

Immersive Virtual Reality with Touch Response: Proposal for Complete Experience

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Abstract. This work proposes the development of an immersive virtual reality environment that includes a haptic device, in order to create a better user experience by adding the sense of touch, with the intention of being applied in both recreational and training projects, such as virtual labs or exploration environments. As a case study, the gymnasium of a higher education institution is reproduced with the original idea of promote the facilities and motivate their use as well as the participation of students in different disciplines, an Oculus Rift device is used together with a Touch 3D stylus haptic device.

Keywords: Haptic devices, virtual reality, tactil retroalimantation, immersive environments.

1 Introduction

In recent years, immersive virtual reality environments are increasingly being used in different areas and are becoming more relevant in training and educational aspects. However, most of this type of environment uses only the sense of sight and hearing, leaving aside the other senses, being that the sense of touch in many occasions can be more important since it allows perceiving sensations that other senses do not. A clear example is the interaction with objects, most of cases the only way to know their texture or rigidity is through contact with them.

In addition, virtual reality environments that incorporate tactile sensations allow greater interaction with the user.

As mentioned in [4], the sense of touch is the only one with immediate outer perception: because of this, touch is the most important sense and the one that teaches the most. Without this sense we would not be able to understand our physical form. According to [8] in order to create sensation of touching a virtual object, a haptic interface device needs to calculate the position of the device by means of sensors and transmit it to the computer, which in turn calculates in real time the force that should be sent to the actuators in the haptic interface, in

order to obtain appropriate feedback and the user can have a tactile perception of the virtual objects.

Likewise, in the last years, the use of computers has become indispensable for the daily life of the human being, however, the human-machine interaction has been mainly focused to be visual and auditory.

According to [7] Virtual Reality is a simulation of a three-dimensional environment generated by computers, in which the user is capable of seeing and manipulating the contents of that environment.

This work arises from the earthquake that occurred in Mexico on September 19, 2017, in a higher education school in the south of Mexico City. The buildings destined for classrooms were affected, making it impossible to carry out normal activities, this caused the furniture to be removed from the buildings and located in the gym, preventing the access of students to it and therefore the performance of sports activities.

This situation has caused that students, mainly newcomers, do not know the facilities that this school has. In addition, not being able to use the gym facilities has caused students who participate in sports teams such as basketball, volleyball, etc., to lose interest and motivation, and has also prevented new students participate in these activities.

Currently, most virtual environments offer only visual and auditory feedback, leaving aside the rest of them, like the sense of touch.

According to [3], two types of interaction variants with virtual environments are recognized: immersive and non-immersive modes. In the immersive mode the user “immerses himself” completely in the simulation through the use of specialized hardware devices, on the contrary, the non-immersive user is constantly distracted by events unrelated to the simulation of the computer, therefore, his brain unconsciously perceives that the virtual environment visited is not part of his reality.

This work proposes the creation of an immersive virtual environment that allows knowing the sports facilities that the school has, in order to promote and motivate the participation of students in various sports activities, since an immersive virtual environment can allow users to immerse themselves in a simulation and thereby motivate them to carry out sports activities.

2 Related Work

There are several works that have to do with virtual explorers or haptic devices, such is the case developed by [6] which allows a complete tour with a virtual reality viewer in order for people to know English Pantheon of Real del Monte town through a cell phone with Android operating system. In another developed project, a virtual environment is proposed that allows the rehabilitation of the upper limb, in which a haptic device is included in a non-immersive way, but with a tactile response [9].

There is also the development of a Virtual Reality application that allows moving around a virtual environment on the Vera campus of the Polytechnic

University of Valencia with the Oculus Rift device [10]. Similarly, the system created by [2] allows users to simulate activities that are carried out in the natural movement of their limbs, these activities are typically with the help of a haptic device to have feedback.

Finally, the work of [11] shows the incorporation of a haptic device that allows a keyboard to be perceived within an immersive virtual environment.

3 Method

This work was developed in Unity[®], the various components and devices used in this work and the way they interact are shown below.

