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Mixed Reality and Automated Machinery

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Prior to coming to Syracuse University, he was an Assistant Professor at the Wentworth Institute of Technology (WIT) in Boston and taught Industrial Design coursework at the University of Cincinnati (DAAP).

Schneider earned a diploma in Product Design at the Kunsthochschule Berlin Weißensee in Berlin, Germany. A competitive stipend from the German government (Deutscher Akademischer Austausch Dienst) supported graduate coursework at The University of Cincinnati (UC), Cincinnati, USA, where Ralf Schneider was awarded a Master in Design degree in 2005.

He worked as an Assoc. Director/Senior Design Researcher at the Live Well Collaborative, founded by Procter & Gamble and UC with a unique mission to foster the collaborative, interdisciplinary design process between industry leaders and academia. In this role Schneider worked with Hill-Rom and P&G on various projects.

Ralf Schneider is interested in solving complex problems with interdisciplinary teams. His current research focuses on mixed reality, head mounted displays and the impact on design.

Mixed Reality and Automated Machinery

When reality is augmented with digital information, it is called Mixed Reality (MR) [1][2]. Machinery on factory floors is increasingly automated and system integrated [3]. The potential to support the design, sale and operation of automated machinery with a mixed reality device is tremendous. This paper shares takeaways from a collaboration of industrial design students, mechanical engineers, field technicians and technical writers to investigate the innovation potential of applying mixed reality in a manufacturing environment.

Project Path

The semester-long project was organized according to the user-centered design thinking process [4], navigating from the understanding phase to the ideation phase and concluding in the refining phase. At the beginning of the project students researched the topic mixed reality, learned about its origin about 50 years ago [5] and explored MR capabilities with the Microsoft HoloLens, a state of the art MR device.

Student teams were asked to respond the question "How could mixed reality impact machinery solutions for industrial process automation and integration". Over the course of the semester, students were expected to respond to these important issues:

- Explore and identify a design opportunity around a specific theme in which mixed reality is a game changer
- Design a system that includes a design concept for a mixed reality experience
- Ideate scenarios that demonstrate an improved task flow enabled by mixed reality
- Tell the story of why mixed reality makes this specific experience better
- Visualize details of the mixed reality design
- Apply the user-centered, stakeholder-focused design process

Bartell Inc. in Rome, NY, a manufacturer of tire bead machines for the tire industry, served as a client. They are shipping their products worldwide to a variety of tire manufactures [6]. The tire bead is a ring made of rubber-coated wire that ultimately holds the tire on the rim. The automated machining process is complex and state of the art. The link provides an overview of how a tire is made (https://www.youtube.com/watch?v=HjViHN6xuwk). Bartell's machinery produces discussed components at timestamp 7:10.

While secondary research on the topic provided a general understanding, the students needed to gain a thorough understanding of automated and integrated machinery and experience the equipment in person.

The Field Trip and Debrief

The students visited Bartell in Rome NY for a half day. At arrival, the students learned about the safety requirements for walking the manufacturing floor. The steel toe slip-ons provided material for humor and revealed that none of the students ever had a factory experience before. The group saw the shipping area where raw materials come in. On the way to the tire bead machine, the students were able to get an overview how various parts are manufactured. The tire bead machine is assembled out of multiple components and occupies an approximate area of 60ft x 20ft. A field technician explained how the machine works and demonstrated how technicians operate the various terminals. Seeing the machine in action made the students aware how fast the parts are made and helped them to understand the job role the operator is responsible for. They were also introduced to technical terms, which are crucial when effectively communicating with engineers.

After seeing the tire bead machine, the group observed a future add-on component, a robot arm that removes the individual tire bead rings and places them on an automated sled. The automated sled would deliver the product to a storage facility or directly to the vulcanization machine. This experience clearly explained where the future of manufacturing is heading: maximizing efficiency in production while reducing labor costs [7]. Furthermore, the interaction with the field technician provided insights of his needs during operation or installation.

After leaving the manufacturing area, the group had an opportunity to debrief with two engineers and a technical writer. During the conversation, the fact that multiple stakeholders have varying needs became obvious.

The design students learned that the process of selling, making, installing and operating a tire bead machine involves many people. A sales person communicates with the customer and defines both commercial contract and technical requirements. Three to five people from design engineering (Electrical & Mechanical) design and develop the equipment. Once the final design is approved, procurement sources all components required to build the equipment. When the parts and materials have arrived, the product is built and tested on site. After ensuring proper performance, the equipment is then shipping to the customer. Field service technicians support installation.

One of the engineers shared that they would like to utilize 3D printing technology in order to visualize a new components or concepts. Currently it is time intensive to reduce the complexity in a SolidWorks assembly before being able to 3D print the machine component in scale. The engineer also stated that previewing their build configuration in an augmented reality setting before committing to the final design would be desirable.

