Industrial Augmented Reality: 3D-Content Editor for Augmented Reality Maintenance Worker Support System

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ABSTRACT

Supporting maintenance with 3D object enhanced instruction is one of the key applications of Augmented Reality (AR) in industry. For the breakthrough of AR in maintenance, it is important that the technicians themselves can create AR-instructions and perform the challenging task of placing 3D objects as they know best how to perform a task and what necessary information needs to be displayed. For this challenge, a 3D-content editor is being presented wherein a first step the 3D objects can roughly be placed using a 2D image of the machine, therefore, limiting the time required to access the machine. In a second step, the positions of the 3D objects can be fine-tuned at the machine site using live footage. The key challenges were to develop an easily accessible UI that requires no prior knowledge of AR content creation in a tool that works both with live footage and images and is usable with a touch screen and keyboard/mouse. The 3D-content editor was qualitatively assessed by technicians revealing its general applicability, but also the requirement for a lot of time to gain the necessary experience for positioning 3D objects.

Keywords: Augmented Reality, 3D content editing, User interface, Maintenance.

Index Terms: Human-centered computing → Mixed / augmented reality; Human-centered computing → Interaction design process and methods

1 INTRODUCTION

Maintenance of production facilities is faced with challenges to increase productivity, increasing product variety, and an ageing workforce. Augmented Reality (AR) could support maintenance workers tackling these challenges. Despite, the plethora of research and prototypes developed for this application area [1, 2], AR maintenance support application are only finding their way to the shop floor slowly.

In the Horizon2020 Project PreCoM (Predictive Cognitive Maintenance Decision Support System) we are developing two tablet-based AR tools to support maintenance workers on the shop floor [3]. The developed AR tools are evaluated for 10 months at three industrial use cases: grinding of precision gears, milling of wind power plant hubs, and paper tissue production. The development of the AR tools is based on an initial requirements analysis encompassing user, technological, regulative, and environmental perspectives [4]. One result of this requirement analysis was, that for an AR-instruction tool to actually be used it is mandatory that the AR-instruction can be created and updated by the maintenance technicians or engineers themselves in an as easy as possible way. They are having the most knowledge about the task and therefore should be the creator of the AR instructions. Unfortunately, the maintenance technicians and engineers usually are unfamiliar with AR and it is very cumbersome for them to position the instruction content in reference to the real objects. AR experts have the technical skills for doing that but are usually completely unfamiliar with the maintenance task an AR-instruction should be created for, resulting in a lot of time-consuming communication between the maintenance expert and the AR expert.

Further issues when creating AR-instructions for maintenance tasks is, that the creator needs to have continuous long-term access to the real machine to correctly reference the virtual content. Additionally, it is also a problem that many maintenance tasks require a certain disassembly of the machine. In a producing factory, neither long-term machine access nor the partial disassembly of the machine is possible.

Considering these real-world challenges, it becomes clear that the AR-instruction creation must be doable with as little as possible access to the real machine and by a maintenance technician or engineer. Existing approaches require AR expert knowledge [5], a 3D model of the machine [5, 6], or long-term access to the machine [7, 8]. In this work, we present an approach for a 3D-content editor aimed to be used by technicians, without the need for 3D models of the machine and with minimum access time at the real machine.

2 CONCEPT AND UI DESIGN OF 3D-CONTENT EDITOR

The 3D-content editor is part of an AR-instruction authoring tool allowing to create step-by-step instructions. For each step screen fixed textual information can be added in addition to 3D objects. Here, only the definition of the 3D objects for each step using the 3D-content editor will be emphasized.

The principle idea of our concept for the 3D-content editor for AR-instructions is that almost the entire 3D object placing can be done comfortably at a desktop PC using only a 2D image of the machine. Only the fine-tuning of the 3D objects-position needs to take place at the machine using live footage with the tablets the AR maintenance application runs on. The user interface (UI) in Figure 1 is the same for PC and tablet operation.

In (1) the content window where the 3D objects are placed and adjusted is depicted. It shows a picture or rendering from a CAD model of the machine with the AR marker or the live video footage.

