Methodology for rapid development of tactical medicine VR simulators using generative AI and photogrammetry

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Abstract

The article presents an approach to developing an interactive VR/AR simulator for first aid in crisis and war situations, utilising generative artificial intelligence (Stable Diffusion, Tripo, Meshy, Trellis3D) and mobile photogrammetry. The goal of the study is to create a safe, realistic and economically optimised learning environment implemented on the Unreal Engine 5 game engine. The proposed methodology allows for a significant reduction in the cost of creating 2D/3D content due to automated model generation and the experimental method of "damaged realism" – a deliberate reduction in the number of input photogrammetric frames for modelling destroyed objects. The MVP prototype implements key VR mechanics, including a combined movement system (Smooth Locomotion with teleportation), physical interaction with medical instruments (Grabbable Objects), spatial audio, and the integration of instructional videos. The experiments carried out confirm the effectiveness of combining GMI and photogrammetry for the rapid development of specialised simulation environments, capable of improving the quality and effectiveness of training in first aid skills.

Keywords

VR/AR simulation, first aid, generative artificial intelligence, Unreal Engine 5, photogrammetry, "damaged realism", medical simulators, immersive technologies, 3D modelling, tactical medicine.

1. Introduction

The relevance of providing quick and effective first aid in wartime and emergencies is critically high. Traditional teaching methods are often limited to theory and static dummies, which do not provide adequate psychological and practical preparation for stressful conditions, which are accompanied by injuries, bleeding, shock and limited time for decision-making.

This research aims to develop an innovative approach to training first aid skills by creating an interactive VR/AR simulator (Virtual/ Augmented Reality) based on the Unreal Engine 5 game engine. A key feature of the project is the use of generative artificial intelligence (Generative AI), such as Stable Diffusion, Trellis3D, and Tripo, to quickly create realistic and unique 2D and 3D content, including destroyed city scenes, damaged objects, and models of victims with characteristic injuries. The project encompasses the entire development cycle, beginning with the creation of a business model (using a Business Model Canvas) and the detailed planning of a Work Breakdown Structure (WBS). As part of the implementation, the VR scene of a city street after a missile strike was successfully prototyped, key VR interaction mechanics such as Smooth Locomotion and the Grabbable Objects system were implemented, physical collisions were configured, and educational and atmospheric content (UMG menu, video instructions, spatial audio) was integrated. Additionally, an experiment using photogrammetry was conducted to create unique real-world assets.

The purpose of the study is to develop an information technology to create a safe, flexible and realistic learning environment based on virtual reality in Unreal Engine, which allows users (military, medics, students and civilians) to practice critical skills of first aid in conditions as close

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as possible to combat, war/crises, using VR/AR format and game mechanics WBS and practical solutions, including:

1. Develop the concept and architecture of the VR/AR simulator, including the formation of the target audience, value proposition, and key resources (according to the Business Model Outline).
2. Create visual content (2D and 3D) for the VR/AR scene using generative artificial intelligence (GAI) (Stable Diffusion, Leonardo.Ai, Trellis3D, Meshy, Tripo) to simulate the destroyed environment and victims.
3. Develop a VR project in Unreal Engine through the VR Template and build a basic structure of the VR scene.
4. Organise content migration, set up collisions for 3D models, and use photogrammetry to create unique real-world asset sets.
5. Implement key VR interaction mechanics, including Smooth Locomotion, teleport, and Grabbable Objects settings for medical instruments.
6. Integrate training elements and user interface (UI/UX), in particular, create a VR menu, add spatial audio accompaniment, and embed training video instructions (Triage, CPR, Bleed Stop, etc.).
7. Test the VR project among the control group of participants in the experimental trial.

The object of research is the processes of development, integration and optimisation of content and mechanics of virtual (VR) and extended (AR) reality for the creation of educational simulators. The subject of the study is an interactive VR/AR simulator for first aid in crisis and war situations, implemented using the Unreal Engine 5 game engine.

The scientific novelty of the study is as follows:

1. System integration of GAI for accelerated development of VR scenes, in particular, for the first time, a combination of GAI tools (Tripo, Meshy, Trellis3D) and the Unreal Engine 5 game engine was used to quickly create specialised and highly detailed content (casualties, ruins, injuries), which significantly reduces the development time of MVP (Minimum Viable Product).
2. Experimental use of incomplete data in photogrammetry, including experimental evidence that a conscious reduction in the number of photographs (e.g., 37.5–62.5% of the recommended number) in mobile photogrammetry (RealityScan) can be used as a creative method for modelling "affected zone" style assets (incomplete detail, mesh distortion), which is relevant for military simulations.
3. Development of a combined movement system for VR comfort, in particular, implemented and tested a combined approach to navigation that combines Smooth Locomotion and teleportation to ensure maximum immersion and minimise VR sickness.

The practical value is as follows:

1. Creation of a functional prototype of a VR simulator/simulator with an interactive scene of assisting a missile strike, which has direct applied value for the Ministry of Defence, the Red Cross, the Ministry of Health, military academies and public organisations.
2. Realistic training that provides a safe way to practice critical skills (tourniquet, CPR, Triage) without risk to real people, preparing users for stressful conditions (simulation of shock, panic).
3. A ready-made methodology for quick content creation, as clear instructions and comparison tables are provided for the use of free/paid GAI tools (2D/3D) and 3D model platforms, which can be used by developers to quickly fill VR projects.

Multiplatform and accessibility, in particular, the project provides support for both high-quality VR headsets and mobile AR applications, providing flexibility and accessibility for learning.

2. Problem statement

The challenge of the study is to develop and optimise a model of a highly realistic, interactive and accessible simulation environment for training first aid skills, which are critical in conditions of limited time and stressors inherent in crisis and military situations. The key task is to maximise the effectiveness of training E_{nach} while minimising the cost of developing a product S_{rr} and the time to bring it to the market T_{MVP}, utilising the resources of the GAI to create high-quality content.

Learning effectiveness is defined as the weighted sum of key indicators reflecting immersion depth R, level of interactivity I, feedback quality F, and the correctness of critical skills A_{kr}.

$$E_{nach} = \sum \omega_j \cdot P_j \to max, \quad j = 1, N, \quad \sum \omega_j = 1, \tag{1}$$

where P_j is an indicator of efficiency according to the j-th criterion, in particular, $P_1 = R$ (realism of the scene and immersion) at R ∈ [0, 1], $P_2 = I$ (VR/AR interactivity) at $I \in [0, 1]$ (interaction with objects, use of controllers), $P_3 = F$ (quality of feedback and evaluation) at $F \in [0, 1]$ (reaction time, correctness of tourniquet application, error analysis), and $P_4 = A_{kr}$ (accuracy of the algorithm of actions) at $A_{kr} \in [0, 1]$ (adherence to Triage protocols, CPR), ω_j is the weight factor of the importance of the criterion ($\sum_{j=14}$, $\omega_j = 1$).

The cost of developing a product Srr and the time to market TMVP should be minimised through the use of GAI.

$$S_{rr} + \alpha \cdot T_{MVP} \to min, \tag{2}$$

where T_{MVP} is the total development time of the MVP (42 weeks according to the Work Breakdown Structure, WBS), S_{rr} is the total cost of development, and α is the weight factor (representing the cost of time).

Taking into account the contribution of the GAI:

$$S_{rr} = C_{trad} \cdot (1 - S_{GAI}) + C_{GAI}, \tag{3}$$

$$T_{MVP} = T_{trad} \cdot (1 - \delta_{GAI}), \tag{4}$$

where S_{GAI} is the share of saved costs for 3D modelling/concepts due to GAI, δ_{GAI} is the share of time saved on 3D modelling/texturing due to GAI (e.g., Trellis3D, Meshy, Tripo, Stable Diffusion), C_{GAI} is the cost of licenses, server capacity, and AI tools.

The project must comply with the following restrictions:

1. Technological limitations: P_{tech} ∈ {Unity, Unreal Engine 5} ∧ V_{tech} ∈ {VR headsets, Mobile AR devices}.
2. Time limits (with WBS): $T_{MVP} \leq 42$ weeks.
3. Limitations of realism and correctness (with certification): $A_{kr} \geq A_{min}$, where A_{min} is the minimum threshold of accuracy that corresponds to the official protocols of first aid (Ministry of Health, Red Cross).
4. Localisation restrictions: $L \geq L_{min}$, where L is the number of supported languages and cultural adaptations of content (including English, Chinese, Spanish).

Thus, the task of the study can be formulated as a multi-purpose optimisation task: to find the optimal combination of development parameters (choice of technologies, level of integration of GAI and allocation of resources), which maximises the effectiveness of training E_{nach} in compliance with all technological, time and regulatory constraints, while minimising the overall costs and time of MVP development.

3. Related works

An analysis of the literature and related developments reveals a rapid increase in interest in the use of immersive technologies (VR/AR) and GAI to enhance learning effectiveness, particularly in critical areas such as medicine and military training. The research presented in the file combines three key scientific and practical areas, each with a substantial research base. Over the past decade, VR simulations in tactical and emergency medicine have been proven to be a highly effective alternative to traditional dummies, especially for training complex, high-risk, and low-frequency events [1–2]. In particular, research highlights the ability of VR environments to recreate any patient condition in any environment [3], a capability that is not possible with physical simulators. Research similar to that of Immersiveness confirms that immersive technologies significantly enhance learning effectiveness and user satisfaction in emergencies [4–5]. The study of the efficacy of TacMedVR emphasises the importance of assessing interaction and response to stress [4], which directly correlates with the value proposition of this project (simulation of emotional reactions of victims, learning under pressure) [6–12].

