Virtual Reality for Education and Workforce Training

Daniel W. Carruth,
Center for Advanced Vehicular Systems,
High Performance Computing Collaboratory (HPC^2),
Bagley College of Engineering,
Mississippi State University,
200 Research Blvd., Starkville, MS 39759.
Email: dwc2@cavs.msstate.edu

***Abstract*—The advent of inexpensive consumer virtual reality display technology has made new possibilities for delivering education and training in immersive and engaging ways widely available. In the past, technical challenges and prohibitive cost have impeded progress of virtual reality in education. Educational institutions and industries are now moving rapidly to adopt virtual reality as a key training tool. Virtual learning environments have been very successful in generating positive learning outcomes in a variety of domains. The powerful sense of presence and effective immersion created by virtual reality applications promise to provide on-site training in a safe and controlled environment. Virtual learning environments can provide trainees with access to cost-prohibitive equipment in impossible locations. It can provide a space for students to explore problem spaces and test solutions without risk. Despite these successes, questions remain regarding the capabilities and limitations of current technology, particularly regarding the effectiveness of knowledge and skill acquisition in virtual reality. The process for developing effective educational training virtual environments begins with understanding the learning objectives, re-creation of the real-world task(s), and assessing user performance and learning. Each stage of the process presents unique challenges and opportunities.**

***Keywords*—Virtual Reality, Augmented Reality, Training Tool, Workforce Training**

I. Introduction

Providing effective training for future workers can present significant challenges. Hands-on real-world training requires access to real equipment or physical mock-ups. If training occurs 'on the job', there is an increased risk of loss of productivity, damage to material, and injury. Training may be performed away from the actual job site and require dedicated space that may not accurately represent the actual worksite [1]. Real-world training requires logistical support to set up training sites and coordinate training times. Training may require teams of personnel dedicated to re-creating training scenarios (e.g., medical and first responder training [2], [3]). Low frequency events may be difficult or impossible to recreate in the real-world. For example, workers need training in how to respond to mechanical failures, fire or medical emergency, power outages, etc. These cases require specific responses that workers may only rarely have the opportunity to practice and, when it is possible, the training may be superficial in nature leading to possible errors in the event of an actual incident. Similarly, some training may only be available at specific times of the year. For example, workers may need training in how to handle snow and ice conditions. Many jobs require workers to operate in dangerous conditions (e.g., military, law enforcement, firefighting) that are difficult or impossible to recreate in the real-world. In some cases, it may actually be impossible to perform training. The work may involve work spaces or tasks that are still being designed or environments that cannot be recreated (e.g., space). Real-world training also may not provide support for adequate metrics. It may not be possible to objectively monitor worker performance, stress, and workload to determine when a worker is fully prepared to perform the work in the real-world.

Virtual reality may provide solutions to many of these challenges for training. Virtual reality has key strengths that help to address many of the issues identified and its application to education and training has been demonstrated in many domains.

II. Virtual Reality Applications

Virtual reality has been used to provide training for first responders [2] and has been investigated as a training tool for CBRN response training [3]. Virtual reality training systems have been developed for teaching aircraft cabin safety procedures [4] and for improving communication skills [5]. Virtual environments have been successfully used to provide individuals with spatial knowledge that transfers from the virtual environment to the real-world [6]. There are numerous industrial and medical virtual reality training applications (e.g., laparoscopic surgery [1], automotive manufacturing [7], working with robots [8], using CNC machines [9] [10], and tool use [11].

Some of the largest companies in the United States (e.g, Walmart [12]) are now adopting virtual reality as a training tool. As virtual reality is more broadly adopted for education and training, understanding the true strengths and weaknesses associated with the technology and properly designing and validating training tools is critical to ensuring the effectiveness of virtual reality training tools.

Fig. 1. Virtual Reality Head-mounted Displays: Oculus Rift, Samsung Gear VR, and HTC Vive

III. Capabilities of Virtual Reality

Virtual reality has a number of strengths that support its use as a training tool. First, virtual reality can be very accessible. Prior to the Oculus Rift and HTC Vive platforms, immersive head-mounted displays could be cost prohibitive. However, the current immersive virtual reality solutions are more affordable with many individuals owning a virtual reality ready mobile platform. Virtual reality training tools can also be designed to have limited or no physical prototypes [13] [14]. Of those that do have physical interfaces, it is possible to use a hybrid of physical and virtual objects [14] or combine non-immersive virtual reality with physical mock-ups of interfaces (e.g., [15]). With haptic-capable interfaces, an immersive environment can support complex interactions with no physical components [16]. Virtual reality training tools are also far easier to modify to train for variants of models (e.g., multi-model assembly) or for new versions of equipment [13]. Virtual reality training can also be used with limited supervision [9] allowing trainees to access training at their convenience without requiring a trainer to provide constant supervision.

