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VR FIRE EMERGENCY SCENARIO COMPONENTS DEVELOPMENT

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Abstract. This research focuses on the development and implementation of advanced control components and intuitive interaction systems within a virtual reality simulator which is designed to simulate various dynamic smoke and fire hazard scenarios. The main goal of this VR simulation is to enhance realism and responsiveness by incorporating the use of VR controllers and gesture-based inputs to enable intuitive and immersive interaction. Advanced algorithms are used in order to effectively translate user commands into precise actions by synchronizing multi-modal input methods, including both hardware-based controllers and gesture recognition systems, which can greatly increase realism during training. The users can manipulate virtual objects and navigate through complex environments as well as execute tasks (smoke and fire in confined spaces) like ship cabins or engine rooms, within scenarios that reproduce the unpredictable nature of fire spread and smoke propagation in a confined environment. Additionally, they are able to perform realistic actions like opening doors, operating equipment, or signaling for evacuation. Realistic modeling of smoke propagation is of utmost importance for achieving the most effective simulation experience and training benefits. Computational Fluid Dynamics (CFD) analysis is used to accurately simulate the spread of smoke and heat. The complex results of the analysis are then converted into a suitable format, using custom-developed code, for integration into the VR fire emergency scenario. By accurately modeling smoke behavior and integrating user interactions, this simulator provides a training platform for emergency responders as well as the crew members of a ship and allows them to practice critical decision-making and advance their skills in a safe and controlled environment. The system leverages complex programming techniques and fluid dynamic models to accurately mimic the behavior of smoke and fire under various conditions. All the visual and physical simulation models are integrated into a real-time rendering engine, allowing for seamless interaction between the user's actions and the simulated environment. The results of this research demonstrate the effectiveness of using VR technology to simulate dynamic smoke management in shipboard fire scenarios. The developed simulator provides a valuable tool for training maritime safety personnel, allowing them to improve their skills and also their ability to respond effectively to real world emergencies.

Keywords: Virtual Reality; Control System; Gesture Recognition; Fire Simulation; Smoke Propagation; Emergency Training; Maritime Safety.

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1. INTRODUCTION OF THE PREMISE

Virtual reality (VR) is increasingly recognized as a valuable tool for safety training, particularly in high-risk and complex environments such as the maritime industry. Its ability to simulate hazardous scenarios in a safe, controlled, and cost-effective manner offers significant advantages over traditional training methods– especially for rare but critical events such as fires. The immersive nature of VR enhances user engagement and improves the overall learning process.

Research indicates that the heightened sense of presence and perceived risk within a virtual environment can influence decision-making and behavioral responses in simulated emergency situations (Russell, Bonny, and Reed, 2024). Maritime environments and specifically the confined spaces within vessels such as engine rooms and cabins, present unique challenges in the event of a fire, making realistic VR training for these scenarios particularly beneficial. Virtual Reality technology presents a promising solution by enabling immersive and repeatable training scenarios without exposing participants to physical danger or depleting real-world resources.

The maritime industry has begun exploring VR technology for training, though adoption remains relatively slow compared to other sectors. According

Figure 1. Nautical simulator, Bay of Kotor.

Figure 2. Cabin view in VR simulation.

to (Vukelić et al., 2023), VR applications in maritime firefighting training face several challenges, including the need for physics-based fire and smoke modeling and improved immersive solutions for evacuation procedures. A study by researchers investigating firefighting training in VR found that the modality of control devices affects user experience, with physical tool representations enhancing immersion compared to standard controllers (Jeon et al., 2023). Current VR fire simulations often emphasize interaction with fire extinguishing equipment; however, the nuanced control and realism required to accurately simulate dynamic smoke behavior remain underdeveloped. Advancing this aspect is essential to improving the overall realism and educational effectiveness of VR-based fire training tools.

This paper addresses the need for effective and realistic control and interaction mechanisms for dynamic smoke management within virtual reality (VR) fire simulations. The focus is on a small-scale fishing vessel, specifically the *Fisher 22*, used as the basis for simulating onboard fire scenarios such as those occurring in the cabin or engine compartment. The objectives of this research are threefold:

(1) to explore various control methods suitable for immersive VR environments,

(2) to propose an integrated combination of software and hardware solutions aimed at achieving high levels of realism,

(3) to provide blueprint-based implementation examples using Unreal Engine 5 (UE5).

Figure 1 shows a view of the Bay of Kotor, which is part of the nautical simulator. The simulation emphasizes dynamic smoke behavior and interactive fire control within realistic emergency scenarios.

Using the *Fisher 22* as the modeled environment, we simulate critical incidents such as cabin and engine room fires. Both user-level interactions (e.g., grabbing and operating a fire extinguisher, opening doors and hatches, activating alarms) and system-level controls (e.g., toggling ventilation fans, adjusting airflow mechanisms) are incorporated to manage smoke propagation and support training realism. Figure 2 shows a view from the cabin in the VR simulation.