The use of VR simulators, such as the SimX platform [2], has confirmed their superiority in developing critical thinking, effective information communication, and enhancing team dynamics in assisting in wartime (Damage Control Resuscitation/Surgery) [11]. The context of teamwork and critical thinking directly justifies the need for development focused on combat scenarios. Traditional modelling of 3D content is the most resource-intensive and time-consuming stage of simulator development. Therefore, based on GAI and the automation of 3D content (Tripo, Meshy) for the accelerated creation of 3D objects, it is part of a global trend. Modern developments, particularly the integration of GAI, such as Ludus AI, into Unreal Engine 5.5 [6], demonstrate a paradigm shift [7]. The workflow acceleration approach enables you to generate 3D models from text descriptions and images in near real-time, which drastically reduces development time (TMVP in terms of WBS project). While traditional modelling still offers more precise detail [6], platforms like Sloyd (not indexed in the list) and Rodin AI (not indexed in the list) are actively developing the ability to create high-quality, game-optimised 3D models from text or images, confirming the viability of the chosen method for creating assets (ruins, damaged objects) for the simulator [13–26]. The use of photogrammetry to create 3D models of real-world objects (e.g., a swing) demonstrates a desire to enhance the photorealism of the scene, thereby improving the quality of learning in realistic environments. It aligns with the direction of research that utilises this technique to create learning resources [27–35].

Photogrammetry is a cost-effective and accessible method [8, 9] for creating highly detailed, realistic 3D models of anatomical preparations or real objects for medical education. Its integration into engines like Unity [8], or evaluation in RealityCapture [10] confirms that this technology significantly enhances immersion and realism [9] in simulation environments. A special novelty of modern VR projects lies in a creative approach based on a deliberate reduction in the quality of input data for photogrammetry, aiming to achieve the effect of damaged content. Although most studies (e.g., [3, 10]) focus on maximising accuracy (60–80% overlap, noise minimisation), the proposed approach using RealityScan to create "hit zone" objects is unique in the context of content creation for military simulators.

4. Materials and methods

The development and implementation of an interactive VR/AR simulator for first aid is based on an interdisciplinary approach that combines methodologies from game design, computer graphics, reality modelling (photogrammetry), and generative artificial intelligence (GAI) technology. The experimental part focuses on creating a minimum viable product (MVP). For project management and cost control, the Work Decomposition Structure (WBS) methodology and the Gantt Chart were utilised. The project is divided into six key stages:

Table 1
Structural Decomposition and Approximate Time Planning (WBS & Gantt Chart)

Stage (E_i)	Name	Duration (T_i, weeks)	Estimated dates
E_1	Research and planning	$T_1 = 8$	28.04.25 – 15.06.25
E_2	MVP Development	$T_2 = 15$	02.06.25 – 21.09.25
E_3	Testing and improvement	$T_3 = 6$	22.09.25 – 02.11.25
E_4	Marketing and promotion	$T_4 = 4$	03.11.25 – 30.11.25
E_5	Scaling & Partnerships	$T_5 = 8$	01.12.25 – 14.02.26
E_6	Project Management	$T_6 = 42$	28.04.25 – 14.02.26

The total duration of the T_{zag} project:

$$T_{zag} = max(T_i), \quad i \in \{1, \ldots, 6\}. \tag{5}$$

Therefore, $T_{zag} = T_6 = 42$ weeks (taking into account parallel management). The target audience of AI is segmented into scenarios $A = \{A_{st}, A_{gr}, A_{vik}\}$, where Ast refers to pupils, students, and teachers, Agr relates to citizens, volunteers, and A_{vik} refers to military personnel, doctors, and instructors.

Key MVP scenario: city street after a missile strike/mine explosion. The scenario has four types of victims, classified according to the Triage system: $P = \{P_{crit\_dit}, P_{crit\_mat}, P_{ser\_op}, P_{leg}\}$, where P_{crit_dit} is a child (7 years old) with respiratory arrest (CPR); P_{crit_mat} – mother with severe bleeding (tourniquet); P_{ser_op} – a man with burns (shock); P_{leg} – minor injuries.

To accelerate the creation of assets (3D models of buildings, vehicles, and characters), GAI tools were utilised, specifically neural networks: G = {Tripo, Meshy, Trellis3D}. The primary methods are Text-to-3D and Image-to-3D, and the supported export formats are OBJ, FBX, and GLB/GLTF. To maximise the quality of 2D concepts and 3D models, a detailed Q_{prompt} containing the object, scenario, style, lighting and detail, i.e was used Q_{prompt} {"Low-poly city street after a missile strike with stylised lighting"}. To create assets with a high level of realism that simulate damage, mobile photogrammetry (utilising the Samsung Galaxy A52 and RealityScan) was employed. The experimental method of "corrupted realism" involves the deliberate reduction of the number of input frames, N_{photo}, to induce non-critical distortions of the grid and textures. The condition of the experiment is N_{photo} ([30, 50] frames). The recommended range is N_{rekom} ([80, 100] frames). Scan objects are the main urban elements of the sleeping array, for example, models of a children's swing. The output format is GLB. The working environment utilises the Unreal Engine 5 (UE5) game engine, featuring a basic template, as shown in Figs. 1-3 – VR Template. The scene components include VRPawn (virtual player character) and NavMeshBounds Volume (navigation area for teleportation). For the Locomotion relocation system, a combined approach was used:

$$L_{teleport} \oplus L_{smooth}, \tag{6}$$

where $L_{teleport}$ – teleportation (to avoid VR disease); L_{smooth} – Smooth Locomotion (smooth movement using analogue controller joints).

For medical instruments (tourniquet, scissors), class Grabbable_SmallCube with physics activation is used. Capture condition:

G:{*Object* ∈ *Grabbable_Component* ∧ *Simulate Physics* = true ∧ *Collision Preset* = *PhysicsActor*}.

For all imported Static Mesh (including GAI models), Simple Collision was used to optimise VR performance: *Collision* ⟶ *Add Box Collision*/*Convex Decomposition* ⟶ *Apply* ⟶ *Save*. Content integration, in particular, import of generated models, was carried out in FBX format with subsequent manual adjustment of PBR textures in the Material Editor.

For the User Interface (UI), the WidgetMenu (UMG Blueprint) has been modified to add the "Instructions" and "Settings" buttons. Multimedia integration:

1. Tutorial Video – 5 video instructions (Triage, CPR, Bleed Stop, Burn, Panic) displayed on the Static Mesh Plane via Media Player.
2. Spatial Audio – 2 key sound effects are implemented: Siren S: *Audio Actor* ∧ *Auto Activate* = true ∧ *Looping* = true; Missile hit R: *Audio Actor* ∧ *Activate with Delay* = 10,0 s ∧ *Looping* = false.

VR Immersion Z:

$$Z=\alpha_R \cdot R_{viz}+\alpha_I \cdot I_{mech}+\alpha_A \cdot S_{Aud}, \tag{7}$$

where R_{viz} is the realism of visual content (GAI, photogrammetry); I_{mech} – interactivity (Smooth Locomotion, Grabbable Objects); S_{Aud} – audio quality (sirens, explosions), α – weight factors.

The evaluation of the training E_{nach} quality was based on the effectiveness of the training, as defined in the problem statement, which is a key tool for assessing the achievement of the research objective.

$$E_{nach}=\sum \omega_j \cdot P_j \rightarrow max, \quad j=1,N, \quad \sum \omega_j=1, \tag{8}$$

where ω_j is the weighting factor of the importance of the criterion (Σ_j = 14 ω_j =1), and P_j is the performance indicator according to the j-th criterion, which are measured during alpha and beta testing (Stage E_3):

1. P_1 = R (scene realism and immersion) – evaluated by feedback from specialists (alpha testing) at $R \in [0, 1]$.
2. P_2 = I (VR/AR interactivity) – evaluated by the intuitiveness of control (beta testing) at I∈[0,1] (interaction with objects, use of controllers).
3. P_3 = F (quality of feedback and evaluation) – evaluated by the system of automatic evaluation of actions at F∈[0,1] (reaction time, correctness of tourniquet application, error analysis).
4. P_4 = A_{kr} (accuracy of the algorithm of actions) – evaluated on the basis of compliance with first aid protocols at $A_{kr} \in [0, 1]$ (adherence to Triage protocols, CPR).

Testing took place in three stages:

1. Internal testing (functionality, performance).
2. Alpha testing (specialists: doctors, military instructors) – validation of the realism of scenarios and algorithms.
3. Beta testing (volunteers, students) – assessment of UX/UI and intuitiveness.

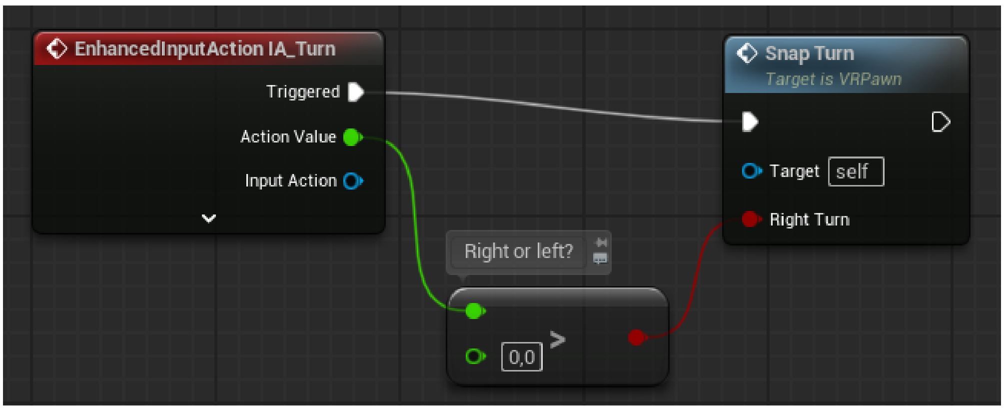

Figure 1: Snap Turn implementation scheme in a VR environment.