Another key strength for virtual reality is the ability to create a strong sense of presence in the user. Users in immersive virtual reality can become fully engaged in the virtual environment so that they effectively forget about the real world and believe that they are present in the training environment where they can act as they do in the real world. For example, participants in our virtual reality studies will walk around a virtual table and, in fact, some will find it difficult to force themselves to walk through the space the table occupies. Also, participants in virtual reality have been observed setting their controllers down on a virtual table and accidentally letting them fall to the ground in the real world. For a generation of technologically-minded students, virtual reality presents a new way to engage students in learning [17]. Virtual reality has been shown to result in higher levels of engagement in learning compared to traditional teaching methods [18].

The virtual environment can allow a user to explore and experiment with an environment that in the real world might be dangerous. Because the virtual environment and the resources in the environment are not real, the user can use materials in a way that might be wasteful in real world training. The virtual environment is also a safe environment. The user can learn through experience and perform actions that might be costly or embarrassing without concern [9].

While the costs of mistakes in virtual reality are low compared to the potential physical costs in the real world, it is much easier to provide objective measurements of performance, and immediate feedback on the results of performance, in virtual reality compared to the real world [11].

IV. Advent of Low-Cost Solutions for Virtual Reality

Despite the potential and the significant amount of research investigating virtual reality applications for education and training, the technology has had limited use until recently. Modern consumer hardware and software has made low latency, high resolution, and low cost systems available not only to consumers focused on gaming but also to schools and corporate training teams. Virtual reality hardware platforms are now widely available in two general categories: tethered

PC or gaming console head-mounted displays and mobile smartphone-based head-mounted displays.

A. Consumer Head-Mounted Displays

The tethered PC and gaming console head-mounted displays are most similar to the immersive virtual reality displays familiar to researchers. Currently, there are four major efforts (Sony PlayStation VR, HTC Vive, Oculus Rift, Microsoft's Mixed Reality family of head-mounted displays) and several smaller efforts to bring head-mounted display virtual reality technology to the mass market. All of these efforts are similar. The head-mounted displays are directly connected to a PC and provide high resolution, high frame rate, attractive environments, and support for many options for interaction. Despite these advantages, these systems are less accessible than mobile virtual reality systems largely because they require significant computational power, are tethered to limited area, and are expensive.

B. Mobile Systems

The mobile virtual reality systems use an individual's smartphone to provide a display and the basic sensor suite for tracking head orientation. The head-mounted display is primarily a housing for the smartphone and a pair of lenses. The Samsung Gear VR (see Figure 1) and Google Daydream are more comfortable and more immersive solutions while inexpensive solutions such as the Google Cardboard promise to make virtual reality applications available to anyone with a smartphone. The benefits of a mobile platform are that they are wireless, portable, and the smartphones are ubiquitous. However, because they use smartphones as the computing platform, mobile solutions typically have less processing power, lower fidelity environments, and are limited by battery life. In addition, current mobile solutions have limited support for advanced modes of interaction.

Recently, hardware companies have announced standalone virtual reality headsets that promise to attempt to bridge the gap between tethered PC headsets and smartphone-based headsets [19]. It remains to be seen what advantages the standalone systems will have over smartphone solutions and whether the cost will be sufficiently low to make it an attractive option for education and training.

V. Building Virtual Reality Training Tools

Improvements in hardware and software have made virtual reality more broadly accessible. However, all virtual reality experiences are not equal and there remain challenges in building effective virtual training tools. The primary objective of a virtual reality training tool is to facilitate the transfer of knowledge and skill from the virtual environment to the real world. It is important to note that a related objective is to avoid transfer of inappropriate or incorrect knowledge or skills from the virtual environment. The secondary objective is to maximize presence and realism to the level necessary to support the primary objective.

The goal for the virtual environment is to create the workspace and the functions necessary to perform the task of interest in an interactive environment. [13] presents a general process: import CAD into virtual reality, program the interactions, add interfaces, and test to verify that the desired knowledge and skills successfully transfer. In addition to these steps, a training tool should begin with a careful examination of the task. This can be performed with a formal task analysis [14] or consultation with subject matter experts to determine the specifics of what must be re-created in the virtual environment.

