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Applied Practices on the Application of VR/AR/MR Technologies to LVC Training Systems

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Abstract

The Republic of Korea (ROK) Army is developing the Army Synthetic Battlefield Training System and plans divisional-level Live, Virtual, and Constructive (LVC) integrated training. This study proposes a plan to apply VR/AR/MR (Virtual Reality/Augmented Reality/Mixed Reality) technology to LVC integrated training systems to enhance the efficiency and effectiveness of future LVC integrated training. The study investigated immersive military training systems in the ROK and advanced countries. As a result, we confirm that immersive technology can significantly improve the efficiency and effectiveness of military training. Accordingly, we review the key technologies required for building a defense training system with immersive features and propose training subjects that can be enhanced in effectiveness and efficiency when built with an immersive approach. We also propose a plan to apply immersive technology to the Live, Virtual, and Constructive systems for the development of future LVC integrated training system.

Keywords: *AR/MR/VR, immersive, LVC Integrated Training, Simulation, STE*

1. Introduction

Immersive technologies such as virtual reality (VR), augmented reality (AR), and mixed reality (MR) are rapidly developing in the era of the 4th Industrial Revolution. These technologies are being used in a variety of fields, including military training, where they can improve the efficiency and effectiveness of training by providing a simulated environment that is similar to the real world. Additionally, immersive technologies can enable training in dangerous or expensive environments, thereby improving safety and economic efficiency.

The Ministry of National Defense (MND) is developing a state-of-the-art training system to accelerate immersive training. As part of the 4th Industrial Revolution Smart Defense Innovation Plan, the MND is pursuing the development of a 'Science-Based Training System Expansion,' as well as expanding 'VR·AR-based Virtual Simulated Training Systems' for the cultivation of real-world warriors and units, and establishing a 'LVC-based Synthetic Battlefield Training Environment' to support the development of the Army Synthetic Battlefield Training System[1].

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LVC (Live, Virtual & Constructive) is a technology that integrates real-time virtual environments and real environments to conduct military training. LVC training systems support soldiers to experience various situations and scenarios in a realistic training environment and to train effectively.

This paper explores the application of immersive technologies to LVC training systems. It reviews the features of major immersive technologies and proposes methods for effectively applying them to LVC training systems. It also analyzes and presents the effects of LVC training systems that have adopted immersive technologies.

2. Immersive Technologies in Military Training

2.1 Korean Military Case study

The Korean military operates a variety of training systems that utilize immersive technologies, as described below. Some examples are given in Figure 1[2].

- Tank and armored vehicle simulator: A VR simulator in the form of actual equipment is used to train the operation and gunnery of tanks and armored vehicles. The K2 tank is built-in, allowing for individual training for crew members and integrated team training.
- Helicopter flight simulator: Flight simulators for various helicopter types are in operation. The air tactical training simulator, which can be used for team training, can change the control stick and communication system to various types of helicopter.
- Game-based training: VBS, CSTAB, and VR-Engage is used to repeatedly train individual combat skills and mechanized unit tactical tasks. This provides high immersion and training accessibility[3].
- Parachuting and HALO/HAHO: Parachuting simulators support training of parachute control skills in an environment similar to the air, and HALO/HAHO simulators improve the ability to freely move the body in the freefall stage.
- Hyeon-gung simulator: The Hyeon-gung simulator is a training simulator for anti-tank guided weapons that is similar to the real thing.

Figure 1. ROK Army Synthetic Battlespace Training System

- Small unit tactical training system: is an extended reality (XR) installed at the Korean Military Academy. It allows for a variety of realistic training, including precision shooting training, two-way attack and defense training for squads, and tactical training for platoons.
- XR-based trauma care training system: is implemented by combining medical twin technology and MR technology to enable doctors and nurses to train in trauma patient care.
- VR/AR-based flight simulator: This simulator implements an environment similar to a real aircraft to train pilots to improve their flying skills and situational awareness.

In addition, Korea Aerospace Industries (KAI) has developed a method for connecting LVC between aircraft (L), simulators (V), and wargame models (C). They also conducted virtual simulated combat training by integrating MILES (Multiple Integrated Laser Engagement System) equipment into the Light Armed Helicopter (LAH).

2.2 U.S. & Some Advanced Countries' Military Case study

The United States is actively adopting immersive technologies in the field of military training.