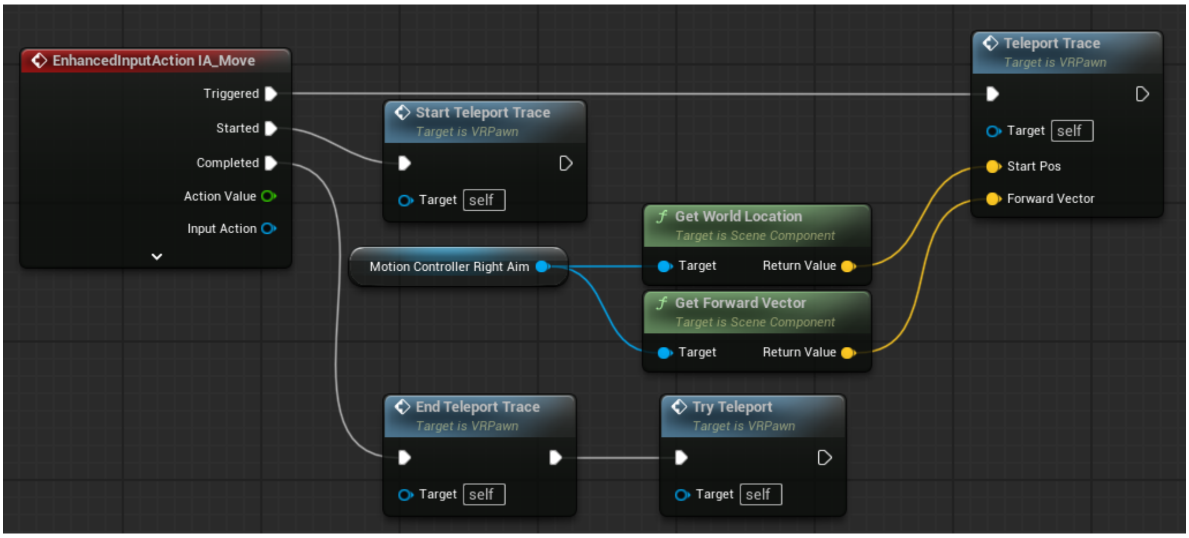

Figure 2: Scheme of implementation of the teleportation system (Teleport) in the VR environment.

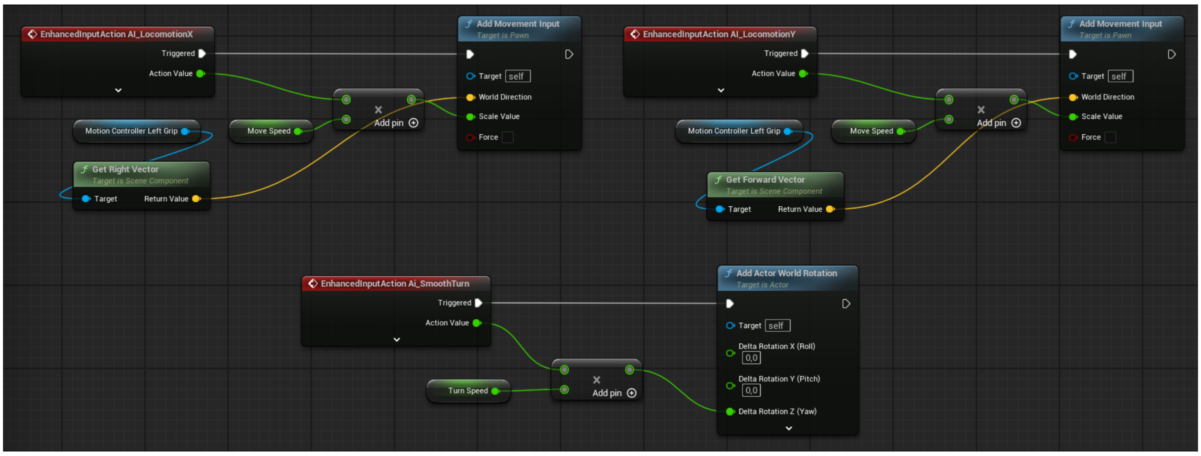

Figure 3: Scheme for implementing Smooth Locomotion in a VR environment.

The effectiveness of using GAI in content creation (i.e., minimising S_{rr} and T_{MVP}) was evaluated by comparing the time spent on creating assets using GAI with traditional modelling estimates.

$$S_{rr} + \alpha \cdot T_{MVP} \rightarrow min. \tag{9}$$

It confirms the economic feasibility of the methods used.

Educational content, including video instructions and interactive prompts, is integrated into the system and is based on official protocols for first aid (Ministry of Health, Red Cross) (Fig. 4 -7). Content validation condition:

$$L \in \{Official\ protocols\ of\ the\ Ministry\ of\ Health, Red\ Cross, Military\ medicine\}. \tag{10}$$

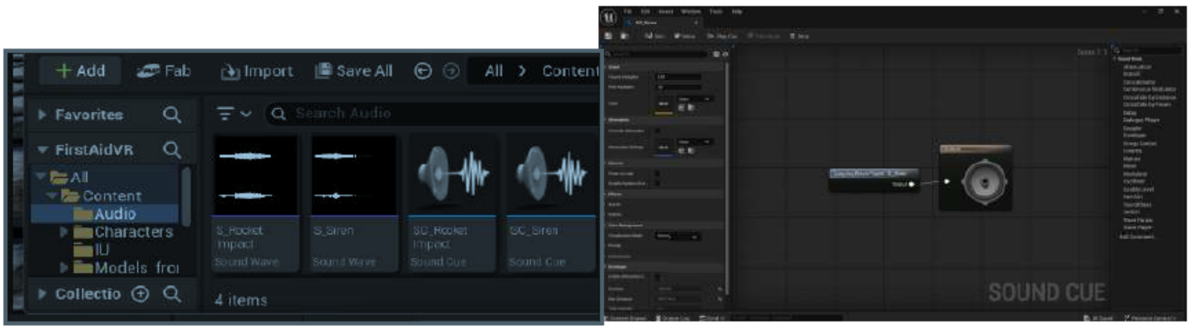

Figure 4: Scheme for the implementation of starting the siren sound.

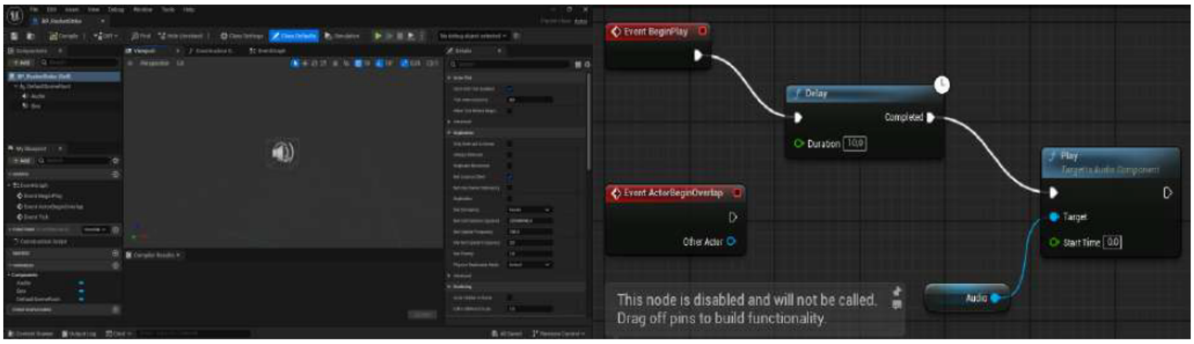

Figure 5: Scheme for the implementation of the launch of the sound of a rocket/mine explosion.

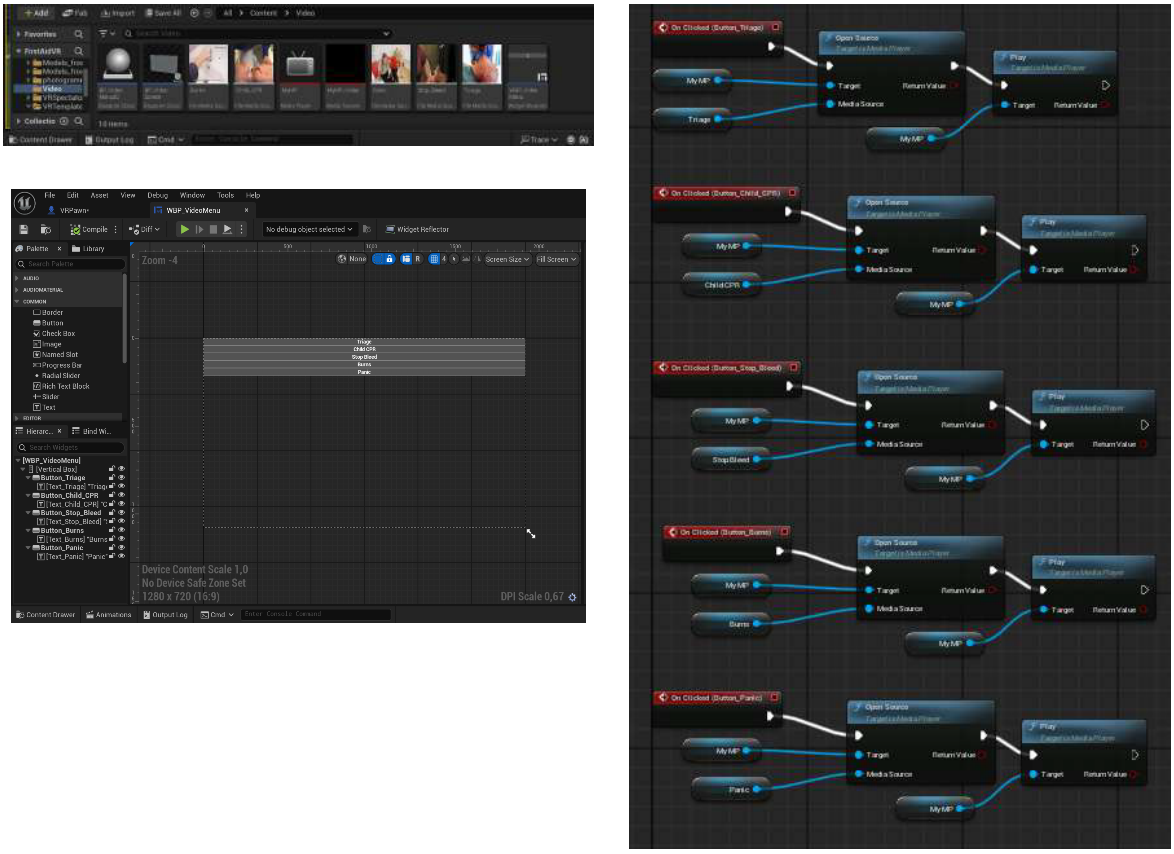

Figure 6: Scheme for the implementation of the display of the educational video.