Simulator sickness is a common issue with virtual reality. It is common to have drop out rates of 10% to 20% and we have observed drop out rates as high as 50% in older participant groups. See [14] for a thorough discussion of simulator sickness and strategies for mitigating the effects.

A. Identify Learning Objectives

In the following sections, application of the general development process will be applied to two virtual reality training tools. The goal is to provide brief examples of application and describe differences in how the tools will be developed based on the learning objectives and the details of the tasks of interest.

1) Industrial Workspace Training Tool: The goal for the workspace training tool is to expose new low-skilled workers to the fundamental knowledge and procedures necessary to perform the task. Virtual reality is a good candidate for the task because of difficulties associated with training: First, the work area is a critical work unit at the manufacturing facility and is rarely available solely for training activity. Second, when the work area is available, a combination of personal protective equipment requirements and limited space in the work area makes it very difficult for a trainer and a trainee to work together in the space. A virtual reality training tool will allow the trainee to learn the fundamental skills - what the basic function of the job is, how to wear the personal protective equipment, how to identify and use the tools - in a separate location until the trainee demonstrates basic knowledge as measured by the virtual reality training tool.

2) Tool Use and Safety Training Tool: The objective for the tool use and safety virtual environment is to provide low-skilled novice workers with a safe space to be exposed to and to experiment with a variety of tools. For each tool, the goal is to identify the tool, demonstrate proper use of the tool, identify recommended or required personal protective equipment to be worn when using the tool, and teach the trainee to identify wear and tear or damage to the tool that may make it unsafe to use. This task is a good candidate for virtual reality training because the virtual environment can provide access to dozens of tools in a limited space where it is safe to learn about the tools without risk of injury or embarrassment to the trainee.

B. Implementation: Environments and Behaviors

Every element of the training environment must be digitally created. Elements in the virtual learning environment can be categorized into three types: contextual, fundamental, and interactive elements [14]. Contextual elements help to orient the user to the general idea of the scene. For example, in the tool use and safety training tool, the context could be a workshop or a garage. For the industrial workspace, our context is already defined explicitly by the task of interest. Fundamental elements provide the structural elements of a scene. In the workshop, tables, cabinets, lighting fixtures, etc. are fundamental parts of the scene but may not support interactions. The interactive elements are those parts of the scene that are the focus of the training and will either be directly or indirectly interacted with. In the tool use and safety training, this would include the tools and any work material (direct interaction) as well as storage areas and safety signage (indirect interaction) that make up the training experience. Figure 2 shows the contextual environment and some of the interactive tools in our tool use and safety training environment.

Generating the geometry and audio content for the virtual environment requires a significant portion of the time and cost associated with developing a virtual reality training tool. There are many methods for generating geometry for the training environment. In training environments, a popular method is to use CAD models of work spaces and tools when they are available [13]. CAD models are good-to-excellent representations of the real-world objects of interest. CAD models may not include surface texturing or coloring and often include technical details that may not be necessary for the virtual environment. Often CAD models will require modification when importing into the virtual environment.

When CAD models are not available, digital artists can create the geometry necessary to recreate the real world environment in the virtual environment. For common objects, models of objects can be easily acquired from online asset stores. It can be a challenge to create a consistent look-and-feel when using art purchased online. In our tool use and safety training environment, we use art assets from a single artist to help ensure consistency in the environment. For projects that will require specialized models, working with one or more artists to generate the entire environment will help ensure that the quality of the art assets is consistent.

Fig. 2. Screenshot of workshop environment and models for tool use and safety training. Models from [20]

Photogrammetry is a technique that uses photographs to create a map, measurement, or, in our case, a 3D model of the object or environment. By taking multiple photographs with different views of the object of interest and establishing corresponding locations in the two images, it is possible to produce 3-dimensional coordinates for points of interest in the image. With sufficient photographs, a 3D model of the object can be created. There are commercially available photogrammetry software packages including RealityCapture [21], Agisoft Photoscan [22], and others. Some software packages support combination of laser scan data with photographs to improve the quality of the output [21]. While direct capture of objects and environments results in detailed and impressive virtual environments, the output often includes gaps and flaws in the representation that, given the high fidelity nature of the data, requires talented artists to refine for use in applications. In addition, direct capture can easily generate complex models with millions of vertices that present computational challenges, particularly for mobile VR development. In our industrial workspace training tool, we are using photgrammetry to create a very realistic representation of the work environment (see Figure 3).