- DSTS (Dismounted Soldier Training System): A VR-based training system that supports training from individual soldiers to teams, tracking the movements of soldiers' weapons and simulating weapon firing[3].
- AITT (Augmented Immersive Team Trainer): Marines use AR goggles to project virtual images, indirect fire effects, aircraft, vehicles, and simulated people onto the real environment, creating a dynamic training ground[4].
- VBS4 (Virtual Battle Space 4): Designed to realistically conduct ground, sea, and air training and mission rehearsals using commercial video game technology[5].
- ENVG-B (Enhanced Night Vision Goggle-Binoculars): A binocular night vision goggle that provides battlefield information through AR functions, helping soldiers to quickly identify and engage enemies even in night operations[6].

Immersive technologies are being actively used in military training in a number of other advanced countries, including the United Kingdom.

- The United Kingdom's UBVT (Unit Based Virtual Training): a virtual training system that supports unit-level training. It provides a 3D virtual environment that allows soldiers to conduct a variety of operational training at the unit level[7].
- The French SPARTE system: a PC-based tactical training game that simulates equipment and weapons to help soldiers learn how to use and operate them.
- The Israeli Merkava MK 4 Barak tank: conduct independent training using a 3D VR simulator built into the tank. The immersive interface drone system allows a soldier wearing AR goggles to remotely control the drone while viewing the surrounding environment in real time through the drone's lens[8].

2.3. The effects of using immersive technologies

Immersive technologies have the potential to revolutionize the efficiency and effectiveness of military training. The use of these technologies can make it possible to train in a simulated environment that is similar

to real combat, which can improve soldiers' combat skills. Additionally, the ability to repeatedly train in a variety of situations can improve soldiers' crisis response capabilities.

The ROK military is also pursuing educational and training innovation through the introduction of training systems that utilize immersive technologies. If these efforts are aligned with the development plan for the future LVC training system, it will be possible to build a training system with higher usability.

3. Application of Immersive Technologies in Military Training

3.1 Advantages of immersive training

According to a report by the United States Naval Research Laboratory, "video game players have better developed vision, better visual memory, and faster processing of new information than people who do not play games." Additionally, according to research by educational psychologist Edgar Dale, immersive learning (speaking + actual action) showed much higher effectiveness than traditional learning methods, and VR-based education has been linked to improved concentration and academic performance in students[9].

One of the purposes of introducing immersive technologies to the military is to quickly improve the capabilities of military organizations, such as by reducing the number of troops and shortening the length of service, so that units can fully perform their missions.

Methods to improve the effectiveness and efficiency of defense training by introducing immersive technologies are presented in Table 1.

Table 1. Ways to improve the effectiveness and efficiency of military training

Training Environment	Ways to Improve Effectiveness & Efficiency
shortage of training facilities and training equipment	implementation of virtual training facilities and simulators
lack of realism comparable to real equipment	implementation of actions similar to real equipment
difficulty in implementing a variety of tactical situations	implementation of various virtual tactical situations
accidents caused by lack of experience, fear, carelessness	strengthening the safety of training
affected by season/weather/time	make a 24/7 all-weather all-season training environment
"long wait times due to insufficient training equipment	reducing the wait time for training

3.2 Technologies for building a Realistic system

The following are the key technologies and requirements that need to be considered to build a realistic defense training system.

3.2.1 VR Technology

VR technology is a crucial element for the innovation of defense training systems, and it should consider important technical factors such as resolution, refresh rate, rendering, response time, adaptive resolution, field of view, color representation, and contrast ratio. To prevent headaches, eye fatigue, nausea, and motion

sickness for the wearer, it should provide a resolution of at least 1080x1200 pixels, a refresh rate of over 90Hz, a response time of less than 1ms, adaptive resolution, a contrast ratio of over 1000:1, and a field of view of over 100 degrees[10].

3.2.2 AR Technology

AR technology plays a role in blending the real world with the virtual world, and key factors include display, real-time image synthesis, spatial alignment, and accuracy in positioning and orientation. To ensure smooth representation of virtual object movements in response to the user's actions, a frame rate of at least 60Hz is necessary. Utilizing markerless technology and achieving spatial and positional alignment are essential for seamlessly integrating the real and virtual worlds.

3.2.3 Haptic Technology

Haptic technology provides tactile feedback to users, delivering realistic sensations when interacting with objects in a virtual environment. It enhances user experience by utilizing haptic feedback devices, force feedback devices, hand motion tracking, and spatial perception technologies[11].

