Using a Combined Approach of Software Engineering and XR Engineering to Create Virtual Job Onboarding Environment: A Case Study

Marko Jäntti
Centre for Measurement and Information Systems
Kajaani University of Applied Sciences
Ketunpolku 1, 87100 Kajaani, Finland
Email: marko.jantti@cemis.fi

***Abstract*—Digital transformation projects, such as creating virtual collaboration spaces with Extended Reality (XR), require new types of skills and knowledge from software engineers. While fundamental elements of software engineering and managing software projects are still useful, there are many new aspects that software engineers need to manage in Extended Reality (XR) projects. In this paper, we present results of a case study focusing on creating a virtual job onboarding environment for a Finnish forest machine operator. The content that was selected for the virtual onboarding space included company-related material for increasing awareness of green transition, such as recycling waste resulted by forest logging operations and training mandatory issues on occupational safety. The research problem presented in this study focuses on how software engineering and XR engineering can be used together to create virtual job onboarding spaces. Differences between traditional software engineering and XR engineering are also addressed. This study contributes towards practical implementation of commercial and open source resources for building a virtual job onboarding environment, through the combination of software engineering and XR engineering processes. We argue that this combined approach offers a good choice for managing the development of virtual spaces.**

***Keywords*—Digital transformation; Software Engineering; job onboarding; virtual collaboration space; Extended Reality (XR).**

I. INTRODUCTION

Digital transformation is changing the way how organizations are training their employees, partners and end-users. An increasing number of training events is organized in virtual learning platforms instead of traditional classrooms. The job onboarding is a business process where quality of training and introduction plays a critical role. Through the process, organization aims at transforming job candidates into top-performing employees It is a process that also directly affects employee satisfaction and employee productivity.

Unfortunately, many organizations fail in making the job onboarding process employee-friendly. According to Sibisi and Kappers [1], poor onboarding may result in lower confidence among employees in their new roles, worsened levels of engagement, and an increased risk to quit job and start working for a competitor. Caruzzi [2] reveals that organizations with a standardized onboarding process experience 62 % greater new hire productivity and 50 % greater new hire retention.

Virtual reality has been widely used by various domains. Military domain has been the forerunner in applying virtual reality (VR) technologies. The military has used VR for various military tasks such as simulating combat first-aid and surgical procedures to correct battlefield injuries [3]; team training, battlefield review and tactics development [4]; and providing Virtual Reality Exposure Therapy (VRET) for veterans with Post-Traumatic Stress Disorder [5].

Additionally, virtual reality provides new opportunities for increasing safety awareness in industrial sites such as factories and mines. Bell and Fogler [6] have applied VR to chemical engineering education, for example, demonstrating the consequences of not following proper lab safety procedures. Liang et al. [7] have developed a VR-based interactive game for safety trainings in underground mines. Moreover, many companies started their virtual reality journey because of COVID 19 health measures. Boyd et al. [8] report findings on using virtual reality for minimizing the spread of Covid-19 on construction sites.

In this study, we focus on virtual onboarding spaces and instead of VR and use a broader term Extended Reality (XR) instead of VR. Extended reality consists of three main elements: Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR). Development of XR spaces and applications (we call this process XR engineering) requires new types of skills and knowledge from software engineers. While fundamental elements of software engineering and managing software projects are still useful, there are many new aspects software engineers need to manage in Extended Reality (XR) projects.

In the IEEE Standard Glossary of Software Engineering [9], software engineering is defined as the application of a systematic, disciplined, quantifiable approach to the development, operation, and maintenance of software. In XR engineering, development, operation and maintenance activities aim typically at producing and maintaining either games or virtual spaces. From this paper, game development is excluded. Software engineering lifecycle activities can also be a target where XR can be used. Elliott et al. [10] have studied the benefits of using virtual reality for live coding and code reviews. Virtual reality environments have also been used for collaborative software modeling [11].