3.1 Haptic Device and Virtual Reality Device

In this work, the 3D System Touch Stylus haptic device manufactured by 3D Systems, Inc. was used. [1] This device is in charge of making the user perceive tactile sensations, it has six degrees of freedom with three of them feedback which allows feel the weight, texture and shape of objects.

The virtual reality device Oculus Rift developed by Oculus[®][5] was used, which allows exploring the virtual environment through its left controller. This device has two controllers and three sensors (Gyroscope, Accelerometer and Magnetometer).

For the incorporation of these devices, libraries are necessary, available in the Unity Store[®], which must be integrated in the virtual environment and work together.

3.2 Construction of the Sports Promotion Instalations and Creation of 3D Objects

This project has a scale representation of the sport instalations, Revit program was used, detailing the spaces of doors and windows to facilitate the construction of a complete virtual environment, with the walls completed, these were exported to a compatible format with Unity to be integrated, the figure 1 shows the bench for men's locker room designed for this project.

The creation of the 3D objects was carried out in Solidworks program. In which furniture and objects contained within the sports development facilities of the school were created, such as lockers, tables, books and others.

Objects were created in two ways:

- Piece, in this way objects were made that can be created without using various objects such as lockers, tables and books.
- Assembly, this way was carried out by joining two or more pieces such as the bathroom benches and sinks.

At the end of object creation in SolidWorks, a format accepted by Blender was elected to be later included in Unity, once each of the objects are included in the virtual environment, the necessary scale, position and rotation are given.

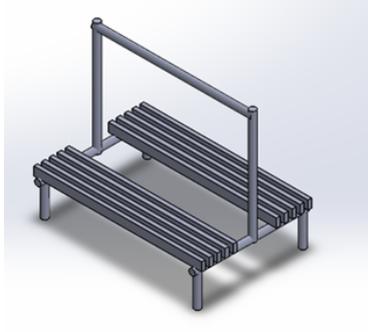


Fig. 1. Benches of men's locker room.

3.3 Virtual Environment

Once the structure of the building and the objects had been designed, the haptic device was integrated, calibrated and configured, likewise, its pointer was inserted as shown in figure 2. It is important to mention that the device must be previously installed on the computer.

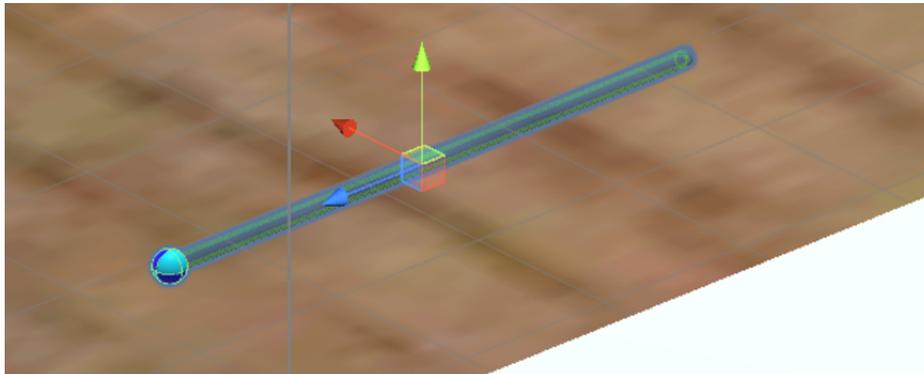


Fig. 2. Haptic device pointer.

This is followed by the integration of the virtual reality viewer, in this case, the Oculus Rift device, which has its own software to configure it on the computer.

In this project, only one Oculus touch controller was used, in this case the left one. So the movement will be completely assigned to this control, the right controller was deactivated and part of the movement code of the left controller was modified to change the functions of buttons and scrolling.

The functions assigned to the Oculus Touch left controller are as follows:

- Command lever: Move the Player through the virtual environment (forward, backward, left and right).
- X button: Player rotation 45 degrees to the right.
- Y button: Player rotation 45 degrees to the left.
- Trigger: Open and close doors.

