Industrial Augmented Reality: Connecting Machine-, NC- and Sensor-Data to an AR Maintenance Support System

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ABSTRACT
Access to machine control data, e.g. axis positions inside an AR maintenance support application can potentially increase the usefulness of AR in maintenance. Technicians walking to the machine control for looking up information would be avoided. However, the machine control interface and data are machine manufacturer depended, making it necessary to customize the interface between the machine control and the AR maintenance support application. Here, we present a solution integrating machine control access from three different machines using a middleware box. A qualitative assessment with technicians confirms the usefulness direct machine data access from an AR maintenance support application.

Keywords: Augmented Reality, NC control, Machine control, Maintenance.

Index Terms: Human-centered computing → Mixed / augmented reality; Computer systems organization → Embedded and cyber-physical systems

1 INTRODUCTION

Industrial Augmented Reality (AR) applications are finding their way into more and more companies. One major application of AR in the industry is the support of maintenance with AR-instructions [1]. This advancement is joined by developments under the roof of Industry 4.0 with machines getting equipped with additional sensors and their integration in IT-landscapes [2]. Here opportunities for AR maintenance support applications arise, by making these machine and sensor data available to the technician [3]. During some maintenance operations, it is important for the technician to check information about machine parameters, e.g. axis position, hydraulic pressure levels, software flags, or vibration levels. Usually, such information is not accessible in state-of-the-art AR maintenance support applications, so that the technician has to go to the machine control each time s/he wants to check such information. This interrupts the maintenance task and cost time, which can be up to several minutes in case of large machines. Additionally, the sought information is usually not present on the main panel of the machine control and has to be looked up, which requires a certain level of knowledge on how to operate the machine control.

In the Horizion 2020 project, PreCoM (Predictive Cognitive Maintenance Decision Support System) a tablet-based AR maintenance support application was developed allowing the technician to check live data from the machine whilst following AR step-by-step instructions [4–6]. The developed AR maintenance support application is currently used in three diverse use cases: a paper mill producing paper tissue, a grinding machine manufacturing high precision gears, and a large-scale milling machine processing hubs of wind power plants. All three machines are equipped with different machine controls and additional vibration sensors surveilling critical machine parts. In this work, we will explain the general obstacles of accessing machine data, describe our implementation approach together with specific integration challenges in Unity as well as the machine data representation in the user interface and, present preliminary qualitative feedback from technicians.

2 ACCESS TO MACHINE CONTROL AND SENSOR DATA

Accessing data of a machine control requires using specific interfaces provided by the machine control builder like ProfiBus or EtherCAT. These interfaces are ensuring fixed cycle times for communicating with an external program. The information accessible via these interfaces from an external program depends on the machine manufacturer's and customer's decisions. Because of these not standardized interface definitions, it is often not possible to access data from a machine control without customization efforts by the machine manufacturer [7, 8]. Often machine customers want to precisely define the information accessible by an external program from a machine control as they are storing their core business secrets: machining parameters and manufacturing programs. Further, it must be made sure that via the interface to the machine control no malicious code can be injected, as worker and machine safety would be at risk. All of these aspects are obstacles for integrating information from machine controls in AR maintenance support applications and usually require the cooperation of the machine customer and manufacturer.

In PreCoM the machine manufacturers of all three use case companies were part of the consortium so that no data access obstacles occurred. To avoid implementing three different interfaces for the AR maintenance support system to the individual machine controls, middleware boxes (Savvy Data Systems S.L., San Sebastián, Spain) were installed at all machines. Additionally to the information from the machine controls the middleware boxes also stored the data of numerous vibration sensors attached to critical parts of the machine. This additional layer in conjunction with the built-in security features allows secure access of machine information by the AR maintenance support applications via standard TCP/IP socket connection.

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3 Data Visualization and Selection

After retrieving the machine control and signal data two steps have to be taken to give the technician an efficient access to it, independent of the AR maintenance support application. First, the available parameters need to be analyzed if they could potentially be important for technicians during maintenance operations. For the three use cases targeted in PreCoM 1247, 958, and 791 parameters had to be analyzed for their usefulness. This assessment can only be performed in collaboration with an expert knowing the machine from the programming and maintenance side. This selection process helped to reduce the number of relevant parameters from 1247 to 30, from 791 to 198 and from 958 to 68. Additionally, the remaining parameters were categorized in a way that was meaningful for each individual machine, e.g. 'oil system' or 'spindle'. However, for each machine, the most important parameters were summarized in a 'favorite' category.

