description
1	[8]-[9]	HMD based solutions	In [8] tele-assistance and AR were exploited to establish a communication channel between maintainers and remote experts. In [9], VR and AR were used to remotely support technicians as well as trainees.
2	[10]	ARVIKA	The project was aimed to the design and implementation of a head-worn AR-based user-centered tool to support the development, production, and servicing of complex technical products and systems
3	[11]	STARMAT E	This was one the first examples of multimodal augmentation, where virtual objects, textual hints and audio messages were used to guide and support the maintenance of mechanical parts.
4	[12]	Collaborativ e frameworks	Used to train technicians in assembly tasks of complex systems such as aircraft engines.
5	[15][1 3][14]	ARMAR	The authors of these papers considered advantages and drawbacks of various hardware and software solutions for maintenance job aiding in the military field.
6	[16][1 7][18]	Maintenance procedures	Schwald and Laval focused on the usage of AR solutions for maintenance operations in generic industrial scenarios [16] In [17] and in [18], AR was used to simulate and validate the programs of Computer Numerical Control (CNC) machines.
7	[19][2 0]	PLAMOS	AR is referred to as *mobile* to denote the possibility for the users to move, typically in an industrial site, in order to find objects to be maintained. The goal of the PLAMOS project [20] was to support owners and operators in plant maintenance and repair.
8	[21]	AROMA-FF	In [21], an AR-based Operations and Maintenance Fieldwork Facilitator (AROMA-FF) was proposed, with the goal to reduce the time needed for the end-users to locate target objects.
9	[22]-[24]	Handheld AR(HAR)	Kahn et al. proposed a HAR solution able to support the overall lifecycle of construction and facility management [22]. AR-based training systems for maintenance applications using mobile devices are illustrated in [23]-[24].

Although many applications of AR could get a higher social value, solutions of AR-based maintenance tailored to end users, i.e., not for specialists, are quickly growing as they promise to have a significant influence on everyday life. In fact, any dematerialization process is expected to produce a social impact [25] and, sometimes, the traditional interaction procedures can be even toppled. Table 2 describes such recent advancements.

Table 2.Recent advancements in maintenance projects

Sr. No.	Ref No.	Name of project	Description
1	[26]	Car routine maintenance of Audi A3	It is possible to recognize more than 300 individual components of the Audi A3 both on the instrument panel and under the hood. In this way, relevant how-to information and virtual overlays of maintenance procedures can be conveyed to the user directly onto his or her personal device. For example, after framing the engine with the device's camera, the AR application could provide an animated overlay of virtual objects, with instructions on how to locate the engine coolant and refill it to the appropriate level [26].
2	[27]	Metaio	A company leader in AR technology and solutions [27] recently announced the development of the first-ever hands-free marker-less augmented automotive manual using Google Glass.
3	[28]-[30]	For furniture manufacturing	Some assembly tasks could also take advantage of AR technology [28]-[30]. For instance, assembly of pretty simple objects, such as furniture items, could be effectively supported by AR solutions.
4	[31]	preview of customizable furniture	Several applications for mobile devices already provide end-users tools for a virtual preview of customizable furniture in the environment, thus implementing an enhanced digital catalogue [31].

Other examples are represented by solutions developed by Mitsubishi Electric and NGRAIN 3D. In the first case, installation and maintenance processes of heating and cooling products are explained by an AR application. In the second case, an application for training on the maintenance of industrial parts is provided. Some companies also quantified benefits obtained by adopting AR. For instance, a toymaker (Lego) provided users a tool for enhancing the assembly experience and observed that sales increased by 15 percent after the introduction of the tool. Examples above clearly show the potential impact of AR on daily activities in the maintenance, repair and assembly domains.

