Exploring Training Modes for Industrial Augmented Reality Learning

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ABSTRACT

In this paper, we present a conceptual approach and the first prototype of a mobile training system to provide non-expert users with helpful information about the functionality of complex automated industrial systems. The system uses an augmented reality (AR) tablet application to visualize information about internal processes, sensor states, settings and hidden parts of a production system directly in the field of view of a user. The available information can be accessed via four different methods which combine elements of step-by-step tutorials and open exploration. Our prototype aims to support users to better understand automated systems. While such systems will become more complex in future, we believe that augmented reality is a key concept that could help humans to better understand and experience automated systems and its consequences in general.

CCS CONCEPTS

• **Human-centered computing ~ Interactive systems and tools** • Human-centered computing ~ User interface design • Human-centered computing ~ Tablet computers

KEYWORDS

Augmented Reality, Automated Systems, Automation, Learning, Industry 4.0

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1 Introduction

Due to the ongoing digitalization and automation, future industrial production systems will become more complex and heterogeneous [1]. As a result, the number of experts and instructors for certain production systems might decrease significantly in the long term. At the same time, the presence time of experts for the training of new employees will further decrease because of their more extensive involvement in the field of conception and building.

Consequently, non-expert workers will be increasingly confronted with unknown complex automated systems and processes. In order to continue to ensure the controllability of these systems, concepts must be developed to train non-experts to safely interact with automated systems without the presence of an expert at side.

For an independent induction and training at a production system, the worker usually has access to paper-based or digital manuals from the system manufacturer. Because of the high complexity, however, these conventional learning tools are no longer suitable to act as a learning medium. In order to deal with the increasing complexity, future training systems will have to become more interactive and, if possible, should create a spatial link between the real object and the associated information. In this context, digital assistance systems based on augmented reality technologies, which are increasingly used to support workers in industrial environments, are a promising solution to create interactive learning scenarios. Especially the use of augmented reality and the possibility to visualize information directly into the user's field of view could be a significant improvement [2, 11].

2 Related Work

Augmented Reality technologies have been used for various applications in the industrial sector to support workers during training or daily work processes [7, 11]. Most of these systems, however, are mainly focused on specific tasks or activities: For example, Funk et al. [9] presented a collaborative smart glass application for the training of maintenance tasks on virtual and real machines. Werrlich et al. [16] described a system to support an assembly training process for automotive motors based on smart glasses. In addition, various existing stationary systems support the training of manual assembly activities on

the basis of in-situ projections [3, 5, 8, 14]. In this context, Korn et al. investigated the effects of gamification [12].
Developments for a general acquisition of knowledge about complex automated production systems, on the other hand, are rather rare to find: Fehling et al. [6] and Müller et al. [14] presented a shared augmented reality and virtual reality-based learning system for industrial printing machines based on tablets, which provides users with information about internal processes and virtual presentations of hidden parts. They also implemented guided sessions led by an instruction. Another system was presented by Liu and Chiang [13]. It supports users on inspections, troubleshooting activities and indoor guidance via a smart glass application. Their system also provides general information about the factory area. A first version of the system presented in this paper was introduced in Heinz et al. [10]. The system supports the training of users at complex systems with four different instructional and explorative modes via an augmented reality tablet device.

3 Concept

Our approach (Fig. 1) aims to support the induction and training of non-expert workers to work with automated systems on a daily basis.

