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AI-Supported Immersive Training for Call for Fire: Integration of VR-AR Simulator Kit within Fire Support Coordination

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Abstract

The paper presents the Virtual Reality (VR) - Augmented Reality (AR) Simulator Kit designed for Call for Fire (CFF) training within the framework of fire support. It describes the system's modular architecture, the use of mixed reality, voice control, and Artificial Intelligence (AI) based analysis of standardized CFF communication. Pilot validation confirmed the technical functionality of the solution, as well as its ability to objectively assess procedural correctness and monitor reaction time and error rates. Its main contribution lies in linking immersive training with the broader context of fire support command and control. The originality of the paper consists in integrating VR/AR, AI, and analytical evaluation into a single training ecosystem.

KEY WORDS: *fire support, artillery, Call for Fire, immersive training, virtual reality, augmented reality, artificial intelligence, command and control*

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1. Introduction

Contemporary high-intensity armed conflicts, particularly the lessons derived from the war in Ukraine, have once again confirmed the crucial importance of artillery and effective fire support coordination [1]. In the conditions of the modern battlefield, characterized by high dynamics, information saturation, and pressure on rapid decision-making, the ability to request fire support in a timely and accurate manner represents one of the key prerequisites for the successful employment of ground forces [2]. Forward Observers (FO) and Joint Fires Observers (JFO) play an irreplaceable role in this context, as they connect sensors, maneuver units, and fire assets into a single functional command and control chain. Their performance directly affects reaction time, strike accuracy, and the reduction of unintended collateral effects of fire [3].

Successful execution of artillery fire support, however, is not the result of isolated individual action, but of a coordinated process involving all elements responsible for requesting, approving, transmitting, and controlling fire [4, 5]. Although current automated fire control systems are primarily designed for rapid digital data transmission, voice-based fire requests continue to retain essential importance in real operational conditions [6]. The standardized Call for Fire (CFF) procedure remains an indispensable tool, especially in situations where digital systems are unavailable, degraded, not shared by all relevant elements, or where the dynamics of the situation require immediate and understandable voice communication [7]. Proper mastery of the CFF structure therefore represents not only a matter of individual professional preparedness, but also a factor of interoperability and the effective functioning of the fire support system as a whole [8].

Traditional training of FO and JFO specialists is nevertheless associated with a number of limitations. It is logistically demanding, financially burdensome, and constrained by safety, spatial, and time-related factors [9]. At the same time, it is difficult to systematically and objectively evaluate communication quality, the correctness of the sequence of individual CFF steps, reaction speed, or the ability to operate under stress in realistic yet controlled conditions [10]. These limitations have led to increasing interest in the use of immersive technologies, which make it possible to create safe, repeatable, and analytically assessable training environments [11].

The literature confirms the growing significance of virtual reality (VR), augmented reality (AR), mixed reality (MR), and artificial intelligence (AI) in military training [12]. These technologies are applied particularly in the development of situational awareness, decision-making processes, teamwork, and coping with cognitive load [13]. At the same time, research points to persistent gaps, including the limited number of studies focused directly on artillery training and fire support, the lack of standardized evaluation methodologies, and the weaker integration of immersive simulators with the broader context of command and control systems [14, 15]. Most existing solutions focus either on isolated training of individual tasks or on technological demonstrations without deeper integration into the procedural and organizational logic of the real fire support system [16].

The use of virtual, augmented, and mixed reality in military training has become a dynamically developing field of research in recent years. In general terms, the literature emphasizes that military training is among the domains in which VR and AR have exceptionally high application potential [17]. At the same time, systematic review studies indicate that research most frequently focuses on combat and weapons simulators, team training, and procedural practice, whereas deeper analytical performance assessment or the standardization of evaluation frameworks remain less developed or not developed at all, especially with regard to the specific nature of military use [18].

A number of authors also confirm that the benefit of immersive technologies lies not only in the visualization of the environment itself, but above all in the possibility of integrating spatial perception, interaction with tools, and the decision-making process into one unified training experience [19]. An important issue therefore becomes the question of what degree of environmental fidelity actually contributes to better task comprehension and higher training effectiveness [20]. Research shows that greater technological sophistication does not automatically mean better performance. For example, studies focused on the use of extended reality in military tactics instruction demonstrate that advanced 3D display technologies may improve perceived usability or reduce cognitive load, yet they do not always lead to clearly better results in terms of accuracy or speed of decision-making [21]. This suggests that the key factor is not only the technical level of the simulation, but above all the quality of its pedagogical and procedural grounding [22].

