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Short Paper

Da Vinci Effect – multiplayer Virtual Reality experience

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Abstract

Virtual Reality is a technology of choice for time traveling. VR applications enhance museum collections and cultural heritage sites with exciting opportunity to experience the life in the past. Da Vinci Effect (DVE) is a multiplayer VR game for teenagers aiming to introduce them with works of Leonardo da Vinci and his paramount role in history of mankind. In this paper we present the process of application design and development, as well as the users' impressions showing how powerful Virtual Reality is in edutainment of young generations. We describe the novel approach which utilizes the "inside-out" tracking capabilities of the Oculus Quest and Quest 2 mobile VR headsets.

CCS Concepts

• ***Human-centered computing*** → ***User studies;*** • ***Computing methodologies*** → ***Virtual reality; Simulation types and techniques;***

1. Introduction

In early research [BYB*] it became apparent that immersive technologies could provide a more effective means of conveying knowledge and skills compared to conventional educational tools. Based on experiments with 360-video as educational tool, the next step was to explore more interactive "6DoF" (6 degrees fo freedom) immersive formats. Based on this, the concept of a teacher and students exploring Leonardo DaVinci's workshop in VR, and interactively recreating his invention evolved. This concept was adapted to a more compact version for the purpose of the Creative Europe collaborative project "Real Heroes".

The project is a joint effort across creative and cultural boundaries to develop a fully operational cross-platform mixed reality storytelling model to invite young people to engage and interact with the superstars of European science, art and society, their stories and heritage. It aims at inspiring young people to think boldly, to persevere, concentrate and invest in a meaningful career, durable paths of research and long-time goals. The pilot story is focusing on Leonardo Da Vinci, the iconic Renaissance genius, as a self-made authentic thinker, artist and scientist.

The goal of this research was to explore the effectiveness of multiple users performing a series of collaborative puzzle-solving tasks in a "co-located" virtual environment. We will show how this interactive storytelling methodology contributes to learning about cultural heritage in young population. The technical contribution is development of the novel approach which utilizes the "inside-out" tracking capabilities of the Oculus Quest and Quest 2 mobile VR headsets.

In Related work section we analyze similar projects and identify their advantages and drawbacks. Application design and structure are described through assets creation, historical research and visual styling, creating the workshop, photogrammetry and 3D modelling, filming the actor and music and sound design processes description. In Application development section we present the collaborative programming of the multi-player VR application. We describe the initial impressions of users in User experience section and at the end we offer conclusions and present the lessons learned during the project implementation.

2. Related work

Increase of player's effort in competitive multiplayer gaming is shown in [Man02]. Cases and research about multiplayer Virtual Reality games used for learning purposes can be found in [Var18, FDS20, SGMFM08, GSFR17, DAdK*22]. Findings by Paraskeva et al [PMP10] indicate that adolescents are spending a significant time playing digital games and they also tend to identify with their characters. Harteveld and Bekebrede [HB11] claim that a multiplayer approach is a better fit if broad and abstract insights need to be derived or if the learning objectives are socially oriented.

In order to create a multiplayer game in VR environment, we analyzed various related projects. [BSM19] explored the role of

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physical co-presence in multiplayer room-scale VR, and concluded that physical presence of players in the same room is important for the experience. Another example is “Star Trek Bridge Crew” is a Mulitplayer VR experience where the players control a star ship [Sta] in which the problem of locomotion was avoided. In games such as Arizona Sunshine [Ari], and Dead and Buried [Dea] the player is physically standing, but is restricted by his/her physical space, and (in case of tethered PCVR systems) restricted by the length of the cable.

Physical “free roaming” multiplayer VR are another possibility. In this case the user needs to be “tracked” in the physical space, to control the position of the virtual avatar. This requires optical or magnetic motion tracking systems such as Vicon or OptiTrack. A well-known example is “The Void” [Voi]. Due to high cost, this organization had to seize operations.

The last major challenge is calibration; with multiple user sharing the same space, the devices need to be aware of each other’s positions. A game called “Space Pirate Trainer” [Spa] achieves this to a certain degree, by requiring the users to have a 10x10 m2 play area. This is the maximum play area accommodated by the Quest-device. The system is not perfect, and does not allow for high-accuracy in terms of physical user interaction.

We created the **Holojump system**, a software framework which solves all of the above issues. With mobile VR headsets (Quest 2), and without the need for third-party tracking systems, or permanent facilities, a shared-space multiplayer experience can be set up anywhere with enough floor space to match the size of the designed game. The downside is that the graphical fidelity is limited by the capabilities of the current generation of mobile VR headsets. However, the framework is fully modular, and cross-platform. Therefore, it was possible to work with scenes designed by designers in remote locations, and implement these in the Holojump framework.