The prefab object of the haptic device created by 3D Systems was assigned to the main camera of the Oculus rift viewer, with this the haptic device inherits the position and rotation of the viewer, in this way the user can move over the entire virtual environment and can touch everything that is around him.

Finally, the physical properties of the objects that would have in reality, including weight and hardness, were added to the virtual environment in Unity, likewise movements were added when opening doors, bouncing a ball or touching the volleyball net to give more realism to the environment.

In order to users can move through the virtual environment in a more fluid way, 5 scenes were created between they can move, this is done through contact with a transparent object in which the code was developed to indicate which scene must move when having contact, the scenes in which the environment was divided are gym, hallway, office, men's locker room and women's locker room, each of these allows users navigate, see, touch and interact with different objects (see Fig. 3).



Fig. 3. Virtual environment scenes.

3.4 Hardware

For the development and testing of this project, a computer with a 9th generation Core i7 processor with 16 GB of RAM, a GeForce RTX 2060 video card, 4 USB 2.0 ports and an HDMI port was used.

4 Unit Tests

Our users had the following characteristics. Tests were carried out with five people of different ages, genders and different approaches to video games and virtual environments, as illustrated in Table 1.

Table 1. Test users characteristics.

| User | Age | Gender | Approach to virtual reality |
|------------|-----|--------|-----------------------------|
| Subject 1: | 22 | Female | Yes |
| Subject 2: | 23 | Male | No |
| Subject 3: | 23 | Male | Yes |
| Subject 4: | 24 | Male | No |
| Subject 5: | 37 | Male | Yes |

Before the tests each of the users were given a brief introduction on how to make use of the movement control, after having a first contact with the simulation only with the Oculus Rift, the haptic device was incorporated so that they could make a full scan.

The tests consisted of taking a free tour of the facilities, the subjects could move, touch and interact with any object in the scenes. At the end they were asked about their experience and how they felt after removing the 3D viewer (see Fig. 4).



Fig. 4. Subject performing the test.

The tests were carried out separately for each user. In each test the ability to move around the environment was evaluated, how immersed they were in the simulation and secondary effects at the end of the simulation. The results are shown in Table 2.

Table 2. Tests observations.

| User | Observations |
|------------|---|
| Subject 1: | At the end of the simulation she was abruptly disoriented. |
| Subject 2: | He experienced nausea and loss of balance. |
| Subject 3: | When the simulation ended, it took him a while to get used to the real world. |
| Subject 4: | Are comfortable navigating the virtual environment. |
| Subject 5: | He showed good control in handling the 3D viewer and the haptic device. |

The test subjects commented that they felt really immersed in the virtual world, they did not notice big differences between the real world and the virtual world. With the exception of subject 5, at the time of being immersed in the virtual world, the subjects moved the haptic device from their original position.

5 Conclusions and Future Work

It can be considered that one of the contributions of the project is to allow a total exploration within the three-dimensional virtual environment including a tactile feedback, which makes it possible to perceive textures, apply force to objects, in addition to very fine sensations that cannot be captured by the other senses.

Some of the problems that arose during the development of the project occurred when placing all the rendered objects in the virtual environment, this caused saturation of GPU, causing the visualization in the 3D viewer to be slow.

This incident was resolved by separating the scene that contained all the rendered objects into 5 scenes: gym, hallway, office, women's locker room, and men's locker room, which only contain the objects for the scene, in order for the user can move freely, it was necessary to create a script that loaded the scene that needed to be accessed.

During the tests carried out, the participants showed great amazement when they felt part of the virtual environment, the integration of the haptic device helped users to feel more immersed in virtualization, improving their experience.

Considering the discomforts presented by two of the test subjects, caution is advised to use this project.

It is worth mentioning that the current project is a case study that allows applying this proposal in other areas, such as risky or inaccessible areas, educational and/or training environments, it is possible to improve the project by connecting a non-pedestal haptic device to allow user greater movement.

As a future work, it proposes the reproduction of the entire campus as well as using this proposal to create virtual laboratories or other learning environments.

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