Another key insight was that the technical writer currently creates operation manuals for the machine and often does not receive the latest changes made in the engineering group. In addition, proper translation for international customers is time consuming and expensive. Changing the paradigm from printed manuals to augmented maintenance support would be a game changer [8].

Lacking a detailed questionnaire and fatigued by the impressions on the manufacturing floor, some students were not able to ask questions that further identified clear insights. During the debrief the following week, this missed opportunity was discussed. Back in the classroom, the students started to analyze the problems that they would solve as part of this project based studio course. Both production and maintenance related issues where documented.

Concept Development Proposals

At this point in the semester, the students also gained a thorough understanding of the potential of MR and automated integrated machinery. Many insightful questions were asked and answers sought. When working on a project without many case studies for comparison, it is critical to be an advocate for the user and to understand the stakeholder's needs. One of those questions was "In which part of the process selling, producing and operating a machine does it make sense to implement augmentation?"

The students also discovered ethical concerns regarding the technology. If a computer is used in the communication of multiple individuals, how could misuse be detected and controlled? After the opportunity areas were defined, the teams envisioned future scenarios that illustrate an improved operator task flow with the integration of mixed reality technology. A head-mounted display (HMD), the Microsoft HoloLens, was chosen to allow hands free operation. As part of the multidisciplinary teamwork, the technical limitations from the mechanical engineering point of view had to be understood as well as the current limitations regarding the software and hardware of the HMD device.

Follow up conversations with engineering lead to a more thorough, holistic understanding. The students clarified assumptions from the visit, e.g. to learn more in-depth about maintenance protocols. This interaction allowed the students to practice writing professional emails. The pedagogical approach was to provide the students with the engineer's email address, encourage them to take responsibility in formulating the questions and to copy the professor on the email.

The midterm presentations accelerated decision-making, formalizing ideas and creating a sequence of comprehensive visualizations that describe the concepts. An external expert from the industrial and user experience design consultancy Tactile Inc., Rich Hanks, critiqued the work and provided valuable feedback for future design decisions. This guidance came at a critical time to align the project direction. In the weeks after the midterm the students were asked to develop the story of their concept through advanced visualizations.

Thingworx from PTC is one of the available tools for the MR development process. This software allows one to import CAD files into an augmented setting and add interactive elements. The scene is then published to a server. Through the Thingworx app on the HoloLens, the scene is loaded with a marker that also serves as an orientation and scaling tool. The students were able to demo the software [9]. Due to the duration of the project, it did not seem feasible to introduce the software Unity, which is the current standard tool for MR development.

Final Mixed Reality Proposals

For this paper, only the two best team projects were selected and described in detail. Team 1 focused on installation and maintenance while overcoming language barriers. Team 2 saw an opportunity in improving communication during development. The final mixed reality proposals envision how the human-machine interaction will improve in the future. The teams developed their own framework and unique solutions to the problems they discovered. Students utilized 3D user interface guidelines to support the decision making process [10].

Team 1 | Installation and Maintenance

Since the installation of a new tire bead machine is quite complex, two to three field engineers support the customer throughout this process. Due to Bartell's international customer profiles, language barriers are typical. Team 1 took this opportunity to implement a translation function in the MR user interface, which improves the interaction with customer employees during assembly. MR could also streamline unpacking and the proper installation process. A video chat function allows calling in additional technical support.

Figure 1: MR Illustration of auto translation and video chat

Based on the extensiveness of the maintenance schedule for an entire bead machine, Bartell's engineers recommended focusing on one piece, the Winder. The Winder has 73 lubrication points and has the most moving parts of any component on the line. These factors contribute to the Winder being the most likely component of the line to be improperly lubricated. Many of the lubrication points can be difficult to identify. Moreover, it is difficult to find out whether lubrication was correctly performed. Improper lubrication can cause premature failure of moving of components such as bearings. Therefore, it is critical that the operator inspects moving components for damage, and excessive wear.

Figure 2: MR Illustration of lubrication points

The students used this maintenance example to visualize how the MR product would assist the operator. By tapping into the machines sensors and the maintenance schedule, the operator would wear a HMD and see a lubrication map overlaid on the winder. Then, the operator would begin by referencing the lubrication charts, which list lubrication types, amounts, and intervals. Performing the lubrication routine would be documented and accessible for future maintenance and supervisors. The automated and integrated machine turns into an IoT device.

Team 2 | Communication during Development

This design solution creates a communication network with the HoloLens and HoloTablet that connects the entire development team though a unified software platform. The app that runs on both HoloLens and HoloTablet provides the opportunity to see assembly, prototype, and “trial running” of machines. The engineering team can test virtual parts on existing machines or new parts on virtual machines as holograms. During decision-making meetings, regardless of their location, engineers can join the MR experience.