A specific area is the training of fire support personnel, forward observers, and artillery specialists [23]. It is precisely here that several studies can be found confirming the suitability of VR/AR approaches for practicing target acquisition, fire control, and Call for Fire procedures [24, 25]. Earlier works dealing with the training of military observers already show that augmented and mixed reality can replace part of live training. Of particular importance is the possibility of freely simulating targets, supporting elements, or the effects of fire [26].

More recent works focused directly on military education in the field of fire support emphasize the importance of realistic 3D models, the integration of authentic military assets, the use of geographic and topographic data, and the embedding of simulation into the broader framework of educating students in artillery specializations [27]. This direction is important because it indicates a shift from isolated technological demonstrators toward training systems linked to the specific needs of professional military education [28].

In addition to immersion itself, the issue of objective performance assessment is also appearing more and more frequently. Many solutions do enable realistic visualization and interaction, but they support automated or semi-automated user evaluation only to a limited extent. The importance of this gap increases especially in activities that are procedurally well defined and whose quality depends on the correct sequence of steps, reporting accuracy, and time discipline. Call for Fire clearly belongs to this category, where success depends not only on locating the target, but also on the correct structure of voice communication, speed, and the ability to make corrections in cooperation with the Fire Direction Center (FDC) [29]. It is precisely here that space opens up for the use of artificial intelligence and tools for the automated analysis of voice input [30].

A significant trend can therefore be seen in the integration of artificial intelligence. Here, AI does not function merely as a tool for scenario generation or the control of virtual entities, but increasingly also as a means of performance evaluation, input data interpretation, and decision support [31]. More recent studies show that AI can contribute to more adaptive, personalized, and data-driven training [32]. In the context of tactical and command activities, the need is simultaneously emphasized to connect AI with a specific military procedure and not to use it merely as a technological add-on without clear operational significance [33].

The VR-AR Simulator Kit, developed as a modular system to support teaching and research at the Department of Fire Support of the University of Defence, responds to these shortcomings. The system is built on the Unity VR/MR platform and combines mixed reality tools, real-time network cooperation, voice control, and AI-based speech recognition [34]. Its architecture is based on the separation of the control component from the simulation environment itself and on the distinction between the roles of Supervisor and Student. The instructor prepares and manages the scenario through the Holotable interface, while the trainee performs training tasks in a realistic virtual environment. The system includes several training modes, ranging from familiarization with the Moskito TI device through Grid and Polar scenarios to field training with a voice-based CFF procedure in the English language. The solution also contains an analytical layer enabling the recording of session progress, reaction times, error rates, help usage, and communication transcripts [35].

This paper presents the system as a tool for immersive fire request training and, at the same time, as a means of more objective and data-driven evaluation of such training. The paper aims to demonstrate that technological innovation in training should not replace established procedures, but rather strengthen their standardization, clarity, measurability, and repeatability. In this sense, the integration of VR/AR technologies, artificial intelligence, and analytical evaluation may represent an important step toward improving the quality of preparation of forward observers for the conditions of the contemporary battlefield [36, 37].

2. System Architecture and Methodology

The present paper is based on the design, implementation, and pilot validation of the VR-AR Simulator Kit system, which was developed as a modular application in augmented, virtual, and mixed reality to support science, research, innovation, and education. From a methodological point of view, this is applied research aimed at creating a functional training solution that integrates an immersive environment, instruction with a selected sensor for target observation, procedurally standardized Call for Fire (CFF) practice, voice communication, elements of artificial intelligence, and analytical evaluation of user performance. The system was not designed merely as a standalone technological demonstrator, but as a training platform capable of supporting multiple levels of forward observer preparation while at the same time reflecting the logic of the broader fire support system.

The application was built on commercially available Meta Quest 3 hardware, which makes it possible to distribute it to multiple devices within a relatively short period of time and also creates conditions for future transfer to newer platforms. From the outset, the solution was designed with an emphasis on modularity and long-term extensibility, so that it can be continuously modified in the event of procedural changes, the addition of new requirements for scenarios, equipment, or training tasks, and similar needs. At the same time, the system can be further developed by building entirely new modules focused on issues that will be currently required with regard to the present and future situation on the battlefield and the needs of training or education. This approach fundamentally changes the view of military simulators, which are often closed, difficult to modify, and tied to specific hardware solutions. Their further expansion, increase in the number of devices, or adaptation to new requirements is therefore often limited, or requires the repeated purchase of a new system at considerable financial cost.