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Using a picture, the technician can roughly place the 3D objects in reference to the machine at her/his computer without the need for accessing the machine. Of course, also a part of a machine that is usually only visible if the machine is partly dissembled can be used for placing the 3D objects. When the technician is satisfied with placing the 3D objects using the picture s/he can go to the machine with the 3D-content editor running on the tablet and check with the live footage if the placed 3D objects are referenced correctly or need to re-adjusted. We are aware that using this approach depends a lot on the perspective the selected picture or rendering is taken from and the 3D imagination capabilities of the technicians. As technicians are accustomed to read and draw 2D technical sketches they are having high 3D imagination capabilities. When the technicians are gaining experience with the 3D content editor we assume, that they will be able to produce better pictures for referencing the 3D objects. Using a 3D model of the machine instead of a picture would of course be a far better solution. However, the companies owning machines usually do not have access to the 3D model of the machine, and the machine manufacturers are usually not providing a 3D model of their machine to prevent product piracy. Additionally, the CAD 3D model would need to be reduced in complexity so that it can be rendered in the 3D-content editor posing another major obstacle for its practicability. Additionally, there are no 3D CAD data for many machines in the field as they were constructed using 3D sketches. Also over time machine customers sometimes perform changes at the machine so that the real machine is not matching the 3D CAD data anymore.

To achieve accessibility for users not experienced in AR-content creation the UI has been reduced to the minimal amount of functions necessary to add 3D objects into an AR-scene.

- Background feed (both live and from picture/video)
- Addition/Duplication of existing 3D-objects (from library or import)
- Selection of 3D-objects in the scene
- Manipulation of the 3D-objects position in 6DOF
- Highlighting specifics with free drawing

We are aware that more functionalities like animations are needed to create a more sophisticated scene. However preliminary talks with the targeted user group revealed that more complex options quickly hit the threshold of how much they are willing to learn outside of their area of expertise for a significant portion of maintenance technician.

Figure 1: UI-Screenshot of the 3D-Content Editor using a machine rendering as background feed

In panel (2) in Figure 1 switching between image and live mode as well as uploading an image can be done. (3) shows the parameter inspector where size and 6 DOF of the 3D objects can be defined. In (4) the latest used 3D objects are accessible. Via button (5) a 3D model library is accessible containing the 3D models of standard tools and parts so that they do not have to be created by the technician. The 3D model library also allows adding new 3D models, which can then be used for AR instructions. Lastly, panel (6) enables the technician to add small 3D sketches and arrows to the AR instruction. All menus are retractable to allow for a full screen view of the AR-scene.

3 Implementation Challenges in Unity

To create an authoring tool for technicians is it paramount to make a workflow that requires as little IT knowledge as possible. To achieve this, the tool needs to behave in the same way both in live or image mode. Since current object tracking libraries do not support prerecorded files as input source a direct show filter had to be implemented to emulate the pictures as a webcam in the used system. Additionally, it was necessary to reduce the user input to the selection of the 3D content and manipulation if position and orientation in 6 DOF space through axis input or sliders. The structure and development of the scene are handled by a state machine and does not require further attention from the user. The data exchange can be handled through a cloud connection or manual save-file transfer for industrial sites without mobile network access. Importing further 3D models into the library can be achieved by selecting the corresponding .fbx in a file picker.

4 Assessment of 3D-Content Editor

A preliminary qualitative assessment of the 3D-content editor with the technicians from the three production companies participating in PreCoM revealed mixed results. After a presentation and demonstration of the 3D-content editor, the technicians were asked about their opinion and practicability. There was a generally positive reception, but also an agreement that creating the AR instruction with 3D objects seem very time-consuming. Further, some technicians responded, that they are not very skilled using computers in general so that they think it is very unlikely for them to be able to operate the 3D-content editor. The technicians who were confident, that they would be able to create AR-instruction, defined an AR-instruction under the supervision of the authors. All technicians responded, that creating the AR-instructions was not easy, that it needs the experience to make such instructions, and that they would be unable to create AR-instructions in addition to their normal workload. However, the technicians still were confident, that they could define AR-instructions with the 3D-content editor given the necessary time.

5 Conclusion

In this work, we presented a 3D-content editor, which is part of an AR instruction authoring tool intended to be used by maintenance technicians. The 3D-content editor should allow the technicians to place the 3D objection into the AR instruction with minute access to the machine by using an image of it. Only for fine-tuning of the 3D objects-positions, live footage of the machine should be needed. A preliminary qualitative assessment with technicians revealed that the computer affine technicians would be able to use the 3D-content editor, although it would require a lot of time to gain the necessary experience.

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