IEEE Standard for Augmented Reality Learning Experience Models

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***Abstract*—Augmented Reality has found its way into training scenarios, e.g., when used in companies to deliver close-to-practice instruction. As a prerequisite for wide-scale adoption, however, there is need for a structured approach to model and formalize training activity. For this reason, the Augmented Reality IEEE standard ARLEM was defined. The standard was developed with the help of a reference implementation, MIRAGE·XR, to demonstrate how real-life training applications can be created and edited using an Augmented Reality editor for learning experiences. With IEEE ARLEM and Mirage·XR, standardized and interoperable learning content can be created and exchanged.**

Keywords—Mixed Reality, Augmented Reality, Wearable-Enhanced Learning, ARLEM

I. Introduction

Speed is paramount for businesses when innovating and implementing the connected change. Consequently, there is a shift in companies' mindsets to enable employees to take part in lifelong learning activities more than ever before, and to provide them with more piecemeal talent development opportunities in their career to keep up-to-date with recent advances and emerging requirements [1]. Novel organizational structures replace large hierarchies with team networks, new leadership strategy, and a more dynamic workforce composition involving also contractors and freelancers. This shift raises the requirements for new training systems that enhance a company's workforce skills in a more real-time oriented manner.

Recent developments in mixed reality like the Microsoft HoloLens and Augmented Reality-compatible smartphones provide an opportunity to create new learning experiences. Such advanced Augmented Reality and mixed reality systems can provide an effective solution where content can be conveyed on-demand without the need for an expert to be present. Moreover, mixed reality training applications offer visual content and hands-on guidance which helps trainees to remember the training.

II. Background

Technology-enhanced learning systems have evolved over the past decades from the exchange of learning resources to Web-based systems to mobile apps, traversing phases of digitization, scaling, and adaptation [2]. The first phase is signified by the digitization of learning content, distributing resources using, e.g., mails or FTP servers. After that and with the invention of the Web, naturally a scaling process happened which commodified effective and efficient management of learning content and its distribution using Web-based platforms. The third phase saw mainstreaming of adaptivity of learning material so that personalized and interactive Web applications and mobile apps can be created. We are now entering a fourth phase, probably best identified by renewed capabilities for "disintermediation", where learning content is liberated of the constraints of a particular delivery medium or container. Users are directly immersed in learning content, integrated into their surroundings using mixed reality technology like wearables, smart textiles and embedded systems. Features like ghost hands [3] and ghost tracks [4, 5] are now possible and can display recordings of experts as virtual content in the real environment. This way, trainers can prepare contents once by demonstration and distribute to employees to access any time and in parallel.

Using markers and computer vision, training content routinely now augments objects of interest. More recently and with the help of the new IEEE ARLEM standard, such object-centric experiences can be extended to feature augmented learning activities, guiding learners through practical exercises, supplementing engaging 3D visuals with meaningful instruction. This way, re-use of 3D learning objects is facilitated, allowing content to star in different learning environments. The standard was created to represent training in standardized data structures suitable for delivery in Augmented Reality applications.

III. IEEE ARLEM Standard

The established Augmented Reality IEEE standard ARLEM defines two description languages for Augmented Reality training content [6]. The first part is an activity description language that contains the information how a learner interacts with real and virtual objects. From a high-level perspective, this activity description language defines a system of branching actions that are part of the learned process. Each action can be triggered and has enter and exit events. For each of these events, it can be defined which content augmentation is activated and deactivated. The activity description links to a workplace description. This second part of the ARLEM specification defines which elements are present in the learning experience. Since the standard targets Augmented Reality use-cases, the covered elements include real things, persons and places in the environment but also hardware like sensors and devices, as well as detectable markers and virtual augmentations.

ARLEM has the goal to simplify the process of creating Augmented Reality training content. Even complex task operations can be illustrated and explained in an understandable and visual manner. By complying with one standard, the large range of specialized and bespoke Augmented Reality authoring applications can be replaced with applications that obey the standard. This way, their produced data becomes interoperable and can be exchanged between applications. Data from other sources (like Web-based editors), can also be integrated into an Augmented Reality training platform if they use the standard's definition. The longevity of standards also means that such Augmented Reality training applications are future proof, safe-guarding companies' investments and planning strategies regarding training activities.

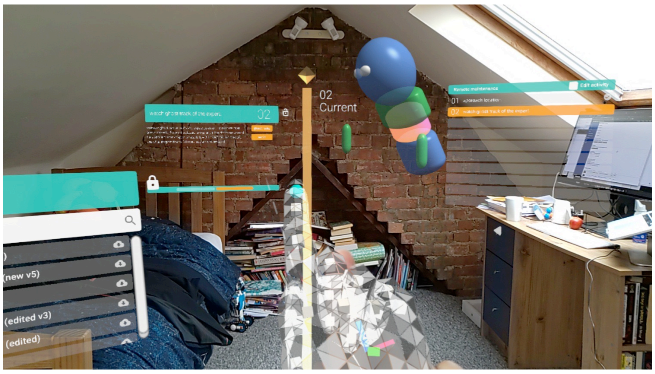

Fig. 1. Screenshot of the MIRAGE·XR application showing the ghost track and activity menus

IV. MIRAGE·XR

MIRAGE·XR [1] is the reference implementation for the ARLEM standard. It is based on the results of the WEKIT project [5] and it has additionally been supported by the XR4ALL and ARETE projects. The application is available as Open Source. It provides a cross-platform player for the Microsoft HoloLens 1+2, as well as smartphones, to the user in which new activities can be defined, executed and edited. In the background, the Mirage·XR editor constructs the ARLEM-conform activity and workplace descriptions.

