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Context-aware Maintenance Support for Augmented Reality Assistance and Synchronous Multi-user Collaboration

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Abstract

Maintenance processes are generally subdivided into tasks with specified goals for the concerned practitioners. Collaboration is achieved through coordination, cooperation and communication. Smart devices and the Internet of Things (IoT) improve communication between men and machine alike, so the potential gain on cooperation and coordination in an IoT-enabled environment is examined. In this approach a concept for a framework is proposed to create Augmented Reality based collaboration assistant systems. AR is not only a tool for the visualization of maintenance data, but also for team-wide communication and the display of warnings or other coordination-related indications. The framework is validated with the presented use case in a laboratory environment.

Keywords: Collaboration; Augmented Reality; mobile devices; maintenance

1. Introduction

“Industry 4.0” aims to achieve high flexibility and short lead times to face the growing competitive pressure between companies, therefore increasing automated production processes and resulting in a rising complexity of machinery. In this context maintaining one’s machinery becomes ever more important to guarantee reliability and thereby ensure the company’s supply capability [1]. Unsurprisingly, a major part of life cycle costs originates from the maintenance, repair and overhaul (MRO) processes. Therefore, it is essential to consider them in the life cycle engineering [2]. As terms like “Industry 4.0”, “Internet of Things”, “Brilliant Factory” or “Smart Planet” emerge more often it becomes clear that the increasing amount and complexity of data will continue to challenge today’s engineers. The term “Smart Maintenance” [3] is used to address new structures and platforms for maintenance services. It emphasizes the connection between asset management, sensor data and intelligent on-site maintenance support to create a reliable condition based maintenance strategy.

In the course of IoT-related innovation and emerging trends for product service systems (PSS) the improvements in prediction and simulation capabilities help to calculate the MRO costs [4]. Furthermore, the usage of standardized architectures for IoT enabled devices and the corresponding multi-platform support systems enable a vast advantage for the detection of errors, especially in big fleets of machines [5].

Interactive augmented reality (AR) technologies support the operators on shop-floor level as much as they provide the user of an AR application with a big amount of easy to understand context-relevant information. According to Syberfeldt et al. [6], the AR technology will be an integral part of future factories. Dini [7] states that even today the vast majority of AR application in a through life engineering (TES) context is used in maintenance (54%) or inspection (24%). Furthermore, a problem with AR applications is their static nature due to the high amount of preparation work needed. A dynamic, intelligent AR application would improve the state of the art in AR development for maintenance. Regarding the fact that Smart Devices are state of the art nowadays, the usage of these

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devices is no hindrance for today's personnel [8] and as a result, they could be utilized for AR supported maintenance.

In order to reduce costly downtimes, maintenance activities could be performed by multiple technicians in a collaborative process. Leimeister [9] defines collaboration as a systematically organized activity performed by two or more individuals working jointly on the same material with the purpose of realizing a shared goal. To achieve this common goal, coordination, cooperation and communication among the related actors is necessary. The involved roles can be differentiated between the collaboration engineer, practitioner and facilitator [9]. In recurring high-value collaborative processes the collaboration engineer designs and documents the collaborative process, whereas the practitioner acts as a facilitator by both executing and organizing the defined process. Collaboration among its participants exists in different dimensions regarding the categories organization, location and time. The characteristics of each category can be divided into same and different organization, location and time [10].

Based on the authors' previous work [11] where context-sensitivity in machines was discussed a simplistic AR approach that can be used in the field by multiple technicians was designed. In the following sections we determine requirements for a collaborative AR-driven maintenance assistant, define the planned functionalities, describe the theory behind the graph-based evaluation and coordination of technicians and validate our approach in a laboratory environment.

2. Aims and requirements

Based on our previous work [11] in which we used the mobile AR technology for interactive input methods, the main goal of the paper at hand is the improvement of on-site collaboration by means of interactive coordination and individual work instructions. The main tool to enable technicians to receive instructions and send and receive coordination relevant data (for simplicity called messages further on) is a smart device. The smart device hosts an enhanced version of the assistant system described in [11]. As described before collaboration can be characterized through the organizational form, location and time that it is conducted in. The approach at hand will focus on synchronous collaboration on the same facility with working environments apart for the individual technicians.

Porcelli et al. [12] mention a computer system for running the application as a necessary core component of typical AR systems. A digital camera captures the real scene, whereas a displaying device, such as a Head Mounted Display (HMD), a handheld computer or a projector is needed to see the augmented content. A tracking system tracks the position and movement of users as well as objects and links the augmented content to real elements. For the interaction with the above mentioned computer system, input devices such as gloves, tablets or PDAs deliver required data. Due to the advantages of user-friendly consumer hardware [11] and their vast acceptance [8] we focus on smart devices, which also combine the components stated before into a single device. HMDs might offer advantages over in the field of visualization [7], but lack the maturity level of industrial tablet PCs.

According to Wang et al. [13] the multidisciplinary collaboration will be future standard, however there are current deficiencies of collaborative Augmented Reality systems. Approaches utilizing AR in a collaborative manner such as [14], [15] and [16] only to some extend address the elements of collaboration defined in [9] and previously described in the introductory section.

Especially recurring high-value collaboration processes, on which we focus in this approach, require well-structured and easily executable activities performed by the practitioners [9].

In addition to the requirements regarding the AR system and the collaboration among the related actors, the collaborative maintenance process itself and the information retrieval need to be considered in our approach. It needs to support the core elements of collaboration, i.e. coordination, cooperation and communication. Furthermore, the users should be able to receive context-aware information about the machine's status

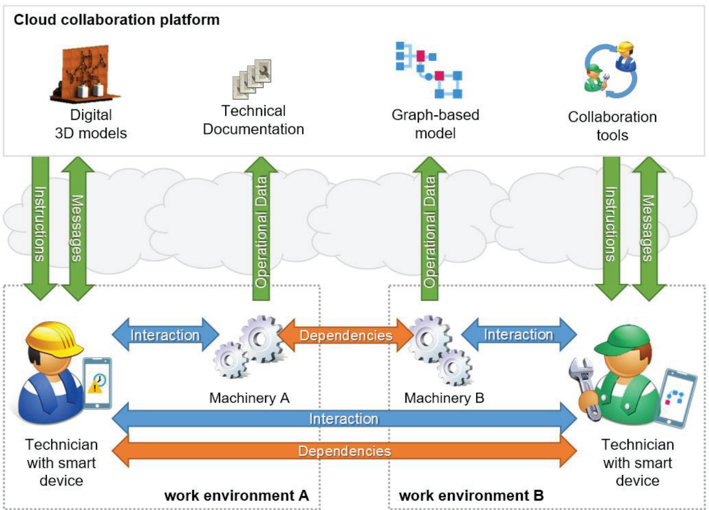

Figure 1: Overview of the proposed architecture