EMERGING TECH CONFERENCE – Edge Intelligence

Volume 01, 2022, Page 230 – 235

Proceedings of Emerging Tech Conference: Edge Intelligence 2022

Immersive and Interactive VR Experience for Highlighting and Interpreting a Historic Event

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Abstract

This paper presents the initial results of a proposed workflow towards highlighting and interpreting a historic event with the use of an immersive and interactive VR experience utilizing the user's multiple senses developed in the framework of the project Personalised interaction with Culture Realities Virtually Enhanced (CuRVE) [1]. More specifically, we present results from tests performed for the reconstructed battleship torpedo boat 11 (T11), where the users visit the shipwreck of the battleship Fethi Bulent, visit the battleship T11, navigate the ship deck, and interact with its reconstructed parts in order to experience the torpedoing and sinking of battleship Fethi Bulent in Thermaic Gulf of Thessaloniki during the night of October 18 / October 31, 1912, by Lieutenant Commander Nikolaos Votsis, commander of battleship T11. The specific event caused excitement on the Greek side as it was the most impressive success of the Greek Navy during the First Balkan War. The proposed workflow is an approach towards the development of a game-like environment where the users can learn about a historical event and supports the integration of the equipment for a high-level immersive realistic experience in a detailed and interactive virtual environment.

1. Introduction

Dynamic simulation of the real world with the use of VR technology allows the user to navigate in the virtual environment, interact with 3D objects, and access information through gestural interaction [2]. With VR the users can visit inaccessible sites (such as underwater monuments) and perceive the interactive knowledge in fully or partially immersed environments, where the sense of presence is created by multimodal interfaces. The natural experience in VR is enhanced by locomotion so that users can make physical movements such as walking and running in a vehicle-or- body centric approach that constrains them in a fixed position, proxy gestures, and redirected walking [3].

This paper presents the initial results of a proposed workflow toward visualizing and interpreting a historic event through a fully immersive and interactive VR experience utilizing the user's multiple senses. More specifically, we present the workflow as it was implemented for the event of the torpedoing of the battleship FB in 1912, where the user is to navigate through the shipwreck, visit the ship T11 the night of the event, and take part in the action by interacting with various elements and characters.

Nomenclature

VR Virtual Reality

T11 Torpedo boat 11

HMD Head-Mounted Display

UE4 Unreal Engine 4

FB Fethi Bulent

UDP User Datagram Protocol

2. Methodology

For the development of the specific immersive VR application, the UE4 was used [4]. It allows the creation, editing, and management of scenes (levels), materials, characters, animations, and extensions in the functionality and the user interface. The immersive virtual visit takes place with the use of a VR treadmill. The selected virtual reality system was HTC Vive and its components. HMD has been used for the visualization of the scene, the Vive base stations have been used for room-scale tracking, and the Vive trackers for tracking the wrist position and rotation.

The proposed workflow can be used for a personalized tour (by an avatar) and interaction in a virtual immersive environment of cultural interest associated with the exhibits of a demonstration workshop. Visitors will have an immersive experience by visiting FM in the underwater space for an introduction and to visualize the shipwreck in the background and in a state similar to that in which the FB wreck is today. Then the visitors can move to the deck of T11 where they can navigate using a treadmill to watch the torpedoing of the FB, but also to participate in the action as part of the crew; The immersive VR application allows also the users to visit the virtual room where they can observe virtual exhibits related to the historical event and interact with selected 3D virtual exhibits.

Interactions in an immersive VR environment with virtual objects can be done through i) tactile gloves where the user uses their hands as in the real world. Haptic gloves have the advantage of accurate mapping of all fingers and therefore a more realistic result; ii) the controllers of the VR headset where their buttons correspond to specific commands (object selection, rotation, menu options, etc.).

2.1 Design of the Virtual Environment

The underwater virtual site consists of (Fig.1) of a terrain for which material with sand characteristics has been chosen. It also contains flora and fauna typical of a seabed. Seaweed is a 3D moving object that repeats itself over the terrain. Special effects such as underwater bubbles are implemented through the UE4 Cascade Particle System, a fully integrated and modular particle effects processor for real-time processing of various complex effects. For an enhanced underwater effect UE4 Volumetric Fog has been used, which calculates the density and lighting at every point visible from the camera, while photorealism of the underwater environment has been enhanced with the use of caustics.

Figure 1: Underwater virtual site

The main scene consists of the 3D reconstruction of the two main ships of the event, the FB and the T11, and the scenery of the Thessaloniki city, as provided by the film production company N-CODE [5], a simulated sea system and with the proper volumes and particle effects we simulate the weather conditions of that night, foggy and rainy (Fig. 2).

Figure 2: Left: Main scene in UE4. Right: Weather conditions simulation

2.2 Hand Tracking and Haptic Feedback

Vive Trackers have been used to enable hand tracking. These have been enabled with SteamVR and programmed through UE4 to follow the position and rotation of virtual hands. Vive Trackers have been used also for tracking the position and rotation of the wrist.

Haptic feedback was implemented with the use of a commercially available pair of haptic gloves which act like wireless controllers for Extended Reality (XR) providing precise wrist and finger tracking along with a haptic feedback effect for each finger. It allows interaction with five fingers, with one vibration motor under the last phalange of each finger. Inertial sensors provide the measurements of the fingers and hand movements. The integration of the gloves was done with the UE4 plugin provided by the company. Sensors on the gloves automatically provide the fingers' position, while data for the haptic feedback, need to be sent dynamically through a User Datagram Protocol (UDP). After a connection is established, the proper JSON string is sent, with information about the desired vibrations (left or right hand, finger index, vibration type, and vibration duration). The whole process is accomplished with two plugins for socket communication. Currently, visualization and animation of the hand a performed through the default hand mesh of the UE4.

