A VIRTUAL REALITY APPLICATION FOR THE TRAINING OF DEMINERS

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As virtual reality (VR) tools continue to improve, more fields are finding ways of implementing the technology to take advantage of training opportunities that reduce costs, alleviate logistical challenges, and more. Where humanitarian deminers must prepare for dangerous work, VR facilitates training that minimizes the danger while giving trainers a level of control over the different conditions of the training and the ability to easily monitor and instruct the user. For this purpose, the American University of Beirut (AUB) and the Beirut Research and Innovation Center (BRIC) developed a VR application for the basic training of deminers, which is called the VR Demining Trainer (VRDT). The first version of the VRDT, presented herein, teaches trainees how to turn on a metal detector, test the detector, conduct soil compensation, and start searching in a virtual minefield. These activities can be done in a closed room, regardless of time of day or weather conditions. Different training scenario attributes—including soil properties, landmine types, and locations—can be easily selected beforehand via software. The VRDT, which is a lab-ready prototype being developed using the Unreal Engine software and the Oculus Quest VR device, is not meant to replace but supplement field training, cutting down on training time and logistics by performing basic training phases in a VR-controlled environment.

Benefits of Virtual Reality in Training Deminers

In the case of demining, VR eliminates many requirements such as the need for ideal weather conditions, logistics, physical training objects, or location setup. When using VR, trainees can practice anytime and anywhere, as all requirements can be controlled in a virtual environment. Terrain can be changed (e.g., from flat to mountainous), vegetation type can also be controlled, and the location of landmines can be altered by the software. With VR, the demining process becomes more cost-effective, modular, less time-consuming, and easy to monitor.

VR in Different Applications

VR is continually being used in training programs ranging from military to medical applications. One example of an existing application is the "Officer of the Deck (OOD)" VR simulation in which a naval officer is trained to navigate a submarine safely into port. Using OOD was found to improve the performance of trainees, proving its effectiveness. Another example is the "Firefighting Trainer" application used by the US Navy for training personnel to utilize optimal procedures to fight fires on ships. A comparison between two different groups, in which only one took the VR training, showed measurable improvements in the group with VR training. Moreover, medical applications are another utility for VR and are used to provide medical students with adequate training for real-life situations. This is the case at Dallas' Southern Methodist University (SMU), where their VR-developed program allows for numerous medical students to practice the steps for performing a radical abdominal hysterectomy within a specified time and degree of accuracy. Another medical application, Virti—which is a medical training platform focused on building *soft skills* in augmented and virtual reality simulations—utilizes artificial intelligence (AI) and natural language processing (NLP) to analyze decision-making, leadership, communication, and other capabilities that are not typically a focus of medical school training. Hence, VR systems are time-efficient ways of providing basic training for these surgeons.[1]

VR Demining Training System

In the case of demining, VR eliminates many requirements such as the need for ideal weather conditions, logistics, physical training objects, or location setup.

Figure 1. Oculus Quest device and two-handed controllers.
All figures courtesy of the authors.

The system is expected to train deminers faster and at a lower cost. The VRDT version presented in this article can be thought of as a precursor for trainees before going to demining schools and before ever stepping onto a training field.

The VRDT system is based on two key components: hardware and software. Hardware includes the headset used by the trainees and the hand controllers that simulate a handheld metal detector (MD). The headset is an Oculus Quest (priced below $300)[2] used to render the environment and provide mobility through sensors and controllers, which are provided with the Oculus Quest (see Figure 1). Software creates the virtual demining environment and its associated objects, and translates the movements, actions, and feedback between real-life and virtual environments.

The VRDT system was developed over the course of nine months. It is important to note that the main requirement has been for the VRDT to be practical for use, and to offer the real-life expertise that deminers possess in the field. This means that the VRDT should provide distinguishable responses to the different types of targets faced in the field, and be able to give the user information about the class of the target, e.g., whether it is a landmine or clutter, and possibly the type of the landmine. While a preliminary lab-ready prototype has been made, more work is under way to produce a more practical and complete prototype that can be easily deployed.