3. Application design and structure

The Da Vinci Effect application has the following game mission: "use the History-Hologram to visit Da Vinci’s workshop and figure out what was on the blank page. You will need to work together to figure it out! Before you can go inside you of course need to wear your Hologram-Helmet (Quest-headset). And remember, the machine uses a lot of power and will only work for 8 minutes at a time. So be smart, be quick, and don’t forget: Work together!"

Three players are coded by colors and need to perform the following tasks:

Red Player should find the easel with Mona Lisa and a brush to restore the painting. Green player should find a a lens-grinder and a missing crank-arm. Blue player should restore the ball-bearing finding the missing ball.

When all tasks are completed for each player, three coloured cylinders appear in front of the discovered objects, with footsteps. All three players now need to stand in their cylinders and watch animations about the objects’ discovery and creation by Leonardo.

Once all three Leonardo’s inventions have been discovered, three more coloured cylinders appear, this time near the fourth corner of the workshop. Once activated, Leonardo da Vinci materializes in the corner. He looks at the Mona Lisa, the Lens Grinder, and the Ball Bearing. Then he looks at the three players and thanks them for their mission.

The collaborative aspect of the game is expressed in the moments when, after completing each task, all players have take positions in their cylinders and watch the explanations about Leonardo’s discoveries they just have restored.

4. Assets creation

Da Vinci Effect application (DVE) production started with assets creation, including 3D modeling of the workshop and all elements inside it, creating the panoramic illustration of Florence that will be visible out of the windows and balcony, filming the actor playing Leonardo, composing music and designing the soundscape of the environment.

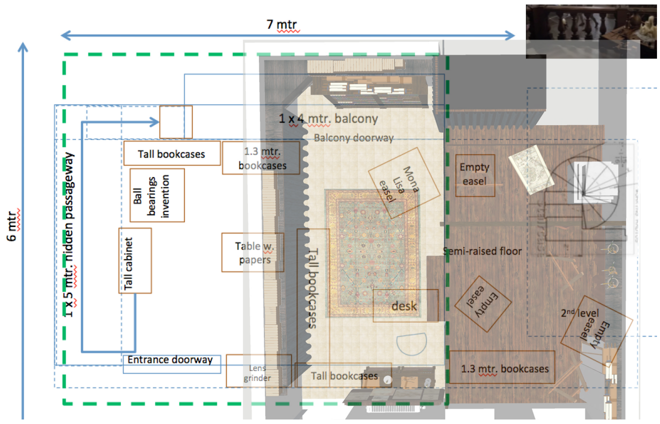

Figure 1: *Proposed layout for the Da Vinci workshop.*

Figure 2: *Objects obtained from photogrammetry used for the Da Vinci workshop.*

Instructions for the possible room layouts for Leonardo’s workshop were provided by experts art historians and set designers and images of spaces that match the time frame were used for reference. One of the proposed layouts, which is most similar to one that was implemented in the application, is shown in Figure 1. The majority of the workshop was created from models obtained by photogrammetry, including the ceiling, the dome, windows and curtains. These objects are shown in Figure 2.

Some small objects such as easels and paint palette were also created using photogrammetry, while the rest of the workshop objects such as tables with paints and brushes shown in Figure 3, shelves with artefacts and Leonardo's inventions were modelled.

All of the objects in the workshop were meant to be interactive, so it was mandatory to make the models as accurate as possible since users could take them in their hands and turn them around, getting very close to them and seeing them from all angles.

Further on, the workshop had a secret passage leading to the balcony. The secret passage can be accessed through the fireplace when the user solves one of the puzzles. Both the balcony and the secret passage were made by 3D modelling using reference images provided by experts art historians. To achieve the correct atmosphere in the workshop, we used different light sources to simulate the golden hour. The view from the balcony was created using five overlapping Florence illustrations shown in Figure 4, placed at different distances from the user, to create the illusion of view depth and distance.

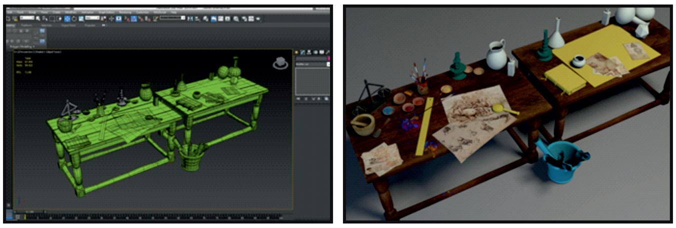

Figure 3: *Objects created by 3D modelling.*

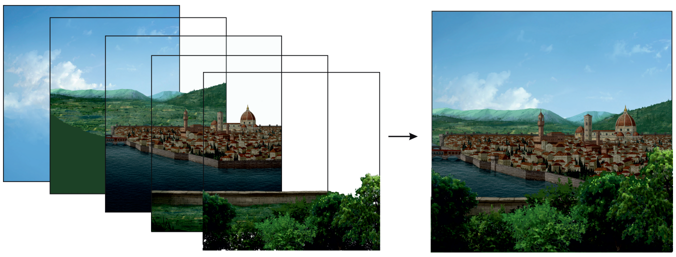

Figure 4: *Florence illustrations used for the view from the workshop balcony.*

5. Application development

We developed a multiplayer "co-location" platform which formed the technical framework for the Da Vinci Effect. Generally, VR experiences are designed for players each being in their own physical environment (living room, office, etc.). In those cases it is assumed that the user is certain that no physical objects are obstructing the