The user interface is designed with an emphasis on intuitiveness, the minimization of cognitive load, and realistic interaction. The system is controlled by natural hand gestures, which corresponds to current trends in mixed reality applications and supports the natural movement of the user when working with virtual objects. An important role is also played by spatial anchoring, that is, the anchoring of virtual elements in real space, thanks to which the user can, for example, walk around the Holotable and observe the situation from different angles. In training modes, the student is guided by instructional voice-overs, while the system simultaneously provides visual feedback during measurement, targeting, or the completion of individual scenario steps.

A fundamental part of the system methodology is the automatic collection of analytical data, which takes place in the background of each training session. Recording begins at the moment the simulation is launched, and the collected data are sent to the backend server after the session is completed. The system records both general identification data and detailed performance metrics. These include in particular User ID, Session ID, Timestamp, scenario name, session status, total duration, the number of attempts required to complete the task, communication transcript, help usage time, the duration of individual steps, and information on whether specific parts of the scenario were skipped.

This analytical layer is of crucial importance for the objectification of training. The instructor is no longer dependent solely on personal observation or partial subjective evaluation, but has access to a data record enabling both retrospective analysis and long-term monitoring of the student's development [38].

From the technical perspective, the application is developed in the Unity 3D environment, which provides 3D graphics rendering, physics simulation of objects, and management of application logic. Network communication between session participants is provided by Normcore, which synchronizes object transformations, scene state variables, and room connections based on pairing codes. User interaction is implemented using the Meta Interaction SDK, which enables hand tracking, work with controllers, object manipulation, and the anchoring of virtual elements in space. Speech processing and language functions are handled through the Wit.ai platform, both in the voice-to-text and text-to-voice directions. Geospatial data, elevation models, and satellite imagery are provided by the Mapbox SDK, which is used for the creation of tactical maps as well as the terrain environment [39]. The system backend is based on communication via REST API and data persistence in a MongoDB database [40]. The server infrastructure simultaneously ensures user management, storage of analytical records, handling of voice communication recordings, and dynamic management of 3D models [41].

The application architecture is conceived as a comprehensive modular system whose functional scope and user interface are dynamically derived from the assigned user role [42]. The basic principle is the separation of the control component from the simulation environment, which enables not only realistic student training, but also active instructor supervision over the course of the session, its configuration, and its subsequent evaluation. From a methodological perspective, however, even more important is the fact that the entire platform was designed as scalable and extensible, which enables the future addition of further scenarios, devices, or expansion to other links in the fire support command and control chain.

After launching the application, the user is prompted to log in and choose a role. The administrator, that is, the Supervisor, verifies identity by entering an access code, while a regular user in the role of student logs in by selecting an identifier. In this way, the system simultaneously provides role management and basic access permissions. After successful login, the user is directed to the relevant module through the main menu, which serves as a gateway to either the control or the training part of the system. The Supervisor role is intended for the instructor, who prepares the scenario, sets simulation parameters, launches the training, monitors its progress, and works with the planning and control interface. The Student role is intended for the trainee, who performs the role of task executor corresponding to the procedures of learning, observation, target localization, and requesting fire in the simulated environment without the need for complex system configuration.

2.1. Supervisor Module

The control component of the system is represented by the Supervisor module, the core of which is the Holotable interface (planning table). This interface uses elements of mixed reality to anchor a virtual tactical map into real space and enables the instructor to work with the training scenario in the form of a spatially displayed battlefield, as shown in Figure 1. The Holotable serves not only for session configuration, but also for continuous supervision of the student. Here, the instructor can monitor tactical reports and system responses, verify whether the target is visible from the given position, and monitor the resulting projectile impact, which makes it possible to assess mission success. In this way, the student's individual performance is embedded within the broader framework of fire effect control and evaluation.

