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Augmented Reality in Maintenance: An information-centred design framework

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Abstract

Augmented Reality (AR) visualization capabilities can impact on maintenance. From enhancing performance to retrieving feedback, AR can close the information loop between maintenance information systems and the operations supported. Though, the design of AR applications is not aligned with current information systems, which prevents maintenance information to be used and improved properly.

In this paper, industrial collaboration contributed to determine a framework for AR integration in maintenance systems. The framework describes information types, formats and interactions modes for AR to enhance efficiency improvements in maintenance of complex equipment. Semi-structured interviews and surveys with maintainers were conducted to determine the maintenance challenges and also to validate the framework proposed. Therefore, exposing future research in topics such as multimodal interaction, information contextualization and performance analysis to achieve the complete integration of AR in maintenance.

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Keywords: Augmented Reality; Maintenance; Information.

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1. Introduction

The maintenance industry is facing significant challenges nowadays. Safety and availability at minimum cost are demanding objectives, owing to the increasing complexity, longer life-cycles and geographical dispersion of the maintained equipment. Therefore, the focus has turned into maintainers and the support given to them when performing their operations. In this competitive context, it is a recurrent challenge for industrial maintenance to obtain and use information [1].

Augmented Reality (AR) is a relatively new form of human-machine interaction that overlays computer generated information (virtual data) on the world environment (real objects) [2]. Since the early 1990s, several AR prototypes have already shown good results in terms of task efficiency, and decrease risk of accidents, demonstrating that this technology can enhance maintenance implementation [3].

Moreover, researchers have identified other applications for AR in maintenance. Performance measurement [4], diagnosis, training or even tools for easy application development (authoring) [5] are some of those in which several studies have focused their efforts. Thus, AR can be useful for many situations in maintenance where users require additional information [6]. Furthermore, if properly used and developed, AR visualisation capabilities can transform maintenance processes. Nevertheless, as AR research in maintenance applications is still at a prototype stage [5], a complete integration of AR in maintenance systems has not been pursued yet.

In this paper, we present an information framework that analyses the information requirements for a complete integration of AR in industrial maintenance systems. It helps to determine the type of data and information to be acquired from and displayed in the AR systems, as well as how to relate it with existing maintenance information.

The paper is structured as follows. Section 2 describes the literature review conducted to examine AR applications in maintenance and the data needed. In Section 3, the industrial challenges regarding information management are investigated through the collaboration with maintenance experts. Section 4 provides an overview of the framework that covers the information requirements of AR integration in maintenance systems, based on academic and industrial challenges. In section 5, the expert surveys conducted to validate the framework are detailed. Finally, section 6 offers the conclusions derived and the subsequent future works proposed.

2. Literature Review

Different authors have already offered state-of-the-art reviews of AR applications in the maintenance industry [4,5,7]. They classify the research proposals based on the maintenance applications (diagnosis, repair tasks, performance measurement, collaborative maintenance, etc.). Apart from the development of hardware and software techniques to improve the effectiveness of AR systems (e.g. better tracking algorithms or real-time sensors interaction), the later authors point out two main areas in AR research to achieve its complete integration in maintenance systems: authoring and context-awareness.

In the AR context, authoring is any development tool that allows to create, edit and update AR contents [2]. In maintenance, the focus has been on providing maintenance experts with no programming skills with the tools to enable the transfer of knowledge [8]. Authoring tools enable to manage existing data in order to display to the maintainer the information required at each step of the maintenance processes. Thus, aiming to reduce implementation costs and obstacles while using existing information and knowledge [9]. However, four main challenges can be found in the literature regarding AR authoring for maintenance:

- **Authoring tools' users and ease-of-use:** the types of authoring and the skills required to use authoring tools are important topics when developing them. Authors like [8] or [9] emphasise on the use of easy GUI's (Graphical User Interface) to generate low-cost applications. While others like [2,10]focus on the type of users (engineers, technicians or maintenance experts) and when they would be able to create content (on-site, online and offline authoring). Nonetheless, when creating authoring tools all researchers stated the need to transfer knowledge as easy as possible, pointing to the use of animations as a type of data to be rendered to maintenance operators.
- **Visualisation challenges:** one of the problems when using animations to explain complex tasks is the rise of visualisation challenges. Problems like occlusion or photorealism have to be considered in order to allocate virtual content in the most effective way [11]. Tools like SUGAR [8] try to solve these problems, considering