Industrial Augmented Reality: Concepts and User Interface Designs for Augmented Reality Maintenance Worker Support Systems

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Abstract

Maintenance departments of producing companies in most industrial countries are facing challenges originating from an aging workforce, increasing product variety, and the pressure to increase productivity. We present the concepts and the user interface (UI) designs for two Augmented Reality (AR) applications, which help to tackle these issues. An AR Guidance System will allow new and unexperienced staff to perform medium to highly complex maintenance tasks, which they currently incapable to. The AR Remote Service System enables technicians at the machine to establish a voice/video stream with an internal or external expert. The video stream can be augmented with 3D models and drawings so that problems can be solved remotely and more efficiently. A qualitative assessment with maintenance managers and technicians from three producing companies rated the AR application concept as beneficial and the UI designs as very usable.

Keywords: Augmented Reality, User interface, Maintenance.

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

1 Introduction

Augmented Reality (AR) applications supporting maintenance workers can play an important role in tackling the challenges originating from an aging workforce, increasing product variety, and the pressure to increase productivity [1, 2].

One aim of the Horizion2020 project PreCoM (Predictive Cognitive Maintenance Decision Support System) is to bring AR maintenance support to the worker on the shop floor [3]. Since 2017 we are developing two tablet-based AR applications, which will be evaluated in three industrial use cases: a paper tissue machine, a largescale milling machine for wind power plant hubs, grinding machines for high precision gears. We gathered the diverse requirements coming from the user, technology, industrial environment, and regulation domains which form the base for the AR applications [4]. We developed a detailed user interface (UI) designs for both AR applications, which developers of industrial AR systems might find helpful for their applications.

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2 Issues in Maintenance and AR Solutions

Maintenance departments are often under-manned, with very few and often older experts knowing everything about every machine. New or younger colleagues are in general skilled to maintain machines but lack the specific knowledge and experience about medium to complex maintenance tasks and the behavior of the machines on the shop floor. Maintenance departments are also working closely together with their machine and component suppliers who are frequently asking for advice and perform parts of the maintenance tasks. Staff from the machine and component suppliers coming to the companies often means intercontinental travel for easy and quick repairs that could have been avoided with enhanced communication. In PreCoM we designed two tablet-based AR applications to tackle both issues: AR Guidance System and AR Remote Service System.

The AR Guidance System enables new or unexperienced maintenance staff to perform medium to high complexity tasks by following step-by-step instructions that usually only the very few highly experienced workers would do. By digitalizing and customizing existing paper-based instructions and enhancing them with AR visualization pictures and videos this shift of work and a maintenance time reduction can be achieved. The users will further be able to create videos and pictures with notes and drawings that can be integrated into the instructions for future use or notify the maintenance management via Email. In contrast to existing similar AR applications, live machine and sensor data (e.g. axis positions) is accessible in the AR Guidance system, so that walking time to the machine control can be avoided.

The AR Remote Service System enables the local maintenance staff to start a voice/video stream with internal or external experts. Using live footage a faster and better communication process is possible. Both sides are further able to augment the video stream with drawings, text notes and 3D-models, take screenshots and videos as well as sharing documents. This should lead to fewer travels from external experts and the walking of internal experts.

3 User Interface Design Method

A good UI should be an extension of a person reflecting their capabilities, responds to their needs, which is easy to learn, fun, and effective to use [5]. Following these principles, we apply the 6 most important rules of Shneiderman et al. for designing effective UIs for our AR applications [6]: 1. **Consistency**: a sequence of action, consistent terminology, color, layout, font. 2. **Universal usability**: recognizing the needs of diverse users, i.e. age ranges, disabilities.

3. **Design dialogue**: an organized sequence of user actions. 4. **Prevent errors**. 5. **Easy reversal of actions**. 6. **Simplified display of application** to reduce short-term memory load.
First, the task requirements, the user's age, and colorblind accessibility were analyzed. Second, the hand-drawn wireframing tasks [7] and its fast paper prototyping [8] were constructed (see Figure 1). The paper prototyping process resulted in a first structure of the UIs, in order to organize the sequence of the potential user behavior. During this process, there were several peer feedbacks, which improved through questioning the intuitiveness of use and the smoothness of the usability. Third, the first hand-drawn wireframing tasks were elaborately visualized as a digital format due to the two different wireframing methods: Task Flow and Wireflow. Task Flow consists of Start/End, page, decision node, and interaction.