3.2.4 Interactive technology

Interactive technology is a technology that helps users to perceive and manipulate realistic content. Technologies such as motion recognition and speech recognition are being researched[11].

3.3. Application Strategies for Immersive Technology in Defense Training

3.3.1 Factors for Applying Immersive Technologies

The most essential aspect among immersive technologies is VR/AR technology, and it is necessary to understand its characteristics and explore ways to apply it to training. Consideration factors related to this are presented in Table 2[12].

Table 2. Considerations for Applying Immersive Technologies

	VR	AR
Characteristics	Providing virtual images similar to reality(with freedom of material and location)	Overlaying virtual information on the real world (or 3D terrain)
Training method	Limited in the use of equipment, difficult to access the field	Experiential training using real equipment or field
Interaction	workable	workable
Info. sharing	workable	workable
Mobility	low	high

VR technology provides a virtual world without constraints on location or material, making it useful when it's difficult to utilize real equipment. AR technology overlays virtual information onto the real world and is suitable when real equipment or on-site environments can be utilized.

Interactivity refers to situations in training where there is interaction between objects in the real or virtual world. Information sharing indicates whether there is a need to share information among participants in training. Mobility represents the extent to which participants need to move during training.

3.3.2 Subjects Suitable for Immersive Technologies

To identify subjects in the defense training system where the application of immersive technology is expected to enhance the effectiveness and efficiency of training, a review of the ROK military's training system mentioned in the previous chapter was conducted. This review considered subjects requiring improvement, subjects included in the national defense medium-term plan[13], and new subjects for educational and training innovation[14]. After analysis, a total of 41 subjects were selected for immersive technology applications. Table 3 summarizes the list of subjects.

Table 3. Training Subjects that apply immersive technologies

Category	Training Subjects
driving/ operating	- AR-based military vehicle driving - VR Tank, Self-propelled Artillery, Armored Vehicle, KAAV Operation
fixed-wing flight	- VR Aerial Formation Combat Training - VR Air Tactical Training - VR/AR-based flight training
helicopter	- Helicopter Piloting/Tactical Training
ground weapon operation	- LOGIR/Hyeongyung Training - Gunnery and Maneuver Training
shooting/firing	- Day and Night Firing Training - VR/AR Counter-drone training - VR/AR Anti-Drone Training - KP-SAM(Shin-gung) Simulation
combat training	- AR Tactical Situational Awareness Enhancement - MUM-T Training - VR/AR Surveillance and Reconnaissance - VR Remote Base Bilateral Combat Situation Response Training - Joint Firepower Training - VR Game
tactics/command and control	- AR-based Tangible Operation Table - Communication and Electromagnetic Warfare
equipment operation/maintenance	- VR/AR Equipment Operation and Maintenance - AR-based (Small)Arms Disassembly and Assembly
disaster/NBC	- VR Disaster Response Training - VR/AR NBC Training
medical care/treatment	- VR Nursing Simulation Training - VR Rehabilitation Training
handling explosives	- VR/AR Engineered Demolition Training - VR/AR EOD Training
parachuting	- VR Individual/Team Parachuting
AI instructor/ trainer	- VR Overseas Deployment Training - AR Training Camp Basic Training - Basic Military Training/Battlefield Leadership - VR-based Individual Combat Training

3.3.3 Application Strategies for Immersive Technologies

To find ways to apply immersive technology in defense training, the following approach is proposed:

Evaluate the individual subjects within the training system as presented in Table 2, considering the four characteristic elements: ①Training Method (Experiential, Lecture), ②Facilities and Equipment (Adequate, Insufficient), ③Interaction Among Training Objects (Interaction, Information Sharing), and ④Mobility During Training (Various Paths, Slight Move, No Move). Then, based on the characteristics of VR/AR technology presented in Table 3, determine the suitable technology for each subject.

For instance, when a small military unit at the team level aims to implement a training system for team exercises in the field for special missions, it is recommended to consider high-spec AR technology based on the following four criteria:

① Training Method: Experiential

② Facilities and Equipment: Adequate (Available)

③ Interaction Training Objects: Interaction

④ Mobility During Training: Various Paths

Therefore, this training system can be implemented using advanced AR technology, allowing soldiers to interact with the training system and maneuver through various paths during the training.