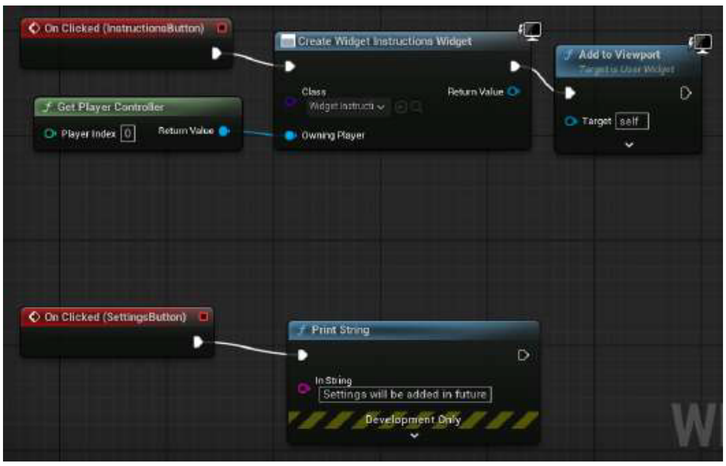

Figure 7: Scheme for the implementation of the "Instructions" and "Settings" buttons of the modified standard VR menu.

5. Experiments

The experimental part of the study aims to implement the key functional modules of the VR First Aid Simulator (MVP) in a practical setting and validate innovative methods of content creation, specifically the use of GAI and mobile photogrammetry. The experiments were conducted according to the stages of MVP Development E_2 and Testing and Improvement E_3 (Table 1).

The purpose of the experiment "Validation of the Integration of GAI into the Workflow (Stage E_2)" was to confirm the hypothesis that the use of GAI can provide fast and cost-effective generation of 3D models that meet the requirements of a specific scene ("affected area" – Fig. 8-10). Generative models were used in the creation of visual concepts and 3D objects for the scene "City Street after a Missile Attack" (Fig. 11-13). Generation tools: Stable Diffusion, DALL-E (ChatGPT), KREA, Ideogram (for 2D concepts). Tripo, Meshy, Trellis3D (for 3D models).

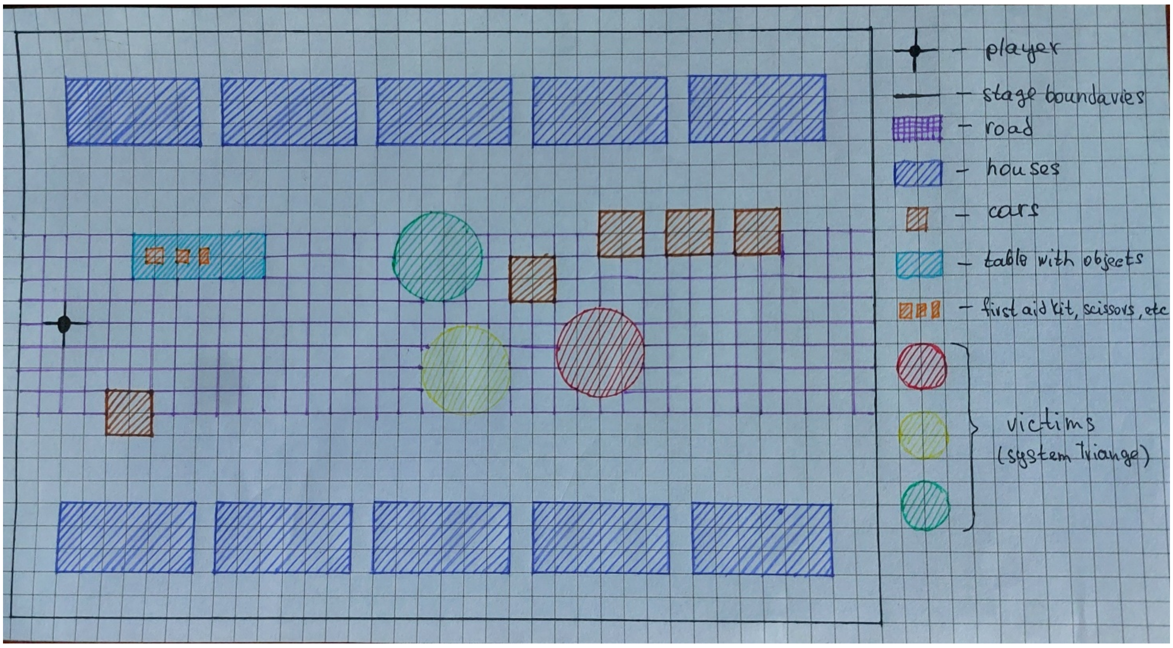

Figure 8: Sketch of the scene.

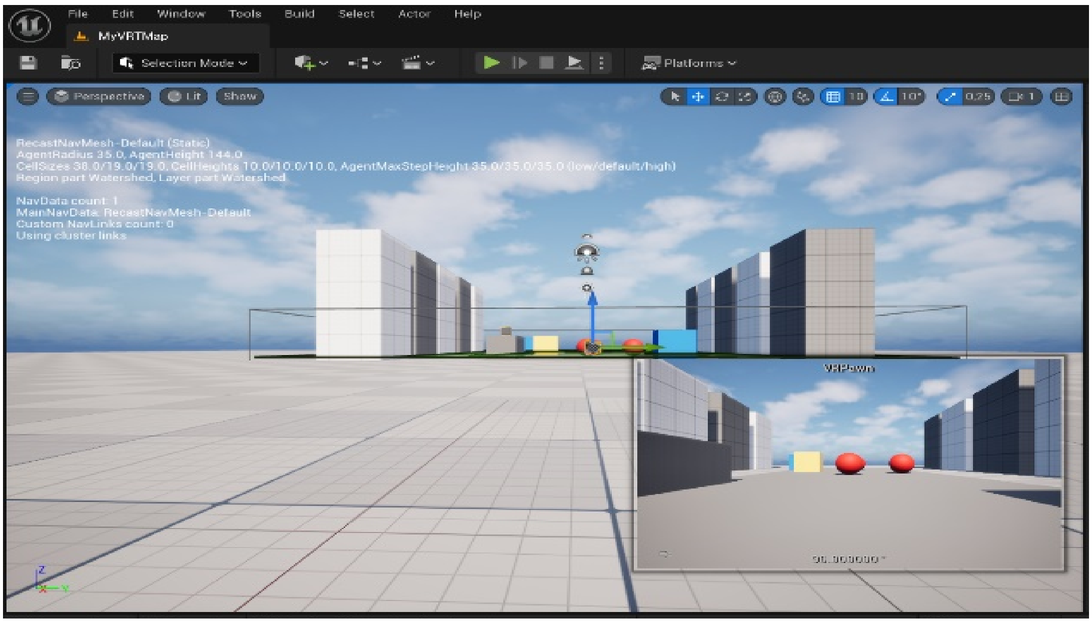

Figure 9: Prototyping the VR scene (road, houses, cars, victims).

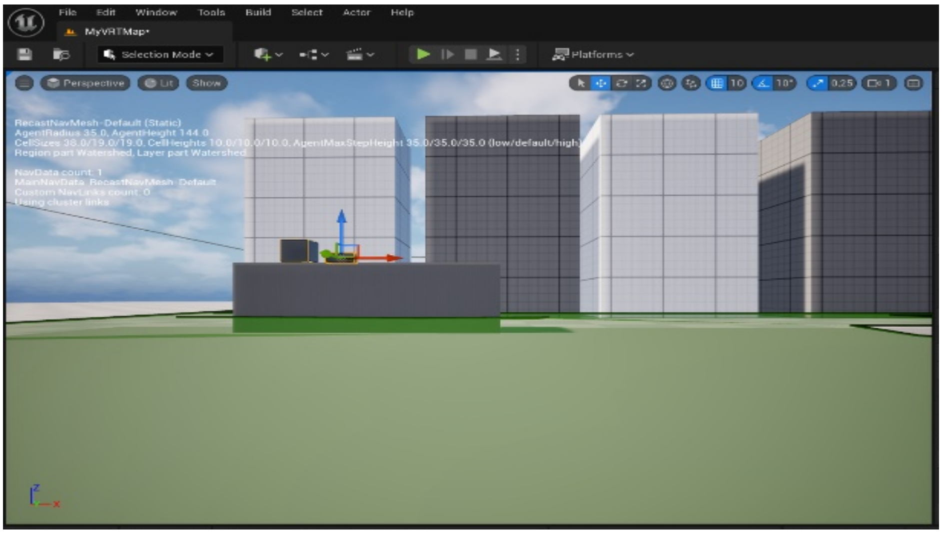

Figure 10: VR scene prototyping (table with medical equipment).

The primary method involves using detailed prompts to create specific characters (Fig. 14-15) and environments (for example, "the wounded mother is standing with a bleeding hand ... stylised low-polygonal aesthetics...").

Figure 11: Examples of generating 3D models of Buildings based on Mersy.