The work has faced several challenges: the main one being the ability to exactly replicate the MD responses for different target types and in different terrain and soil conditions. For example, the MD produces a certain response for an anti-personnel No. 4 landmine and a different response for a buried metal pin. These two responses themselves change when the soil has more or less metal content, and when the terrain changes. The main challenge has been for the VRDT to be able to produce all these different responses and associate them with their respective targets. Other challenges involve configuring the Oculus Quest controllers, which are lighter and have a different form factor than an actual MD, to more accurately simulate the real thing. The system will be updated with additional functionality to make it suitable for all demining stages and embed the controllers in an MD-like device that would provide additional realism to the system. It is worth noting that obtaining a suitable interaction in addition to a high frame rate were the main challenges regarding the software part of the system.

Hardware Component of the System

The VRDT application requires a powerful VR device to efficiently render the virtual demining environment. Moreover, trainee mobility is an essential application requirement since deminers must move in order to sweep a field and locate landmines. The Oculus Quest was chosen to support the VRDT system because of its performance and its ability to integrate user mobility into the system through its sensors, enabling it to be used indoors without any wiring or space limitations. The VRDT supports casting to other devices such as Google Chromecast, a feature that enables instructors to view the stream on a separate monitor. This function, in addition to video recording, allows instructors to monitor the actions of the trainees in real time, and feedback can be relayed to the trainees at any time during the VR training. The controllers are used to simulate the hands of the trainee during demining, and each button on the controllers controls a specific function such as resetting the view or changing the settings of the currently simulated environment (e.g., soil properties).

Software Component of the System

The Blender software is used to create the environmental objects (e.g., the MD model, the vegetation, etc.). The interactions with the environment are coded using Unreal Engine, which utilizes blueprints or pre-designed blocks of code that provide all functions needed within the system. In addition, the Unreal Engine offers several graphics rendering options compared to other platforms and a relative ease of implementation. The simulated MD is a CEIA MIL-D1, which is implemented with all its functionalities, including an *on/off* switch, a sensitivity knob, and a volume knob. All interactions happen when the virtual hands, controlled by the Oculus Quest's controllers, come into collision with the virtual objects (MD and its different parts and controls). A frame rate of sixty-eight frames per second (FPS) is achieved, which minimizes the latency time between user action (i.e., pressing a button) and the simulated counteraction within the VR environment, making for a smoother user experience. Gravity is also implemented in order to make the simulation as close to reality as possible, meaning an object in the scenario can be picked up, handled, and dropped, and is interactive—especially in regards to the MD. Moreover, the software enables the environment to be easily adapted to account for different terrain, vegetation types, and landmine types and locations. Other MD types can also be designed in Blender or other 3D software and added to the Unreal Engine environment.

Implemented Demining Stages

Figure 2. VR model of CEIA MIL-D1 MD metal detector.

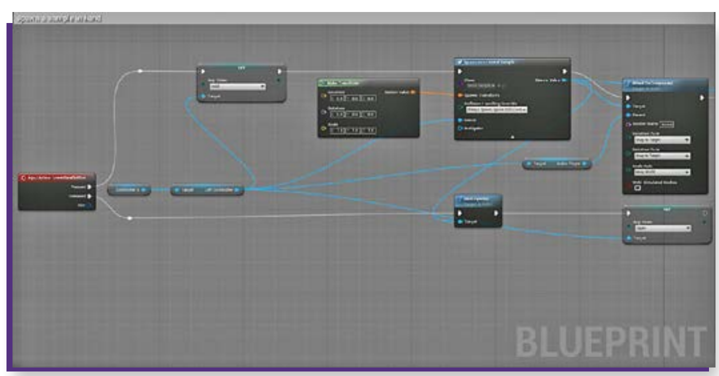

Figure 3. Sample of an Unreal Engine blueprint.