2. CURRENT METHODS OF RENDERING FIRE AND SMOKE IN VR SIMULATIONS

Computational Fluid Dynamics (CFD) is a numerical method that simulates fluid flow and heat transfer by solving the Navier-Stokes equations. It excels in accurately modeling complex fluid behaviors such as turbulence, boundary layers, and multiphase flows, making it invaluable in engineering and scientific applications like aerodynamics and combustion analysis. However, CFD's high computational demands and lengthy simulation times render it impractical for real-time applications, particularly in interactive environments like virtual reality (VR) (Glujić et al., 2024).

Integrating CFD directly into Unreal Engine for real-time VR simulations is currently unfeasible due to these performance constraints. While Unreal Engine supports importing pre-computed CFD data for visualization purposes, this approach lacks real-time interactivity. Real-time fluid simulations within Unreal Engine are typically achieved using the Niagara system, which approximates fluid behaviors through GPU-accelerated particle systems. These simulations can respond to user inputs and environmental factors, offering a visually convincing representation of fluid dynamics suitable for VR experiences (Unreal Engine, 2025).

3. SOLUTION TO THE PROBLEM

We developed a VR-based fire simulation using Unreal Engine 5, featuring an interactive model of the *Fisher 22*. This system allows users to train for navigation aboard a fishing vessel, within a modeled environment of Bay od Kotor, utilizing moderately detailed 3D vessel geometry suitable for VR real-time rendering and a basic physical model that responds to dynamic weather conditions. Although advanced hydrodynamic calculations are not yet fully implemented, the simulator retrieves wind speed, direction, and wave height from scenarios and adjusts control parameters to provide users with a sense of how environmental conditions affect the vessel. Collision detection is also implemented, and most onboard systems (e.g., pumps, navigation equipment) are currently under development or partially scripted. Figure 3 shows a view of the bay that includes some of the interactive AI controlled ships and the city of Kotor in the distance is depicted.

The environment of the vessel includes key compartments of the boat where fires can originate, enabling users to perform firefighting actions while the system dynamically responds—smoke flows adapt, alarms are triggered, and ventilation systems engage based on user input. This real-time feedback loop enhances both the immersive experience and the educational effectiveness of the simulation.

The success of a VR training application depends heavily on intuitive and realistic interaction mechanisms. Within the context of the *Fisher 22*, various VR input methods were evaluated. Motion controllers

Figure 3. Nautical simulator used for maritime VR training.

were identified as particularly suitable due to their precise tracking capabilities and their support for direct manipulation of virtual tools and controls. This paper presents the design methodology, implementation process, and technical details of the simulation. We also discuss the broader implications for realism, usability, and the future development of VR-based maritime safety training systems tailored to small vessels like the *Fisher 22*.

3.1. Requirements for Acceptance of Virtual Reality (VR) Simulators in STCW-compliant Maritime Training

As maritime training embraces emerging immersive technologies, Virtual Reality (VR) simulators are increasingly being explored as effective tools to enhance safety training for seafarers. However, for such systems to be officially integrated into STCW-compliant training programs, they must meet a strict set of technical, pedagogical, and regulatory criteria. A VR simulator must fully comply with the competency requirements defined in the STCW Code, particularly Section A-VI/1-1 – Personal Survival Techniques (PST) and Section A-VI/1-2 – Fire Prevention and Fire Fighting.

It must also follow the guidelines of the corresponding IMO Model Courses, including Model Course 1.19 – Personal Survival Techniques, Model Course 2.03 – Advanced Training in Fire Fighting (AFF). These courses outline the minimum training standards and performance criteria for maritime safety and emergency preparedness.

To be effective and acceptable, a VR training system must support the demonstration, practice, and assessment of required competencies through highly realistic scenarios. For PST and AFF, this includes abandon-ship procedures, life raft/lifeboat launching and boarding, use of lifejackets and immersion suits, survival at sea in challenging conditions (e.g., rough weather, darkness), identification, control, and extinguishing of fires, use of firefighting equipment and breathing apparatus, and rescue and evacuation procedures in smoke-filled environments. The simulator must provide high-fidelity visual, auditory, and procedural realism, faithfully replicating onboard conditions and emergency response equipment.

To be used in education and training, VR simulator must align with STCW standards and must enable: interactive training modules with real-time decision-making; monitoring and logging of trainee actions; feedback mechanisms for learning reinforcement; performance assessment based on predefined learning outcomes and competencies; and finally, approved for used in certified training. Crucially, any VR system intended for use in STCW training must be approved by the national maritime administration or flag state authority.

3.2. User Interaction Design

Within the software domain, leveraging the advanced capabilities of Unreal Engine 5 (UE5) is essential for developing a realistic and immersive simulation environment. UE5's state-of-the-art rendering technologies, such as **Nanite** for virtualized geometry and **Lumen** for real-time global illumination, enable the creation of highly detailed and visually compelling virtual settings. These features allow for accurate representation of the *Fisher 22*, as well as realistic simulation of dynamic fire and smoke effects critical for effective training scenarios.

