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# Augmented reality application to support remote maintenance as a service in the Robotics industry

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**Abstract**

Maintenance of manufactured products is among the most common services in industry and its cost often exceed 30% of the operating costs. Modern manufacturing companies are shifting their focus from products to combined ecosystem of Products- Service Systems (PSS). Towards that end, the main objective of this work is to develop a cloud-based service-oriented system that implements AR technology for remote maintenance by enabling cooperation between the on- spot technician and the manufacturer. The proposed system includes the methods for the record of the malfunction by the end user, the actions required by the expert so as to provide instructions in an Augmented Reality application for maintenance, as well as the cloud- based platform that will allow their communication and the exchange of information. In addition to the above, the proposed system consists of smart assembly/disassembly algorithms for automated generation of assembly sequences and AR scenes and improved interface, aiming to maximize existing knowledge usage while creating vivid AR service instructions. The proposed system is validated in a real-life case study following the requirements of a robotics SME.



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*Keywords*: Augmented Reality; Remote Maintenance; Product Service System

## 1. Introduction

In the era of mass production and in the emerging era of mass personalization [1][2] with increased competition between manufacturers, it has become really important to come up with new ways to improve customer satisfaction. Many manufacturers attempt to achieve that by offering high- quality Product Service Systems (PSS) throughout the product's life cycle [3]. PSS is a value proposition strategy that offers products-services and is designed to be: competitive, satisfy customer needs, and have a lower environmental impact than traditional business models. Maintenance service is one of the most commonly used, especially in products that require maintenance frequently. Towards supporting this interface between IT systems and avoiding isolated work, Cloud Manufacturing has been regarded as an enabler and has already formed the basis for new business models [4]. Furthermore, this approach takes into account the usage of CAx systems in manufacturing and the need to develop new instructions providing systems that are more intriguing and more accurate than the traditional ones. Augmented Reality (AR) is a rapidly evolving technology that is used more and more in different manufacturing fields in the last few years [5], [6]. Using the CAD three-dimensional geometries and assembly information, enriched with intelligence, the manufacturer can create a series of AR scenes to support service sequence.

Targeting the Cloud manufacturing and remote maintenance, the main objective of this work is to develop an internet-based, service-oriented system that implements AR technology for enabling tele- maintenance by cooperation of the end user and the manufacturer.

## 2. State of the art

Maintenance is a core activity of the production lifecycle since it accounts for as much as 60 to 70% of its total costs [7]. This has led to increased need for maintenance planning through product's life cycle and the implementation of more



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and more new technologies (cloud manufacturing [4], Dynamically Adaptive Systems for self- maintenance [8], machine monitoring [7]). Despite the effort to limit machine downtime [9], most of service impact on productivity accounts for unexpected breakdown, as it cannot be predicted and quantified in terms of time and required effort. And despite some effort on the field, it requires a time-consuming process which has a negative impact on machine availability. Augmented Reality (AR) is another enabling technology used for dealing with the increasingly complex maintenance procedures [10]. Either by using head-mounted displays [11], [12] or portable devices [13] a number of solutions have emerged, testing various ways of AR system- user interaction (voice commands, gestures, devices- hosted menus). The potential of the newly introduced technology in supporting maintenance tasks is renowned even by large manufacturing companies (BMW [14], Bosch [15]). More recently, the concept of enabling communication between an expert and the on- spot technician (tele- maintenance) has arisen [16], [17] delivering some promising results in synchronous and asynchronous information exchange.

Apart from maintenance, AR has found fertile ground in other fields of manufacturing. Firstly, AR can be used as a mean to vividly project the current status of a warehouse or a production line, allowing constantly monitoring its current status, communication and planning [18], [19]. Secondly, Augmented and Virtual Reality have been proved valuable tools in prototyping and collaborative design [20]. They allow the fast and costless creation of visual prototypes that can be manipulated by more than one user and also, overlaid on top of existing products so as to facilitate customization and reusable engineering [21], [22]. Moreover, Virtual and Augmented Reality have been widely used as means of training technicians in performing assembly tasks [23]. Those technologies provide an intriguing experience for the technician [24] and thus, they are more efficient than the traditional methods [25], [26].

Meaningful information generated by IT tools should be seamlessly shared across the enterprise in order to support different business functions. Cloud manufacturing enables this ubiquitous information provision and enables the creation of intelligent factory networks reshaping the manufacturing business models. Cloud computing systems and cloud manufacturing may play a critical role in the realisation of "Design Anywhere Manufacture Anywhere" philosophy [4]. Another recent study [27] presented the key benefits to manufacturing as a result of adopting the Cloud technology such as scalability to business size and needs, ubiquitous network access [28], and visualisation. However, security and data protection are still challenges that need to be addressed [29]. Issues, such as the resource location multi-tenancy and authentication also need to be tackled in a combined way [30].

The literature review makes apparent that Augmented Reality systems are welcomed in manufacturing. A field that already has implemented cloud features in many of its applications. The contribution of this development compared to existing approaches is the creation of an asynchronous AR remote maintenance support system that implements cloud-based communication between the end user and the manufacturer that facilitates the reuse of existing knowledge. In addition to that, the developed internet-based and service-oriented system is supported by an assembly/disassembly algorithm that enables the automated generation of the AR scenes and increases the level of automation. The implemented platform is designed to be provided for Product-Service support throughout a product's life cycle so as to reduce the impact of Mean Time to Repair in machine availability, especially in unexpected breakdowns, where external expert contribution in malfunction detection and service sequence may be needed. The developed platform utilizes a cloud database that enables ubiquitous data access and permits the technician to upload the malfunction report and receive the corresponding service sequence in AR scenes by the manufacturer easily. Moreover, the cloud platform facilitates the supervising mechanic in AR scene creation by keeping record of older service sequence that can be fully or partially reused.

## 3. Architecture design of tele- maintenance system

This paper proposes an innovative Product- Service System that enables tele- maintenance support through Augmented Reality scenes. The platform includes the deployment of a cloud system that will facilitate the communication between the on- spot technician and the expert by enabling feedback reports and maintenance instructions exchange. Fig. 1 presents the architecture of the proposed system and the data exchange between the technician and the manufacturer representative mechanic. In order to achieve the proper functionality of the proposed platform, some key features are established. Each time the remote maintenance framework is called, a three-step procedure is required: (i) malfunction report composition, (ii) diagnosis and AR maintenance instruction generation and, (iii) maintenance and evaluation.

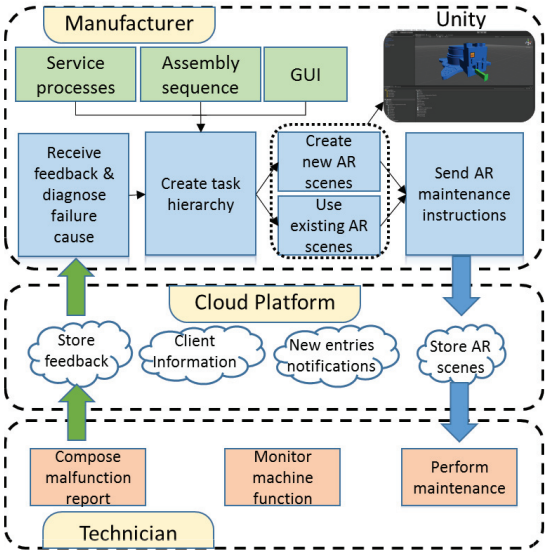


Fig. 1. Architecture of the developed framework

The first step in the proposed system is registering the malfunction report. Whenever a service is required, regardless