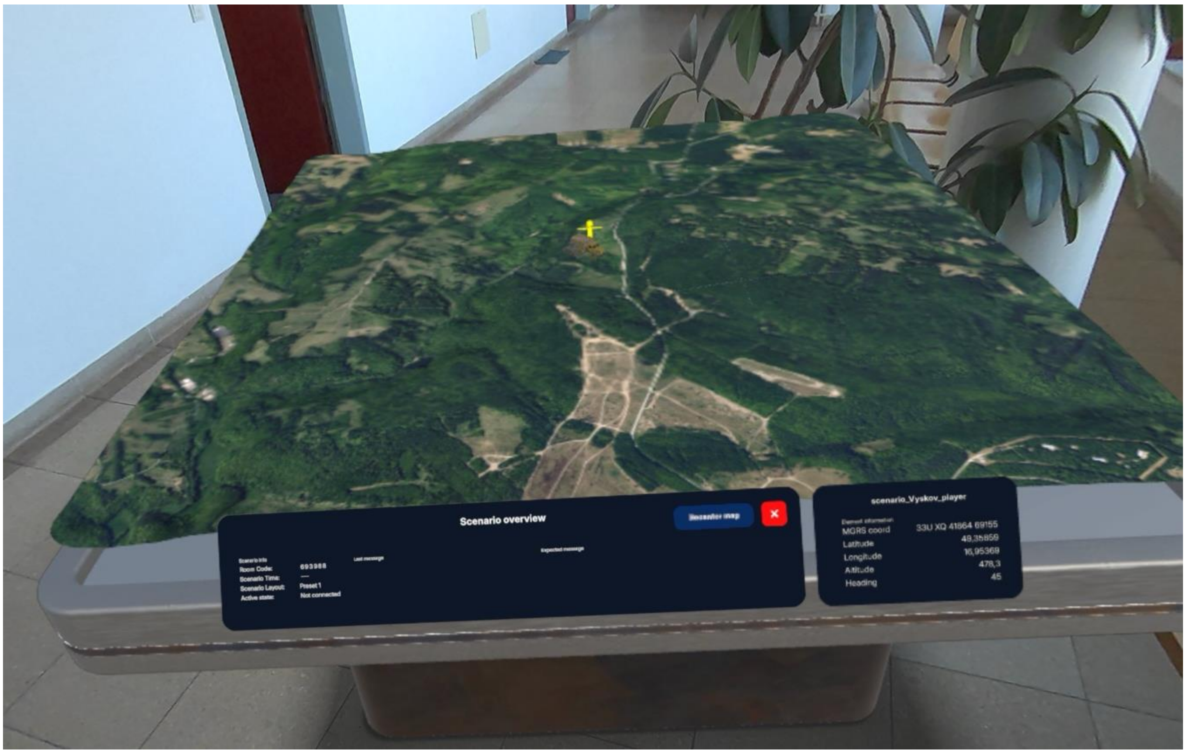

Fig. 1. Holotable interface for training scenario control and supervision.

The Supervisor has access to a set of tools for simulation configuration. The instructor can choose from several pre-prepared scenarios, generate a unique access code for the student role for a specific session, and subsequently activate it באמצעות the Start Scenario function. An important feature of the system is the possibility of further scenario adjustment through an accompanying configuration file stored in the smart glasses device. At this level, it is possible to modify the student's coordinates, the target's coordinates, the number of targets, and their type. Such a solution increases the flexibility of the system and makes it possible to prepare not only fixed training situations, but also partially variable scenarios corresponding to different educational objectives and conditions.

2.2. Student Module

The Student module is intended for the actual execution of training. Four basic types of scenarios are available, ranging from elementary equipment handling to fully procedural training of voice-based Call for Fire (CFF).

The first scenario, Moskito TI Equipment Training, is focused on technical mastery and familiarization with the use of the Moskito TI sensor device without time stress. Here, the user interacts with a realistic 3D model of the device, can virtually grasp it, inspect it from different angles, and become familiar with its ergonomics, as shown in Figure 2. Instructional voice-overs simultaneously explain the individual parts of the device and their functions. The student thus learns basic operations such as distance measurement, switching between thermal imaging and night vision modes, and general work with the observation device. This scenario serves as the entry level of training, building technical confidence before transitioning to tactical tasks and, in particular, providing thorough instruction.

