Multi-Control Virtual Reality Driving Simulator

Nicolae-Adrian Țocu, Valentin-Cătălin Govoreanu,
Teodor-Marian Nițescu and Gabriela-Alexandra Luca

November 3, 2019

Multi-Control Virtual Reality Driving Simulator

Țocu Nicolae-Adrian
Connected Intelligence Research Center
Lucian Blaga University of Sibiu
Sibiu, Romania
nicolae.tocu@ulbsibiu.ro

Govoreanu Valentin-Cătălin
Connected Intelligence Research Center
Lucian Blaga University of Sibiu
Sibiu, Romania
valentin.govoreanu@ulbsibiu.ro

Nițescu Teodor-Marian
Computer Generated Solutions
Bucharest, Romania
teodor.nitescu@gmail.com

Luca Gabriela-Alexandra
Marquardt Schaltsysteme S.C.S
Sibiu, Romania
gabriela.alexandra.luca@gmail.com

***Abstract* — Immersive technologies (virtual and augmented reality) started gaining a lot of ground over the past few years initially in the video game industry, followed by simulators and finally integrated into many other classic applications. This paper aims to analyze how users respond to using new controlling devices in a scene designed as a driving simulator (race car track). The landscape and the controls are specifically tailored for interactions within immersive environments. In order to understand the capabilities of the experimental application and evaluate the new controls, several tests were conducted. The results are presented from a user experience perspective, emphasizing qualities, side-effects, and problems of such an approach.**

Keywords* — *Virtual Reality; User Experience; Car simulator;

I. Introduction

This paper presents the usability of multi controllers in a virtual reality (VR) environment and the way users react to specific scenarios generated by an experimental driving application. For delivering a diversified experience, the scene integrates gamification components in order to guide the users to complete several tasks.

To ease the testing process, a race game simulation was chosen, as most users already have some sort of experience with car video games. To have a full experience, users must complete tasks such as: interacting with the virtual steering wheel, press virtual buttons, action the lever and do specific hand gestures to control the car in various situations.

To monitor and analyze the user experience, a series of metrics were measured while playing the simulation, and a post-game feedback was also recorded from each user.

For testing the user experience, we opted for three different kinds of VR controllers: HTC Vive Controller [1], Leap Motion [2] and Manus VR [3]. A real steering wheel [8] wasn't used because the focus was on the interaction with the virtual objects.

This application was tested on the HTC Vive headset, and the Vive controllers are optimized for this headset. Together, they offered an awesome experience to the user and because of these controllers, the virtual interaction was easier. The exploration of a virtual environment with the user's bare hands was also a target, which led to the use of Manus VR and Leap Motion Controller.

Manus VR is a set of gloves that allows the user to have a natural interaction with the virtual environment. The gloves have integrated haptic feedback to improve the user's experience.

Leap Motion gives the user the possibility to interact with virtual objects without grabbing or interacting physically with a real device. This controller is attached to the headset. It records the user's hand movements and reproduces the movements in the virtual space.

II. The Environment

The testing environment (see Figure 1) is a non compete (no opponents) race car track, consisting of a racetrack and a system of interesting points, or sometimes referred to as "waypoints" [6], where the user must cross the finish line as fast as possible.

Figure 1. The virtual environment. Aerial view.

There are only a few intuitive rules (similar to all other car racing games) that are usually explained by the assistant before any new user starts the simulation.

The track has four points of interest (POI):

- Start - is the first POI from where the car starts. The user decides when to start after he accommodates and understands the controls.
- Two checkpoints - when the car passes through one of these, its position and rotation are saved. When a car crash occurs: the car is spawned to the last checkpoint, if the car didn't pass any checkpoint before a crash, it's spawned back at the Start point.
- Finish - when the car reaches this point, it stops moving and the simulation is over.

To increase the user's competitiveness, the race has a counter that measures the time it took for each user to finish the race, a car crashing counter to monitor how many crashes each user made, and a brake counter to check how often users needed to use the brakes. The timer does not reset when the car respawns at one of the checkpoints.

The user's virtual position is in the car, in the driver's seat and it can drive with the help of the virtual steering wheel. During the development process, controlling the steering wheel as naturally as possible was the main goal. The sensitivity calibration was done individually for each control device and was the longest pre-experimental process.