The engineers are running back and forth between inspecting the machine on the factory floor and working in their office. Therefore, a portable tablet design that contains the functions of the HoloLens while preserving the control ability of traditional computers or tablets allows for flexibility and safety.

Figure 3: HoloTablet and interface design

Miscommunications can arise between the design development team and the customer in regards to the spatial orientation of the equipment in the factory. Sometimes the layout drawing of the factory does not match the real world space, e.g. a support beam in a location that is not identified, and thus impose machine configuration constraints. The HoloLens could be used to spatially scan the factory space for the intended equipment.

Internal miscommunications during the design and build process do occur, primarily related to the actual function of a part or the exact assembly requirements. The app allows viewing the interactions of parts that have been created by multiple users in SolidWorks.

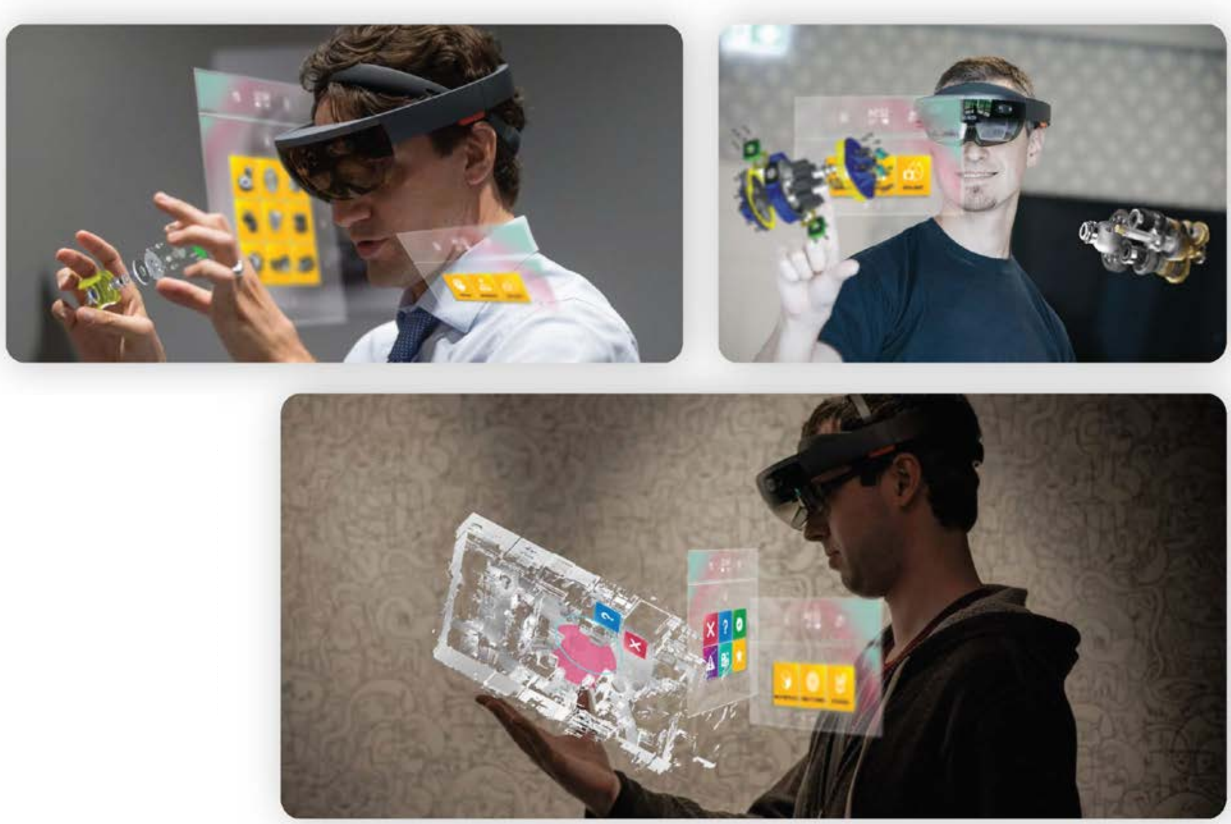

Figure 4: MR photo-collage illustration of interaction

Key Learning Issues for the Students

In this project-based course, students had to assess what issues they needed to solve through critical thinking. This collaboration with the engineers uncovered insights and allowed the teams to verify the importance of the problems they had identified.

Upon graduation, interdisciplinary collaboration skills are highly regarded. The framing of the project allowed the students to practice solving complex issues on a system level including communication and participation of the key stakeholders.

The students learned about implementing new technology in an existing process. While gaining an understanding of the project environment, they were exposed to technical terms and manufacturing processes.

The field of vision is critical for the safety of the operator in a factory setting. Design teams constantly have to question how much or how little information is overlaid in the environment.

The students gained valuable experience in designing a user interface (UI) for a MR experience. They learned that the level of interactivity in a MR experience needs to be adjusted to the task at hand. The proper management of information is a key element in the user interface.

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