Figure 5: *Green player in Leonardo's workshop*

virtual playspace. In multiplayer experiences, each player is physically in a separate area, while virtually the player-avatars can be in the same room. In these scenarios "locomotion-systems" such as teleportation or joystick-based movement are used to move the avatars around the virtual space. A problem arises specifically with educational and/or training applications where it is beneficial for users to physically be in the same space. In "LBE-applications" (Location Based Entertainment) this same problem is addressed by combining existing motion-tracking systems such as Vicon and Optitrack with VR-systems contained in backpacks worn by the users. These installations are quite cost-prohibitive and require custom and costly hardware and software solutions to be implemented in tandem with the motion-tracking systems.

This problem was solved with a novel approach. We developed a proprietary software framework which utilizes the "inside-out" tracking capabilities of the Oculus Quest and Quest 2 mobile VR headsets. With this solution, users can be in the same physical space (for example, a large gym or conference hall) while their virtual avatars are synchronized with the physical positions of the users. In "regular" multiplayer systems users often experience delays in the shared experience, aka "lag". In this solution voice communication does not require any voice-over-ip implementation since the players are within acoustic proximity, allowing users to normally converse in the real world, while they visually see each other in the virtual world.

Additionally, since users can naturally physically traverse the environment, there is no need for implementation of a locomotion-system. This means the users have less controls to learn, making entering and using the virtual world significantly easier, since less "onboarding"-time is required.

After setting up the workshop layout and objects, to make the single-player version of the game, we added a Virtual Reality camera and controllers. The next step was adding colliders and limits on all objects and walls. Adding limitations on movement in Virtual Reality is a challenge since it is not possible to limit the movement of the user in real space. To overcome this problem, we showed white blurry sight to the user if they try to walk through the walls, shelves or any object that should not be walked through. This overlay is shown until the user physically returns to the allowed walking space. This way, we managed to keep the users in the virtual workshop, while forcing them to stay inside of the physical dedicated game space (Figure 5). Contrary to the multiplayer game that was developed later, in a single-player game, the user could take any object and therefore solve any puzzle. However, all the scripts were prepared in a way that can be used for multiplayer afterwards with as few adjustments as possible.

6. User experience

We have done some informal user testing at the end of application production. The first public play through was performed at the **Tuzla Film Festival** in Bosnia and Herzegovina. A few bugs were spotted here and there, but the biggest problem was periodical losing of the calibration. In the first test, we also had some very young children and it proved to be a bit difficult for them to follow the goal and much more fun just to run around chasing each other. That confirmed our decision to set minimum target user age limit to 13.

The **JEF film festival** is a festival for kids organized in several cities in Belgium. There is a big media lab with audio visual installations and games to show innovative storytelling. The Da Vinci Effect was shown for two weeks in the media lab. We conducted a number interviews with visitors and hosts of the set up and we are very happy with the results.

All interviewed kids and parents highly appreciated the Da Vinci Effect, particularly the fact that it is multi user experience where everybody has to cooperate. According to them, solving puzzles together, finding the secret passage and climbing through the fireplace, screaming for the little spiders on the ground, all add to a very immersive and educative virtual reality experience. We can say without exaggeration that The Da Vinci Effect was one of the most appreciated installations during the festival.

7. Conclusions and lessons learned

This paper presents a methodology for successful development of VR multiplayer application and immersive storytelling experience of historical narrative. We explored the effectiveness of multiple users performing a series of collaborative puzzle-solving tasks in a “co-located” virtual environment. We unrevealed the magnificent work of Leonardo Da Vinci to teenage users through an educational game enabling them to learn about this great historical personality in a fun and attractive way. We involved a multidisciplinary team of art historians, graphic designers, 3D modellers, sound designers, music composers, cameramen and VR developers to create a visually appealing and technically sound application that can be showed at youth festivals. We developed a novel approach which utilizes the “inside-out” tracking capabilities of the Oculus Quest and Quest 2 mobile VR headsets.

A key experience for future projects is to work in shorter development cycles to locate code issues earlier in the process. Also, it would be better to set up and run a custom, private hosted Git-like repository system to more easily manage different code-branches, without the size limitations of a traditional Git-setup.

We found that for the participating venues, this space requirement was not always taken into consideration. When the floor space was found, other aspects such as lighting control and internet access were also challenging. For future events, it is key that the requirements are well-known and sufficiently provided by the venues.

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