The VR user is embodied via a tracked avatar (i.e., using motion controllers and hand tracking). We handle VR input by extending the UE5 *MotionControllerPawn* with our custom code. Each controller (left and right hand) is tracked, and each user hand is tracked in VR space.

We bind input events (e.g., grip, trigger) to grab and use objects for both motion controllers, as seen in the Figure 4. Interaction methods include:

- **Grab and Manipulate Objects:** We implemented a VR grip mechanism. For example, the fire extinguisher model can be grabbed (via the controller's grip button or user hand movement) and swung or aimed by the user. The extinguisher has subcomponents (e.g., safety pin, lever) that respond to actions, such as pulling the pin with a button press to "activate" it.
- **Toggle Controls:** Push buttons or pull levers in the cabin are also interactive. When the user's virtual hand collides with a switch component, a Blueprint event triggers an action.
- **Open/Close Doors and Hatches:** The user can reach out and "grab" a handle. Pulling the trigger rotates the door – we implemented this by lerping the door's Yaw rotation in blueprint code when grabbed.

For operating the virtual fishing boat, several control mechanisms can be implemented. Steering could be achieved through a virtual steering wheel that users can physically grasp and rotate using motion

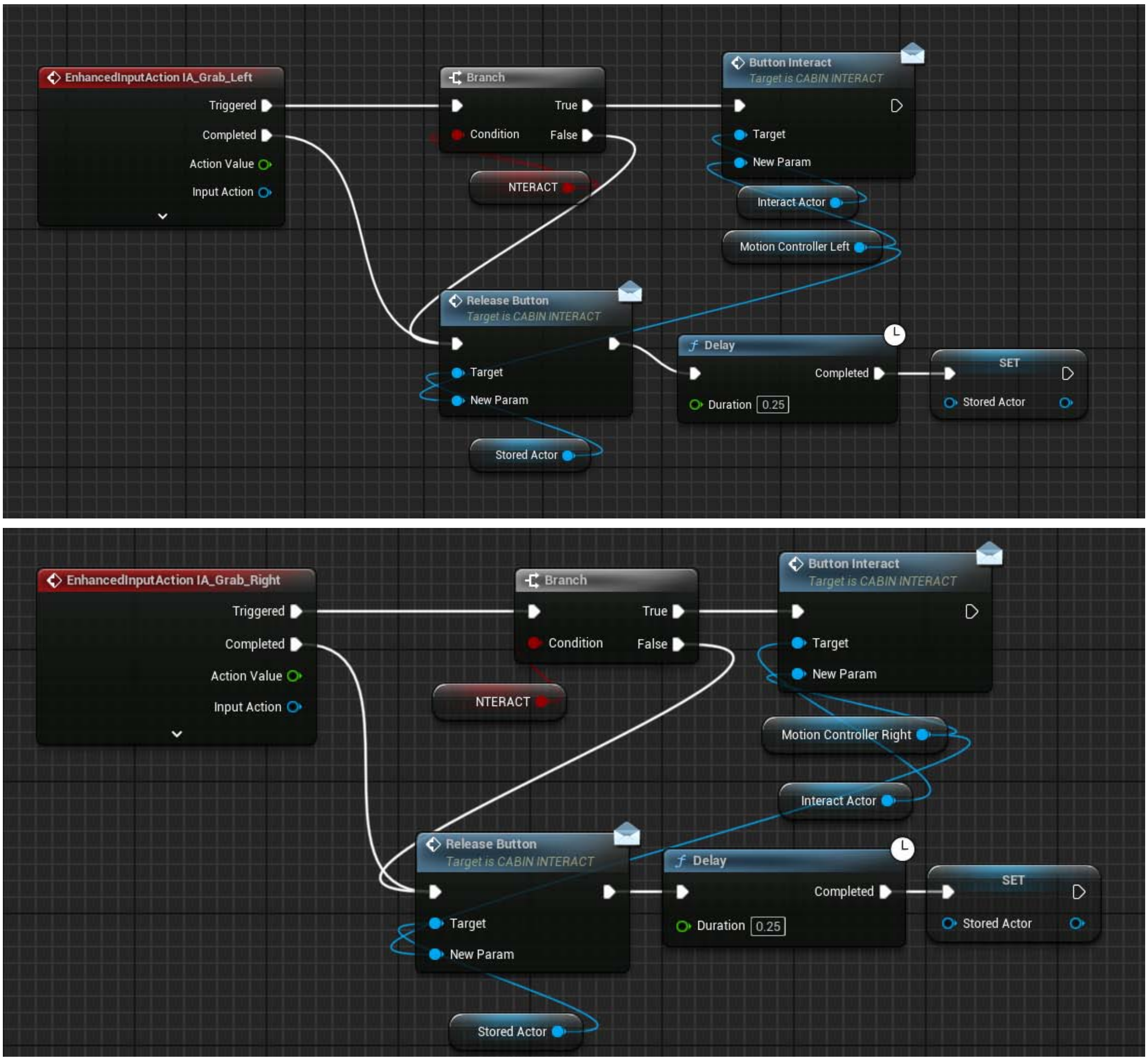

Figure 4. Blueprint code for the grabbing components.

controllers–an approach we found to enhance the realism of the simulation. Alternatively, joystick-like controls, utilizing the thumbsticks on the motion controllers, could be used for steering, offering a more abstract but potentially more convenient method, especially for continuous adjustments (Unreal Engine – Epic Games Developers, 2025). The boat's throttle could be controlled via a virtual lever or slider within the VR environment, manipulated by motion controllers or thumbstick input (Yuxiang and Guozhen, 2024).