Figure 1: The paper prototyping process

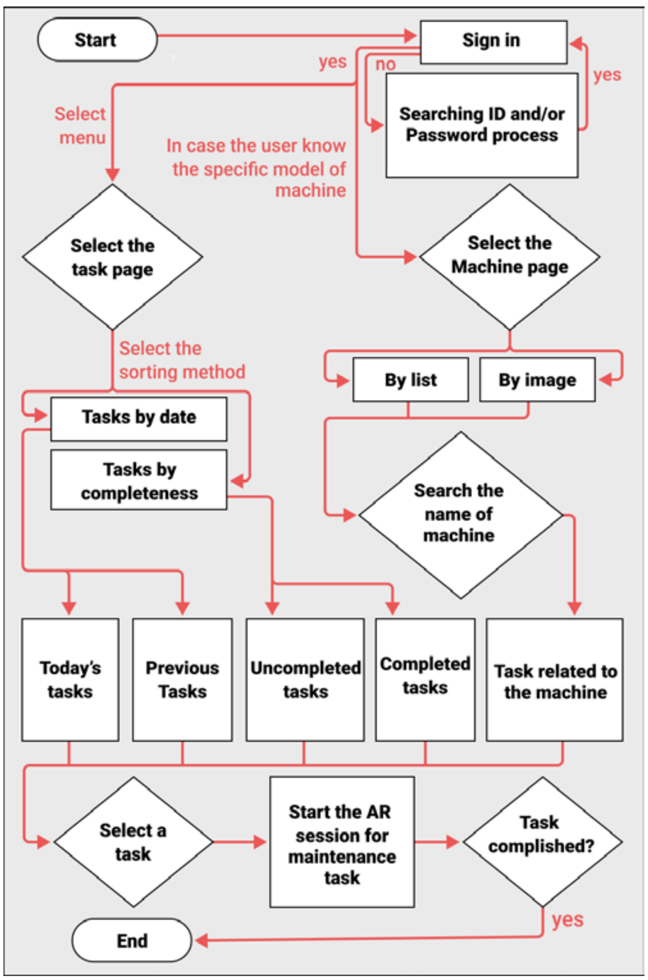

Figure 2: The wireframing task (Task flow)

As Figure 2 illustrates, the Start/End buttons made up of rectangles with round corners. The pages are in the form of rectangles. The decision nodes are inside of the rhombus. The anticipated user interaction is written on the red wire with the same color. Based on this Task Flow stage, the Wireflow process could have developed within the realistic graphic images and the potential user action. For example, the illustration of the application and the tablet shows the step-by-step process of the sign-in procedure in the AR Guidance System (see Figure 3). The sequential images and the triggers of interaction in each page are wired to its result. Throughout this wireframing process, the stage of accurate the AR applications mockups, proofs-of-concept, and prototypes were able to be composed of the fast mock-up prototyping tool Figma Design (www.figma.com). Due to this realistic feature and interaction, the meticulous peer feedback was possible. Last, the design was optimized through discussion and usability inspection [9] to prevent errors, and the product was presented to the potential users, in order to gather opinions and apply them into the system.

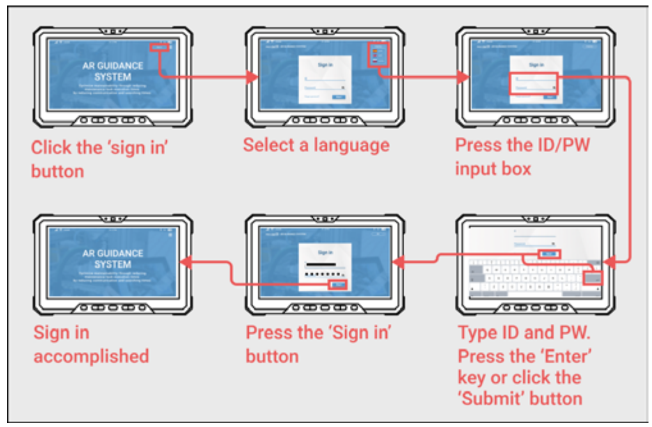

Figure 3: The 'Log in' part of wireframing task (Wire flow)