In addition to the visual elements, audio elements also play a key role in establishing realism, supporting immersion, and creating a sense of presence in the virtual environment. As with visual elements, the realism of audio elements can range from abstract representations of sounds to realistic recreations using real-world recordings. The realism of the audio elements should match the realism of the visual elements.

Fig. 3. Screenshots of 3D model of industrial workspace generated using photogrammetry

C. Interaction and Feedback

Programming the behaviors that provide the interactivity with the environment is as critical as importing the geometry that makes up the scene. Interactions include basic physics, collision detections, interaction with simulated system interfaces, and user interfaces [13]. How the users interact with the environment will dictate what and how they can learn [6]. The specific goals of the training will dictate the types of interactions necessary to meet the required level of fidelity. In the tool use and safety training tool, it is critical that the users are able to pick up the tools, manipulate them, and, as much as possible, explore a full range of physical interactions with the tools. In the industrial workspace training tool, the objective is to provide a general introduction to the task and interaction with the tools could be reduced to simplified point-and-click actions that would still allow the user to learn the tools and procedures related to the task without requiring complex physics modeling and haptic feedback support.

Interactions should be natural, easy to use, and easy to learn [13] [14] [9]. In addition to ensuring usability, the more sensory channels that are used to inform the user (balanced against the possibility of information overload) will improve learning in the environment [11]. Multi-sensory feedback will facilitate task performance and learning [14] [11] [13]. Visual feedback in both of our training environments will include visual aids (highlights, signs, and other augmented cues) that are expected to improve performance, usability, and training outcomes. Audio sensory information plays a significant role in both of our target tasks and the use of power tools.

Haptic feedback can allow users to 'feel' virtual objects in the virtual environment. This can include interaction with virtual objects that are recreations of real-world objects used in training as well as interaction with user interface objects. When interacting with virtual objects, haptic feedback helps to recreate the real-world sensations associated with touching and interacting with the object improving realism of the simulation [13]. Force feedback effects can be created through the use of vibrating motors, instrumented gloves, hybrid prototyping [14] [13] [11], and physical surfaces [14]. For example, in the tool use and safety environment, haptic feedback can provide sensory inputs that support user's ability to touch and manipulate the tools much as they would in the real world. Without haptic feedback, the user must rely on primarily visual cues for manipulating the tools.

D. Measuring User Performance and Experience

A common method for assessing user task performance is to measure the time required to complete the assigned task. The unit of measurement could be an individual action (possibly better characterized as a reaction or response time measurement) or a measurement for completion of a simple task or even a collection of tasks. In virtual reality, timing of task performance can often be easily implemented by logging all of the user's interactions with the virtual environment. In our virtual environments, we log controller inputs, controller and head position and orientation, interactions with objects including user interface elements. In addition, we record the position, orientation, and actions of other agents in the environment. For example, in our industrial workspace training tool, new materials arrive at the workspace from an external source. In our virtual environment, we create new materials and push them into the workspace to recreate a co-worker moving materials from their space into the trainee's workspace. We record the creation and all movements of the material as part of our data logging system. This allows us to later analyze actions of the trainee in response to the actions of objects outside of their direct control. In this particular instance, we use the arrival of new materials to create a time pressure on the trainee to complete their current assignment.

Another common metric for assessing a trainee's task performance is to evaluate their accuracy. In our industrial workspace training tool, accuracy is assessed based on the percentage of the material that was processed using the tools available to the trainee. Based on the task, we could evaluate the trainee's performance by evaluating the specific tools used for specific phases of the task and sections of the material. This kind of tracking of a trainee's performance both at the simplified and the detailed level would be very difficult to execute in the real-world.

In our tool use and safety training tool, accuracy is measured based on proper tool selection, proper personal protective equipment selection, inspection of the tool (recognizing or failing to recognize that a tool was damaged), and proper application of the tool to the problem. Proper application of the tool requires specific analyses for each task-tool combination and evaluates the position/orientation/movement of the tool relative to the task elements. Again, while many of our metrics are pass/fail in this tool, the virtual environment is able to continuously monitor every interaction the user has with the tools. The virtual reality tool does not require a trainer to spend one-on-one time with the trainee and the virtual reality tool never gets frustrated with the user.

Completion time and accuracy can be easily recorded in a virtual environment at a level of detail and objectivity that is very difficult to achieve in the real-world. The virtual reality tool supports exploration and experimentation while providing endlessly patient feedback based on real-time analysis of the data.