These controllers offer a good balance of precision and ease of use, making them suitable for a wide range of interactions, from grabbing virtual tools to operating complex machinery. On the other hand, hand tracking, which utilizes cameras and sensors to track the user's hands directly, offers a more natural and immersive way to interact with the virtual environment. In our simulation, besides the classic motion controllers, we use hand tracking data provided by the Meta Quest 3 headset and use it to interact with the VR environment and objects. In our simulation, we utilized this method as the main method of interaction and complemented it with the use of motion controllers as a second possibility for the users.

3.3. Steering Wheel and Throttle Interaction Components

Implementing the control and interaction components in Unreal Engine 5 can be effectively achieved using its Blueprint visual scripting system, which is based on C++ and which offers a user-friendly way to create complex logic without extensive coding. Core VR interactions, such as object manipulation, can be implemented using the built-in grab component available in the VR Template project (Epic Games Developers, 2025), or through custom Blueprint logic that detects hand proximity and controller input, which is the approach that we implemented. Button presses on the motion controllers can be easily handled through input events, by utilizing the Enhanced Input Actions, allowing for the triggering of actions like activating alarms or initiating the discharge of a fire extinguisher. Figure 5 depicts part of the code for the steering wheel of the boat, where the clamped values of the raw input are used to determine the controller's yaw and set the boat rotation based on them. This rotation value can then be used to influence the boat's movement by setting its velocity. The approach we used applies forces through a movement component and affect the boat's rotation based on the user input. Figure 6 shows the code that runs every frame and takes the motion controller's position from the world coordinate system and transfers it into local coordinates that are used to drive the steering wheel and rotate the ship.

The throttle control can be implemented by mapping the controller input to the position of a virtual throttle lever, which can be animated using timelines or by directly setting its relative rotation. Figure 6 depicts the Blueprint code that we used to implement that system, utilizing Blueprint Interfaces (BPIs). BPIs transfer the controller or hand location to the throttle Blueprint and set its rotation in the world reference space. This input value was used to control the boat's speed, which synchronizes with the throttle's rotation. Haptic feedback on the controller is also triggered at specific throttle levels using the PlayHapticEffect node, as well as the mod-

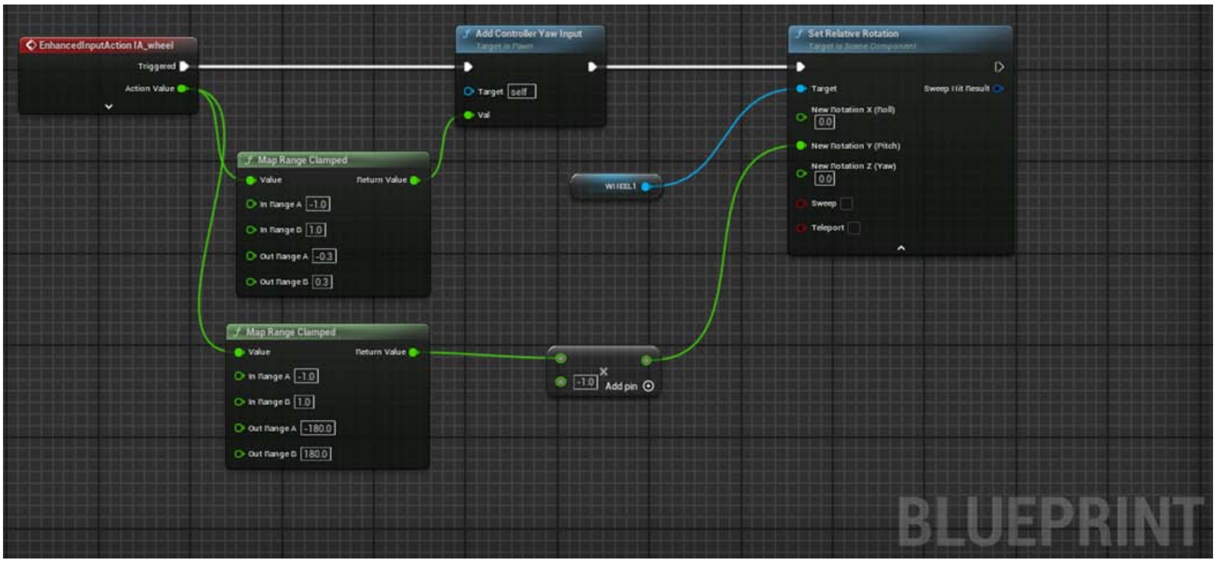

Figure 5. Blueprint code for the wheel controller.