According to Sommerville [12], a system is a purposeful

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collection of interrelated components of different kinds that work together to deliver a set of services to the system owner and its users. An XR-based system is typically produced by using game engine software (Unity, Blender, or similar) or cloud-based services (e.g. Amazon Sumerian, Google ARCore) and used by end-users through virtual reality glasses or XR-enabled web browsers. WebXR is an open standard which allows VR apps to run directly from web browsers. WebXR Device API removes interoperability problems because it brings AR and VR capabilities to the web [13] and a user can thus avoid downloading heavy installatioin packages.

In this paper, the goal is to answer the research problem: How software engineering and XR engineering can be used together to create virtual job onboarding spaces? The main contribution of this paper is to show findings of a case study where we trialled and implemented both commercial and open source instances of a virtual job onboarding environment by using a combination of software engineering and XR engineering methods. The case study was performed by a Finnish digital innovation hub. The case organization is a forest machine operator company located in Eastern Finland Nurmes. The study was implemented in October 2021 - May 2022.

In Section 2, research methodology of the study is presented. In Section 3, case study results are presented. Section 4 is the analysis and finally, the conclusions are given in Section 5.

II. Research Problem & Methodology

According to Yin [14], a case study is an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context especially when the bondaries between phenomenon and context are not clearly evident.

The case study research method was selected to study and increase understanding of a real-life phenomenon: improvement of job onboarding. The context for the research is also interesting. We got access to a Finnish forest machine operator company through EU-funded digital experiment. This was a new type of case organization for us. For the case organization, job onboarding was a high priority improvement target.

The research problem of this study is: How software engineering and XR engineering can be used together to create virtual job onboarding spaces? The research problem was divided into the following research questions: 1) How software engineering and XR engineering fit together in creating virtual job onboarding environment and how they differ from each other? 2) How employees express benefits of virtual job onboarding? 3) What types of challenges may exist in creating virtual job onboarding environments?

A. Case Organization

Motoajo is a family company, whose experience in forestry contracting begun in the 50's. As a result of organized development and patient growth, the company (an SME) offers job for 70 workers. The company's office is located in Nurmes, Eastern Finland, where the company also mainly operates. While loggin and transporting roundwood and coppice, Motoajo always pays attention to the nature and operates by all means to protect it. The company's vehicles are modern and made according to current emission standards. With harvesters the company follows the Measuring Instruments Act with random sampling of tree trunks. All the vehicles are equipped with loader scales. Motoajo's aim is to work cost-effective and on schedule with professional staff and modern vehicles also in challenging environments, not forgetting safety at work.

Motoajo's personnel consists of trained and experienced professionals. Drivers' workmanship is constantly improved by taking part to courses of quality, environmental and work safety. Motoajo Oy has a comprehensive spare part stock and a service with professionals and vehicles. Through the experiment, Motoajo seeks solutions organizing delivery of forestry liquids to remote locations as well as innovative methods to carry out job introduction to new forestry employees. The company consumes annually around million litres of fuel and huge amount of forest machine supplies. Job onboarding is important for Motoajo from following reasons: First, it is an effective way to increase productivity of employees. Second, it is directly linked to occupational safety. Job onboarding ensures that employees are aware of issues affecting their job safety and are able to perform their work activities both safely and effectively. The existing way to conduct job onboarding is baically based on personal job introduction performed by a senior employee. New employees shall receive access to job introduction (general overview of the organization, organizational policies, occupational safety, maintenance of machines etc.) material in Google Forms.

B. Data Collection Methods

The data collection for the study was performed by Arctic Data Intelligence Digital Innovation Hub. The goal of AIKA Digital Innovation Hub is to act as a one-stop shop that helps companies of Kainuu region in tackling digital challenges (especially AI, HPC, data analytics and digital transformation). Case study evidence was collected during Green and Digital Forest Service Management experiment from multiple sources:

- Documentation: Quality manual, experiment hand book, 3D model import guidelines document
- Archival records: Job onboarding material in Google forms, video scenarios from a foreman
- Interviews/discussions: Focused interview with CEO (February 9th, 2022, 30 min), discussions with virtual space providers
- Participative observation: field visits in Motoajo's storage, participation in digital experiment work meetings, Towards digital and sustainable forestry webinar (Youtube)
- Direct observations: Observations during the field visit in logging destination, how a forest machine driver operates in the forest, how fuel container has been placed on the logging site.
- Physical artefacts: Matterport 3D models, plastic IBC containers, recycling containers

C. Data Analysis

The case material was analyzed by a within case analysis technique [15] by using researcher and method triangulation

[16]. The research team consisted of Digital Innovation Hub employees and external consult of Motoajo. The digital experiment progress was reported to the case organization systematically and frequently and communicated also to non-academic audience such as stakeholders of the digital innovation hub. A qualitative content analysis technique was applied for case study material.