This way, it allows companies to define training processes with a visual language and with multi-media content. For each workspace, the user can define a common anchor point. For instance, on aircrafts, a marker can be placed on a wing in order to realign all relative training content. All virtual content is placed relative to this marker. This also has the effect that the training scenario works globally in different places. For instance, maintenance personnel working on a specific plane model in London can transfer the training data to staff in Sydney who work on the same type of aircraft. If the marker is placed on the same part, the virtual content will appear at the same position on the plane. Recorded activities are uploaded to a cloud, so that other users can download the activities onto their own devices.

The visual nature of hands-on training instructions bears the advantage to reduce translation costs, as animated content can be understood by users independent of their spoken languages. Moreover, the concrete step-by-step guidance automatically highlights necessary controls and parts to users. This means that, if necessary, non-experts can also perform technical tasks. Since content is pre-recorded, trainees across the entire organization receive a consistent level of information and the same high-quality training lectures. As a result, trainees who undergo the same operational task training, finish the training with a comparable level of skills in the particular area.

Mirage·XR provides holographic guidance in form of the ghost tracks depicted in Fig. 1. Experts can show how to perform a task and record their movements, gaze, and audio. The recorded data then can be visualized as a virtual 'ghost', an avatar that mimics the experts' behavior. Once saved, the ghost tracks allow users to follow in the footsteps of the expert and they can follow the experts' visual ghost demonstration for each step, in order to fulfill the task at hand. Users not only see the ghost's actions but hear the expert's voice recording. This way, explanations can be conveyed in a distraction-free and hands-free manner.

Moreover, visual glyphs and additional audio, image, and video content can be recorded and placed in the environment, activated for each action. Users follow each action step at their own pace, with the possibility to repeat steps or go back to previous actions if necessary. They act as guides to express the task step and the perspective that the expert had when performing the training procedure.

When a trainee enters a particular action step, the underlying ARLEM model defines what content is activated. When leaving an action, it is marked as completed and the ARLEM-compliant data specify which contents are hidden and which step is entered next.

This way, trainees can develop competence while at the same time gaining practical work experience. This combination allows trainees to start work with a higher level of efficiency and productivity. Since no experts are needed on-site, this increases the autonomy of workers. This saves production costs, improves efficiency, reduces error rates, and leads to overall faster training and knowledge exchange.

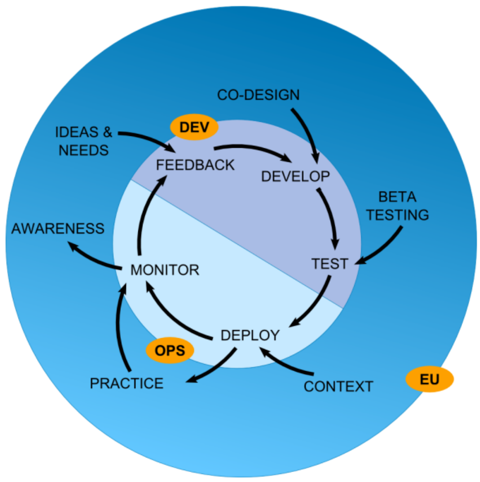

Fig. 2. DevOpsUse Cycle [8]

V. DevOpsUseXR

Software engineering is known to benefit from end-user involvement as part of a co-design process [7]. This can be achieved on the basis of a DevOps cycle. DevOps define effective and efficient processes how developed updates for

[1] https://platform.xr4all.eu/wekit-ecs/mirage-xr

an application can be deployed to target devices in the most stable way without risking downtime due to errors in the running system. Automated testing and continuous integration play an integral part in this, supporting developers with tools and process when adding changes to a project. Moreover, deployed applications are monitored, and based on collected insights, feedback is given the developers to help prioritize their next tasks. In this context, the DevOps cycle can be extended to DevOpsUse [8] as illustrated in Fig. 2, adding explicit support for end-user involvement. As part of each DevOps activity, further user-centered activities are conducted. For instance, the development phase can be supported by customers who actively contribute requirements and tasks for the developers. During testing, users can be involved to trial the unreleased software. Further activities include, e.g., rising awareness in a community, collecting feedback about the application, and discussing ideas.

Recently, we proposed an extension, DevOpsUseXR, which brings the DevOpsUse process to mixed reality environments, where developers and end users can meet to collaborate seamlessly in virtuality with the support of agile project management methods. In the virtual environment, which can be set up both in Augmented Reality and in virtual reality, the developers and users can directly interact with the requirements and tasks in a spatial manner. Moreover, collected analytics data can be visualized using immersive and three-dimensional diagrams. Using DevOpsUseXR, effective instructional designs can be created with the help of MIRAGE·XR.

VI. Conclusion & Outlook

The ARLEM standard provides a cross-compatible format for defining Augmented Reality training content. It consists of an activity definition and a workplace definition. Combined, they cover the relevant environment and behavior description for Augmented Reality training scenarios. The Open Source project Mirage·XR is the reference implementation of the ARLEM standard. It provides an Augmented Reality editor which gives users the option to place virtual content like ghost-recordings of experts, audio, images, videos, text, glyphs, etc. Therefore, activities which have been created with MIRAGE·XR can be opened with other players that support the standard. Its visual editor allows users to intuitively author training content. Uniform data allow the worldwide interchange of training activities, e.g., in globally active companies.

Additionally, more tools can be developed around the standard, e.g., to verify that a given description conforms to the data format or which provides further editing tools.

Mirage·XR is a configurable platform which can be adapted to company-specific requirements and branding. With the help of DevOpsUseXR methodology, we ensure that the individual requirements of trainers and trainees can be considered and integrated into the development process easily. This leads to a continuous, agile, and scalable development process for extending the already rich feature-set of Mirage·XR.

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