A Research Agenda to Deploy Technology Enhanced Learning with Augmented Reality in Industry

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ABSTRACT

To apply Technology Enhanced Learning (TEL) with Augmented Reality (AR) in industry, a suitable methodology is necessary. This work focuses on how to deploy and evaluate AR learning scenarios in industrial environments. The methodology evolved within the two EU projects FACTS4WORKERS and iDEV40 and has been improved iteratively. The first step is to investigate the use case at the industry partner. Then the appropriate concept is defined. The next step is to develop a first prototype. This prototype is then improved during several iterations according to the feedback of the industry partner. When the prototype reaches an appropriate Technology Readiness Level (TRL), a final evaluation is carried out to verify the software artifact against the gathered requirements.

KEYWORDS

Augmented Reality, AR, Technology Enhanced Learning, TEL, Problem-based Learning, On-the-job Training

1 INTRODUCTION AND MOTIVATION

Industry is changing rapidly at the moment. IT-driven, often highly disruptive changes are affecting many businesses, especially, but not exclusively, in the manufacturing industry. This process is often referred to as Industry 4.0 [12]. New devices and technologies addressed at both private customers and industry are emerging on the market. Digitizing companies and keeping pace with new devices, technologies and software is a great challenge. In order for companies to adapt quickly, it is very important to train and teach employees how to use these new technologies. Bridging the gap between new technologies and their application in industrial and educational settings, however, can be a very demanding task. Therefore, a methodology is needed to integrate new technologies in educational and training-on-the-job scenarios. Especially after smart glasses, such as Vuzix, Google Glass, Microsoft HoloLens and Magic Leap, were rolled out, there were several attempts to apply these technologies in industry. Stocker et al. [14] deployed a software demonstrator for smart glasses, which presents a checklist in the user's field of vision to help workers doing maintenance and assembly tasks in the automotive domain. The assistance tool was evaluated by experts in automotive production. Although they were skeptical about interaction techniques such as touch and speech recognition, the evaluation clearly showed the potential of these devices and technologies. The context of use was rated as promising if the quality of the devices were to improve. The current generation of smart glasses offers distinct improvements in display quality, speech recognition and input options. Therefore, it is necessary not to focus on the specific device but more on the context of use and whether the smart glasses scenario makes sense. The hardware is rapidly improving and smart glasses manufacturers are launching new devices at short intervals.

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2 TERMINOLOGY

Technology Enhanced Learning

Browne, Hewitt, and Walker [5] define TEL as any online facility or system which supports learning and teaching. A great challenge for TEL is that simply digitizing analog learning material is not sufficient. Teaching methodologies also need to change [10]. This does not only apply to education in general but also to educational scenarios in industry settings.

Augmented Reality

An early AR survey was carried out by Azuma [2], who describes AR as a variation of Virtual Reality (VR): While the user is fully immersed in VR and cannot see the real world around him or her, AR allows the user to see the real world with virtual objects superimposed upon or overlaid with the real world.

3 RESEARCH AGENDA

We developed a research agenda to plan, conduct and evaluate TEL AR projects in industry. This research agenda evolved during two EU research projects, namely FACTS4WORKERS and iDEV40. In FACTS4WORKERS, we developed a prototype to help maintenance workers to clean the lens of a laser cutter [13]. In iDEV40, we are developing an AR-based assembly support system prototype in a special purpose engineering domain. In FACTS4WORKERS, we gathered the requirements for a TEL AR system from the industry partner as a first step. During an on-site visit, personas and problem scenarios were identified. The AS-IS situation was analyzed and a TO-BE situation was developed [6]. After identifying the requirements, we defined a suitable didactic concept. The main use case focus for this research agenda is on maintenance and assembly tasks. A significant challenge when learning how to do maintenance tasks is that workers usually do their training directly on the machine. This means that during this training phase, the machine cannot be used to produce anything.

The challenge is not only to create a didactic concept which reduces the downtime of the machine, but also to ensure learning success. The next step after creating the didactic concept was developing the first prototype. This step is very important in order to verify the gathered requirements. At the beginning, the actual user requirements are often unclear and only become more defined once users from the target group have started testing the first prototype to get an initial idea of the features [1]. The next step is then to gather feedback from the industry partner, especially from users from the target group. After that, the qualitative feedback from the users is considered for the next iteration of the prototype. To improve the prototype iteratively, common agile software development practices are followed [4]. After several iterations, when the prototype reaches the desired Technology Readiness Level (TRL), a final evaluation is carried out to validate the software artifact against the predefined requirements. The validation framework that was used was developed to fit various kinds of use cases and the different industry partners [8]. Figure 1 summarizes the research agenda.

Figure 1: Research agenda for TEL AR in industry

Use case investigation

In the first phase, an on-site visit at the industry partner is necessary to gather the real-world context of the use case. Current processes and challenges are identified using interviews and by observing users from the target group. Another important aspect of the on-site visit is to get into direct contact with the workers to build trust and to involve them in the development of the TEL AR prototype.