4. Application of Immersive Technologies to LVC Training Systems

4.1. Features of LVC training systems

The LVC Training System (Live, Virtual, Constructive) integrates two or more of these elements to conduct military training. It offers several advantages, including real-time integrated training, a cost-effective and safe training environment, large-scale training operations, and enhanced training effectiveness through the integration of real and virtual environments.

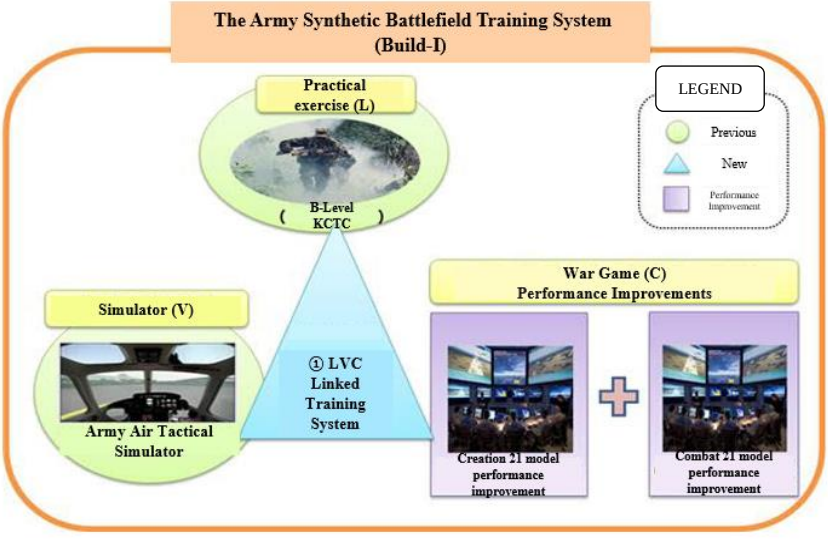

Figure 2. ROK Army Synthetic Battlespace Training System

The ROK is currently developing the Army Synthetic Battlefield Training System (Build-I), as shown in Figure 2. Upon completion, it will enable division-level LVC integrated training, allowing for the practice and training of various battlefield scenarios in a more realistic simulated environment[15].

4.2. Application Strategies of Immersive Technologies

The following are the implementation plans for applying immersive technologies to LVC training systems.

First, the interface and protocol for linking should be included when acquiring training systems. This will ensure that systems that apply immersive technologies can be linked to LVC training systems.

Second, subjects that are essential to be linked to LVC training systems should be prioritized in the acquisition plan. To do this, the priority should be set by considering the need for linking and difficulty, etc., for the training subjects presented in Table 2.

Third, the subjects that are not prioritized should be integrated into the linking plan of the Army Synthetic Battlefield Training System (Build-II). This will help to improve the completeness of the LVC training system composition.

In addition, the application plans for immersive technologies for L, V, and C training environments in LVC training systems are as follows.

4.2.1 Live Training Environment

The live training environment is where one subordinate unit of the training unit and a professional counter-force unit conduct autonomous mobile training. The V training environment is the air force supporting the training unit, and the C training environment simulates the higher and adjacent units of the units participating in the live training environment.

The Live training environment of the Army Synthetic Battlefield Training System, which is currently under development, is linked with the V and C training environments to share interaction information such as neighboring unit information, unit positions, obstacles, superior artillery fire, and aerial capabilities.

Enhancing the integration of the live training environment with the V and C training environments to simulate more scenarios can improve training effectiveness. To achieve this, the scope of interaction for virtual objects simulated in V and C must be expanded so that participants can perceive and engage in actual combat. This requires the introduction of the following AR technologies:

(1) Utilizing AR glasses to visually represent the Live training environment and projecting virtual fixed-wing aircraft simulated in V and virtual combat equipment and troops simulated in C onto the screen for visual representation,

(2) Implementing the capability for training participants wearing AR glasses to recognize virtual objects (aircraft, drones, robots, combat personnel, etc.) as targets in the Live training environment and engage in shooting,

(3) Implementing the capability to collect shooting data from training participants in the Live training environment, process damage assessment of virtual objects in V and C, and synchronize the results, etc.

4.2.2 Virtual training environment

The Virtual training environment links interaction information such as information on ground mobile equipment objects in the L training environment's live-action training situation and information on

armored/mechanized unit objects that are targets in the training situation simulated in the C training environment, and ground-to-air firing information based on air defense operations.