4 UI Design of the AR Applications

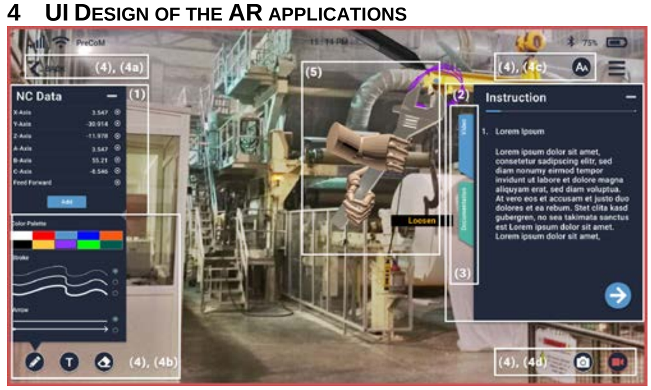

Figure 4: UI-Design of the AR Guidance System demonstrated in an industrial maintenance scenario

In the AR Guidance System, instruction starts with a cover page showing potential hazards, required tools/spare parts, and available manuals. After checking this information, the user reaches the AR page (see Figure 4). The AR page consists of the camera feed in the background and is overlaid with 2D/3D UI-elements. At the top-left, the NC data panel (1), displaying live machine and sensor data is placed. The panel giving the textual instructions for each step is located top-right (2). It also provides access to videos and manuals via vertically placed tabs (3). At each corner of the screen, buttons grouped after functionality are placed (4). At the top-left, a web-browser inspired back-button is located (4a). Drawing-, text- and eraser-tool buttons are bottom-left (4b). With these tools, the user can augment the video feed to take an image to record an event or task for both a feedback loop of the guidance system and further documentation of the maintenance process. The font size adjustment button is located top-right (4c). The documentation tools for taking a screenshot and recording a video bottom-right (4d). Associate with each instruction step is 3D-objects (5), which are placed using marker-based tracking. Considering principals for universal usability the font size is changeable [10] and background/text colors of the panels (NC data, instructions) show a notable contrast[11]. Also, the color palette of the drawing tool provides colors distinguishable for color-blind users [11].

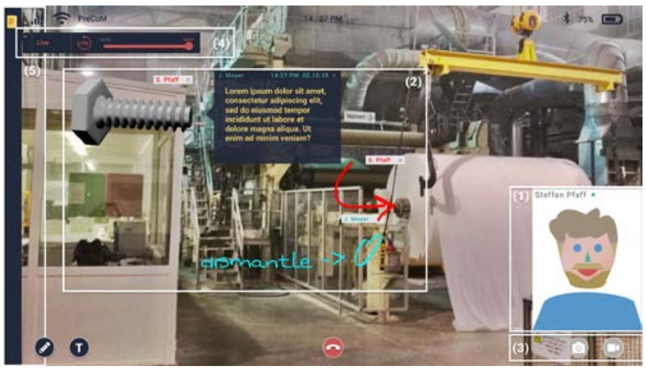

Figure 5: UI-Design of the AR Remote Service System demonstrated in an industrial maintenance scenario

Figure 5 shows the UI of the AR Remote Service System with an established voice/video stream. Both sides are seeing the footage taken by the back-faced camera of the maintenance technicians' tablet, who is at the machine needing advice. The communication partner's face is displayed bottom-right (1). Figure 5 shows the case when text boxes, drawings, and 3D-models are augmented into the live-stream (2). Both users can record a video and take screenshots using the buttons bottom-right (3). They can pause the live-stream and rewind the last 20 seconds using the control top-left (4). The sidebar at the left (5) gets extended on tapping and provides access to shared documents and the taken screenshots and videos, which can be sent via email or stored in a cloud.

5 Assessment of UI Design and AR Application Concept

The concepts and UI designs of both AR applications were presented to the maintenance and production managers and the team leaders of the maintenance technicians of all three industry partners involved in PreCoM in individual sessions. Therefore, we prepared one use case per AR application with clickable mock-up UIs using Figam Design and explained the usage concept. The presentations lasted 45-60 min per partner. After the presentations, 15-30 min interviews took place. No partner had any objections or concerns about the functionalities, nor about the UI design. Partners assured that their maintenance staff could use the AR applications including senior colleagues and were confident that the expected benefits will be achieved.

6 Conclusion

In most industrial countries, the maintenance departments of producing companies are faced with the challenges of an over-aging workforce, increasing product variety, and the pressure to increase productivity. In PreCoM we develop two AR applications that should help to tackle these challenges. The AR Guidance System will allow maintenance departments to let new or unexperienced staff perform medium to high complex tasks. The AR Remote Service System will speed up maintenance tasks by allowing voice/video communication with internal and external experts, which can be augmented with drawings, notes, and 3D-models. This will help in solving more problems occurring during a maintenance task remotely. A quantitative assessment with maintenance managers and technicians confirmed the concept of the AR applications and their UI design as beneficial and usable.

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