Extending the Design Space in Industrial Manufacturing Through Mobile Projection

Abstract
This paper illustrates design opportunities for future systems in industrial manufacturing based on mobile projectors. We present a projection-based augmented reality (AR) assembly assistance system that supports users in the production process by projecting picking and assembly information into the physical workspace. Based on insights gained with a first prototype system using a stationary projector, we consider the availability of mobile projectors and the extended design space as a huge opportunity for AR applications in industrial manufacturing. Within this paper, we describe design ideas for extending our concept and for applying mobile projection in the context of industrial manufacturing.

Author Keywords
Augmented Reality; Mobile Projection; Manufacturing.

ACM Classification Keywords
H.5.1 Multimedia Information Systems: Artificial augmented and virtual realities.

Introduction
In present industrial manufacturing a couple of trends are observable that might change the way we manufacture products [6]: First, the paradigm of
producing shifts from mass production to “mass customization”, allowing the manufacturing of individual products. Second, product life cycles become shorter, requiring production facilities to be easily adaptable. Through the first two trends, the lot size of many products decreases, up until a minimum of one.

Production practices have been a topic of HCI research for several years now, in particular in the context of prototyping practices and research on the maker scene. Our research, however, focuses on how to support users in industrial manufacturing facilities. Since we believe current manufacturing practices change beyond increasing the degree of automation, we want to analyze how new technologies can assist the users in the highly automated world of industrial manufacturing. In this paper, we describe our current research focus on projection-based augmented reality (AR) in manufacturing and give an outline of concepts for possible future systems based on mobile projectors.

Related Work

In projection-based AR systems, digital artifacts are projected into physical spaces and onto existing physical surfaces. Besides the early work of Cruz-Neira et al. on projections for virtual reality [3], one of the first uses of projection-based AR was the “Luminous Room” by Underkoffler et al. [11]. They built a room where both projection and image capturing was possible for all surfaces. Based on the room, they developed multiple use cases for AR with stationary projectors. Using projections can create AR environments that can even span whole rooms [7]. The availability of mobile projectors extends the design space for creating AR environments in production facilities. Otto et al. [8] have used projections augmenting floor surfaces to visualize layouts of assembly stations with a stationary system. Systems for the assistance of users in manual assembly (fig. 1) have been described, but based on smart glasses, such as [9] and [10] or on handheld devices (smartphones or tablets), e.g. [1]. While studies show that these systems have huge benefits, e.g. in reducing the error rates in assembly [10], drawbacks of the systems are evident: smart glasses usually cover parts of the field of view and create problems for people that require visual aids. Handheld devices need to be held and restrict the work. Also when it comes to picking assistance, the benefits of AR applications have been described: Guo et al. [5] show that picking using a head-mounted display and an AR application is much faster than picking with the help of traditional paper-based instructions. While the mentioned assistance systems use smart glasses or handheld devices, we focus on the use of projection-based AR for combined picking and assembly assistance. Previous work has shown that AR applications in general are very useful in the industrial context of manual assembly. We believe that presenting information as a projection – potentially from mobile projectors – is superior to the other technologies, since projection-based AR eliminates some of the drawbacks of the other AR systems.

Supporting Humans with Projection in Industrial Manufacturing

We developed an assistance system for manual assembly in manufacturing which uses projection-based AR to project virtual artifacts into the physical space. Our prototype system allows users to assemble LEGO sets without previous knowledge about the set and without any other instruction. Two types of information, developed in multiple iterations, are projected into the user’s workspace:
Picking information: The system highlights the box in which the next part for assembly is located ("pick-by-vision"). Multiple animated white rectangles are shown that move towards the center of the related box’s label. This is similar to the attention funnel presented in [2]; the visualization creates attention, even if the box is not in the user’s focus (fig. 2).

Assembly instruction: The projected instruction is an image taken from a 3D model, turned in a way so that the next part to mount is clearly visible. In a previous prototype, the presentation was projected next to the work piece on the table in front of the user, where the product can be mounted. First evaluations showed that most users assemble the emerging LEGO set in their hands, which seems to be more practical for small products. To better support this way of assembly, we chose to place the panel in front of the user (fig. 3). Future work might use in-situ projections as presented in [4].

For our prototype system, we have mounted a projector above the user’s head (fig. 4) closely to the assembly station, so that information can be projected right onto the physical workstation without disturbing the user and without causing shadows. When using our current prototype, users have to proceed to the next step with the help of a foot pedal. We are investigating other input methods such as gesture control or computer vision technologies to improve the interaction with the system by recognizing the progress in the assembly process automatically.

Currently we are working on a user study about the system. First user tests indicate that the system is perceived as more helpful and more engaging compared with a similar system using AR smart glasses or an assembly station without assistance. In particular, a double-digit number of participants tested our system and all users have been able to assemble the parts correctly without any other instruction.

Extending the Design Space through Mobile Projection

Having presented our concept and prototype for supporting manual assembly work with projection-based AR, we believe that there is a broad range of applications in industrial productions as projectors become smaller and wearable. Hereinafter, we present some of the concepts we are currently investigating and evaluating in terms of feasibility:

Extended Assistance Systems

Our present assistance system has the drawback of being limited to a single spot in a manufacturing facility. In current industrial practice, workers often move around from one workplace to another to assemble one product with multiple tools or machines in different physical locations. Wearable projectors would allow assistance systems to support a user with assembly instructions during the entire work process.

Supported Maintenance

While the amount of manual work decreases with automation, machines will always have to be maintained in an automated production facility. Engineers could use mobile-projection-based devices to virtually 'see through' housings of machines or to have a virtual layer of digital information presented on the machines, such as information about last maintenances or previous problems that occurred with the machine.

Superimposed Controllers

Physical machine controllers in manufacturing have to be very robust due to the rough environment in production facilities, e.g., high humidity or dusty...
environments. By using mobile projectors combined with computer vision technologies, physical controllers could be replaced by virtual controllers that are projected on machines and controlled by visually recognizing the hands of the user.

Flexible Floor Lighting
In today's production facilities, floor layout is usually painted on the floor, showing for example areas around machines that must not be entered for security reasons or paths for mobile robots. Having more flexible production facilities in which floor layouts change regularly questions the practice of permanently painted layouts. While [8] describes the projection of the floor layout for planning purposes, we believe that projectors mounted to machines or worn by users could project the information and create highly flexible floor lighting.

Conclusion
In this paper, we presented our research with applying projection-based AR in industrial manufacturing scenarios. Our prototype assistance system projects information into the physical workspace of an assembly worker. Our ongoing user evaluation indicates very positive results in terms of helpfulness of the system. We introduced multiple concepts for the application of mobile projectors in industry scenarios, which we are currently investigating in terms of feasibility.

References