The VRDT focuses on emulating the three stages of the demining process as described in CEIA's tutorial videos.[3]

Startup phase. The first phase teaches the trainee how to start the MD and operate it. The trainee begins by turning the sensitivity control to the red dot and the volume knob to maximum. These actions all occur in the VR environment. Then, while virtually holding the MD at about 1 m above the ground, the trainee pulls the *on/off* switch to the on position, which generates a series of beeps followed by the confidence click. In order to ensure that the MD is operating according to factory specifications, the trainee inverts the MD and places the arm rest on the ground, and then passes a reference metal sample across the search head, from side to side, and in two different directions in order to hear the target tones in both directions. This confirms that the MD is operating properly. Finally, the trainee adjusts the search head to make it parallel to the ground in preparation for the next phase, which is soil compensation. All details in this phase are provided by the VRDT system using various blueprints in Unreal Engine.

Soil compensation phase. In this phase, the trainee accounts for the metal composition of the soil apart from the metal content of any target landmine. It should be performed every time the detector is turned on. For this purpose, a 1 m by 1 m metal-free box is designed for use in the VR environment, and the trainee starts by holding the MD

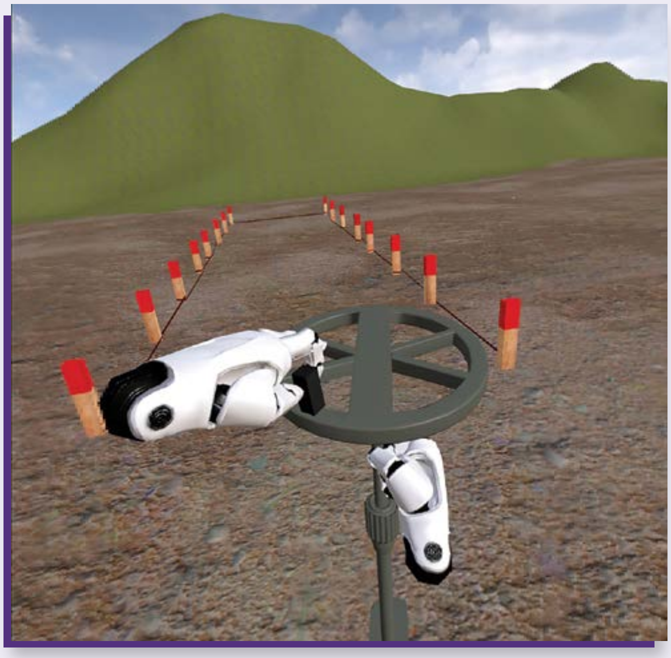

Figure 4. The trainee testing the MD with the reference metal sample.

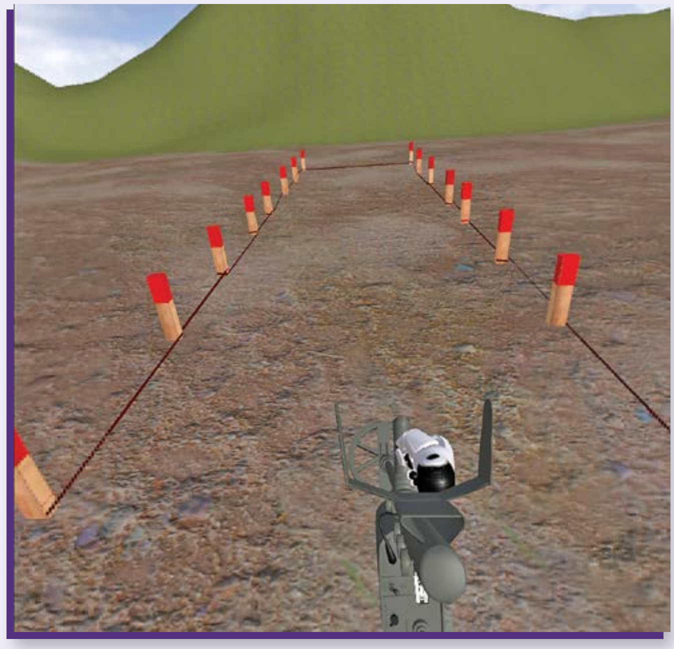

Figure 6. The trainee doing target detection over a marked search lane.

