

Sarajevo War Tunnel VR Experience

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Abstract

Some cultural and historical heritage artifacts and monuments cannot be visited or explored anymore. One of those is the Tunnel of hope, which enabled people to cross from the besieged city of Sarajevo to the free territory, bringing essential amounts of food, medical equipment, and weapons. The Tunnel was crucial for the defense of the city during the war in the 1990s. Presently, it is only partially accessible to visitors. The project aims to provide the users with the unique war experience of passing through the Sarajevo Tunnel of hope using immersive virtual reality. At the same time, the user is motivated to learn and to explore, which makes the application both entertaining and educational. The initial user evaluation shows that we succeeded to share the siege emotion and experience through this application.

Keywords: virtual reality, user experience, user immersion

1 Introduction

Virtual Reality (VR) offers the users possibilities to be present and interact in a different space and time. This is particularly useful for the presentation of cultural heritage that cannot be experienced in reality.

The siege of Sarajevo lasted 1425 days and was the longest siege of a city in modern history. One of the key factors that enabled the citizens to survive was the building of a Tunnel under Sarajevo airport runway, which connected the edge of the city with the free territory on the South. Nowadays the Tunnel is closed due to the runway security, so it is not possible to experience passing through this remarkable object anymore. The goal of our project is to enrich the Tunnel museum with the VR application by recreating the emotions of people who were passing through the Tunnel during the war. It is a part of a larger

project where interactive digital storytelling about the Tunnel will be added before the VR experience.

The paper is organized as follows. Firstly, related work is described, with a review of the methods used in projects similar to ours. Explanation of the work progress and project concept follows. In the fourth chapter, user evaluation is given. Lastly, the conclusion based on the previous is presented.

2 Related work

Since the development and usage of VR are in steady growth and considering the popularity of VR technology, there is a lot of research considering this topic, including many applications treating historical and cultural heritage using immersive VR experience. Of particular importance is that, as Roussou states in [7], usage of VR allows users to travel through space and time without stepping out of the museum building, or in broader case, without leaving the place VR setup is placed. This is particularly important in case of destroyed or unreachable cultural or historical artifacts and monuments.

In [9], Tost and Economou investigated whether immersive virtual reality is suitable for learning about archaeology and the past in cultural heritage settings. Their research showed that, in order to be useful in learning, cultural heritage VR presentation has to present an interactive and meaningful reconstruction of the past. This approach is being used in our project through the reconstruction of the tunnel's appearance and atmosphere during the war but also using interactions for presenting information.

Ferrari and Medici in [2] offer a demonstration of possibilities for space understanding from abroad by absorbing reality into a non-interactive virtual environment on the case study of the medieval royal palace in Georgia. The 360 degree video and 360 degree photography were used in order to make the immersive virtual environment. The 360 degree video will also be used in the VR presentation of the Tunnel Museum in order to obtain user immersion.

What we find as a disadvantage of the proposed method by

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Ferrari and Medici that no interactions are available, and the story plot is predetermined.

In [1], Bruno et al. presented the usage of VR for the Exploitation of Underwater Cultural Heritage. The project iMARECULTURE [3] explores the same topic of using immersive virtual reality techniques for presenting European underwater cultural heritage, which is physically inaccessible to the majority. Having the same motivation of showing inaccessible monument and impossible to feel emotions, we are using similar methods.

In [6] authors presented the Virtual Museum application, and showed that this way of presenting cultural heritage "significantly contributes to the promotion of a country and spreading knowledge about its history". The goal of our project is to improve the experience by using virtual environment. In [4] authors propose the usage of game engines in presenting heritage, and conclude that "the use of games engines to create virtual heritage applications has been successful". Similar game-like aspects are being embedded in the tunnel simulation. In [5] authors propose the virtualization of heritage sites through mobile applications, which are affordable and more easy to use than the VR equipment such as HTC Vive we are using, but also gives fewer opportunities to make interaction more natural and the whole experience is less immersive.

In [8] Selmanovic et al. presented how VR can provide a means by which to explore and investigate intangible cultural heritage sites. In this project, among 360 degree videos and storytelling, Mostar Bridge diving is offered to users in VR simulation.