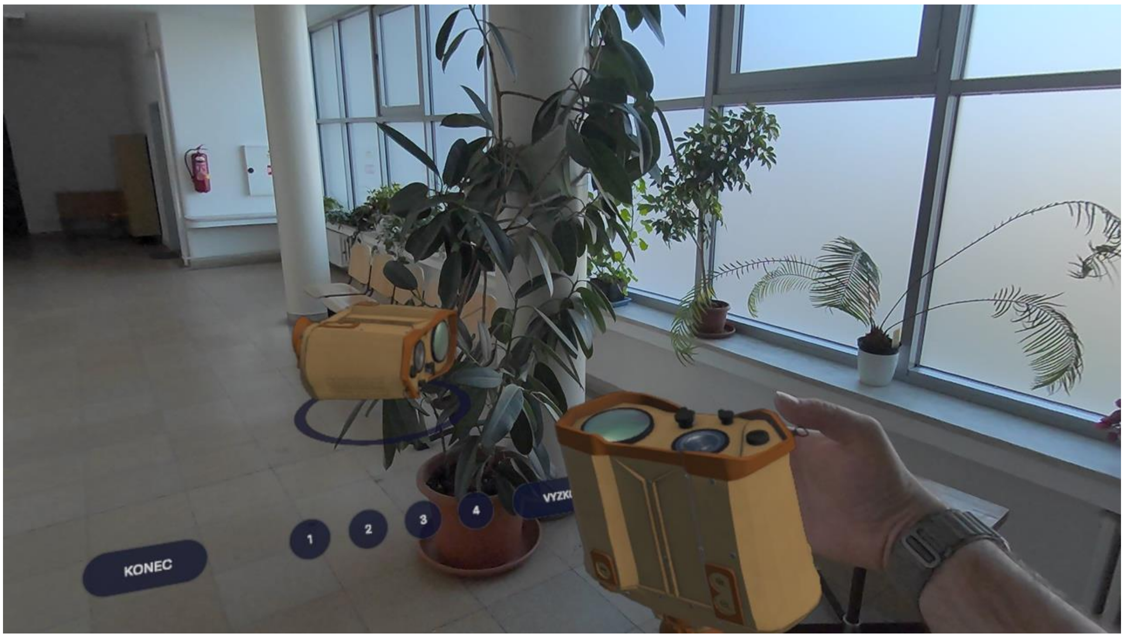

Fig. 2. Moskito TI Equipment Training scenario.

The second scenario is Forward Observer Training – Grid, which represents a basic tactical model focused on target identification and the transmission of its location using grid coordinates, as shown in Figure 3. The student is placed in a realistic 3D environment with visual contact with an enemy target. The task is to use the Moskito TI device to target the objective, read the exact coordinates, and then practice reporting them correctly. The entire process is accompanied by instructional voice guidance. This scenario already integrates work with the sensor, basic spatial orientation, and the procedural aspect of transmitting observational data.

