Integration of Smart Glasses for Knowledge Transfer in Industrial Remote Maintenance: Learnings from Practice

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1 Company Description

CAS Software AG was founded in 1986 and is led and managed by Martin Hubschneider. More than 400 co-creators work together on the CAS Campus in Karlsruhe, Germany, on leading software solutions of the industry that are used across several industries. The company's product portfolio includes cloud-based customer relationship management (CRM) systems and product and quote configurators that help organisations build successful and sustainable business relationships, make better use of corporate knowledge, and increase the efficiency of their employees. The products of the company are customised to several industries, including automobile, energy and utilities industry, research and education institutions, aviation industry, mechanical and plant engineering,

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and manufacturing companies. Over 400,000 users worldwide work with CAS Software products every day.

2 Project Summary

Knowledge transfer is defined as "the conveyance of knowledge from one place, person, system or ownership to another" (Liyanage et al., 2009). Service and maintenance processes in particular require efficient knowledge transfer methods, where knowledge is rarely documented and important skills are limited to a few people (Webel et al., 2013; Zhou et al., 2008). The current worldwide pandemic has necessitated remote digital service processes and collaborative digital tools. These tools should enable information and knowledge exchange between employees of different levels of expertise (Wang et al., 2014) as well as achieve remote services seamlessly with available personnel on the customer end, where conducting service procedures with own maintenance personnel is time-consuming and expensive.

Augmented reality (AR) smart glasses have been identified as a powerful supporting technology in various tasks such as product design, assembly, maintenance, quality control, and material handling (Syberfeldt et al., 2017). In the area of maintenance, the crucial advantages of smart glasses lie in moving away from hand-held devices to head-mounted devices and an alternative control system by voice (Quint et al., 2017; Schulzrinne, 2018). Del Amo et al. (2018) present a systematic review to identify the relations between AR visualisation techniques in authoring, context awareness, and interaction analysis in the context of maintenance applications, to identify which knowledge transfer goals can be achieved by AR. According to Fu et al. (2010), remote maintenance allows time-saving to the traditional process of 60–90%. Despite these exceeding advantages reported in research, adoption of AR in practice by manufacturing companies has been slow (Syberfeldt et al., 2017).

In this project, we investigate the usability and acceptance aspects of augmented reality glasses for maintenance processes of a German manufacturing SME. A voice-controlled augmented reality application was designed, developed, and evaluated. Evaluation results of employees of the manufacturing SME with real-time maintenance use cases are presented. The chapter concludes with an outlook and implications for SMEs in adopting smart glass technology for maintenance in practice.

3 Project Details

The design science research methodology (Peffers et al., 2007) was adopted to define the requirements, design and develop a solution artefact, and evaluate and disseminate information about the artefact. Specifically, requirements were gathered by analysing the current maintenance process of the SME and proposing customer journeys for the targeted maintenance process. Touchpoints with existing CRM systems were identified, and actions and interactions of the service expert and the customer with the intended remote application were prioritised. These requirements were verified by means of in-depth interviews with service experts, and preliminary evaluations of mockup designs.

A comparison of state-of-the-art smart glasses for remote maintenance revealed several advantages of the Realwear[1] head-mounted tablets (HMT) for remote collaboration. (1) The availability of an open-source API compatible for building Unity and Android applications and (2) the availability of documentation and an online support community were two important factors in favour thereof. Moreover, (3) the RealWear enables adaption to the voice control system with its embedded API for WearML, the mark-up language of RealWear. The remote service application was built on Android, and components such as video calling and communication with CRM system were integrated over the Android base. A dedicated open-source video call server was hosted, thus enabling manufacturers to have a data-compliant way to communicate and store their sensitive data.

The remote service application generated identification numbers for each service request, which were sent to both the service personnel and the customer (as confirmation and e-mail invitation). Video call invitations were automatically generated for the specific machine type and

[1] https://realwear.com/products/hmt-1/

service problem and sent along with the e-mail invitation to the assigned personnel. On the application, the list of previous service sessions was fetched from the cloud-enabled CRM system SmartWe2,[2] from a dedicated tenant (database silo) using its REST API. Video calls were initiated by the service employee on the smart glasses using voice command, allowing multiple personnel to join at the same time, from different networks. Video sessions were recorded and cloud links were integrated on the CRM[3] tenant. The CRM tenant thus stored and visualised the complete overview of the progress of the maintenance sessions and tickets, as well as information on video recordings, service-call history, images taken during the service processes, and the corresponding contact details of the service personnel and customer. The information can be administered with the required rights and permissions, to ensure that only relevant service personnel have access to the service process.