Authors conclude that "for preservation, it is not only important to document the heritage, but to transfer the intangible part which can include feelings, perception, drive and motives." What we find as an advantage of the methods used in Selmanovic et al. [8], is that the intangible heritage is being presented and preserved. What we consider a con in the mentioned work is that too much information is being given in narrative form without interaction, instead of focusing on the realism of the simulation and embedding information in simulation.

3 The tunnel simulation

The siege of Sarajevo started on 4th April 1992 and it continued for 1425 days. Units of the former Yugoslav National Army and Serb extremists' paramilitary forces surrounded the city and launched an unprecedented campaign of terror against its 500,000 residents. Water and power supply were cut and the gas supply was reduced. The city started to run out of food. The aggressor fired at the city from all the weapons in its arsenal. Snipers located at the surrounding hills fired mercilessly at pedestrians crossing street intersections. In June 1992, the United Nations assumed control over the Sarajevo Airport. Instead of terminating the siege immediately, they started delivering humanitarian aid under the principle: half to

the aggressor, half to the victim.

In order to survive and obtain at least the minimal amount of food, medical supplies and ammunition, the Sarajevo citizens have built a tunnel under the airport runway. After a few unsuccessful attempts to cease the siege of Sarajevo, and all of them ending in huge human losses, the construction of the tunnel seemed at that moment as the last straw for a change of the extremely difficult situation in the city, but also in the entire territory where the battles for liberation were led. The work on the tunnel started at the beginning of 1993. Consequently, the tunnel was dug by hand, with shovels and picks, and wheelbarrows were used to carry 1,200 cubic meters of detritus away. The tunnel was dug 24-hours a day, with workers working in 8-hour shifts digging from opposite ends. Its construction was supported by the BH State, the Army, and the City of Sarajevo. The workers were paid with one packet of cigarettes per day, an item that was in high demand and a prized bartering possession. The construction of the tunnel was completed on 30 June 1993, when the two tunnels met in the middle. Use of the tunnel began the following day on 1 July 1993.



Figure 1: The map of Sarajevo siege with the position of the Tunnel, photograph from the Tunnel Museum

After the end of the siege and the cessation of the need for communication under the runway, the tunnel was abandoned. It began its decline. Without regular maintenance, it was quickly flooded with water, began to crumble. Day after day, it disappeared meter by meter. Today only the first few meters are accessible to the public.

The idea of making any simulation in VR is not easy, because the main problem is how to make all the actual reality aspects seem realistic in the virtual world. So to make the experience of the simulation as realistic as possible, a lot of effects that will increase the users' sensation have been used, involving audio effects like the storm in the background, bomb explosions, bullets and shot sounds, also visual effects including light flickering and blackouts, as well as the model of the tunnel itself with all the accompanying textures and materials.



Figure 2: A photograph of the real tunnel.

The challenge about this particular model was that the real tunnel had varying height so at some places it was higher and the average sized person could walk normally, yet on other places it was really low so the person had to bend. To achieve this effect in the application, the exact same varying height had to be simulated using colliders on the ceiling. Further, the tunnel was narrow and two persons could barely go by each other, so to simulate that, a man that is pushing a wagon with supplies in the opposite direction was added, and the user has to move to the side in order to move on.

During rain storms the tunnel was often flooded, sometimes to the point that it had to be closed, so the animation of the water level rising was added, in order give the users insight on how would that look to be in a narrow space and with no exit near you. Because the tunnel was dark and the lights that were mounted in it couldn't always help illuminate it, as the result of blackouts due to electricity shortage, a lantern was added so the users can navigate even if it's pitch black.

All the aspects crucial for realism and immersion were added in order to produce a mix of feelings like fear, anxiety and concern yet in the end safety and relief.