III. Results of the Study: Design and Implementation of a Virtual Job Onboarding Environment

Next, we describe the activities of design, implementation and testing/evaluation regarding the virtual job onboarding environment.

A. Service Design

The service design phase started with a field visit to the Motoajo's storage in Nurmes, Eastern Finland. The case organization's representatives indicated the need to address green transition and recycling of forestry waste in job onboarding material. There was a need to increase awareness of staff how to sort different types of forestry waste (chainsaw bars, lubricant tubes, oil filters), to show location of various pieces of equipment, what type of protection is required while dealing with the fungicide, and what an employee should do to prevent fuel leaks while operating in the forest with a forest machine (how to position fuel container safely in the ground). The following list of design and implementation issues was created in the design phase:

- Implementation of IoT based monitoring system for forestry liquids including Tekelek tank level sensors that were installed into plastic IBC containers containing marking dye and Adblue (Diesel Exhaust Fluid)
- Development of mobile app (managing refilling process, monitoring liquid levels, alerts on critical levels), two phase authentication possible / Google authenticator
- Creating first draft of the virtual job introduction environment by using 360 viewer Lapentor
- Creating 3D models of the storage
- Recording videos for hotspots both in logging destination and in storage (video material how to recycle waste such as oil canisters and metal waster coming from logging operations and how to position fuel containers safely in the forest).
- Organizing dissemination activities: two webinars (Digital Afternoon, Towards Green and Digital Forest Service Management) and creation of online articles
- Exploring opportunities for further exploitation of experiment results

For project dissemination purposes, we organized an interview with CEO of the case organization. The CEO highlighted the importance of job onboarding for organizational productivity. Additionally, we conducted 2 webinars where a foreman of the case organization communicated the benefits of job onboarding. Next, a summary of the interview and discussions is provided (narratives related to job onboarding).

Fig. 1. A virtual job onboarding environment in Lapentor

- ”We have been thinking forest machine -related job onboarding. The forest side is even more important for productivity than recycling-related job onboarding.”
- ”This job onboarding system could be sold to any other domain, not only for forest domain.”
- ”It would ge great if a new employee would watch the job onboarding video material during the first working days. Then, he/she would be much more prepared for work tasks.”
- ”An employee can watch videos and repeat them as many times as needed.”
- ”Job onboarding needs to be well documented. It gives as a lot of credibility.”
- ”We have several remote storage areas. We have improved monitoring of liquid containers and job onboarding of new employees. Previously, we have provided personal job onboarding. However, if the new employee is going to work in Vehmersalmi, it's a long way to travel there to take care of job onboarding.”

B. Service Implementation

The prototype of virtual job introduction was created by using open source 360 virtual tour service Lapentor (see Figure 1). Video content was captured by using mobile phone and was later uploaded to Vimeo video sharing platfrom and embedded to Lapentor hotspots. These videos dealt with several work scenarios, such as sorting metal waste, sorting oil canisters, placing a warning sign for a logging site, operating safely with liquids and maintenance of a fuel pump.