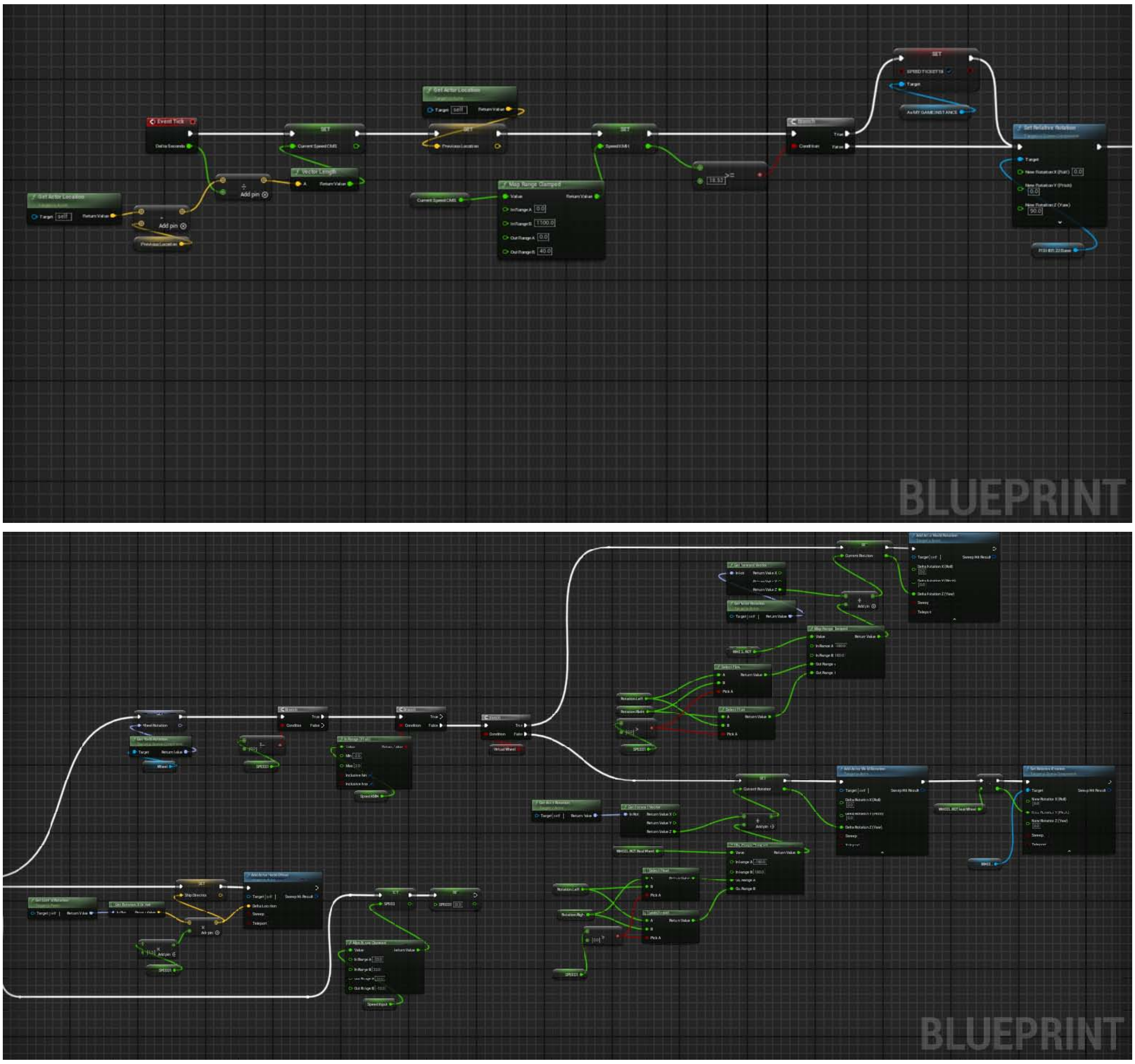

Figure 6. Blueprint code for the throttle component.

ified pitch for the engine audio, enhancing realism. We also ensured that the door, hatch, knobs, and extinguishers, have realistic pivot points and weights so that they can be realistically depicted and animated.

3.4. Firefighting Equipment Interactions

Realistic VR training for fire-related scenarios is essential because the dynamic and high-risk nature of onboard fires demands that trainees develop accurate situational awareness, decision-making skills and motor responses under pressure, and the outcomes that generic or low-fidelity simulations produce are not reliable.

In a confined maritime environment, fire and smoke behavior can change in seconds. Fuel loads and ventilation patterns are unique to each vessel, and even small delays in recognizing a rapidly deteriorating scenario can have catastrophic consequences. By replicating these complexities – thermodynamic feedback, limited visibility, evolving smoke patterns, and spatial constraints at near-operational fidelity – VR training allows crew members and first responders to internalize critical procedures.