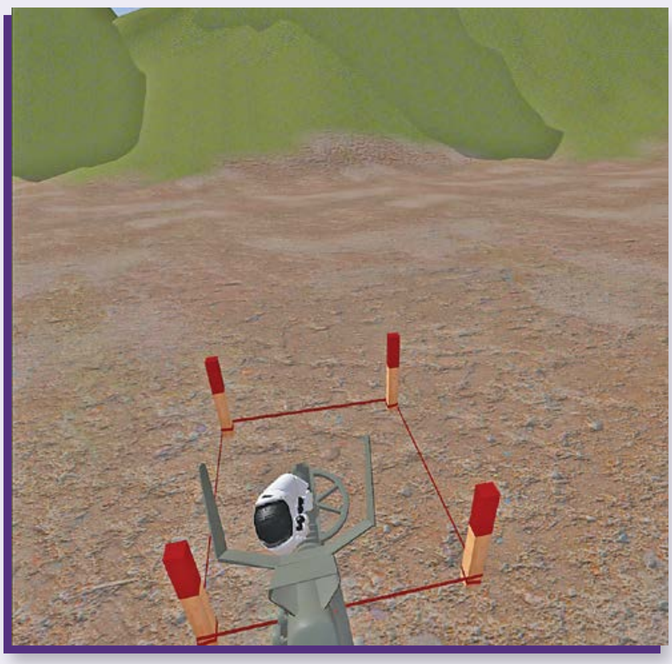

Figure 5. The trainee using a virtual 1 m x 1 m metal-free box to learn how to do soil compensation.

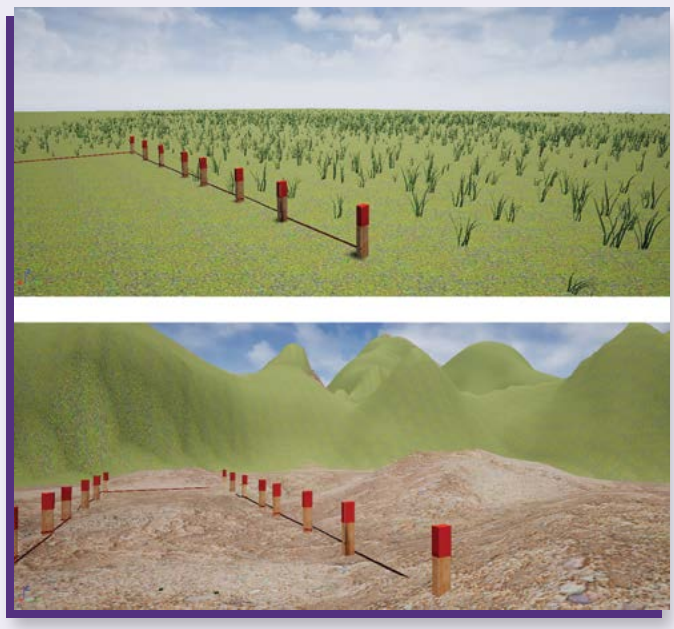

Figure 7. Two different terrain and vegetation types in the VR environment.

above this box (Figure 5) and then holds the switch in the *reset* position until a series of fast clicks is generated followed by a series of double clicks. At this point, the trainee returns the search head to the ground inside the metal-free box, and sweeps side to side close to the ground in order for the MD to acquire the soil characteristics. If the process is successful, the double clicks change into a fast series of clicks. In this case, the trainee lifts the MD up into the air until a single beep is produced, where the MD returns to the regular confidence clicks. The trainee sets the sensitivity, gradually lowering the maximum setting until no alarm is generated when the metal-free box is swept. Every detail of this phase is also implemented in the VRDT system using Unreal Engine blueprints.