The first phase of our project included collecting detailed information about the Tunnel. Even though there is limited documentation about it, since the construction of the tunnel was considered confidential, old footage and images were provided by The Museum of The Tunnel of Life [8]. Also, an interview with a member of the BH Army regiment in charge of the tunnel traffic security was



Figure 3: Rendered preview of the tunnels 3D model created in Blender.

conducted. All of that documentation provided details on the tunnel overall appearance which enabled the start of the modeling phase. The model of the Tunnel has been made in respect to an actual architectural drawing shown in Figure 4. Also, the materials and textures that were used in the project are corresponding to real-life images. The 3D model was made in Blender and Physically-Based Rendering (PBR) was used to make materials and texture files for a more realistic approach.

After the model creation and the preparation of materials, the next step was importing the model into a Unity application. Every object has its own collider, so there are no flaws and possibilities for unrealistic movement. Also, some objects may be picked up. When it comes to lightning, blinking point lights were used, in order to achieve realism and represent possible situations at the time when the tunnel was still active. All of the scripts used in our project were written in C#. The application was then adjusted to use HTC Vive Head Mounted Display.

As currently in progress, the educational part will be added to the application. This part will include a "tour" around the museum and which should lead to learning about the Tunnel's past including information about the happenings in the tunnel during the war in Bosnia and Herzegovina. After the users learn about what the tunnel represented to the people at the time, and how big of a role it played, they will be presented with the short quiz to confirm this newly achieved knowledge. If successful, the user will be granted access to the Tunnel, in order to experience all above mentioned in the simulation.

4 User experience evaluation

In order to confirm that the immersion has been achieved, the initial user experience evaluation was made. The VR application was set in the laboratory and presented to the participants. Participants were asked to complete the questionnaire, made in Google forms, after using the application. The questionnaire consisted of the four

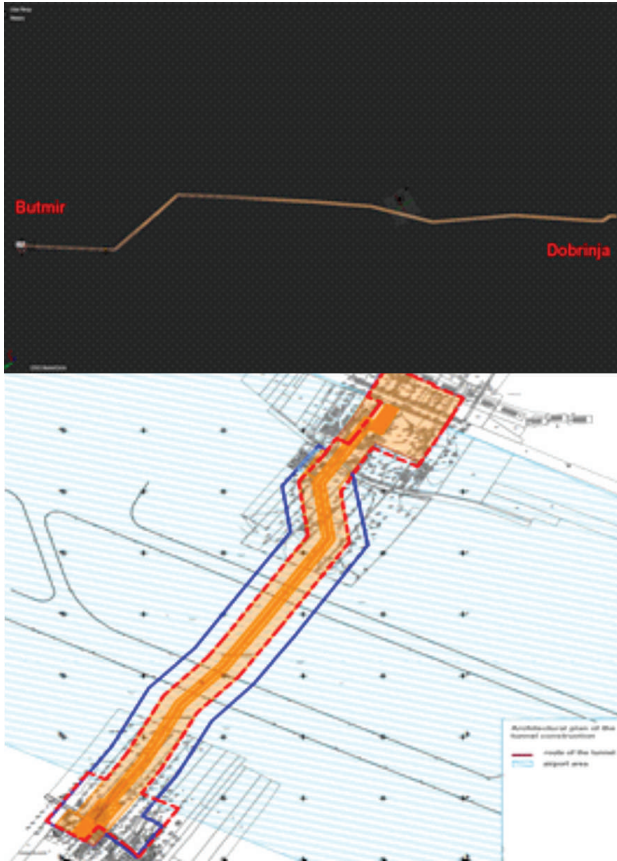


Figure 4: The top view of the 3D model (upper image) compared to the architectural plan of the actual tunnel (lower image).

groups of questions, considering demographics characteristics of users, emotional aspects, ease of use and overall experience.

The initial user experience evaluation study was conducted on 10 participants. Most of them were of age 20-30, and already used applications of virtual reality. One of them passed through the Tunnel as a child during the war, and three of them visited the Museum. Demographics statistics are listed in Table 1.

What almost all of the participants agree of, is that visual and sound effects improve the overall experience of crossing the Tunnel. Also, most of them declared that exiting the Tunnel caused a feeling of relief.

Considering the ease of use, most of the participants agreed they walked through the Tunnel without difficulties, but they did not find the bent walking was natural in the given situation. What amazed users the most, was the realism in presenting the Tunnel, but they disliked the way how walking through the Tunnel was implemented. However, the users that used the Tunnel in the war did not find the bent walking a problem nor unnatural, so this result should be examined further. Results of the



Figure 5: In-game preview.