In late March 2025, the 29.6 m Azimut yacht Ramonda, valued at approximately €10 million, caught fire while moored in the Portonovi marina near Herceg Novi, Montenegro. Initial reports indicate the blaze originated in the galley area of the fiberglass superstructure and rapidly spread to the living quarters, placing nearly 8000 L of diesel fuel at imminent risk of ignition or spillage (Vijesti, 2025). Dockworkers first observed smoke around 18:25 h on 27 March, prompting an urgent response from the Portonovi Protection and Rescue Service and the Herceg Novi Protection and Rescue Service, who prioritized preventing an environmental catastrophe by keeping

Figure 7. Fire and smoke effects in the VR simulator during a scenario involving engine failure and subsequent fire.

the burning yacht from sinking and releasing fuel into the sea (Vijesti, 2025). Utilizing foam monitors aboard the firefighting vessel Jovana (Porto Montenegro) and tugboats from Boka Pilot & Tug Services, responders towed the Ramonda approximately 150 m away from the marina's berth to contain the flames and protect adjacent vessels: The fire was ultimately extinguished by 23:00 h, though the superstructure and hull were completely destroyed (Douglas, 2025).

No injuries were reported, but this incident underscores how swiftly a small equipment or electrical failure can escalate into a large-scale maritime fire and highlights the imperative for vessel operators and marina staff to maintain rigorous firefighting training, conduct regular safety inspections, and implement practiced emergency protocols in order to mitigate such events and enable rapid, effective containment.

Figure 8. The image of yacht Ramonda while on flames (Source: Vijesti, 28 March 2025).

3.5. The Proposed Hybrid Framework for the Realistic Real-time Fluid Dynamics

In this work, we introduce a hybrid framework in which offline Computational Fluid Dynamics (CFD) simulations are used to generate high-fidelity flow fields for discrete spatial sub-volumes (e.g., individual rooms or ship compartments). These CFD-derived parameters (temperature, velocity, soot concentration, etc.) are assigned at runtime via custom Blueprint scripts in Unreal Engine. A minimal set of Niagara-rendered sprite particles then samples and responds both to these stored volumetric values and live forces, such as ventilation changes, fire spread dynamics, structural breaches, or user movement, ensuring that smoke and fire effects remain visually credible yet computationally lightweight.

While most prior VR or game-engine integrations of CFD either import fully baked volumetric data for passive playback (often as 3D texture caches or OpenVDB grids) or employ coarse real-time grid solvers (e.g., Lattice–Boltzmann methods) primarily for flow visualization without coupling to a sparse, particle-driven layer (Harwood and Revell, 2019; Schlüter et al., 2025), our approach occupies an intermediate position: it leverages high-resolution offline CFD to inform a sparse, real-time particle system.

To our knowledge, no published work explicitly combines "CFD → discrete volume masks → Blueprint-driven parameter assignment → minimal Niagara sprites + live force interaction" in a VR fire/smoke scenario. For example, Harwood and Revell demonstrated near-real-time Lattice–Boltzmann solver data streaming into UE4 for an interactive virtual wind tunnel, but their system overlays smoke visualizations rather than driving a low-particle Niagara setup from pre-computed CFD volumes (Harwood and Revell, 2019). Similarly, surveys of UE5 volumetric rendering note OpenVDB support for complex smoke caches, which are used mainly for static or scrub-through playback rather than dynamic, collision-driven interaction with limited particles Unreal Engine Forums, 2022; CG Channel, 2022). Proprietary solutions such as NVIDIA FlameWorks provide real-time GPU-based Eulerian solvers at high resolution but do not integrate pre-computed CFD fields with a separate, minimal-particle layer (NVIDIA Developer, 2014).

This novel and hybrid approach– bridging the gap between fully baked volumetric playback and fully real-time grid-based solvers by using volume-based CFD caching coupled with Blueprint-controlled Niagara sprites – could be a game-changer for achieving real-time realism in smoke and fire simulations. However, since it has not yet been fully implemented in our systems, its feasibility and performance remain to be validated through future testing, performance benchmarks, and VR user evaluations.

The process of interacting with virtual firefighting equipment, such as a fire extinguisher, can be implemented step by step in Blueprint. Responding to fire scenarios within the VR simulation requires specific interaction components. Locating the fire source is a primary objective, and this can be facilitated through visual cues such as flames and smoke (Unreal Engine, 2025). Interacting with alarms, such as activating a manual fire alarm, could be achieved by physically pressing a virtual button or flipping a virtual switch using the motion controllers (Jeon et al., 2023). Using firefighting equipment requires detailed and realistic interaction paradigms.

Figure 9. View of the cabin in VR simulation.

Figure 10. Fisher 22 engine on fire in VR simulator, real-time render in Unreal Engine.

Figure 11. Fire outbreak on the main deck of an AI-controlled vessel within the simulation environment.

Figure 12. View from inside the cabin of the AI-controlled vessel on fire.