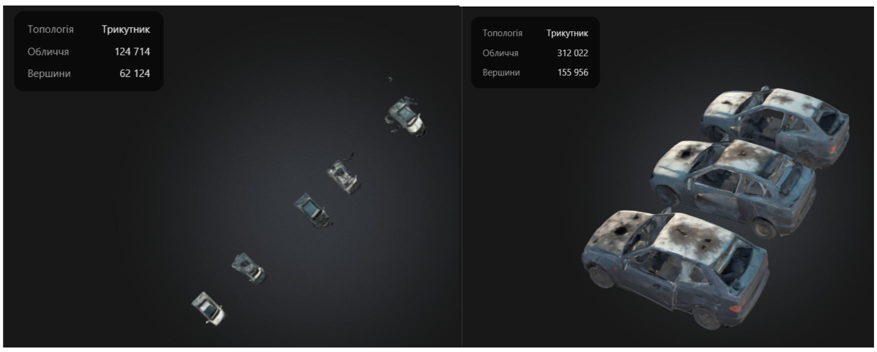

Figure 12: Examples of 3D Model Generation of Mersy-based machines.

Figure 13: Examples of generating 3D models of Tripo-based buildings.

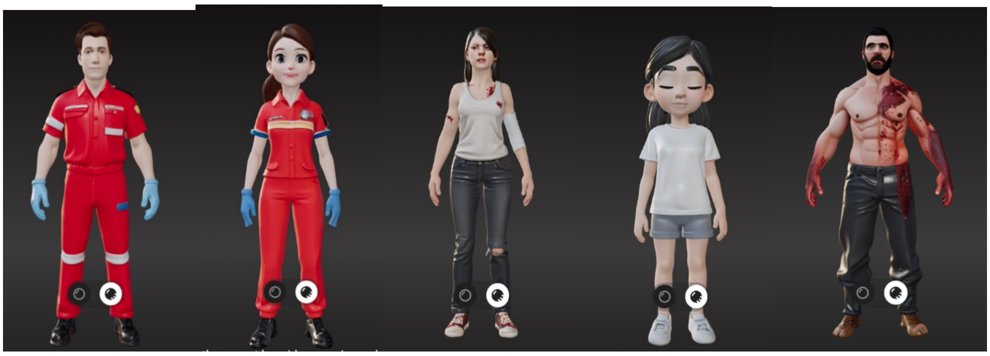

Figure 14: Examples of generating 3D models of Characters based on Tripo.

Figure 15: Examples of generation of 3D models of Characters based on Mersy.

3D models for key aspects of the scene were successfully generated (Fig. 16-17):

1. Damaged environment (destroyed houses, damaged cars).
2. Human models of victims (a child in an unconscious state, a mother with bleeding, a man with burns).

Generative neural networks made it possible to quickly (within the planned time T_{MVP}) create a unique library of 3D assets suitable for further import into UE, which significantly expanded the capabilities of the scene and its plausibility. Models were exported to FBX/GLB formats and imported into UE5.

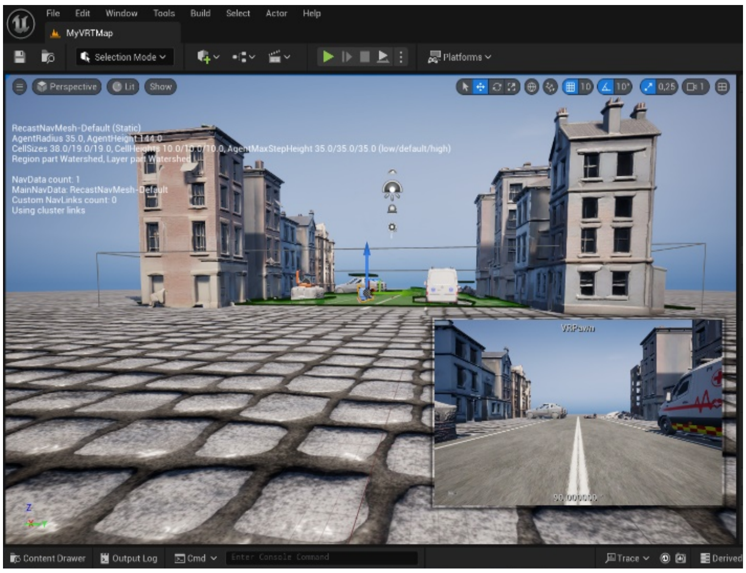

Figure 16: Scene with imported 3D content.

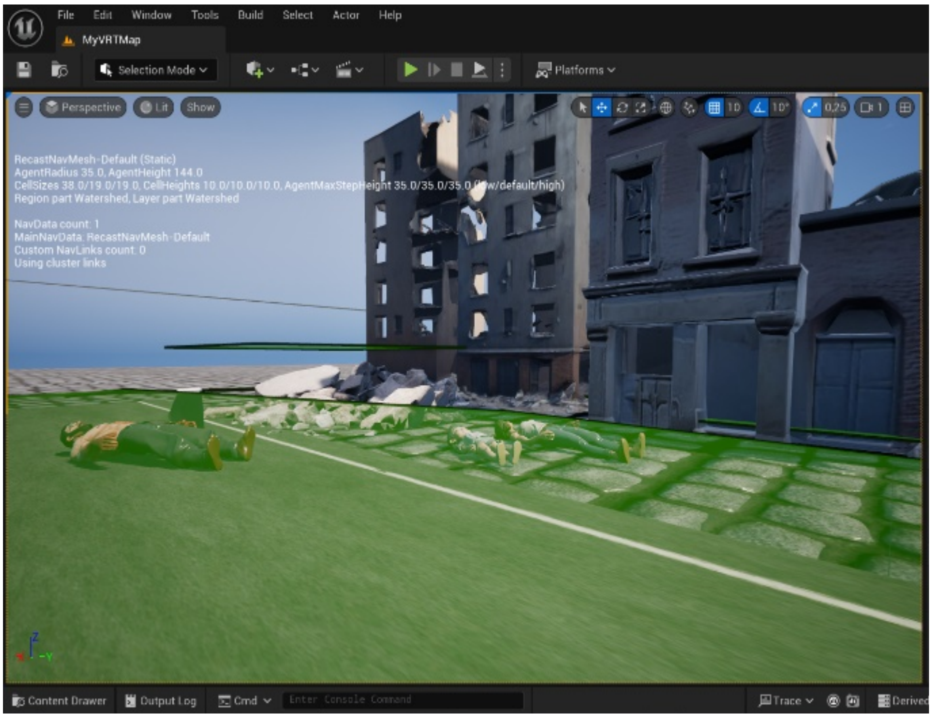

Figure 17: Place of damage by a missile/mine with casualties.

Physical collisions (Simple Collision/Convex Collision) are implemented on the models to ensure the correct interaction of the player (VR character) with the environment (Fig. 18). The models generated by the GAI (Tripo, Meshy) turned out to be suitable for VR scenes, which confirmed the possibility of using the GAI to minimise the cost Srr of artistic modeling.

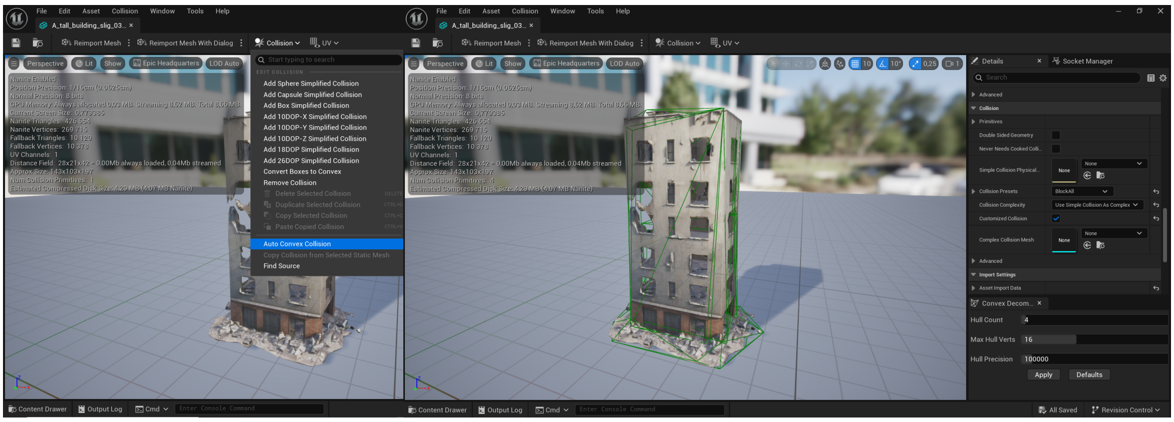

Figure 18: Implementation of collisions for a building object.

The purpose of the experiment "Validation of the Damaged Realism Method through Photogrammetry (Stage E_2)" was to determine whether a controlled reduction in the quality of the photogrammetry input data could be used to simulate damage to objects without additional 3D processing, such as playground objects (5 models). Tool – RealityScan (Epic Games) on a mobile device. The main experimental condition (controlled reduction) was that the number of shots Nphoto was deliberately limited to the range of 30–50 frames, which is approximately 37,5% to 62,5% of the recommended number (80–100 frames). The models were created with partial mesh distortions, unfilled areas and inaccuracies in textures (Fig. 19). The number of polygons ranged from 221,789 to 669,954. The experiment confirmed that consciously limiting the number of photos leads to the effect of a "damaged" view (incomplete detail), which is desirable for the visual style of the affected area and can be used as a creative method for modelling VR environments.

Figure 19: 3D models created in RealityScan.

The goal of the experiment "Implementation and Testing of Key VR Mechanics (Stages E_2–E_3)" is to achieve a high level of P_2 interactivity and user comfort, which is necessary for the successful implementation of the Learning Efficiency function.

The combined approach of $L_{teleport} \oplus L_{smooth}$ ensures optimal immersion and comfort. Two attempts were made:

1. Implementation of Smooth Locomotion exclusively with teleportation disabled. The result was that the character could not move (complete failure of the function).
2. Implementation of smooth movement with teleportation enabled.

The combined approach of $L_{teleport} \oplus L_{smooth}$ turned out to be effective for comfortable use, which confirmed the need to preserve teleportation as a "fallback" to minimise virtual disorientation (Fig. 20).

Figure 20: Screenshot from VR/AR simulator video testing.

The gripping functionality for medical instruments (tourniquet, scissors) has been implemented by:

1. Adding a GrabComponent to an object.
2. Activation of Simulate Physics = true.
3. Collision Preset: PhysicsActor settings.