The second step comprises the efficient integration of the selected machine data into the AR maintenance support application, which greatly depends on the specific system. Figure 1 shows the chosen approach in the PreCoM AR maintenance support application. In a screen fixed 'Machine Data' panel on the left side (a) machine parameters, which were selected by the technician, are displayed. The technician can minimize the panel in case it is not needed for the current maintenance task so that it is not obstructing the AR-instructions unnecessarily. Via the 'Add'-button a machine parameters selection panel (b) opens were all available parameters are displayed category-wise and from which the technician can add the needed parameters to the 'Machine Data' panel.

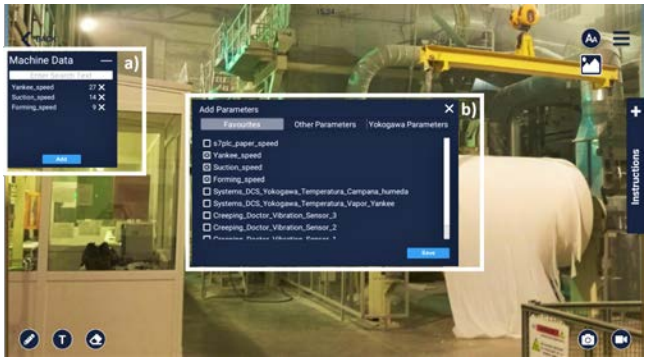

Figure 1: Machine Data and Parameter selection panels in the PreCoM AR maintenance support application

4 Implementation Approach in Unity

A brief description of our implementation approach in Unity might be helpful for practitioners who also want to integrated streamed machine data into their AR maintenance support applications. From the Savvy Box the machine parameters are streamed in a dynamic JSON format via a TCP/IP socket connection. To fulfill the continuous handling of the streamed data and updating of the Machine Data UI panel both processes had to be separated to avoid delays caused by mismatches in processing time and call orders. Like for most network connections a parallel approach is the most feasible way to handle asynchronous tasks. This can be achieved by classical multi-threading with a separate thread handling all network communication leaving the usage and interpretation of the received data to another process. Unity 3D however is not exactly multi-thread compatible restricting all Unity specific functions to the main thread. For that reason we have chosen to use Unitys "Coroutine", a function called in intervals, along with the "async/await" operator to emulate asynchronous behavior. In this way Unity-UI and network communication can be handled independently from each other, causing no delays while waiting for the other.

5 Assessment of Machine Data Panel

A qualitative assessment of the implemented machine control panel was conducted with 1-2 technicians from each of the three use case companies of PreCoM. All technicians confirmed the general usefulness of having machine parameters directly accessible in the AR maintenance support application. However, there were expectable differences depending on the size of the machine. The technicians for the gear grinding company saw it as a nice feature, but stated as the grinding machine is not that large, it would not be a big hassle to go to the machine control panel and look the parameters up there. The technicians of the paper mill and wind power plant hub producers expressed that having the data from the machine controls integrated in the AR maintenance support application was a major time saver for them. Each time they wanted to look up a machine parameter they would normally have to climb down from a part of the machine and walk to the machine control and then get back to the actual place of maintenance. Further, all technicians said that they would additionally benefit if they could also control the machine from the AR maintenance support application, e.g. moving a machine axis. As this would technically be possible without much implementation effort, it would violate the safety regulation. However, this opens an interesting new field of research: How must AR maintenance support application be designed so that a machine can be operated out of it complying with work safety regulation?

6 Conclusion

Integrating access to data form the machine control and sensors into AR maintenance support applications possesses a significant improvement for the usefulness of AR supported maintenance. However, the biggest hurdle of this integration is that machine manufactures and customers are needed as often interfaces providing the machine parameters on the machine control side need to be implemented. Our work presents a solution for three diverse machines using a middleware box with additional security features. After gaining access to the machine parameters, a manual selection and categorization process with a maintenance expert was conducted to avoid overloading the technicians with unnecessary parameters. A qualitative assessment with maintenance technicians confirmed the usefulness of machine control parameter access inside the AR maintenance support application. Although this benefit was perceived lager the bigger the maintained machines were. Lastly, the wish to also control the machine was expressed by the technicians. However, here concepts for ensuring compliance with work safety issues have to be developed.

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