Towards a portable worker oriented solution for 5G and mixed reality supported maintenance

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Abstract: The emergence of high-capable standalone Mixed Reality (MR) consumer hardware and the high-speed high-bandwidth communication technologies, such as 5G, allow to approach the existing maintenance and work processes from a novel perspective. In this poster, we introduce our 5G-enabled MR suitcase, which can be sent to remote locations and includes a MR headset and networking equipment, combined with other necessary sensors and devices for remote trouble shooting. We will develop and iteratively improve this portable suitcase and its software together with the future users over the course of the next three years. It will assist the regular maintenance tasks through visual process guidelines and checklists, support on-site workers to correctly set up the external equipment, display the collected sensor data, and allow direct communication that enriched with shared spatial cues between workers and experts to make the maintenance process more efficient as well as less stressful for the employees involved.

Keywords: 5G, remote collaboration, remote maintenance, IoT

1 Motivation

Today's production industry requires the use of complex machinery that needs regular maintenance. Here, workers perform various tasks based on pre-defined processes, such as cleaning parts and trays, or checking the structural integrity. Workers need to be trained for these tasks and sometimes they also need the support of colleagues or experts. When these machines don't work as expected, experts are often called on-site to inspect, maintain, and repair the machine, sometimes setting up different sensors and cameras in specific positions to investigate the issues. This process not only causes expensive production downtime as well as travel costs, but also a lot of travel and stressful working conditions for the expert. This is costly in several ways for the company and the experts, thus reduces the overall efficiency of the problem solving task. Furthermore, in the case of travel restrictions, as experienced in 2020 due to the global COVID-19 pandemic, experts might not be able to travel at all.

Recent technological advancements in MR and communications technology allow us to approach this problem from a novel perspective. With the help of high-capable standalone MR glasses combined with the high-speed and high-bandwidth capabilities of 5th generation mobile networks (5G) and digital twins designed with CAD software, we propose a solution that allows experts to remotely assist workers with various tasks. With the work sketched out in this poster-paper, we propose to combine several pillars of remote collaboration into

a single package: (1) in-situ video-chat to to connect on-site and back-office workers, (2) working with the virtual model in view, enabling deictic gestures, annotations, and contextual help, (3) remote-rendering of complex 3D models for the MR-view, and (4) linking in other IoT-sensors and views when the task requires.

The proposed socio-technical system will be iteratively developed and refined with a user-centered design process over three years. Requirements have been and will be elicited using a mixed methods approach, including interviews, practice observations and technical data (i.e. technographic approach from the social sciences [AFG+20, Ram07]), as well as workshops, cooperative prototyping, and annual evaluations. This applies not only to technical but also to personal and organisational requirements ("MTO analysis", [SU97]). The changed work processes are designed according to occupational science aspects and their effects on the employees, especially under stress and strain aspects, which is a unique feature compared to most technology-oriented industrial projects.

2 Related Work

Remote collaboration is a prominent research topic in MR. Wang et al. made a comprehensive investigation of MR remote collaboration on physical tasks, identifying general features, use cases, and open issues [WBB+21]. Similarly, Ens et al. conducted a survey of groupware MR research in 2019, highlighting that research focus shifted from realizing the underlying technical aspects to analyzing the more practical prospects [ELT+19]. This is evident in more recent work such as [BSYB20, CTP+21], where researchers analyze the effects of remote collaboration on performance or communication in different settings. Moreover, the recent emergence of market products such as Microsoft Dynamics Remote Assist or Vuforia Chalk that run on off-the-shelf devices also support these findings.

The usage of MR in assembly tasks and industrial training is also an actively investigated research subject. In their survey from 2016, Wang et al. identified bottlenecks in this area as the technical aspects, such as tracking and registration issues or context-awareness [WON16]. More recent work mentions similar findings [DA20], however they also report using MR in assembly tasks would be beneficial and preferred by users. Jasche et al. compared the different visualization types for instructions and found using concrete visualization techniques more advantageous than abstract visualization [JHLW21]. There is also a recent surge of market products such as Microsoft Dynamics 365 Guides and Vuforia Instruct.

Minimum 5G network requirements are defined by IMT-2020 standard [IMT]. Notably, it specifies high downlink (100 Mbit/s) and uplink (50 Mbit/s) data rates, as well as 4 ms latency, which enables a fast transfer of large data that would be needed for MR applications.

3 Mixed Reality Suitcase

Our project aims to provide a simpler and more economical, yet still people-centred solution to emulate the presence of experts on the field. Instead of experts, a suitcase which includes all the necessary equipment and devices will be sent to the field locations. Based on our initial analysis of the use cases, this suitcase will contain: (1) **a smart glass** for hands-free usage,

which will not only allow workers to move around uninterrupted but also share their point of view with the assisting expert, (2) **a tablet**, to display media such as PDF documents, that are not suitable for consumption via smart glasses, (3) required **sensors and additional cameras** for machine inspection and (4) **networking equipment** to connect the devices to an LTE or 5G network.