Subjective analysis of the virtual reality tool and the work task are also valuable tools in assessing the quality of the training and the difficulty of the work task. A virtual training tool should be assessed for usability and for user experience. For usability, a simple assessment using a questionnaire such as the System Usability Scale [23] can provide insight into how users perceive the usability of the training tool. The SUS is a 10-item Likert questionnaire that assesses user perception of system in terms of ease of use and ease of learning. For user experience, virtual reality has two key components. On the positive side is presence. The Presence Questionnaire [PQ] [24] includes 32 seven-point scale items and includes subscales related to sense of control, haptic and auditory aspects, and more. On the negative side is simulator sickness. In virtual reality applications, it is practically inevitable that some users will report feeling nauseous [14]. There are many factors that affect sickness in virtual reality and steps can be taken to try to minimize the effects on users. The Simulator Sickness Questionnaire (SSQ) provides a method for assessing the effects of simulator sickness on users and we regularly assess our users using the SSQ during studies using virtual reality [25].

Mental and physical workload may affect task performance, learning, and even sickness in virtual reality [11]. The NASA-TLX questionnaire assesses mental demand, physical demand, temporal demand, performance, effort, and frustration [26]. The survey is completed after experiencing virtual training or participating in a study using virtual reality. The scores are used to assess user perception of workload.

Motivation and engagement influence effectiveness of learning [18]. [18] adapted a questionnaire for evaluation of motivation during virtual reality training including scales for immersion, control, challenge, purpose, and interest. This evaluation can provide insight into how a virtual training tool is engaging and motivating users and help to identify areas for improvement.

E. Validation

The overall objective of virtual reality training is to facilitate the transfer of knowledge and skill from the virtual reality to the real world. We will verify that the virtual reality training tools are accurate and effective in two ways: First, we will ask subject matter experts to review the virtual environment and the training content to determine the construct validity of the training [13]. Is the simulation accurate? Is the virtual environment exposing users to the knowledge and skills that the tool was intended for. Following expert review, we will expose novice trainees to the virtual environments, collect data on their performance, then transfer them to the real world task and compare real world performance to other trainees that receive only the traditional training.

VI. Conclusions

As a training tool, virtual reality is experiencing a period of explosive growth and development due, in part, to the advent of low-cost and easy to use immersive head-mounted displays and peripheral technology. The effectiveness of virtual reality training has been demonstrated in many different domains from surgical training to manufacturing and assembly. There is a growing body of research examining in detail the factors that influence the effectiveness of virtual reality training and identifying methods for building and evaluating virtual training tools. We have briefly reviewed some of the results of this research and described application to two candidate tasks for virtual reality training. We are leveraging the lessons learned and considering the specific context and objectives for each project. Our future efforts will be to complete the implementation of the virtual environments, validate the effectiveness of the results, and review and revise the design in an ongoing iterative process.

Acknowledgment

The research presented in this paper was supported by the Center for Advanced Vehicular Systems.

References

[1] T. Huber, M. Paschold, C. Hansen, T. Wunderling, H. Lang, W. Kneist, *New Dimensions in Surgical Training: Immersive Virtual Reality Laparoscopic Simulation Exhilarates Surgical Staff,* Surgical Endoscopy, 2017.

[2] A. Mossel, A. Peer, M. Froeschl, J. Goellner, C. Schoenauer, H. Kaufmann, *VROnSite: Towards Immersive Training of First Responder Squad Leaders in Untethered Virtual Reality,* IEEE Virtual Reality, 2017.

[3] A. Mossel, A. Peer, J. Goellner, H. Kaufmann, *Requirements Analysis on a Virtual Reality Training System for CBRN Crisis Preparedness*, Proceedings of the 59th Annual Meeting of the International Society for the Systems Sciences, 1 (1), 2015.

[4] F. Buttussi, L. Chittaro, *Effects of Different Types of Virtual Reality Display on Presence and Learning in a Safety Training Scenario,* IEEE Transactions on Visualization and Computer Graphics, 2017.

[5] P. Khooshabeh, I. Choromanski, C. Neubauer, D. M. Krum, R. Spicer, J. Campbell, *Mixed Reality Training for Tank Platoon Leader Communication Skills,* IEEE Virtual Reality, 2017.

[6] D. Waller, E. Hunt, D. Knapp, *The Transfer of Spatial Knowledge in Virtual Environment Training,* Presence, 7 (2), pp. 129–143, 1998.