3. PROPOSED SYSTEM ARCHITECTURE

Figure 1 shows proposed system architecture which is basically designed for AR based maintenance. The client side uses a mobile AR application specially designed for onsite technician/user. This application will be built by using Vuforia [37] and Unity framework. The server side consists of ASP.net application. AR-based maintenance procedures will be used to support operators in maintenance and repair procedures applied to computer hardware maintenance. To define the scenarios here after described, end-users will get advantages from the state of the art technology. It helped to gain awareness with AR and best-fit the applications. Moreover, a questionnaire survey will be conducted to gather end-users' requirements in terms of usability and application on the field in order to drive the next steps of design and implementation of the AR-based tools.

Circuit board components are closely positioned thus it is challenging to train maintenance operators on a well-defined product. On the other hand, AR technologies can provide valuable support. In particular, the operations that will assess AR-based solutions are listed hereafter:

Operation 1: ordinary maintenance operations. AR will support and guide standard maintenance operations, such as cleaning of RAM chips, USB ports and NIC ports.

Operation 2: repair operations. AR will support and guide common repair operations, such as the repair of SMPS or graphics card.

Operation 3: technical manual instructions. AR will support and guide routine machine assembling procedures.

In order to implement AR tools as support for maintenance activities, videos, images and CAD based 3D models will be used in order to computerize the specific maintenance activities selected. The maintenance activities have been chosen because of their complexity. The implementation of AR tools will allow to interactively support and guide technicians and/or customers in the ordinary maintenance activities. After a preliminary selection of maintenance, different technical procedures would be investigated and implemented.

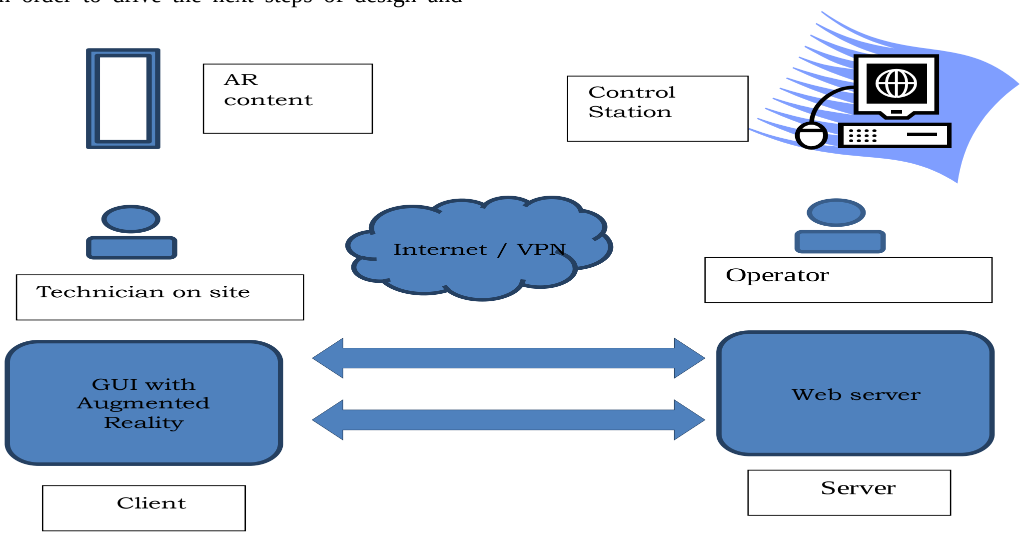

Fig 1: If necessary, the images can be extended both columns

4. CONCLUSION

Development of AR applications in an industrial setting is a complex task, made even more challenging by the need to leverage the full power of native platforms (iOS, Android, Windows Phone). This is certainly the case of modern, cutting edge AR mobile applications. This complex task can be simplified by utilising available software components, technology, expertise and customizable solutions that help managing complexity with reduced time in AR based maintenance. In order to present and educate on the software components needed to develop an effective AR solution for industrial maintenance, the paper offers an overview of the existing systems and required solutions.

The proposed system will be utilizing these features of AR and improve effectiveness of today's maintenance process. It also helps in reduction of repair time & costs, a reduction up to the 20-30% of completion time is expected as compared to paper based maintenance process.

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