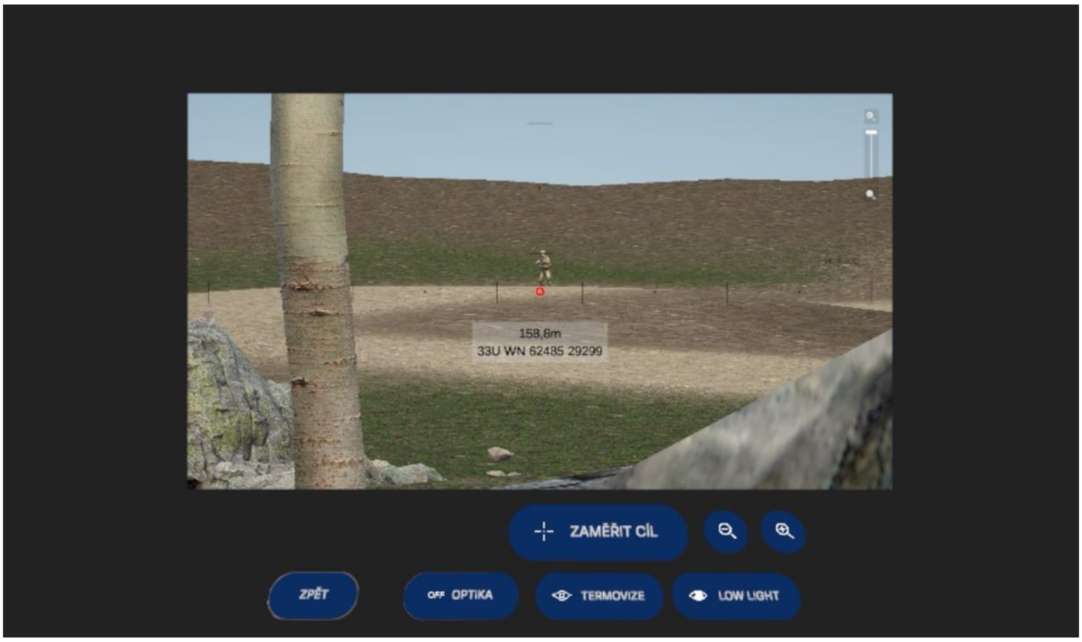

Fig. 3. Target localization using the Moskito TI device in the Forward Observer Training – Grid scenario.

The third scenario, Forward Observer Training – Polar, represents a more advanced training variant in which the student uses several tools simultaneously. In a realistic environment, the student combines the use of a compass, a GPS receiver, and a laser rangefinder, as shown in Figure 4. Successful task completion requires their coordinated use and the correct acquisition of the data needed to determine the target using the polar method. The obtained data are entered by the student into the interface input fields, and the process is completed by the simulated transmission of a fire request through a radio device. This scenario develops the ability to combine multiple information sources and to transfer acquired data into the correct procedural form.

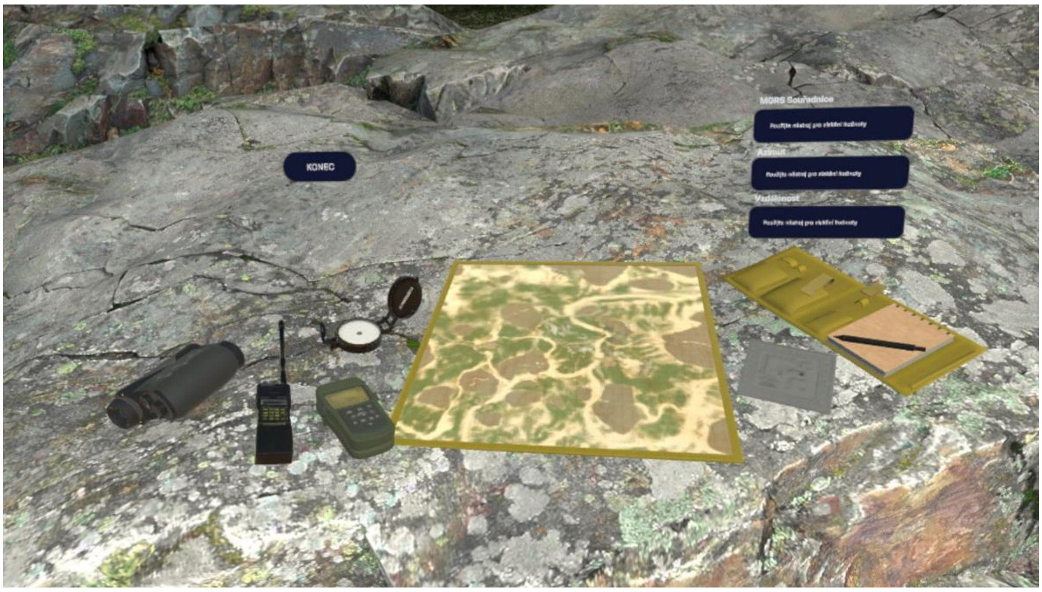

Fig. 4. Employment of navigation and targeting tools in the Forward Observer Training – Polar scenario.

The highest level is represented by the Field Training scenario, which simulates a real combat situation with the requirement of voice communication in the English language, as shown in Figure 5. After entering the unique code received from the Supervisor, the user is automatically connected to the running session. This approach eliminates the need for independent system configuration and makes it possible to focus exclusively on task execution. In this scenario, the student first uses the Moskito TI device to detect and localize the enemy and subsequently performs the Call for Fire procedure through voice input. Here, the system analyzes voice commands, evaluates the accuracy of the phraseology used, and responds in natural language as a simulated fire operator. The student must go through the entire standardized sequence, including unit identification, warning order, determination of target location, target description, fire command, subsequent observation of impact, and possible corrections up to the final battle damage assessment. Training thus achieves high procedural fidelity while at the same time enabling repeated practice without the need for real fire or the deployment of additional personnel.