Detection and Pin-pointing Phase. After the soil compensation is done, the trainee starts looking for landmines. The trainee holds the detector so that the search head is parallel and as close as possible to the ground. The trainee then learns to properly sweep the MD and advance forward over the search area (Figure 6). If no target is found, only the confidence click is heard. When the MD detects a target, the center of the target is located where the alarm tone changes from high to low or from low to high.

Comments and Conclusions

The VRDT aims to accelerate and reduce the cost of the training of deminers while removing weather and some logistical constraints. Other advantages include the ability to change the terrain, vegetation, landmine types, and landmine locations in software. As an example, Figure 7 shows two different terrain and vegetation types in the VR environment. This first version of the VRDT covers the demining training phases of MD startup, soil compensation, and basic detection.[4] Mistakes and errors made by the trainees as well as unsuccessful training phases are reported using messages that appear on the headset screen. Future versions of the VRDT can include more MD brands and types and could focus more on the detection phase.

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BIOGRAPHIES

Lynn Al Khansa
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Lynn Al Khansa is a computer and communications engineering graduate from the American University of Beirut (AUB). She has always been passionate about technology, which drove her to work at a couple of tech startups in Lebanon. She received the "Dean's Award for Creative Achievement" and "Murex Best Innovative Software Development Project" award as a result of working on the project titled, "A Virtual Reality Application for the Training of Deminers."

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Elias Bou Saada is a computer and communications engineering graduate from AUB. He is a recipient of the "Dean's Award for Creative Achievement" and "Murex Best Innovative Software Development Project" award following his participation in the development of the project, "A Virtual Reality Application for the Training of Deminers." Currently, he is a software engineer with Murex Systems.

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Rachid Maalouf's journey as a tech enthusiast led him to major in computer and communications engineering (CCE) at AUB. He holds a degree in engineering, and is currently working as a software developer with Capital Banking Solutions. He is very proud to have been able to work on the project "A Virtual Reality Application for the Training of Deminers" as it has allowed him to explore the world of VR, and to receive the "Dean's Award for Creative Achievement" and the "Murex Best Innovative Software Development Project" award. His plan is to pursue an MBA and further explore the VR world.

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Mohammed Al-Husseini, Ph.D., is a Senior Researcher and the Director of the Humanitarian Demining Research Program with the Beirut Research and Innovation Center (BRIC), Beirut, Lebanon. He received his doctorate in electrical and computer engineering in 2012 from AUB, where he was a recipient of the Kamal Shair Ph.D. Fellowship. In 2012, he was a Visiting Researcher with the University of New Mexico in Albuquerque, NM. Al-Husseini's current research focuses on material characterization and on the use of machine learning for the detection of underground targets.

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Ali El-Hajj, Ph.D., is a Professor of electrical and computer engineering at AUB. El-Hajj has thirty-five years of academic experience, and he assumed leadership positions at AUB in General Education, Academic Program Review, Assessment of Program Learning Outcomes (PLOs), Assessment of Units Outcomes, and Strategic Planning. El-Hajj received an engineering degree from L'Ecole Superieure d'Electricite, France, and a doctorate in engineering from the University of Rennes I, France.

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Hassan Ghaziri, Ph.D., is the Director of BRIC and a scientific consultant with the Swiss Federal Institute of Technology (EPFL-LRE). He conducted his academic activities at AUB, Kyoto University, INSEAD (Fontainebleau-France), and the Swiss Federal Institute of Technology in the areas of machine learning, knowledge management, and decision systems. His research is focused on developing machine learning techniques to improve the decision-making process and the performance of anomaly detection systems in the health, financial, and humanitarian demining fields. Ghaziri has authored or co-authored more than fifty scientific papers and the book, *Knowledge Management*, published by Pearson.

ENDNOTES

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