2.3 Interactions with 3D virtual objects

Virtual 3D interfaces: The user has at his disposal a 3D virtual menu (Fig. 3) through which the management of all the basic settings (volume, exiting the application, language, etc.) is possible. This menu appears in the form of a cube and the user can interact with it by selecting with the hand (while wearing tactile gloves) one of the buttons. By pressing the up or down arrow buttons the user can switch to the language or volume menu respectively. In the language selection menu, the user can choose between Greek or English, while in the volume menu, the user can increase or decrease the volume.

Figure 3: 3D virtual menu. Left: language management, Right: volume menu

Steer the wheel of T11: users can grab the wheel with both their hands. Turning the wheel with the haptic glove (Fig. 4) is also possible. When users close their hand around the handle, vibrations indicating the grabbing movement allow the user to make a natural movement in order to turn the wheel.

Figure 4: Turning the wheel with the haptic glove

View with the use of binoculars placed on the deck: with the HMD the user sees the display of another camera with a smaller depth of field, placed in front of the glasses of the binoculars. To avoid any unwanted motion sickness the transition is displayed smoothly as they place their head closer to the binoculars. The desired result is for the user to inspect closer the battleship FB and the city of Thessaloniki (Fig. 5).

a. b.

Figure 5: a) Initial view of FB from the deck of T11 b) FB closer look with the use of binoculars

Physics: All the elements in the scene follow as realistically as possible the laws of physics. The ships follow a simulated buoyancy system modeled like a lossless spring-mass system around an equilibrium plane called buoyancy level based on the position as follows:

- when xmax: gravity force is enabled
- when xmin: gravity is disabled and a force equal and opposite is given

All 3D objects have mass, collision, and friction enabled so the user cannot enter a virtual object but still be able to interact with them. For example, the torpedo gun will rotate if they collide with it on one end or a barrel will fall if they push it with their virtual body.

2.4 Locomotion Simulation

A body-centric approach has been chosen which strengthens immersion as it eliminates the real-world limitations and enables and allows the user to move freely while performing other tasks, like interacting with objects or gazing in different directions. To this end, a commercial solution (Cyberith's Virtualizer treadmill) [6] has been chosen. It uses a flat, low-friction walking surface and a rotating containment ring, which prevents the user from displacing in the physical space. The walking direction (between 0 and 360 degrees) is defined by the orientation of the ring which contains an adjustable belt system to accommodate users with different body types. The treadmill also provides a vertical movement that enhances flexibility and allows users of different heights to use it effortlessly. To avoid certain fatigue for the user due to the use of the treadmill for a long period of time, while moving freely on the ship, the user stops to interact with the different elements provided (the steering wheel, the binoculars, and other 3D objects).

The integration of the treadmill was made with the use of the device's Unreal Software Development Kit (SDK). The user's movement and orientation are detected by the treadmill's sensors while the user's location is identified by the HMD sensors. The sensor's collected data define the following variables:

- MovementVector: a 3-dimensional vector describing the movement speed value in the three different axes. The Movement Vector is also multiplied with a user-defined variable called speed Multiplier so that the movement speed can be adjusted to each individual walking style.
- OrientationVector: a 4-dimensional vector describing the user's orientation in quaternions. The Orientation Vector is transferred to the player's local coordinate system by multiplying it with the corresponding transformation matrix.
- UserLocation (ULoc): a 3-dimensional vector defining the user's position in the three different axes.

The user's final location is updated in each frame and calculated as:

$$ULoc = ULoc + (MovementVector * OrientationVector * unrealConstant * deltaSeconds),$$

where unrealConstant is a constant variable used for correct unit conversion from the treadmill's input value to Unreal's final output and deltaSeconds (Delta Time) describes the elapsed time since the previous frame.

This formula is used for a smooth and steady walking animation, regardless of the system's hardware or the scene's complexity. An interesting way to enhance the sense of presence is the utilization of the haptic feedback of the treadmill. Small vibrations on the platform indicate that the user reached the boundaries of a predefined path [7] and various vibrations according to the events enhance the realism of standing on a ship (waves, explosion, etc.). The tension and duration of the vibrations are carefully designed so that no further fatigue is added.

3. Results and future work

Our developed system utilized specific hardware devices to engage as many user senses as possible. The HMD offers high visual and auditory stimuli, the haptic gloves along with the Vive trackers provide high-accuracy hand tracking and haptic feedback, and the omnidirectional treadmill for locomotion requires the lowest mental effort and delivers a satisfying sense of presence. The application we designed was a virtual experience for the event of the torpedoing of the battleship Fethi Bulent. It consisted of underwater exploration of the shipwreck, and a visit to ship T11 where the user can be a part of the historical events that took place that night.

This study not only offered insightful suggestions regarding VR user experiences but also pointed to the need for additional research. While it gave us a good idea of the key elements of immersion, comparative research to test the effectiveness of our approach should be of great importance. Additionally, increased use of the Vive Trackers may enhance the immersive experience with the visualization of the whole arm. Similar to [8], a visual representation of underwater drag force perception could increase the sense of presence in the underwater environment. Overall, our method demonstrates that it was quite effective in intriguing people's interest in learning about cultural heritage, and applications like this will undoubtedly be very beneficial to cultural institutions.

Acknowledgements

This research has been co-financed by the European Regional Development Fund of the European Union and Greek national funds through the Operational Program Competitiveness, Entrepreneurship and Innovation, under the call Special Actions in aquaticfarming- industrial materials- open innovation in culture (project code: Τ6ΥΒΠ-00120 -CURVE).

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