For a fire extinguisher, the interaction should closely mimic the real-world PASS technique (Pull, Aim, Squeeze, Sweep). This involves the user physically picking up a virtual fire extinguisher, removing a virtual safety pin (potentially with haptic feedback to simulate the action), aiming the extinguisher by orienting their hand and controller, squeezing a virtual handle or trigger button on the controller to simulate the discharge of extinguishing agent, and sweeping their arm to cover the fire (VR Fire Training – Occupli).

3.6. Additional Steps to Increase Realism

In emergency VR simulations, the design of the user interface (UI) and user experience (UX) is paramount to ensure clarity and ease of use, especially under the stress of a simulated emergency. UI elements should be clear, concise, and readily accessible within the 3D environment, avoiding visual clutter that could be distracting (Westphal, 2025). Spatial UI design, where interface elements are positioned naturally within the 3D space rather than as flat overlays, can be more intuitive and less disruptive to immersion in VR. In our simulator, we use minimal UI approach, where all the interaction elements have their own UI widgets in 3D space. Audio is delivered binaurally through the head-mounted display (HMD) headphones: waves, engine sound, fire crackling and alarms, are spatialized to match the VR scene.

3.7. Hardware Integration

The simulator runs on a VR workstation equipped with modern VR hardware. For HMD, we support devices like Oculus Quest 2 or 3 (Quest via Oculus Link). Also, our setup utilizes wheel controller that has raw input data tied to the virtual wheel of the ship. In the future, we plan to upgrade the simulation with custom-built (3D-printed) physical steering wheel and throttle components, as well as add additional sensors for more realistic tracking in 3D space.

4. RESULTS AND DISCUSSION

We conducted preliminary evaluations of the system's realism, usability, and technical performance. The findings are summarized below. The VR controls were generally intuitive. Although hand tracking can improve the sense of presence and realism in the simulation, it can be less precise than physical controllers, especially during complex tasks or actions requiring fine motor skills. Participants reported that the dynamic smoke behavior contributed significantly to the perceived realism of the experience. For example, when smoke filled the cabin, users noted a heightened sense of urgency and presence. We selected a high-resolution VR headset with 6DoF tracking capabilities and combined it with hand tracking and hardware interactions to ensure immersive visual experiences.

This aligns with previous studies indicating that "VR training provides more effective results in terms of knowledge acquisition by triggering a sense of realism" (Choi and Noh, 2021; Radianti et al., 2020). Although this system can greatly increase the perceived realism, it has its drawbacks that appear in the form of technical and performance issues. Current VR headsets have limited hardware processing and rendering capabilities which can cause bottlenecks and performance drops when using overcomplicated code that relies on per-frame evaluation and advanced visual rendering. In order to maintain the desired quality in par with the current-generation technology for fire and smoke systems, we propose a system that uses a combination of custom-built code with procedurally calculated variables derived from the CFD system. This approach offers improved scalability and performance while preserving the key features that make smoke behavior appear realistic.

4.1. Comparison to Existing Systems

In contrast to many existing VR firefighting simulators, often used in maritime contexts such as training ferries or offshore platforms and which rely on static fire animations and simplified smoke models. our approach introduces dynamic smoke management using Unreal Engine 5. For instance, Tao et al. demonstrated a real-time vortex-based smoke simulator for shipboard training, achieving high realism through a Lagrangian fluid model (Tao et al., 2024). While our implementation using Unreal's Niagara system is less physically precise, it offers a more accessible and flexible solution for real-time deployment that addresses the current-generation performance issues. The trade-off is pragmatic: Niagara, combined with parameter tuning, produces credible visuals with lower computational overhead and easier integration in UE5 environments.

Although conducted in VR, user safety remained a priority. We implemented virtual boundaries (e.g., circular boundary) to prevent physical falls and designed interactions to avoid excessive physical strain (e.g., lifting heavy objects was not required).

4.2. Summary

We developed an immersive VR training platform for firefighting scenarios aboard a *Fisher 22* fishing boat, focusing on dynamic smoke behavior and interactive user control. By leveraging Unreal Engine 5 technologies including Niagara and Blueprint coding, we integrated volumetric fire and smoke effects with realistic user interactions (e.g., extinguishers, doors, hatches), supplemented by optional features like hand tracking and hardware integration. Our findings suggest that, with thoughtful design, VR can effectively simulate the complexity of enclosed-space fires in a compelling and educationally valuable way. Future work will aim to expand physical realism and conduct more extensive user testing to evaluate long-term training efficacy.

VR simulators offer immense potential in maritime training, delivering immersive, cost-effective, and repeatable learning experiences. However, to be adopted for STCW training, such systems must adhere to strict international standards, undergo formal approval, and be integrated into certified training programs. With proper design and verification, VR can play a transformative role in improving seafarer safety, competency, and emergency readiness.