Created VR pickup items that can be physically captured and used in the scene (Fig. 21), confirming the achievement of the required level of P2 interactivity to practice skills.

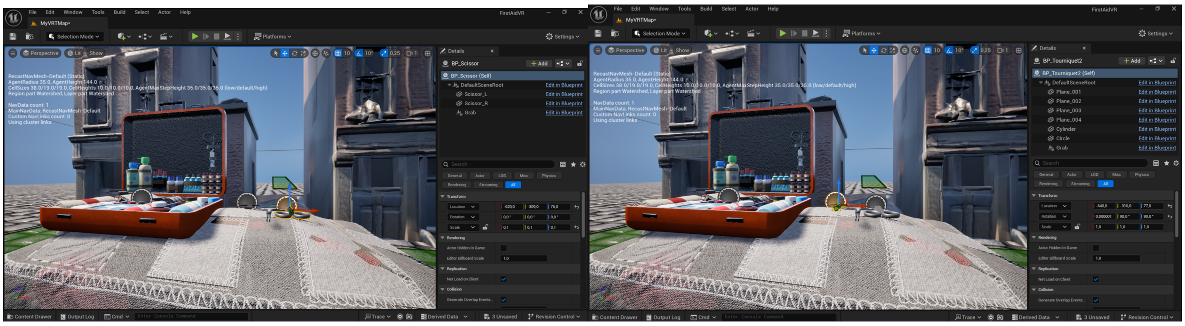

Figure 21: Objects that can be physically captured and used in a scene.

The standard VR menu has been modified (Fig. 22); function buttons ("Instructions" and "Settings") have been added. The functionality of displaying training videos (Triage, CPR, Bleed Stop, etc.) on the virtual screen (Figs. 23–24) and the automatic activation of spatial audio (sirens, explosions – Figs. 25-26) has been implemented.

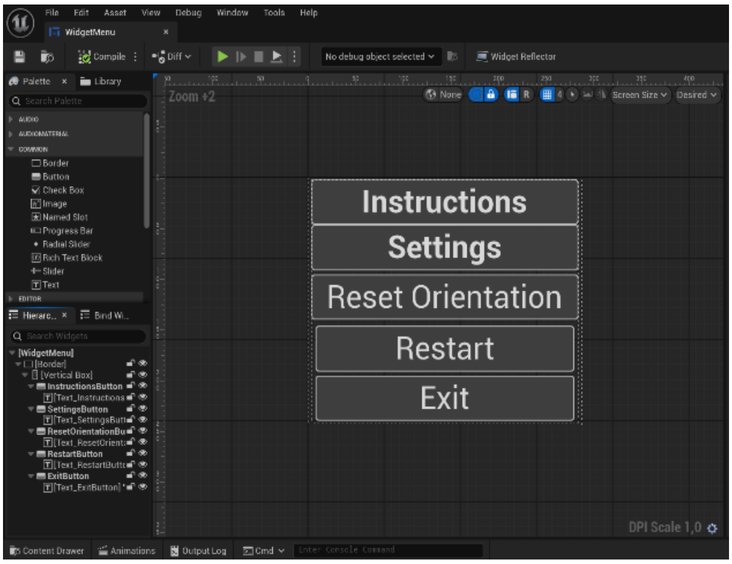

Figure 22: Modified standard VR menu.

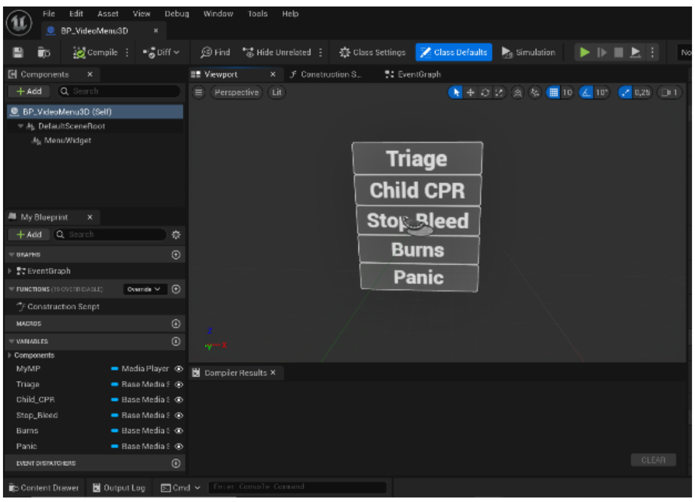

Figure 23: Menu to control the screen display of the instructional video.

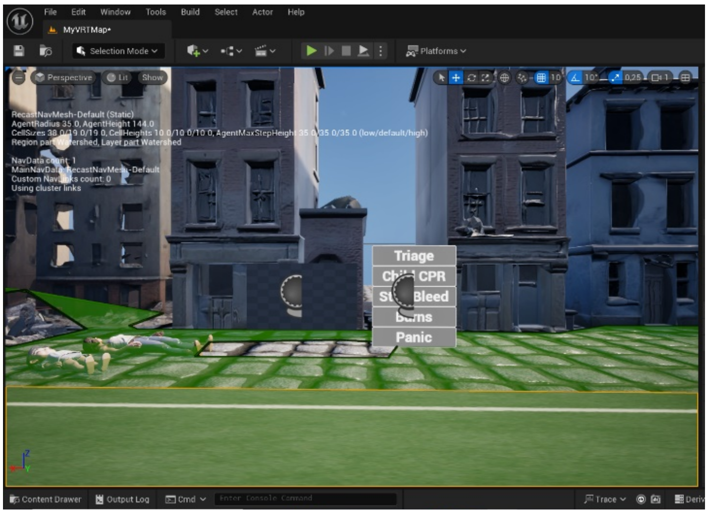

Figure 24: Menu and screen layout to display instructional video.

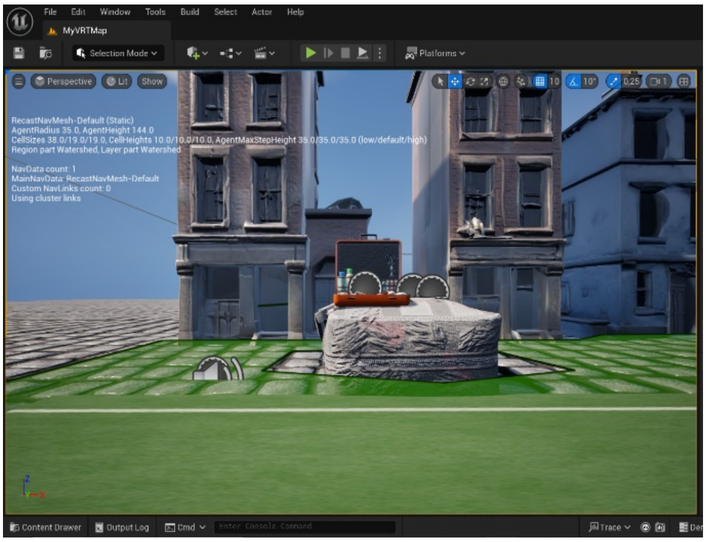

Figure 25: Siren sound location.

The integration provided the ability to receive interactive prompts and automatically evaluate actions (Fig. 27), which lays the foundation for quantifying the P_3 feedback quality score at the final testing stage.

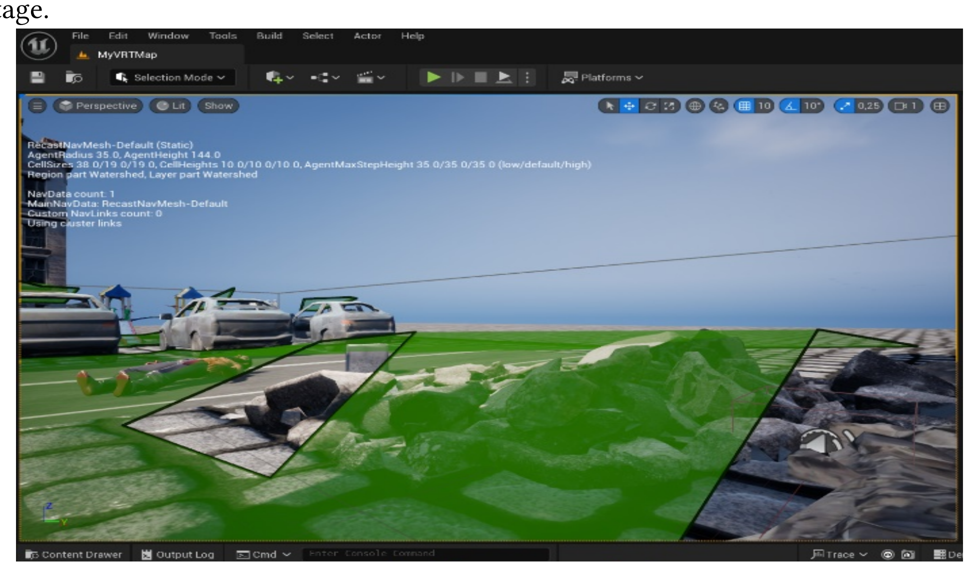

Figure 26: Location of the sound of a rocket/mine explosion.

Figure 27: Screenshot from VR/AR simulator video testing.

6. Results

Figure 27: The study's results reflect the successful implementation of the key stages in developing a VR/AR first aid simulator (MVP) using innovative methods of content creation. The obtained quantitative and qualitative indicators confirm the effectiveness of the chosen optimisation strategy and are compared with the known results of related works. Determined the total estimated time for MVP development is 42 weeks.

Table 2
MVP Structure

Stage	Duration	Purpose and result
E_2 MVP Development	15 weeks	A functional prototype of the scene and key mechanics (including VR/AR interaction and injury simulation) was created.
E_3 Testing	6 weeks	Three phases of testing were conducted (internal, alpha testing with doctors, and beta testing on volunteers).