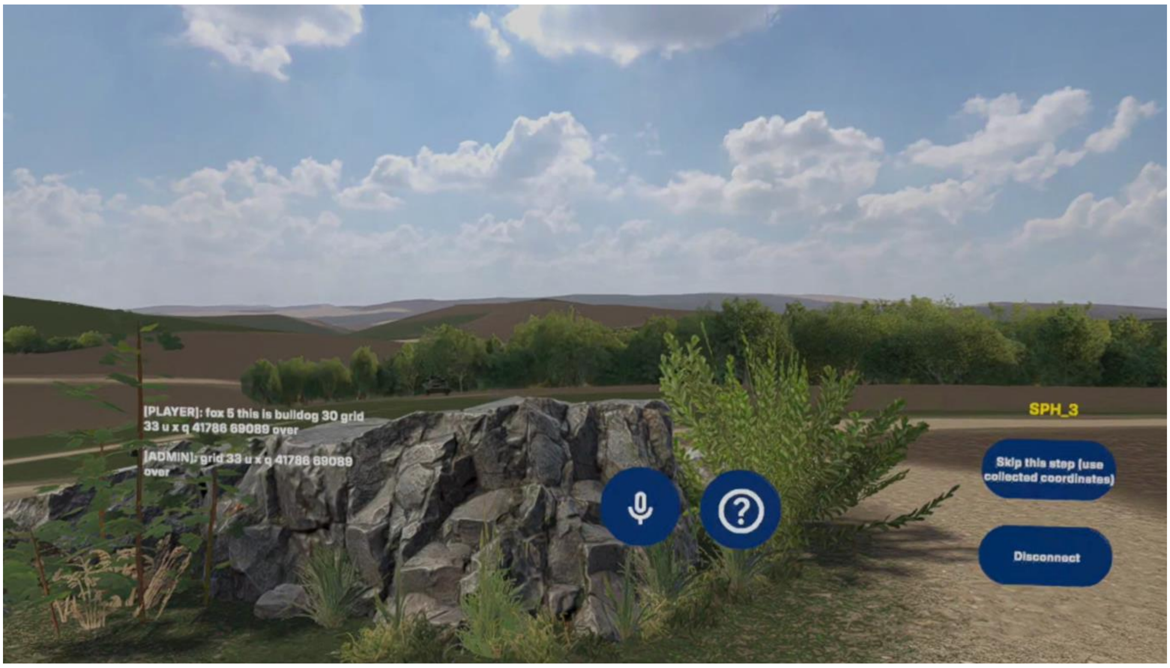

Fig. 5. Observer environment in the Field Training scenario with target localization and AI-assisted voice communication.

3. Results and Discussion

The results of the present study are based on the design, implementation, and pilot validation of the VR-AR Simulator Kit system as a modular training platform for practicing the Call for Fire (CFF) procedure in the context of fire support. The fundamental result of the work is the verification that the proposed solution is technically functional, procedurally usable, and at the same time sufficiently flexible for further development and adaptation to changing military training requirements. The pilot validation confirmed that the system is capable of integrating a realistic immersive environment, voice-guided communication, instructor supervision, and analytical performance evaluation into one functional whole.

The pilot validation of the system was carried out in a controlled training environment through a standardized scenario including the full Call for Fire sequence. During the testing, the technical stability of the system, the accuracy of voice recognition, the continuity of the individual procedural steps, the time parameters of the task, and the basic error rate were monitored. At the same time, qualitative user feedback was collected, especially in relation to perceived realism, clarity of instructions, and the usability of the system for CFF training.

From a technical point of view, it was confirmed that the role-based architecture based on the separation of the Supervisor and Student modules enables effective organization of training. Through the Holotable interface, the instructor can prepare a scenario, modify its parameters, launch the session, and simultaneously monitor the student's activity in real time. The student, in contrast, enters an already prepared environment and focuses exclusively on task execution without the need for additional system configuration.

Another significant result can also be considered the verification of the functionality of the individual training scenarios. Pilot testing showed that this multi-level structure is suitable for the gradual building of skills and that it allows training to be differentiated according to the student's level of preparedness. The pilot validation further confirmed the functionality of the AI-supported speech recognition and evaluation layer, which represents one of the most significant innovative parts of the proposed solution. The system was able to analyze the student's voice input, evaluate the correctness of the phraseology used, and control the continuity of the individual steps of the standardized CFF procedure. This created the possibility of objective and reproducible performance assessment, which goes beyond ordinary subjective instructor feedback. The recorded metrics showed that, during repeated completion of scenarios, reaction time was shortened and users' procedural confidence improved. At the same time, the possibility of storing communication transcripts, session duration, number of attempts, duration of individual steps, and help usage was confirmed, which creates a solid basis for further analytical processing of performance.