In the next phase, we decided to study whether it would be possible to create a virtual collaboration space where a trainee and trainer could meet. For this purpose, we contacted a VR specialist in Kajaani University of Applied Sciences that had a long experience in creating virtual spaces and capturing 3D

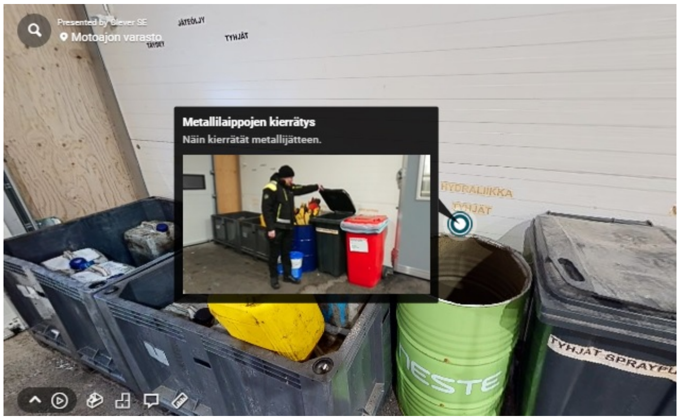

Fig. 2. A virtual job onboarding environment in Matterport: how to recycle chainsaw bars

models with Matterport cameras. Figure 2 shows our virtual storage in Matterport environment.

We needed to purchase server space for Matterport 3D models because we did not want to make the 3D models of the storage publicly available. The following step was to start the bidding process for purchasing the virtual collaboration space. We decided to use Glue Collaboration as a platform to our virtual collaboration space because they seemed to have a clear process and guidelines how to import custom 3D models (a document showing requirements for importing 3D models). However, they stated that importing custom 3D models requires some manual work effort (around 1 working day) from them. The bidding also involved Glue licences for 2 persons. After we had started bidding process, we observed that we should had been more careful in describing 3D rendering requirements to Invitation for Tenders (lightning, objects we wanted to have in the storage). The third party consultant of the virtual collaboration space provider stated that point cloud needs 3D rendering. Luckily, one of the 3D experts of our own organization's VR laboratory was available and took care of 3D rendering.

C. Testing and Evaluating the Service

One of the interesting aspects we planned to have in our virtual job onboarding environment was a digital twin of an IBC container that would have provided a realistic real time data on the liquid levels. This required a significant amount of work effort such as purchasing, installing, configuring sensors, setting up IoT dashboards, creating a mobile app for retrieving data on container refilling events and events when forest machine drivers pick up liquids from the container. Development of real time liquids monitoring system and integrating data to the job onboarding system required more software engineering expertise than XR engineering. Here we applied traditional software engineering activities, such as sofware test cases.

The virtual job onboarding system was presented to the case organization multiple times. In trialling the system, a foreman of the case organization used both laptop and also Oculus Quest 2 VR glasses. As a feedback, they stated that most likely the organization's employees would use the open source version of the job onboarding system (Lapentor) from their laptops or mobile phones. Lapentor is a cost-effective solution for job onboarding and it is easy to add new job onboarding content (hotspots) to the system. New employees can see the realistic view on the storage including waste containers and can click the hotspots in the virtual storage to access the video material. The job onboarding material is available 24/7 for employees and there is no need to purchase expensive XR equipment. As part of the evaluatioin, the CEO of the case organization mentioned that the usage of the system could be extended to the optimizing settings of forest machines. The system was considered very easy-to-use. The drawback of the Lapentor system is that it is not a virtual collaboration environment. If a trainee and a trainer like would like to meet in the storage, they need to access a virtual collaboration space, such as Glue or Mozilla Hubs.

IV. Analysis

The data analysis was performed by using qualitative analysis technique for the case study data. The goal of the analysis was to compare software engineering and XR engineering with 7 patterns. Thus, our analysis technique can be considered as pattern matching. Regarding the first research question, we identifed both differences and similarities (Table I) between software engineering (software development with Java as an example) and Extended Reality (XR) engineering.