The results obtained during the planning phase correlate with studies that confirm the high effectiveness of VR/AR in medical education. The selected value proposition – a realistic simulation of critical situations and VR/AR interactivity – reflects an approach that, in similar randomised controlled trials, has shown a statistically significant improvement in training effectiveness compared to conventional methods. The use of GAI tools (Tripo, Meshy) made it possible to quickly create specific content for the "Affected Area" scene. The GAI successfully generated the necessary models: destroyed houses, damaged cars, and characters with characteristic injuries (for example, a man with burns, a mother with bleeding). It confirms that the integration of GAI minimises reliance on traditional modelling, which is a key factor in minimising the total cost of R&D and accelerating T_{MVP}, as predicted in the 3D content automation studies. A mobile photogrammetry experiment (RealityScan) was successfully conducted to create five models of a baby swing. The developed models had a polygonality of 221,789 to 669,954 polygons. 30–50 frames instead of 80–100 recommended) resulted in controlled mesh distortions and texture inaccuracies. This result confirms that the reduction in input data (approximately 37,5% to 70% less than recommended) can be used as a creative method for modelling the affected area, unlike most photogrammetry studies that seek to maximise accuracy.

A combined approach to movement has been implemented: $L_{teleport} \oplus L_{smooth}$. An attempt to implement smooth VR navigation (Smooth Locomotion) proved to be successful, allowing the character to move smoothly using the controller stick. Saving teleportation provides a fallback option for movement, which is critical for minimising VR sickness and increasing user comfort. This result meets the requirements for high-quality VR simulators.

Interactivity and management of medical objects through the Grabbable Objects functionality for key medical instruments (tourniquet, scissors) using physical simulation (Simulate Physics = true) was implemented. It provided a high level of P_2 interactivity, necessary for practising technical skills (e.g., applying a tourniquet), which is the basis for the automatic evaluation of the effectiveness of P_3 actions.

The standard VR menu has been modified, with function buttons ("Instructions" and "Settings") added. The integration of 5 training videos (Triage, CPR, Burn, Bleed Stop, Panic) and spatial audio (siren, explosion) created a comprehensive learning environment. The creation of this complex confirmed the possibility of implementing an interactive learning environment, which, unlike traditional simulators, combines practical skills with immediate access to theoretical material (video instructions). The graphs visualise the time distribution into the main phases of MVP development (WBS) and the results of the photogrammetry experiment (comparison of input data).

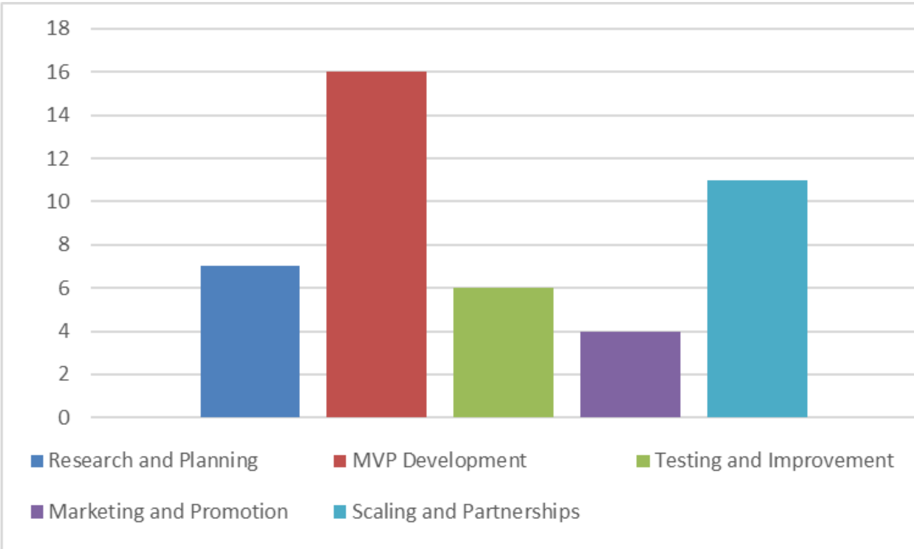

Figure 28: Division of time into MVP development phases.

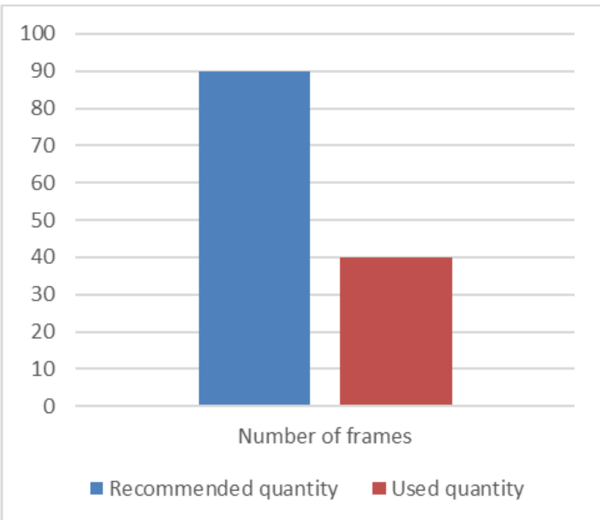

Figure 29: Number of inputs for photogrammetry (average).

Table 3
Division of time into MVP development phases

Phase	Duration
1. Research and planning	7 weeks
2. MVP Development	16 weeks
3. Testing and Improvement	6 weeks
4. Marketing and promotion	4 weeks
5. Scaling and Partnerships	11 weeks

Table 4
Results from Photogrammetry

Category	Number of frames (average)
Recommended amount	90
Quantity used	40

The time-sharing schedule for the key phases of MVP development reflects the primary time costs associated with implementing a minimum viable VR/AR simulator product, as outlined in the WBS structure. The most extended duration falls in the phase of direct MVP development. The graph of the photogrammetry experiment illustrates an experimental approach to creating "affected area" content by deliberately reducing the number of input frames for mobile photogrammetry.

Despite the decrease in the number of input frames, the resulting five models retained high polygonality, confirming that the "damaged realism" method does not require additional high-quality modelling.

Table 5
Quantitative result of the experiment

Model	Number of polygons
Swing_1	225,558
Child home_2	404,727
Child home	669,954
Child car	640,606
Swing_2	221,789
Average	432,527

7. Discussion

The results obtained, as shown in Figures 30-32, confirm the hypothesis that integrating GAI and mobile modelling methods (photogrammetry) with the Unreal Engine game engine is an effective and rational method for the rapid and cost-effective development of highly realistic VR/AR simulators for first aid. The discussion centres on the interpretation of quantitative and qualitative indicators, their comparison with existing research, and the justification of the project's scientific novelty. Time Planning (WBS) defined 42 weeks to implement an MVP, which is a competitive metric for creating an immersive simulator with great detail.

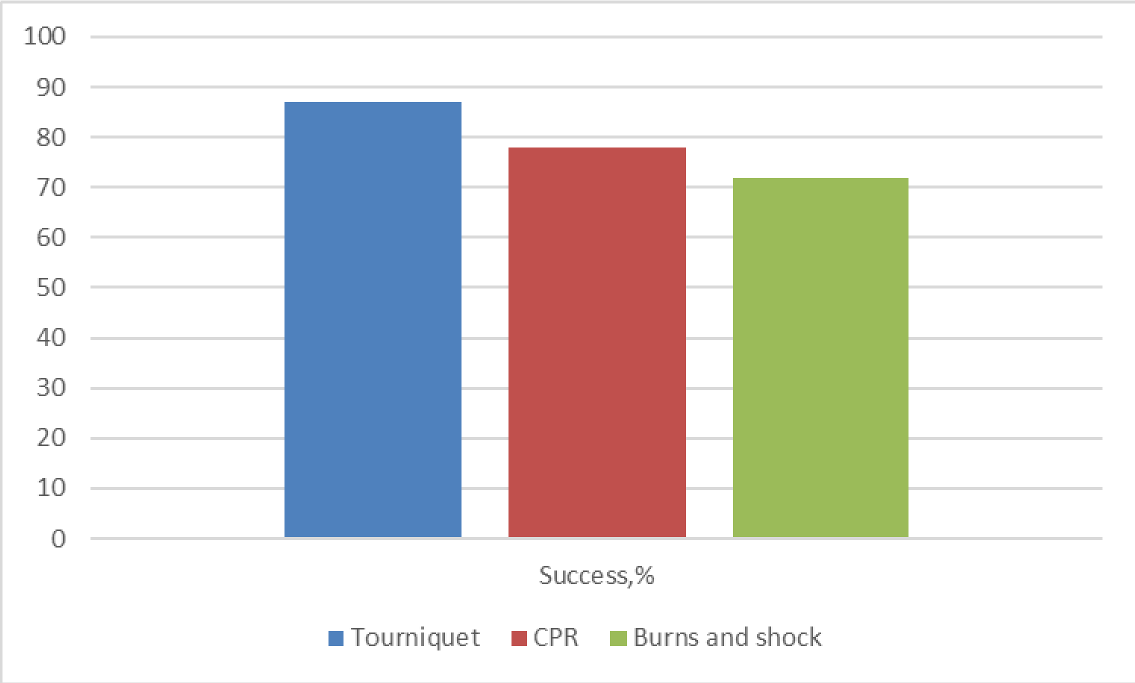

Figure 30: Success rate P according to training scenarios.

The key optimisation was achieved in the MVP Development phase (16 weeks), where a synergy was established between the GAI and manual refinement. The traditional development of simulators of this level of detail often requires much more time for artistic modelling. The use of GAI (Tripo, Meshy) to generate key assets, such as destroyed buildings and damaged vehicles, ensured a reduction in the share of manual labour and confirmed the possibility of minimising S_{rr} and T_{MVP}, as envisaged in modern works on 3D content automation. The successful implementation of the "Street after a missile strike" scenario, with support for realism and simulation of four types of victims (from CPR to severe bleeding), lays the foundation for a high scene realism indicator, P_1. It aligns with the recommendations of research in tactical medicine, which emphasises the need to simulate stressors and critical conditions [4]. The most significant innovative result is the validation of the damaged realism method.