Question	Responses	Number	Percent
Gender	Male	6	60%
	Female	4	40%
Age	20-24	9	90%
	25-34	1	10%
	>34	0	0%
Prior use of VR	YES	8	80%
	NO	2	20%
Crossing Tunnel during the war	YES	1	10%
	NO	9	90%
Visited Museum of the Tunnel	YES	3	30%
	NO	7	70%

Table 1: Question summary statistics for the demographic breakdown of the participants.

questionnaire are shown graphically in Figure 7 and Figure 8.

Overall results of the questionnaire show that realism and immersion were achieved, but also showed the places for improvement considering the way of walking in the tunnel. This is shown in Table 2, where participants gave a lower score on the question Q11. After the completion of the second part of the project, which will embed educational aspects in the application, a more detailed evaluation will be made.



Figure 6: VR setup for initial evaluation.

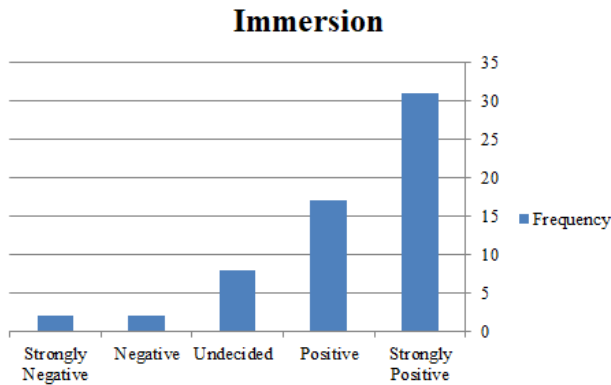


Figure 7: Frequency of responses considering immersion.

5 Conclusions

This paper describes how to use VR technology to recreate war heritage experiences. The Tunnel VR application presents to the users challenges of passing through the Sarajevo Tunnel, carrying weight, in the darkness and mud, under the shelling and sniper fire. The initial user evaluation confirmed our hypotheses on increased sense of immersion that users feel during this experience which helps them to learn about the events from the war history. A more thorough user experience evaluation will be performed after the interactive digital storytelling part of the project is added before the VR part. With that we will be able to evaluate also the educational value of the virtual presentation.

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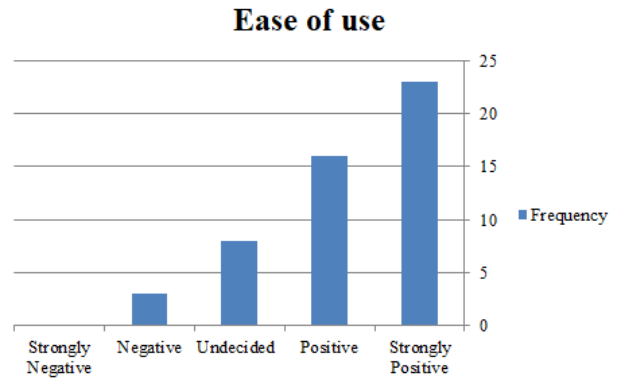


Figure 8: Frequency of responses considering ease of use.

Statement	Mean score
Q1. I felt anxious while crossing the tunnel.	3,6
Q2. I felt as I carry the weight.	3,8
Q3. Low light improved immersion.	4,4
Q4. Sound effect improved immersion.	4,8
Q5. I felt as I'll never leave the tunnel.	4
Q6. I felt relief when I stepped out of the tunnel.	4,7
Q7. I passed the tunnel without difficulties.	3,8
Q8. Walking through the tunnel was reasonably limited.	4,3
Q9. User commands are recognizable and intuitive.	4,6
Q10. Usage of application was clear.	4,7
Q11. Banded way of walking felt natural in a given situation.	3,5

Table 2: Summary of statements score. Responses were assigned the following scores: Strongly negative - 1, Negative - 2, Undecided - 3, Positive - 4 and Strongly Positive - 5, enabling calculation of the mean score, as an average value of user responses.

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