TABLE I. Software Engineering vs XR Engineering

Topic	Soft Engineering	XR Engineering
Focus	Code and data	Media and content
Files	.java, .class, .jar, .dll	.fbx, .stl, .gltf, .obj
SDKs	Java SDK	XR SDK for each VR headset
Skills	Coding, UI, bus. logic, data	Coding, UX, 3D model., rendering
Dev types	Web dev, mobile dev	Web dev, mobile dev, game dev
Reqs	Non-func., func, data	File reqs for 3D models
Navigation	Menus	Teleporting, hotspots, floorplan
Comput.	CPU	GPU
Project mgmt	Agile, increment,, waterfall	Agile

According to our case study findings, XR engineering focuses on dealing with media files and game engines requiring knowhow on 3D modeling, compatibility of media files, 3D rendering such as configuring lightining to virtual spaces and visualizing the storage. One of the issues we learnt during the study was that XR SDKs (for example, Oculus SDK for Windows) vary between VR headsets. While Java developers could enjoy a pretty good interoperability of Java SDK, XR developers need to struggle with headset-specific requirements if they want to test and release their own XR apps. However, in our case study, we did not have to deal with device SDKs because we decided to use existing well-tested virtual tour and virtual space platforms. Rendering scenes in Lapentor is done with krpano software that enables showing panoramic images on the web.

While three architectural layers (user interface UI, business logic BL, data layer) act as a basis of design and development in software engineering, XR engineering focuses on designing interactions and may involve head tracking, motion tracking, hand tracking and eye tracking. These are quite standard interaction design elements for game developers but a new world for a typical software engineer.

Navigation within the virtual space is very different compared to the navigation within a web-based system. Virtual spaces enable teleporting users between virtual rooms. Both in

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Matterport and Lapentor, content for end-users can be added through hotspots (in Matterport these are called Mattertags). Matterport also produces a floorplan view that helps end-users navigating to the desired room easier. While performance of traditional software systems depends on computing nodes, XR developers typically utilize Graphics Processing Units (GPUs). By using GPUs models can be rendered much quicker than by using Computing Processing Units (CPUs).

Regarding project management approach, both software engineers and XR engineers are using agile approaches or some kind of modification of them. Software engineers used to utilize waterfall lifecycle model, incremental models such as Rational Unified Process RUP [17] decades ago. However, agile project management is nowadays a mainstream choice. We did one observation on strict file requirements for 3D models that do not exist in typical software engineering projects. Our XR engineer understood file requirements immediately but researchers with some SE background were not in their comfort zone while reading the 3D model import guidelines.

In order to increase the system quality, we decided to create test cases (typical artifacts in software development) for IoT based container monitoring system that we aimed to link to the virtual job onboarding system as a digital twin of the container. These test cases revealed some interesting defects that were later communicated to system developers. With no doubt, software engineering has more rigorous approach for ensuring software quality than XR engineering. Software testing knowhow would be very useful also for XR engineers to ensure that interactions and hotspots become thoroughly tested. Therefore, we propose a combined approach of software engineering and XR engineering for producing high-quality XR spaces.

Table II shows the analysis of the second research question: How employees express the benefits of virtual job onboarding. The source of the evidence is indicated in the first column.

TABLE II. BENEFITS

Source	Issue
INT	Enables repeated playing of onboarding content
INT	Prepares staff better for their job tasks
DIS	Saves travelling costs and time
DIS	Compliance with regulations
DIS	Eliminates unnecessary waste sorting
PO	Increases productivity
PO	Enables importing custom 3D models
PO	Collaboration in virtual space

It was interesting to follow the discussion and analyze the narratives of interviews and webinars to capture expressions for benefits of virtual onboarding. The case organization's management emphasized the productivity and preparedness of the staff for job activities. The middle management of the case organization highlighted cost savings and time savings and transition to a different model of job onboarding (from personal job onboarding to more scalable job onboarding).

During the study, our research team observed that forest machine drivers need to update their skills and knowledge continously to be able to operate the forest machine. Forest machine drivers need to be aware of the procedures, rules and regulations set by the forest certificates (FSC, PEFC) and contractors.

The last research question focused on the challenges in creating virtual job onboarding spaces. The following list contains a summary of identified challenges.