However, the content of the suitcase is flexible and is designed and developed in three annual iterations with an evaluation phase in between, following the user-centered design standard ISO 9241-210 [ISO19]. The aim of each iteration phase is to determine how far the developed system meets the requirements for the functionality and user-orientation, identify any need for change at an early stage and adapt the suitcase to real world requirements based on our findings. During the overall development, the stress changes in the work processes are taken into account from an occupational science perspective as well as from ethical, legal and social aspects (ELSA).

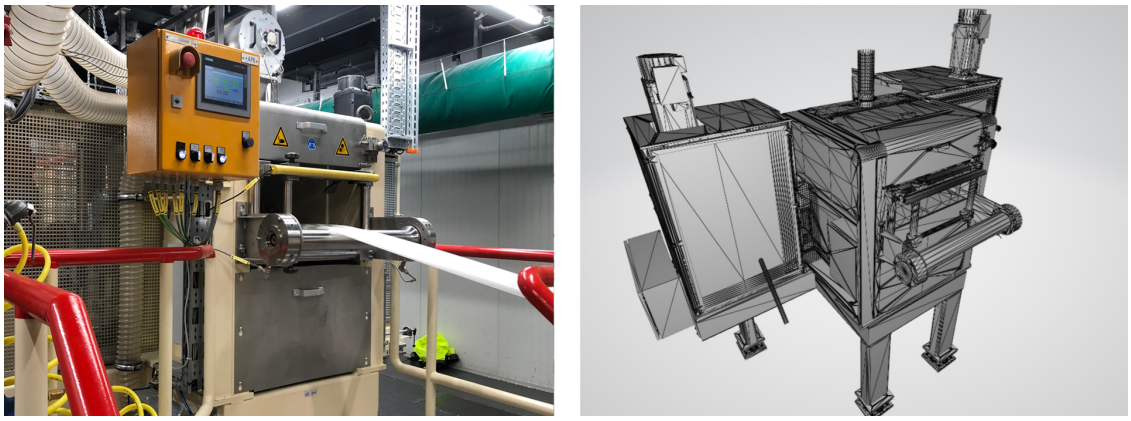

Figure 1: Left: An industrial granulator located in a production facility, which will be the focus on first years use cases. Right: Digital twin of the same granulator.

Our first prototype will focus on a real use case: regular maintenance of industrial granulators. These machines (see Figure 1) reduce waste materials such as defective products or excess material into particles in a continuous operation. Due to their frequent use and nature of their tasks, they require regular maintenance and cleaning. They also need to be repaired occasionally with the help of a specialist. In order to cover these requirements, our system will include the following features:

- **Training:** Granulators have pre-defined procedures for the clean up process. The smart glasses application will explain these procedures to inexperienced employees by displaying instructions directly over the granulator itself. This will also allow workers to learn the tasks while executing them.

- **Sensor placement:** While investigating an issue with the machine, various sensors such as temperature and vibration, or additional cameras could be used to collect relevant information. These should be set up in specific locations to provide useful

data. The MR application will help users to place the sensors correctly by highlighting the previously determined positions.

- **Local maintenance:** Collected sensor data will be visualized directly over the 3D model on the smart glasses to help the local workers to identify possible issues.
- **Remote maintenance:** An expert will be able to access the same data as the in-premise worker and guide the worker through the maintenance process.
- **Video communication:** Whenever needed, in-field employees will be able to call an expert to receive support. Users will be able to enhance the video image using spatial cues and annotations such as arrows or drawings or highlighting different parts of the machine model.

Several challenges have to be addressed to cover all the project requirements. First of all, the MR application will feature digital twins of the machines. These CAD models are the intellectual property of our partners, so they should not be directly accessible to the public. At the same time, smart glasses have notably limited processing power and in many cases it is not possible to render these detailed models natively on the device. In order to address these issues, our current prototype uses (1) a simplified version of the models and (2) remote rendering techniques. Consequently, sensitive data is only available in a non-reusable format and on demand. Nevertheless, we will investigate the effects of loss of detail as well as latency on user performance during our evaluations.

Remote collaboration is one of the major research aspects and challenges of the project. In all three iterations, different presence methods, such as 3D avatars and the aforementioned enhanced video chat, will be implemented and evaluated together with the future users. In this way, both technical and health challenges implied by MR will be addressed. In addition, the collection and visualization of the IoT sensor data is crucial for the remote-maintenance tasks. We will evaluate different visualization techniques for different types of data to provide the most useful and relevant data to users. Furthermore, our overall design will accommodate inexperienced users with a work design that is conducive to learning, while meeting the standards for good work for occupational safety and safety-related issues.

Last but not least, the network communication has a critical importance. 5G connection will enable using features such as remote rendering, video chat and IoT connectivity simultaneously, which is currently not possible with the on-site WLAN coverage (measured download: 36,15 MBit/s, upload: 59,22 MBit/s, latency: 15ms). However, we expect to encounter wireless network coverage issues during our first iteration caused by ongoing construction of the 5G network. To compensate this, our initial prototype will limit some of the planned functionality and also feature strategies to avoid and handle the loss of connectivity.

In summary, advances in MR and communication technologies allow us to approach an existing industry problem from a new perspective. During this project, we will investigate previously explained research topics while providing a reliable solution to our industry partners and a suitable future-orientated work design.

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