REFERENCES

Adrian, R. G. H. & Alistair J. R., 2019. An Interactive, Virtual Wind Tunnel using Virtual Reality and Unreal Engine 4, 2019. Available at: https://www.researchgate.net/publication/352569490_An_Interactive_Virtual_Wind_Tunnel_using_Virtual_Reality_and_Unreal_Engine_4 (Accessed: 22 March 2025).

CG Channel, 2022. Free plugin UnrealVDB lets you import OpenVDBs into UE5. Available at: https://www.cgchannel.com/2022/07/free-plugin-unrealvdb-lets-you-import-openvdbs-into-ue5/ (Accessed: 24 March 2025).

Choi D.H. & Noh G.Y., 2021. The Impact of presence on learning transfer intention in virtual reality simulation game, SAGE Open July-September 2021:1–9 © The Author(s) 2021 DOI: 10.1177/21582440211032178 journals.sagepub.com/home/sgo.

Glujic, D. et al., 2024. Coupling CFD and VR for advanced firefighting training in a virtual ship engine room // Results in engineering, 24 (2024), 103025-103035. Available at: https://doi:10.1016/j.rineng.2024.103025.

Jeon, S. et al., 2021. The More, the Better? Improving VR Firefighting Training System with Realistic Firefighter Tools as Controllers. Sensors 2021, 21, 7193. Available at: https://doi.org/10.3390/s21217193.

Markus, S. et al., 2025. Rendering Large Volume Datasets in Unreal Engine 5: A Survey, arXiv:2504.07485v1 [cs.GR]. Available at: https://arxiv.org/abs/2504.07485.

Nauticmag.com, 2025. Azimut Yacht Ramonda Destroyed in Fire at Portonovi Marina, Montenegro, Nautic Magazine. Available at: https://nauticmag.com/2025/03/28/azimut-yacht-ramonda-destroyed-in-fire-at-portonovi-marina-montenegro/nauticmag.com (Accessed: 28 March 2025).

NVIDIA Developer, 2014. NVIDIA FlameWorks. Available at: https://developer.nvidia.com/flameworks (Accessed: 24 March 2025).

Occupli.com, 2025. VR Fire Training Fighting Fire, without Fire. Available at: https://occupli.com/vr-fire-training-2/ (Accessed: 4 May 2025).

Radianti J. et al., 2020. A systematic review of immersive virtual reality applications forhigher education: Design elements, lessons learned, and researchagend. Available at: https://www.researchgate.net/publication/337836234_A_systematic_review_of_immersive_virtual_reality_applications_for_higher_education_Design_elements_lessons_learned_and_research_agenda.

Russell, M.D. et al., 2024. Impact of Virtual Reality on Decision-Making and Risk Assessment During Simulated Residential Fire Scenarios. Fire 2024, 7, 427. Available at: https://doi.org/10.3390/f ire7120427.

Tao, R. et al., 2024. A unified particle method for fluid simulation in ship fire scenario. Ocean Engineering, 312, 119266. Available at: https://www.sciencedirect.com/science/article/pii/S0029801824026040.

Unreal Engine Forums, 2022. Open VDB and Nano VDB Rendering. Available at: https://forums.unrealengine.com/t/open-vdb-and-nano-vdb-rendering/150807 (Accessed: 22 March 2025).

Unreal engine, 2025. Niagara Fluids in Unreal Engine. Available at: https://dev.epicgames.com/documentation/en-us/unreal-engine/niagara-fluids-in-unreal-engine (Accessed: 20 May 2025).

Vijesti.me, 2025. Firefighters give up trying to put out fire on yacht off Portonovo, fearing oil spill into the sea. Available at: https://en.vijesti.me/news-b/society/751778/Firefighters-give-up-trying-to-put-out-the-fire-on-a-yacht-in-Portonovo--fearing-an-oil-spill-into-the-sea en.vijesti.me (Accessed: 27 March 2025).

Vijesti.me, 2025. Yacht 'Ramonda' completely destroyed in fire, environmental incident prevented. Available: https://en.vijesti.me/vijesti/drustvo/751830/jahta-ramonda-u-pozaru-potpuno-unistena-sprijecen-ekoloski-incident en.vijesti.me (Accessed: 28 March 2025).

VR Template in Unreal Engine – Epic Games Developers, 2025. Available at: https://dev.epicgames.com/documentation/en-us/unreal-engine/vr-template-in-unreal-engine (Accessed: 04 May 2025).

Vukelic, G. et al., 2023. Application of VR Technology for Maritime Firefighting and Evacuation Training—A Review. J. Mar. Sci. Eng. 2023, 11, 1732. Available at: https://doi.org/10.3390/jmse11091732.

Westphal, M., 2025. Designing a user centric VR UI/UX for scientific visualization, *IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW)*, Saint Malo, France, 2025, pp. 178-180, doi: 10.1109/VRW66409.2025.00044.

Yuxiang, S. & Guozhen, S., 2024. Haptic Sensing and Feedback Techniques toward Virtual Reality. Research. 2024;7:0333. DOI:10.34133/research.0333. Available at: https://spj.science.org/doi/10.34133/research.0333.