4 Evaluation

The evaluation was carried out in three phases, wherein the results of each phase were incorporated iteratively into the next phase. The first evaluation was a usability and feature comparison test to evaluate the feature layout, particularly due to the constraints of the screen in the form of design mockups. The second evaluation aimed to evaluate the first prototype with smart glasses. Here, employees of a German SME software provider performed a mock maintenance task by assembling wooden blocks with instructions from another colleague remotely. They provided feedback on usability and specific features of the app, in addition to open feedback. The third evaluation was conducted with the employees of the manufacturer. Participants had to perform a typically occurring maintenance task remotely, with help of an experienced service team at a German SME manufacturer. Aspects such as high noise levels, intermittent network, and environmental lighting issues were also present in this evaluation, thus mimicking conditions of real-life usage.

[2] https://smartwe.de/en/

[3] https://realwear.com/blog/designing-realwear-hands-free-wearhf/

Feedback on AR suitability, usability, and feature design was gathered from 20 participants in each evaluation. Think-aloud protocols (Kussmaul & Tirkkonen-Condit, 1995; Jääskeläinen, 2010) were used during evaluations, where feedback from the users were directly recorded in a structured protocol. The System Usability Scale (SUS) was used to obtain a "global view of subjective assessments of usability" (Brooke, 1996). The SUS is based on a Likert scale (Brooke, 1996; Baumgartner et al., 2021) and has also been used in the analysis of wearable devices (Liang et al., 2018). Acceptance of smart glasses in the area of the usual tasks of an employee was investigated with the questionnaire of Berkemeier et al. (2017). Finally, the AR suitability questionnaire was adapted from Palmarini et al. (2017) to gauge suitability of smart glasses for the given maintenance task, as well as to assess whether AR content and annotations are considered a necessity by the users.

The results of all three evaluations showed that the majority of the participants were enthusiastic about the concept of the prototype. The fictitious as well as real-life maintenance task was fulfilled during the call with the service employee by all participants. In the third evaluation, participants reported that the application allows manufacturers to save their average maintenance time by 46% (measured in days), in comparison to their existing duration. The acceptance of the smart glass application (Realwear HMT-1) was dependent on the use case and requirement of the remote maintenance process. Usability scores of the application were, however, high for both non-maintenance and maintenance firm's employees. This resulted from the use of the recommended UX design guidelines by RealWear HMT3 and the improvements based on findings of previous evaluations. The reported acceptance scores in the second evaluation (by the software provider enterprise) were lower in comparison to those reported by the manufacturing enterprise employees in the third evaluation. Augmented reality content and annotations were not reported to be necessary for a successful application and adoption in this specific use case but was viewed upon as a helpful add-on. The prototype application was coded with open-source libraries and environments, and this information was communicated to the participants, before gathering feedback on privacy concerns. Open-source and dedicated servers are expected to allow SMEs to implement prototypes without lock-in problems, as well as achieve improved digital sovereignty and reduced privacy concerns surrounding the application. This was confirmed by the correlation between low reported privacy concerns and high acceptance scores in the two evaluations, as reported by the participants from the software provider as well as the manufacturing enterprise.

5 Future Outlook and Conclusion

This work demonstrated the process of developing a remote smart glass-based maintenance process for an SME. Whilst usability of the remote service application was reported to be high, the acceptance of technology was dependent on the need for remote processes and digital tools. Acceptance was improved further by integrating the remote tools with existing CRM and maintenance management systems, thus creating a seamless process for the service technician as well as the remote customer.

Limitations in the current design and evaluation process mainly involved the external circumstances of the global COVID-19 pandemic, which led to assumptions during the development and evaluation phase, such as social distancing measures, as well as in the evaluation process—where a complete remote evaluation at the manufacturer was designed. These measures might have led to crucial information about the maintenance process being overlooked during the evaluation. Further, the application was tested on one specific device, the RealWear HMT-1, which might have led to device-specific advantages as well as disadvantages influencing the acceptance scores. Another general limitation in the use of a remote maintenance application is the availability of a stable network connection and adapting video calls for low bandwidth requirements. As of today, there is a lack of ubiquitous high-speed Internet connection, particularly in Germany (Rauschnabel et al., 2015). This resulted in difficult circumstances for the video calls which partly reflected in the usability ratings.

As future work, the above-mentioned points need to be revisited and improved upon in further evaluations with pilot customers. Second, a detailed business analysis should be conducted and a revenue model for different companies would be necessary to facilitate further development and adoption of the technology. Moreover, the application should be developed for different smart glasses towards an accessible and generic remote maintenance application. Since most state-of-the-art smart glasses are Android-based devices, developing an Android application is a promising step in this direction. Integration with existing CRM systems should be expanded to allow for more possibilities—such as re-ordering of service machinery, or pre-shipping maintenance parts before scheduling the remote service procedure. Finally, long-term safety and health consequences on employees for wearing the RealWear HMT-1 have to be investigated, for successful adoption by employees and customers (Kim et al., 2016).

This research provides learnings from practice to increase adoption of smart glasses, particularly in manufacturing industries, where remote maintenance has become the need of the hour. Future work in providing a seamless experience across existing (CRM) systems would not only improve the acceptance of the smart glasses in maintenance but also extend it to areas of application in manufacturing—such as design, development, quality control, and other scenarios necessitating remote collaboration.

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