[7] N. Ordaz, D. Romero, D. Gorecky, H. R. Siller, *Serious Games and Virtual Simulator for Automotive Manufacturing Education & Training,* Procedia Computer Science, 75, pp. 267–274, 2015.

[8] E. Matsas, G.-C. Vosniakos, *Design of a Virtual Reality Training System for Human-Robot Collaboration in Manufacturing Tasks,* International Journal on Interactive Design and Manufacturing, 11 (2), pp. 139–153, 2017.

[9] H. A. El-Mounayri, C. Rogers, E. Fernandez, J. C. Satterwhite, *Assessment of STEM e-Learning in an Immersive Virtual Reality (VR) Environment,* American Society of Engineering Education 123rd Annual Conference and Exposition, 2016.

[10] D. Nathanael, S. Mosialos, G.-C. Vosniakos, V. Tsagkas, *Development and Evaluation of a Virtual Reality Training System Based on Cognitive Task Analysis: The Case of CNC Tool Length Offsetting,* Human Factors and Ergonomics in Manufacturing and Service Industries, 26 (1), pp. 52–67, 2016.

[11] N. Cooper, F. Milella, I. Cant, C. Pinto, M. White, G. Meyer, *Augmented Cues Facilitate Learning Transfer from Virtual to Real Environments,* IEEE Symposium on Mixed and Augmented Reality, pp. 194–198, 2016.

[12] R. Feloni, *Walmart is using virtual reality to train its employees,* 2017. [Online]. Available: http://www.businessinsider.com/walmart-using-virtual-reality-employee-training-2017-6. [Accessed: 25-Sept-2017].

[13] D. Grajewski, F. Górski, A. Hamrol, P. Zawadzki, *Immersive and Haptic Educational Simulations of Assembly Workplace Conditions,* Procedia Computer Science, 75, pp. 359–368, 2015.

[14] J. Jerald, *The VR Book: Human-Centered Design for Virtual Reality.* New York: Association for Computing Machinery and Morgan & Claypool, 2017.

[15] T. Gutiérrez, J. Rodríguez, Y. Vélaz, S. Cadado, A. Suescun, E. J. Sánchez, *IMA-VR: A Multimodal Virtual Training System for Skills Transfer in Industrial Maintenance and Assembly Tasks,* 19th IEEE International Symposium on Robot and Human Interactive Communication, pp. 428–433, 2010.

[16] C.-M. Wu, C.-W. Hsu, T.-K. Lee, S. Smith, *A virtual reality keyboard with realistic haptic feedback in a fully immersive virtual environment,* Virtual Reality, 21, pp. 19–29, 2017.

[17] A. Stratos, R. Loukas, M. Dimitris, G. Konstantinos, M. Dimitris, C. George, *A Virtual Reality Application to Attract Young Talents to Manufacturing,* Procedia CIRP, 57, pp. 134–139, 2016.

[18] B. Pourabdollahian, M. Taisch, E. Kerga, *Serious Games in Manufacturing Education: Evaluation of Learners' Engagement,* Procedia Computer Science, 15, pp. 256–265, 2012.

[19] C. Hall, *Standalone Daydream VR is now a reality, Qualcomm, HTC and Lenovo onboard,* 2017. [Online]. Available: http://www.pocket-lint.com/news/141079-standalone-daydream-vr-is-now-a-reality-qualcomm-htc-and-lenovo-onboard. [Accessed: 25-Sept-2017].

[20] *PBR Tools*. Tirgames assets, 2017.

[21] *Reality Capture*. Bratislava: Capturing Reality, 2017.

[22] *Photoscan*. St. Petersburg: Agisoft, 2017.

[23] J. Brooke, *SUS: A quick and dirty usability scale,* Usability Evaluation in Industry, 189 (194), pp. 4–7.

[24] B. G. Witmer, M. J. Singer, *Measuring presence in virtual environmnets: A presence questionnaire,* Presence: Teleoperators and Virtual Environments, 7 (3), pp. 225–240, 1998.

[25] R. S. Kennedy, N. E. Lane, K. S. Berbaum, M. G. Lilienthal, *Simulator Sickness Questionnaire: An enhanced method for quantifying simulator sickness,* The International Journal of Aviation Psychology, 3 (3), pp. 203–220, 1993.

[26] S. G. Hart, L. E. Staveland, *Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research,* Advances in Psychology, 52, pp. 129-183, 1988.