- Deciding which 360 platform or virtual collaboration platform could be best for our purposes (possibility to import custom 3D models, import custom 3D assets, quality of avatars, number of existing interactions, price of licences, cross-device usage).
- Planning the bidding process for virtual spaces is difficult. How to set a quality criteria and describe it in Invitation for Tenders? XR-engineers are needed to answer the questions from potential service providers.
- Making a plan on 3D rendering. Which textures / objects should be included? What is the quality of lightning? In our case, we had very limited time and a large storage space and we prioritized that waste containers are of high priority.
- Conducting video shootings and 3D model creation in winter conditions. Arctic conditions (-25 celsius outside, -5 to -10 celsius inside the storage) caused challenges for battery duration of cameras.
- Creating digital twin and integrating it to the virtual job onboarding system. Unfortunately, we were not able to bring real time sensor data to our virtual job onboarding environment. Very likely this challenge was related to API/integration limitations of Lapentor and we had very limited resources to investigate the issue.
- Creating job onboarding video content without predefined scripts. While we were in the cold storage and in a logging site in the forest, we did not use any scripts. Usage of scripts might have increased the quality of video material and decreased the time we spent for video recording. On the other hand. we feel that we received more authentic job onboarding material by ignoring the scripts.
- Multi-provider network of actors. Although we had an excellent team, multi-provider network caused communication gaps in implementation of the virtual job onboarding system. As an example, our XR specialist had generated a high-quality, rendered 3D model of the storage. Somehow, the insufficient 3D model was still used in creating the virtual collaboration space (a large part of the storage was of point cloud quality)

It would be very interesting to compare our XR challenges to the challenges encountered by other academians especially on the forest sector. Conducting this case study has remarkably increased our knowledge on opportunities and limitations of XR spaces and their benefits for job onboarding.

V. CONCLUSION

In this paper, we aimed at answering the research problem: How software engineering and XR engineering can be used together to create virtual job onboarding spaces? We used a case study research method to collect data from a Finnish forest machine operator company. Our results and experiences may

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be useful both for software engineers and for XR engineers. The job onboarding system that we developed supports also the Green Transition approach. Thus, our findings can also be beneficial to sustainability engineers.

Next, our findings related to three research questions are summarized. Concerning the first research question (How software engineering and XR engineering fit together in creating virtual job onboarding environment and how they differ from each other?), we observed that software development and XR development have a lot of common. It is fair to state that many academians and practitioners shall really likely consider XR as just one additional type of software development.

However, XR engineering has its own terminology and concepts (polycounts, realt-time rendering, heatmap) that most software engineers might have never heard of. While software engineers' skillsets include software development, cloud, database, and mobile app development, XR engineers typically need the same skills but also game development knowhow. Of course, programming skills are key skills for both XR engineers and software engineers. During our study, we observed that software development lifecycle activities help especially in improving the quality of XR development and planning test coverage. Software test cases are useful in identifying defects in any type of software including XR and virtual spaces. During a relatively short testing period, our test cases manage to reveal some interesting defects during the case study. One defect was found by using administrator priviledges.

For the second research question (How employees express benefits of virtual job onboarding), we captured narratives that referred to benefits of job onboarding. According to our findings, case organization considered as expected benefits of virtual job onboarding: preparing staff better for their job tasks, saving travelling costs and time, ensuring compliance with regulations, eliiminating unnecessary waste sorting and increasing productivity. The organization's top management emphasized overall productivity increase due to better job onboarding.

Our final research question dealt with virtual job onboarding implementation challenges. During our case study, the following challenges were identified: deciding which 360 platform or virtual collaboration platform could be best; challenges in planning the bidding process for virtual spaces; conducting video shootings and 3D model creation in winter conditions; planning and performing 3D rendering; failure in creating digital twin and integrating it to the job onboarding system; creating job onboarding video content without predefined scripts; communication gaps due to multi-provider network of actors in the XR engineering project.

There are certain limitations related to the case study method that we utilized. First, data was collected during a relatively short time period (during a 6-month digital experiment). Interviewing and engaging more end-users to trial the new job onboarding system could have provided new insights and ideas for further development. Second, only qualitative data was used and collected during the study. In the future, quantitative data, for example, from a controlled experiment with new employees could be collected to analyze the impact of more immersive job onboarding. Further research could also focus on extending the scope of job onboarding to adjustment of forest machine settings.

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