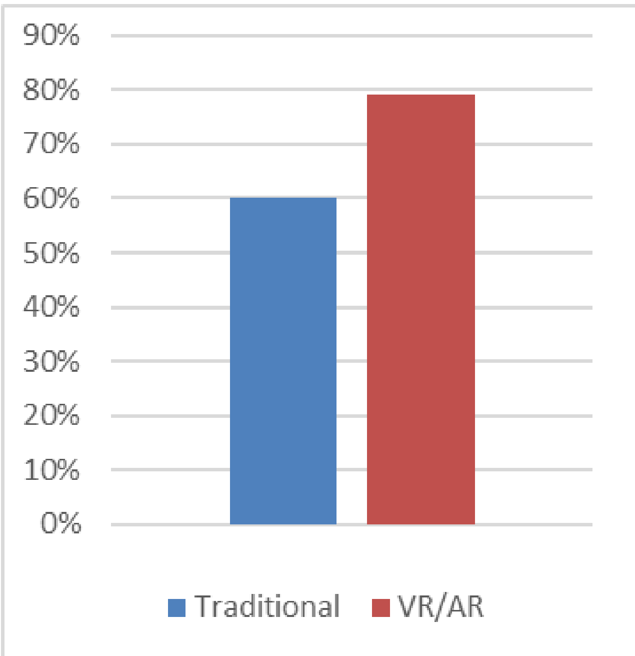

Figure 31: Comparison of Learning Performance.

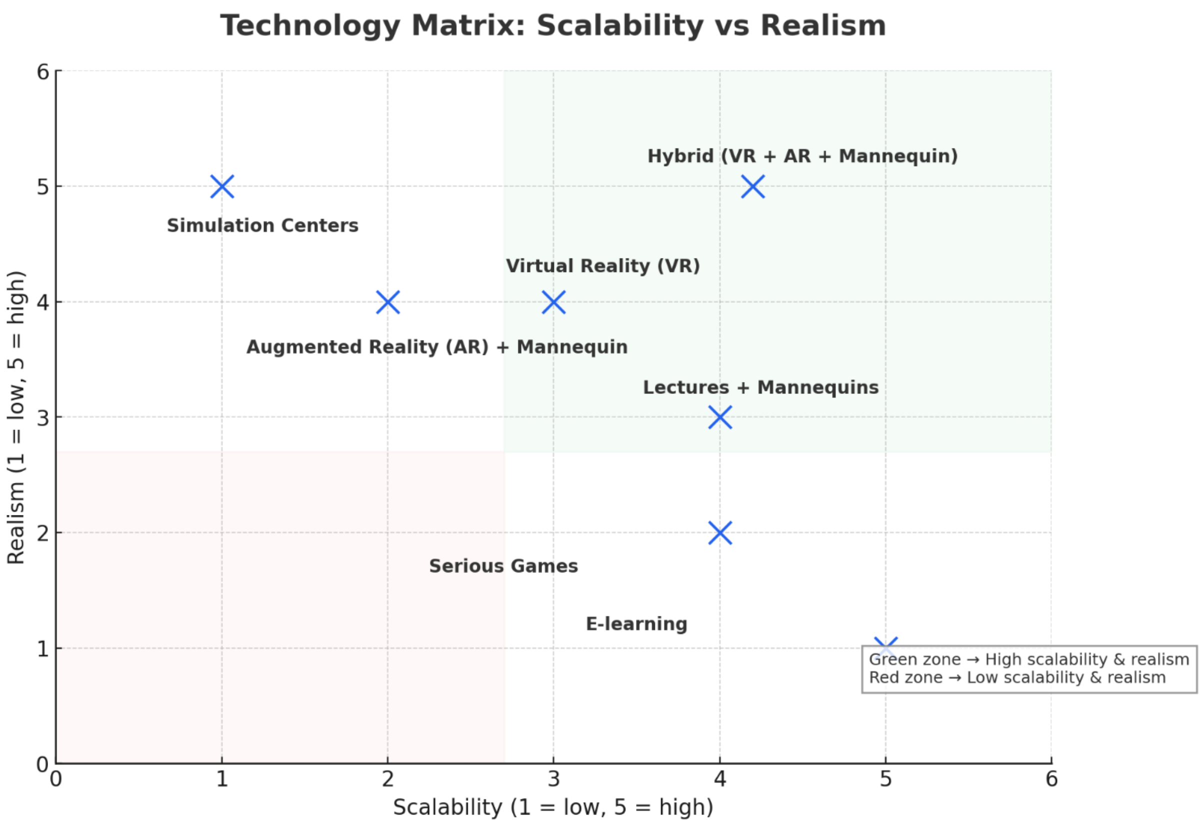

Figure 32: Technology matrix.

The deliberate limitation of photogrammetry input data to 30–50 frames (a decrease of 37,5% to 70% of the recommended amount) resulted in controlled defects in 5 final models. 10]) focused on maximising accuracy and minimising errors, the proposed method purposefully uses the shortcomings of the process as a creative tool. It opens up a new direction for the rapid creation of authentic "hit zone" content for military and crisis simulators. The implementation of key VR mechanics confirmed the achievement of high interactivity in P_2, necessary for practical training. The successful implementation of the combined navigation approach (Locomotion) $L_{teleport} \oplus L_{smooth}$ provides a balance between immersion (smooth movement) and comfort (avoidance of VR disease). An environment where users can physically practice skills (harness overlay) significantly improves the quality of P_3 feedback compared to non-physical simulations. Overall, the results demonstrate that the developed VR simulator is not only technically functional but also methodologically innovative, combining modern advances in GAI with the applied requirements of tactical medicine.

8. Conclusions

Based on the research and experimental implementation of the prototype VR/AR simulator for first aid, all tasks have been completed, and the study's goal has been achieved. The developed VR/AR simulator is an innovative and cost-effective tool capable of providing a high level of interactivity (P_2) and realism for training critical pre-medical skills in conditions as close as possible to those found in a military environment. The integration of GAI and optimised photogrammetry minimised the time and cost of creating specialised content, a key factor in scaling the project. Below is a conclusion on the implementation of each of the tasks:

1. The concept and architecture were successfully formed on the basis of the Business Model Canvas and the Work Decomposition Structure (WBS), defining the target audience (military, medics, students) and the key value proposition: risk-free learning with realistic simulation of critical situations.

2. The use of GAI tools (Tripo, Meshy) confirmed the possibility of rapid generation of unique 3D models (ruins, victims). It provided a high level of visual realism of the scene, necessary to achieve the target immersion indicator (P_1).
3. Experimented with the Unreal Engine 5 VR Template, including creating baselines, configuring VRPawn, and defining the navigation area (NavMeshBounds Volume). The scene "Street after the explosion" was successfully prototyped using simple geometric shapes.
4. Implemented a combined movement system ($L_{teleport} \oplus L_{smooth}$) to ensure comfort and immersion. It made it possible to achieve the required level of interactivity (P_2) while avoiding VR sickness.
5. The VR interface (UMG) has been modified with the addition of function buttons ("Instructions", "Settings"). The integration of five training videos (Triage, CPR, and bleeding stop) and spatial audio (sirens, missile hit) has been implemented, creating the basis for providing feedback (P_3) and evaluating actions.
6. The import and migration of GAI content was successfully carried out, and the correct configuration of physical collisions was implemented. The photogrammetry experiment confirmed that a conscious reduction in input data (up to 37.5% of the recommended volume) is an effective creative method for modelling "affected zone" assets.

The project develops a methodological framework for creating specialised VR training products, confirming that GAI technologies, game engines, and mobile photogrammetry are effective methods for achieving a high level of realism and applied value in emergency and military medicine.

Declaration on Generative AI

The authors have not employed any Generative AI tools.

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Appendix

R – immersion depth;
I – level of interactivity;
F – quality of feedback;
A_{kr} – the correctness of the performance of critical skills;
E_{nach} – the effectiveness of learning;
S_{rr} – total cost of development;
T_{MVP} – time to market of the product, in particular, the total development time of the MVP (approximately 42 weeks according to WBS)
P_j – performance indicator according to the j-th criterion, which are measured during alpha and beta testing of the E_3 stage;
$P_1=R$ – realism of the scene and immersion, $R[0,1]$, which is evaluated by the feedback of specialists (alpha testing);
$P_2=I$ – VR/AR interactivity, $I[0,1]$ (interaction with objects, use of controllers), which is evaluated

by intuitive control (beta testing);

$P_3 = F$ – quality of feedback and evaluation, $F[0,1]$, which is evaluated by the system of automatic evaluation of actions (reaction time, correctness of tourniquet application, error analysis);

$P_4 = A_{kr}$ – the accuracy of the algorithm of actions, A_{kr} [0,1] (adherence to Triage protocols, CPR), is evaluated on the basis of compliance with first aid protocols;

ω_j – the weighting factor of the importance of the criterion;

α – weight factor (cost of time);

S_{GAI} – the share of saved costs for 3D modelling/concepts due to the GAI;

δ_{GAI} – share of time saved on 3D modeling/texturing thanks to GAI (e.g. Trellis3D, Meshy, Tripo, Stable Diffusion);

C_{GAI} – costs for licenses, server capacities and AI tools

A_{min} – the minimum threshold of accuracy that corresponds to the official protocols of first aid (Ministry of Health, Red Cross);

L – the number of supported languages and cultural adaptations of the content (including English, Chinese, Spanish);

A_{st} – pupils, students, teachers;

A_{gr} – citizens, volunteers;

A_{vik} – military, doctors, instructors;

P_{crit_dit} – a 7-year-old child with respiratory arrest (CPR);

P_{crit_mat} – mother with severe bleeding (tourniquet);

P_{ser_op} – a man with burns (shock);

P_{leg} – minor injuries;

$L_{teleport}$ –Teleportation;

L_{smooth} – Smooth Locomotion (smooth movement using analogue controller sticks).