Preliminary findings from the pilot validation simultaneously indicate that the first participation in the experiment had a positive effect on the speed of understanding the instruction as well as on the subsequent application of the acquired knowledge in practice. Participants demonstrated faster mastery of working with the Moskito TI device after completing the introductory training scenario, which was subsequently reflected in its use in follow-up tasks and in real practical activity. At the same time, the first participants showed progress in understanding the working procedures of FO and JFO in requesting fire support through the Call for Fire procedure. A particularly important benefit proved to be the feedback based on AI analysis of communication, which directly identified problematic points in the users' procedure, for example errors in the reporting sequence, in phraseology, or in the completeness of the transmitted data.

The discussion of the results simultaneously confirms the conclusions stated in the literature, according to which it is not only the mere presence of immersive technology that is decisive, but above all its meaningful pedagogical and procedural grounding. Some earlier works show that a higher level of technological fidelity does not automatically lead to greater accuracy or speed of decision-making if the simulation is not firmly linked to a specific training objective [43]. In this respect, the VR-AR Simulator Kit confirms that greater added value is not provided only by realistic visualization of the battlefield, but especially by the integration of spatial perception, interaction with tools, voice communication, and the sequential logic of military procedure into one consistent scenario. It is precisely this integration that proves to be the main advantage of the system.

The final important result can be considered the technological solution of the system itself. The choice of commercially available Meta Quest 3 hardware and an architecture built on the Unity 3D platform created the possibility for relatively rapid distribution across multiple devices and for future expansion of the system.

4. Conclusions

The proposed VR-AR Simulator Kit system solution integrates a modular system architecture, the means of virtual, augmented, and mixed reality, voice communication, and elements of artificial intelligence into a single training complex that meets current requirements for the safety, repeatability, measurability, and flexibility of military preparation.

A significant contribution of the proposed system is its ability to connect the individual training of a forward observer's activities with the broader framework of fire support command and control. Thanks to the separation of the Supervisor and Student roles, the use of the Holotable environment, and the multi-level structure of the training scenarios, an environment is created in which both the technical mastery of equipment and procedural confidence in requesting fire can be developed. Of particular importance in this respect is the Field Training scenario, which integrates target identification, work with the sensor, the correct conduct of voice communication, and subsequent fire corrections into one coherent task. In this way, the system approaches the real requirements imposed on FO and JFO specialists, and it is therefore possible to use this system as a supplementary tool that can make demanding training more efficient.

The pilot validation simultaneously confirmed the technical functionality of the system as well as its training potential. Preliminary measurements and the initial experience of the participants indicate that completing the experiment contributed to faster understanding of the instruction, and improved understanding of the issue of requesting fire support was also observed. The mechanism of AI-supported feedback, which directly showed users the problematic points of their performance, proved to be especially beneficial.

At the same time, however, the limitations of the presented study must also be acknowledged. The pilot validation was carried out in a controlled environment and with a limited number of participants, and therefore it does not yet allow fully generalizable conclusions to be formulated regarding the long-term effectiveness of the system or the transfer of acquired skills into live training or real operational activity. Another limitation remains the system's dependence on a specific technical infrastructure, as well as the fact that the accuracy of voice recognition may be influenced by differences in pronunciation, language variability, or environmental noise. These facts do not reduce the value of the presented solution; rather, they define the boundaries of its current applicability and indicate directions for further development. Future research should therefore focus in particular on expanding the experimental sample, quantifying long-term training effects, further refining language models for voice recognition, and deeper integration of the system with other elements of fire support command and control.

Overall, it can be concluded that the VR-AR Simulator Kit represents a promising tool for the modernization of training for forward observers and fire support specialists. Its main contribution lies in its modularity, openness to further development, the use of commercially available hardware, and its ability to combine immersive training with objective evaluation of procedurally demanding activities. Under the conditions of the present and future battlefield, where the importance of reaction speed, interoperability, and precision of fire is increasing, such a solution may represent an important step toward more effective, more flexible, and data-supported military preparation.

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