To improve the Virtual training environment, the scope of the connection should be expanded to include training situations such as ground-to-air firing information in the L training environment. This will allow training participants in the Virtual training environment to recognize and respond to anti-aircraft fire being operated in the L training environment. To this end, the current VR technology needs to be applied more extensively.

To expand the Virtual training environment, it is essential to integrate with various simulators such as tanks, armored vehicles, self-propelled artillery, drones, robots, and more. The simulators currently in operation are high-cost, large-scale simulators that depict the operational characteristics of actual weapon systems. Achieving integration with these simulators requires significant software modifications and incurs substantial costs.

To solve this problem, it is necessary to develop a reconfigurable simulator based on the RVCT (Reconfigurable Virtual Collective Trainer) concept. By replacing existing large simulators with reconfigurable simulators, the types and quantities of simulators participating in the Virtual training environment can be increased, and it can evolve into an LVC training system that can conduct various tactical training. At this time, if the simulator common platform is first designed, and the HUD (Head-up Display) and Cockpit are combined according to the weapon system when implementing the simulator, the efficiency of system construction can be improved.

4.2.3 Constructive Training Environment

The Constructive training environment, during LVC Integrated Training, simulates higher-level units (-) excluding the units conducting Live training in the Live training environment (L).

While applying immersive technology to the Constructive training environment can be challenging, VR technology can be utilized in training scenarios like the Battle Command Training Program (BCTP) as follows:

(1) The construction of virtual environments using VR headsets enables training controllers to visually and accurately grasp the movements and combat outcomes of training units. This allows training controllers to swiftly detect situations and, based on their decisiveness, identify problem areas and carry out necessary strategic adjustments promptly. This significantly aids in facilitating the enhancement of tactical capabilities for training unit commanders and staff officers.

(2) By utilizing gesture recognition and voice commands in VR environments, training controllers can manipulate wargame situations through hand movements and vocal instructions. Gesture recognition enables complex tasks such as unit rearrangement, alteration of movement paths, and deployment of combat forces to be executed solely through hand gestures. Voice commands allow training controllers to swiftly relay all commands without having to remove their hands. These advantages empower training controllers to support gamers by adjusting training scenarios in real-time.

(3) To apply AR technology in the Constructive training environment, upgrading from low-resolution (unit-level) models to high-resolution (entity-level) models is necessary. Such an upgrade may introduce issues like system performance degradation and an increase in the number of gamers. To address these challenges, leveraging Multi-Resolution Modeling (MRM) technology and Computer-Generated Forces (CGF) simulation techniques can effectively apply AR technology while minimizing system performance degradation and the required increase in gamer resources.

4.3 Advantages of Immersive Technologies Application

The application of immersive technology can bring innovation to the entire defense training system through the advancement of LVC Training Systems. Applying immersive technology to LVC Training Systems can yield the following effects:

First, through immersive technology, it is possible to provide realistic simulations that interact with real environments, enabling training scenarios closer to actual combat situations. This allows soldiers to experience training in various combat situations and enhance their preparedness skills.

Secondly, the use of immersive technology allows for the provision of safe and controllable training environments to soldiers without the need for actual equipment or locations. This minimizes the risks of accidents or injuries and leads to cost savings in training[15].

Thirdly, immersive technology enables real-time coordination and collaboration among soldiers across various locations and platforms. This enhances teamwork and communication skills, improving the preparation process for complex operations.

Fourthly, the use of immersive technology allows for the provision of tailored training content that matches the learning levels and abilities of the participants. Additionally, it can offer a variety of visual elements to enhance the diversity of training [16].

By applying immersive technologies to the LVC training system and expanding the system, it will be possible to conduct a wider variety of tactical training, supporting realistic and practical military training, and greatly increasing the training effect of soldiers.

5. Conclusions

This study proposes a method for effectively applying immersive technologies to LVC training systems. To this end, we investigated the use of immersive technologies in the defense sector of the Korean military and advanced countries and investigated the development direction of LVC training systems. Based on this, we confirmed the need to apply immersive technologies to the Korean military's training system and proposed a method for applying immersive technologies in the L, V, and C systems. We also proposed a method for applying immersive technologies to LVC training systems.

Through this study, we confirmed that applying immersive technologies to defense training subjects and LVC integrated training systems, and expanding the system, can increase the effectiveness of education through the immersive content characteristics of immersion, interaction, and intelligence, and can enable a variety of tactical training to gain experience similar to actual combat. Therefore, it is expected that the suggestions presented in this study will contribute to the development of future LVC integrated training systems.

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