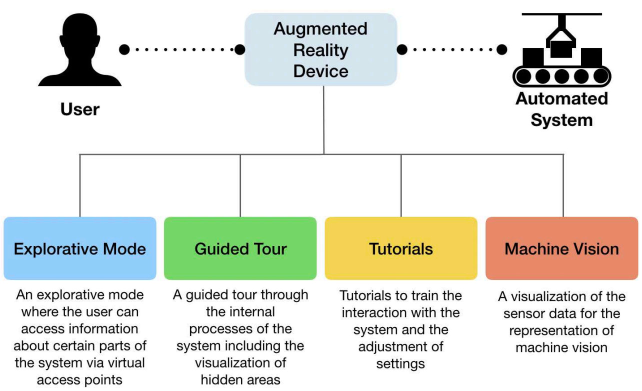

Figure 1: Our approach for a system to support the training of non-experts to work with automated systems

This is done by using an augmented reality device which overlays parts of the viewed automated system with virtual content to display various processes, activities or live sensor data. In addition to the pure visualization of content, these devices also allow to interact with virtual objects. This feature supports the implementation of interactive training and learning scenarios. In this way, new workers can access relevant information about the system on their own without the presence of a human expert. By taken up several aspects of the solutions presented in [6], [13] and [14], we propose the following four procedures for the presentation of the information about an automated system: 1) An explorative mode where the user can access information about certain parts of the system by activating access points visualized at the respective machine part. 2) A guided tour through the internal processes of the system including the visualization of hidden areas and animations of internal procedures. 3) Tutorials to train the direct interaction with the system in order to adjust settings or perform regular tasks. 4) A visualization of the sensor data for the representation of machine vision.
These four approaches will enable users to access the relevant information about a system in an explorative or guided way and thus expand their knowledge.

4 Implementation

Our approach was prototypically implemented at an industrial folding machine for hotel linen (Fig. 2) which is located in the SmartFactoryOWL, a demonstrator factory for projects in the field of industrial digitization and automation [4].

Folding Machine

The folding machine (*Kannegiesser XFM VARIO 20*), is usually part of an industrial laundry system and is used to automatically fold dry laundry pieces after the wash cycle. It uses conveyor belts to transport the laundry pieces through a longitudinal fold and a cross fold process. Afterwards, the folded pieces are placed on one of four available stackers and can be transported out of the machine. The folding processes are done by a combination of changing belt directions and air pressure ejections.

Hardware & Software

For our prototype, which is shown in Figure 2, we used a mini computer, a tablet with augmented reality functionality and a wireless router. Both the computer and the tablet were connected to the router's wireless network. The computer, which acts as a local server, was also connected to the machine via a wired network to gain access to status information, messages and sensor data.

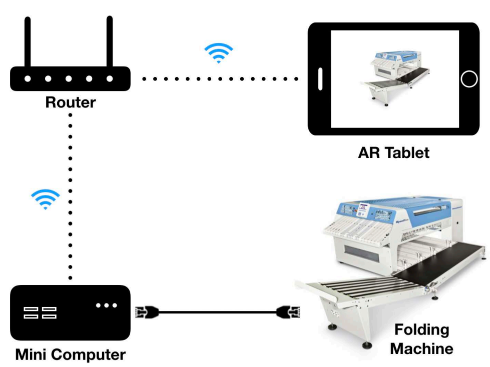

Figure 2: Hardware and communication of our prototypical implementation

On the server side, we implemented a software application to provide the training information as well as object positions and media files. Furthermore, the machine data and sensor states were accessed from the machine via an *OPC Unified Architecture* interface. The transmission of textual and control information to the tablet application was implemented as a *TCP* socket connection. For the provision of media files, we further used a *REST* server application to free up the socket connection. On the tablet side, we implemented a single page augmented reality application to provide users with basic versions of the four procedures proposed in our conceptual approach (Fig. 1).

Tracking

The experience level of augmented reality content particularly depends on the stability of the tracking. To stabilize the tracking of the tablet, we pre-mapped the surrounding of the machine via a build-in mapping process of the augmented reality library. In order to define a global origin for the augmented reality content we further attached a QR code to the front of the machine. After scanning the QR code, the different procedures can be accessed via four buttons at the button of the tablet display. Beneath a textual description, we visualized different virtual objects and animations to improve the provision of information to the user.

4 Features

In this section we present the features used to implement the *explorative mode*, the *guided tour*, the *tutorial mode* and the visualization of the *machine vision*. We will describe relevant aspects and provide exemplary pictures of the different modes.