Didactic concept

With the advent of Industry 4.0, the role of humans in production-related fields is changing. Workers are confronted with new challenges, meaning that they need new skills. One possible solution how to train and teach employees to master these new challenges is to apply and further develop Technology Enhanced Learning in industry. One particular issue is how to support the digitization of domain-specific knowledge without losing any of it. [7]. We use a problem-based learning setting as a starting point [3]. Additionally, we connect a virtual classroom scenario with an in-situ learning scenario at the workplace. The didactic concept is separated into two TEL learning scenarios. First, participants study learning material such as manuals or other documentation. The first TEL phase is a virtual learning scenario in a virtual learning environment where the training object is displayed as a hologram in the field of view of the learner. The maintenance or assembly artifact can be investigated in 3D from different angles and viewing directions. An animation shows the steps that are necessary to complete the learning scenario. The hologram is enriched with symbols and text annotations. Working with teaching material in 3D has the advantage that the 3D animation can be observed from different angles which could improve the learning experience. The success of such learning scenario depends on the spatial abilities of the learner. Learners with low spatial capabilities tend to be cognitively overloaded by the learning situation [9]. In this case other learning materials and scenarios should also be considered. The classroom scenario works in any environment. The real production machine, or any other tools or equipment are not needed. After the classroom training, a feedback and reflection phase follows to ensure that the virtual learning situation was successful. The same situation is then played out again for training at the machine or assembly station. This training-on-the-job scenario is the final step before the participants are able to perform the task by themselves. Figure 2 summarizes the didactic concept. The TEL software used is the same in both scenarios. In the first scenario, the TEL software is a virtual setting. For the second scenario, AR is used to overlay additional information and training material above real-world objects. To enable an easy transition between the first and the second scenario, the same user interface (UI) is used within the TEL software.

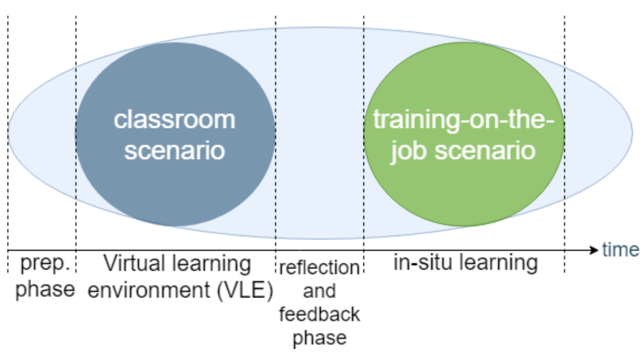

Figure 2: Didactic concept

AR Prototype

In both projects, the Microsoft HoloLens is used to implement the prototypes. The generic methodology can be applied to any kind of AR device. An advantage of using smart glasses is that the users have their hands free to conduct the learning situation. The key feature of the TEL AR software artifact is that the UI is consistent for both TEL scenarios. Figure 3 shows the UI of the application. The UI controls the maintenance or assembly instruction animations. The animations can be paused, forwarded, rewound and repeated. The UI is based on the UI of commodity video players so that it can be easily recognized by the users. The menu can be freely positioned in space to prevent it from blocking the line of sight of the user. The 3D cube can represent any kind of 3D object, such as a machine that needs maintenance or an actual product that is being assembled. The opacity of the computer-generated object can be changed using the cube symbols at the bottom.

Industry partner feedback

The AR prototype is tested at the industry partner and is then improved according to the feedback provided by users from the target group from industry. Several iterations may be necessary before an appropriate TRL level is reached and before the AR prototype is ready for the final evaluation.

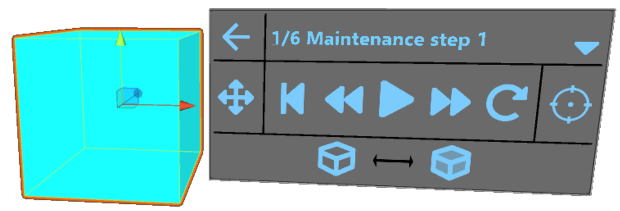

Figure 3: AR Prototype - UI controls

Final Evaluation

Within the FACTS4WORKERS project, an evaluation framework was developed to validate the software prototypes deployed at the industry partners. The framework separates the evaluation into two different strategies. The first strategy is an impact analysis. The second strategy is a quality validation. Both strategies are divided in human-driven approaches and data-driven approaches. Human-driven approaches are surveys, interviews and observations. Data-driven approaches include log analysis and application data. Data-driven approaches are often available at a higher level of maturity of the software artifact. Human-driven approaches also work during the very early stages of the project [8]. Figure 4 summarizes the evaluation methodology. We gathered feedback from several industry partners according to which the FACTS4WORKERS prototypes are a good fit for the defined use cases. As a result, a start-up that is now using the prototype to build products has emerged from the research project.

4 CONCLUSION

To implement TEL with AR in industry, it is necessary to have an adequate research agenda. The research agenda presented here was used in the FACTS4WORKERS project to deploy several TEL AR prototypes at several industry partner sites and is now also to be used in the iDEV40 project. The prototypes were evaluated by users from the target group and were improved iteratively. During the final evaluation in the FACTS4WORKERS project, the software prototype

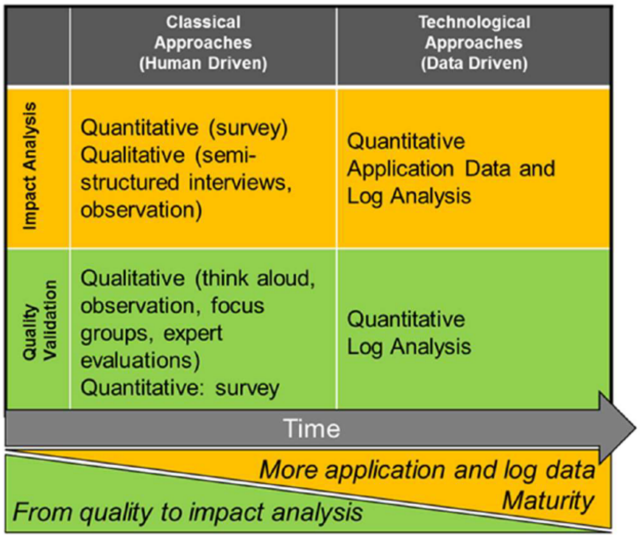

Figure 4: Evaluation framework [11]

could be validated against the requirements defined in the first phase of the project.

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