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Mobile Projection-based Augmented Reality in Work Environments – an Exploratory Approach

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Abstract

Projection-based Augmented Reality (AR) might change the interactions with digital systems in future work environments. A lot of stationary projection-based AR assistive systems have been presented that might support future work processes. However, not much research has been done beyond stationary settings. With moving towards mobile settings, fast and robust object recognition algorithms are required that allow real-time tracking of physical objects as targets for the projected digital overlay. With this work, we present a portable projection-based AR platform that recognizes objects in real time and overlays physical objects with in-situ projections of digital content. We consider our system as a precursor to a future mobile projection-based assistive system. By presenting the system, we want to start a discussion in the HCI community about the potential of mobile projection-based AR in future work environments.

1 Introduction

The development of future human-machine interfaces has an outstanding position among the research tasks in context of *industry 4.0* [BMBF, 2016]. Research has shown that especially *in-situ projections* (which we also call *projection-based AR*) have a high potential to support humans in production processes. Compared to head-mounted displays, in-situ projections provide multiple advantages, such as more natural overlays, only minor restrictions of sight, better fit to the human stereoscopic sight, and less restrictions with optical aids [Büttner, Funk, et al., 2016]. Consequently, a lot of assistive systems have been introduced that use in-situ projections (e.g. Bannat et al., 2008 and Funk, Mayer, et al., 2015).

Even though projection-based AR has been presented in mobile scenarios previously (e.g. Gugenheimer et al., 2015; Harrison et al., 2011; Winkler et al., 2014), the potential of this technology for the support of work processes has not been analysed in depth. With the recent development of bright pico projectors, the mobile use of in-situ projections for assistive systems becomes feasible [Büttner, Sand, et al., 2015]. As an example, we consider "one-piece flow" in lean production, where a single worker is responsible for all steps of the production process. A mobile assistive system could accompany the worker through all stages from commissioning over assembly to the final quality checks. Compared to smart glasses, a mobile projection system could bring the aforementioned benefits into this mobile scenario. Previous research has shown that in-situ projections are beneficial to learning new tasks, but can be distracting for users that do not need support [Funk, Bächler, et al., 2017]. With the introduction of mobile assistive systems, a single system could be used to make a new employee acquainted with his or her work in the individual workplace and handed over to another employee (and workplace) later on.

One key feature and challenge for mobile in-situ projections is a fast and robust object recognition, that allows real-time tracking of physical objects as targets for the projected digital overlay. In this paper, we present our work towards the development of such a mobile projection-based AR system with real-time object tracking. We present our first portable – albeit *not yet* mobile – version of a projection-based AR system that recognizes objects in real-time and overlays physical objects with in-situ projections of digital content. We consider this prototype as a research artifact in the sense of [Zimmerman et al., 2007] and as a precursor to a future mobile projection-based AR assistive system. By presenting our system, we want to start a discussion in the HCI community about the potential of mobile projection-based AR in future work environments.

2 Related work

Several projection-based AR assistive systems have been published in recent years that aim on the support of human work. We divide these systems into three categories, namely *stationary*, *portable* and *mobile*. *Stationary* systems create in-situ projections in a limited and defined work area. Changing the work area of stationary systems requires considerable effort, e.g. for transportation and reconfiguration. A system that is considered *portable* can be moved to a new work area with more ease and with minimal set-up time. Portable systems require a certain intelligence to adapt to location changes. *Mobile* systems realized with hand-held or wearable devices can not only be used at various locations; rather they can also be used while the user moves through the work environment.

One of the early *stationary* systems using in-situ projections in the workspace was Wellner's DigitalDesk [Wellner, 1993]. In an industrial context, Bächler et al. built a stationary assistive system for assembly processes at manual workstations [Bächler et al., 2015]. An RGB camera and infrared depth sensor are used to track the users' hands in order to estimate their position on the worktable. The amount of feedback during the assembly is based on the individual user. Funk et al. [Funk, Bächler, et al., 2017] have conducted the first long-term study on the use of in-situ instructions. Their study shows that the use of the system has a learning effect for untrained workers. But they also observed that, after a few days, untrained workers were distracted by the instructions. A similar effect was observed with expert workers, who needed significantly longer with the instructions.

A *portable* system is Werklicht® Pro by EXTEND3D[1], a system for in-situ projections of technical information onto physical objects. The physical objects are detected with stereo cameras with a CAD model as a reference. Since the device itself is bound to a power source and Ethernet connection and since it is not designed for a mobile use, we do not call it mobile according to our understanding.

A body-worn and thus *mobile* projection-based system that achieved a desirable size has been introduced in the work done by Mistry et al. They introduced a mobile projector-camera setup called SixthSense that used AR to enhance surfaces with visual markers by displaying additional information on e.g. newspapers or airlines tickets [Mistry et al., 2009]. The augmentation of surfaces with a should-worn system has been explored by Harrison et al. Compared to SixthSense, their system OmniTouch does not require markers but rather recognizes surfaces and hand palms [Harrison et al., 2011]. Similar to OmniTouch, the system AMP-D projects digital information onto the palm of a hand or the floor in front of a user [Winkler et al., 2014]. With our focus on an industrial assembly context, we strive for a markerless system that is similar to OmniTouch or AMP-D. However, we do not focus on finding planar projection surfaces, but rather developed a system that can be trained to recognize and augment any kind of objects. With this object recognition feature, we are able to augment relevant objects in the work environment of the users, which is essential for mobile assistive systems.