Explorative Mode

The view for the *explorative mode* (Fig. 3) shows virtual buttons, so-called access points, which allow users to access information about various parts of the machine. Activating one of these points by touching it on the tablet display opens up a panel with information on the associated machine area. At the same time, depending on the area, certain aspects or processes are visualized at the machine in form of images, virtual objects or animations.

Figure 3: The folding machine located in the SmartFactoryOWL with access points for the explorative mode

Guided Tour

The *guided tour* was implemented as an interactive step-by-step tutorial that guides the user through the folding process of the machine. The representation of a step consists of a text-based description of the sub-process at the top of the display as well as virtual references in the form of pictures, virtual arrows and position markers. In addition, various sequences of the folding process and hidden parts of the machine are visualized via virtual animations and pictures. An example is shown in Figure 4, where the longitudinal fold is visualized in form of an animation of the real sequence. The blue objects are representing the adjustable folding shapes and the arrows are representing the air pressure ejection to initialize the fold.

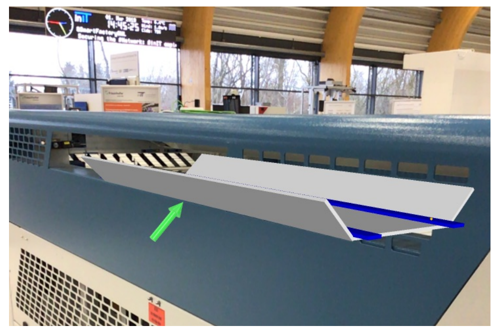

Figure 4: The visualization of an animation for the longitudinal folding process

Tutorial Mode

By choosing the *tutorial mode*, the user can access a list with different predefined tutorials to interact with the system to adjust settings or to perform regular activities. After activating one of the items from the list, the first step of the tutorial is presented to the user. An example of a step from a tutorial on cleaning the light switches on the machine is shown in Figure 5. Here, an animated green arrow and an animated red position marker indicate the target position to the user. The light switches to be cleaned are highlighted as blue boxes. A textual description is also shown at the top of the display.

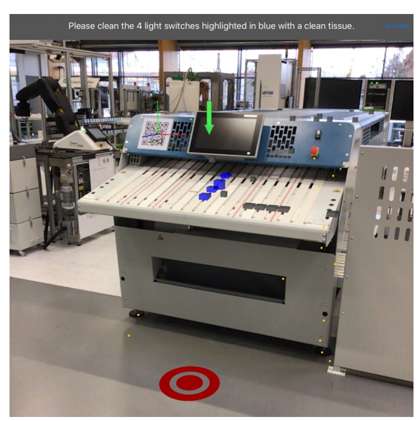

Figure 5: A step of a tutorial to clean the light switches of the machine

Machine Vision

The visualization of *machine vision* was implemented as a live view of sensor activations. Inactive sensors are displayed as grey transparent boxes, while active sensors are displayed as green boxes (Fig. 6). In this way, the progress of the folding process inside the machine can be traced. At the same time, this visualization can be used to detect a sensor malfunction or an open cover as shown in Figure 6.

Figure 6: Visualization of active (green) and inactive (gray) sensors

4 Conclusion & Future Work

In this paper we presented an augmented reality-based application to support the induction and training of workers at complex industrial systems. The system allows to access information about a system via four different methods to support multiple ways of learning. The current approach and the resulting prototype will serve as a basis for further developments and studies in the field of digital assistance systems in industrial environments. The prototype presented in this paper as well as the systems presented by Fehling et al. [6], Liu and Chuang [13] and Müller et al. [14] show the feasibility of such systems. However, the evaluation of these systems is still ongoing work and requires the development of evaluable prototypes. Future HCI research will deal with questions on the design of such systems and its implications: will users be able to better understand automated systems with AR? How can states of automated systems be visualized in AR environments to facilitate a better understanding? Are people able to learn about complex automated systems with AR?

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