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Investigating the impact of human in-the-loop Digital Twin in an industrial maintenance context

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Extended Abstract

In the manufacturing context, the concept of Digital Twins (DT) has over the years emerged to improve manufacturing processes, such as assembly, maintenance, machine monitoring, and optimisation for all physical equipment on the shop floor. A DT can be understood as the virtual representation of a real-world physical entity that provides guidelines and live indication of the entity status and future projections that can assist humans in numerous manufacturing applications. Despite the human expertise being crucial in manufacturing applications, according to literature, the information flow is currently still only one-way: from the DT to the human. As such, the operator's feedback and observations are not utilised within industrial DTs. The presented paper hypothesises that a Virtual Reality Digital Twin framework that includes human sensor feedback in an industrial DT context combined with remote expert support can impact the industrial maintenance cost.

1.1. Introduction

Modern industrial equipment is usually a combination of different devices and technologies that were integrated to perform a complex task. This leads to making one of the most crucial activities in industrial applications, namely maintenance, which aims to minimise cost by reducing downtime, more complicated. The focus of this paper is on unplanned corrective maintenance [1]. Unlike planned corrective maintenance, which is a result of regular/scheduled inspection [2], which is exhaustively studied for prognostic health management of systems in Industry 4.0 [3] based on data analysis [4], unplanned corrective maintenance is performed as an unexpected equipment fault occurs with regards to safety or performance [2]. As modern automation systems are getting more complex with modular, flexible, and plug&produce characteristics, the corrective maintenance processes are getting more complicated and tedious as multiple factors affect the performance and functionality of a component [5]. They require knowledge in several fields and the technician needs to analyse complex systems, applying multidisciplinary perspectives, for performing corrective maintenance. He/she analyse the fault, isolate the faulty element and perform the corrective action [6]. This is especially true with the advancements of Industry 4.0 as several technologies and practices are integrated to improve productivity and data flow. For instance, Virtual Reality (VR) has been utilised and found to be enhancing the efficiency of operators in an Industry 4.0 factory [7]. In this paper, we focus on the use of VR and DT technologies in corrective maintenance. As it is essential to develop a methodology for corrective maintenance in Industry 4.0. Therefore, we propose to include the human operator sensory feedback and observations into the industrial DT to support decision making regarding production maintenance; henceforth, these data can be utilised to digitally represent the human within the DT. In our proposed framework, a remote expert can use these data to assist the local operator considering his/her feedback and observations in guiding, for example, through a maintenance scenario. This paper studies the following 1) application of a DT of the ascription of fault in a complex industrial system 2) the employment of human biological data during a maintenance task, and 3) the use of VR technology that allows remote experts to support operators on the shopfloor.

1.2. Proposed framework

In this paper, a novel maintenance framework for Industry 4.0 is proposed. The framework is composed of a DT model, physical setup, a remote expert, and a local operator. To overcome the challenges of maintenance in Industry 4.0, this paper proposes the compensation of DT that allows remote experts to debug the fault with operator observation and sensory data during the maintenance activity. As Industry 4.0 is more complicated, the remote expert and local operator can work collaboratively to diagnose the fault and isolate the root cause of it. To show how the framework works in practice, an illustrative example in the form of a glueing workstation within a lab environment is described. Fig. 1 depicts the proposed framework for this example. The physical layer contains the robotised dispensing system composed of an ABB IRB120 robot, dispensing unit, local workstation with a Graphical User Interface (GUI) and a remote workstation with a VR system. On the one hand, functionalities related to the robot and the start/end of the dispensing process can be controlled via the GUI. On the other hand, dispensing process parameters, such as dispensing pressure are adjusted manually. The DT layer is composed of a model of the hardware setup that can replicate the physical setup on a live manner. This live link allows the remote expert to understand the current state of the setup using AR, which is collected to the DT via the remote expert's workstation. The complex debugging of physical faults, such as faulty robot, faulty dispensing unit and blocked pneumatic pipes and blocked dispensing syringe, will be executed collaboratively between the local operator and the remote expert. While the DT of the robotic setup with VR gives the remote expert a live insight into the robot configuration, the remote expert will also be able to remotely take control of the setup and bring it into ideal state while the operator performs other maintenance tasks. The DT layer can also have artificial intelligence tools to support both remote and local operators, such as text mining tools on equipment manuals to quickly diagnose the fault and isolate faulty elements. It is believed that such a framework will reduce the downtime and effort required to carry out corrective maintenance, as the remote expert can support different teams in different geographical locations almost simultaneously.

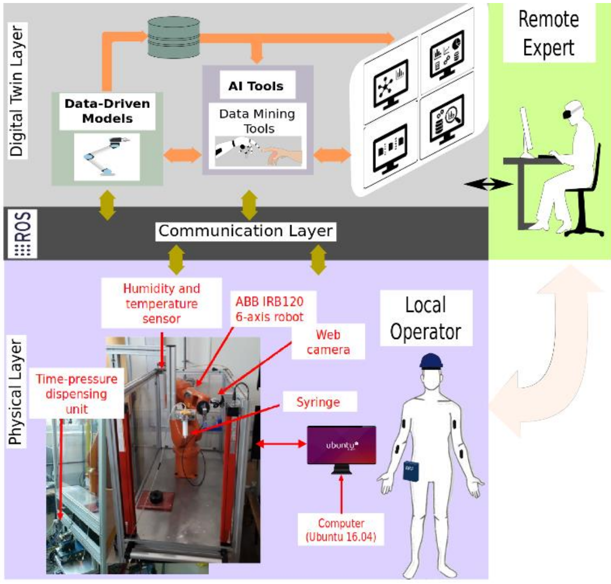

Fig. 1. Illustrative example within proposed framework.

1.3. Conclusions and future work

This paper proposes a novel corrective maintenance methodology for Industry 4.0 based on DT, VR and human representation in a DT layer and is believed to result in shorter downtime, and reduced maintenance cost. An illustrative example of a robotised dispensing process has been described to validate the presented hypothesis. The validation scenario is part of the future work. This includes extending the VR assets to visualise the biological data of the local operator, which will give the remote expert more information on how the operator is doing on the shop floor during the maintenance task and then compare maintenance task with and without remote expert support.

1.4. Acknowledgements

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