3 Concept

We built a first generic prototype platform to analyze the potential of future mobile in-situ projections for work assistance. The prototype platform needs to implement the following two key requirements: First, a light-weight hardware platform is needed that contains an embedded camera system for the object recognition as well as a projection system for the generation of the digital overlay. Second, a generic software

[1] https://www.extend3d.de/index.php

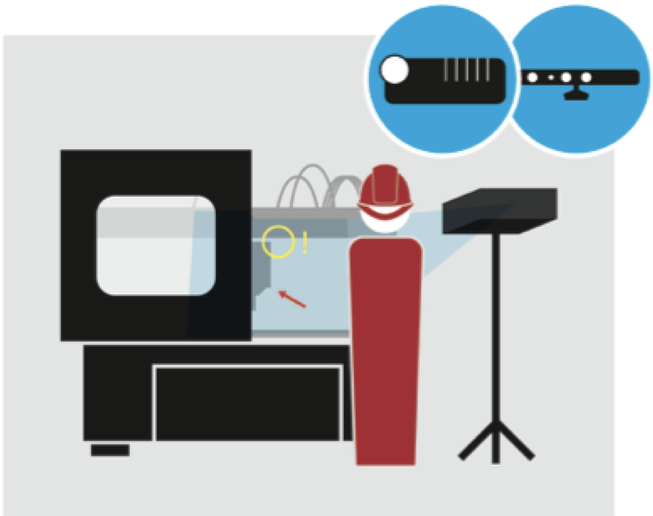

Figure 1: Concept of a portable projection-based assistive system.

platform is required, including basic features for projection-based AR, such as the object-recognition algorithms.

In an iterative process, we created our concept of a portable tripod-based assistive system that can be used at any work place and can easily be moved to its next point of use. This tripod-based system contains a mini computer or mobile device, a camera system (depth and/or RGB cameras), a pico projector, and potentially other hardware devices mounted onto a tripod (see Figure 1). The projector-camera module can be pointed into the direction of the work area. For all of the hardware components, the optimal trade-off between size and performance needs to be found, e.g. a smaller computer usually provides minor computing power and smaller projectors deliver images with a low brightness. Furthermore, we aim for devices that can be powered by a battery pack only, which also has implications on the performance. However, using only light-weight hardware components is essential for moving the system easily and for placing it next to its location of use, which can be any work place, such as workbenches or machines. The software platform needs to provide the basic features for projection-based AR. Since a marker-less tracking is required, the software needs to contain real-time object-recognition algorithms, to recognize the work environment itself, its own location and orientation in the environment and (potentially moving) physical objects as targets for the overlays. The object-recognition feature needs to be easily trainable to adapt the system to new environments and objects. As a consequence, we aim for generic deep-learning algorithms for the recognition that require high computing power – either on the system itself or in the cloud.

Figure 2: (a) The current version of the prototype and (b) the projection of the object annotations.

4 Implementation

Our current prototype (see Figure 2a) realizes the above concept of a portable platform for in-situ projections in workplaces. We implemented the *hardware platform* using commercially available components. The basis for the system is an Intel NUC computer with 8GB RAM and an Intel i5-7260U chip running at 2.2GHz, which runs the operating system and all of the written software, including the object recognition library. As the display we use the Optoma ML750ST projector, which reaches a brightness of 800 lumens. To capture the space covered by the projection and the objects placed there, the Logitech Brio 4k camera is used. We leave it open to use an Intel Realsense camera in further iterations of the system to capture a depth image in addition to the video stream provided by the RGB camera. All the hardware is placed on a tripod with a ball head to allow for flexible positioning and making it possible to use the system for different situations and scenarios in later research. At the moment, the system size is 16 cm x 12.5 cm x 11 cm (H x W x D) excluding the tripod and the cables. The computer is running Ubuntu 16.04 as its operating system. Our *software* is written in Python 2.7. For the object recognition we integrated the open source deep learning framework “You only look once (YOLO)” [Redmon and Farhadi, 2016], which allows us to train and recognize all kinds of objects. At runtime, we capture a video stream with the camera, scale each image to match the target coordinate system and feed the image into the YOLO neural network to get the estimated position and type of the objects in the image. The retrieved information is used for projecting annotations onto the objects (see Figure 2b). If the system is moved, the distance and angle of the projection surface might change. For this purpose, a short calibration routine is part of the software to recognize new settings and to adapt the internal transformation processes accordingly.

5 Future Research

We consider our platform prototype as a basis for future research of portable or mobile projection-based AR systems. As next steps in our research agenda, we plan to discuss use cases with industrial stakeholders beyond the mentioned scenario of stationary assembly and to implement and evaluate those use cases in an industrial context. By realizing assistive systems for specific scenarios on basis of our presented platform, we can analyze the advantages and disadvantages of mobile projection-based AR in work environments. We want to find out which user groups and tasks can be supported by the new technology. While projection-based AR has been intensively evaluated in stationary work contexts, there is only little research on the use of mobile in-situ projections for the support of human work. From a technical perspective, our prototype will iteratively be developed further. We target the implementation of hand and gesture recognition as well as a miniaturization of our prototype. Introducing hand-interaction features into our platform, users will become able to retrieve information about physical objects by interacting with them.

6 Summary and Conclusion

In this paper, we presented a portable version of a projection-based AR platform. Our prototype contains a real-time object recognition algorithm as a basis for augmenting objects with projected overlays. Our system is not meant to be a final system but rather an evolutionary step between the current stationary and a new generation of mobile projection-based AR assistive systems. By developing this prototype, we were able to gain first insights on how to solve certain aspects in the domain of mobile projection-based AR systems, such as real-time object-tracking. With the presentation of our exploratory prototype, we would like to start a discussion about the future of mobile projection-based AR in general, its potential and its use in the future of work.

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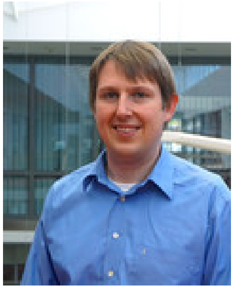

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