To accelerate or to use the brake, a virtual lever was implemented (see Figure 2). The user must interact with it using the virtual devices: if the lever is pushed forward the car will accelerate and if it is pulled backward the car will slow down. The car's top speed, acceleration and brake are the same for all tested controllers.

Figure 2. The steering wheel and the lever.

III. Devices

As already mentioned before, all the controllers chosen for testing are devices that were specifically created to interact within immersive environments. Different kind of interaction can give users different types of enjoyment and can create more comfort levels [9]. To analyze how the user interacts with them, a series of metrics were established to monitor and compare the results.

A. HTC Vive Controllers

Using 24 sensors, the controller's position is determined constantly and synchronized with its virtual counterpart, allowing the user to interact with the virtual environment. The interactions are facilitated by the built-in physical buttons.

The main advantage of these controllers is that the tracking is almost perfect. The virtual models are following the real controllers in real time and they are intuitive to use. These controllers provide haptic feedback by vibrations when the user is grabbing the steering wheel or the lever.

The Vive controllers (see Figure 3) were designed to accommodate most users, so they are intuitive and easy to use. These controllers provide an immersive virtual reality experience using their best possible tracking systems. It was made possible to give visual feedback in the virtual scene by highlighting the interaction buttons to further accommodate users.

The Grip button was chosen to grab the steering wheel and the lever because of its position on the controller, and because pressing it feels like grabbing a real object.

Figure 3. Vive Controllers.

B. Leap Motion

This is a peripheral USB type device with three infrared LEDs and two cameras, which can detect the movement of the user's hands (see Figure 4).

Figure 4. Leap Motion.

This device can be used in two ways: desktop mode and headset mounted. For the current application, this device was mounted on the HTC Vive headset to allow the user to move freely without having to remain in one place.

Leap Motion has a limited space where the hands are visible to the device, this space is called *field of view*. The *interaction box* is within the field of view and the tracking can be lost if the hands are outside of this box (see Figure 5).

The user must keep the hands in the interaction box to properly use the lever. If the user is interacting with the lever or the steering wheel and the hands are outside the interaction box, the tracking can be lost and the virtual hands will disappear.

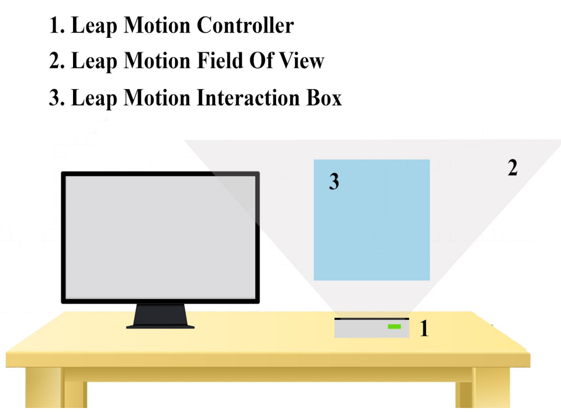

Figure 5. Leap Motion: field of view and interaction box.

In some situations, when the hands are interacting with the steering wheel or the lever, the tracking is lost and the virtual objects can behave strangely - we are still performing tests to analyse this behaviors since it might be influenced by the natural light. Sometimes the car control or the speed of the car are affected without the will of the user. To address these issues, the lever was temporarily removed and its functionalities in the game were replaced with two hand gestures. This solution provided a more simple way of interacting with the virtual environment [7].

C. *Manus VR*

Unlike the HTC Vive controllers, which were designed to feel like natural extensions of the hands, Manus VR makes the user's hands the controller.

By using trackers, Manus VR (see Figure 6) adapted the inverse kinematic concept to map the hands and head position to best predict elbow joint location and generate representation of the user's hands.

These haptic gloves contain a series of sensors to detect the hand’s orientation and to provide the best experience. The magnetometer, the accelerometer and the gyroscope were taken into account when implementing these controllers into the application to enhance the user experience.

Manus VR sensors provide data about hand and finger movement, but they don’t send any data about spatial orientation. Using the gloves without a secondary device, the virtual hands will stay in one point in the virtual environment and only the rotation and movement of the fingers will be tracked. To have a natural interaction and to get the spatial position, it was required to use HTC Vive Trackers. These devices were attached to the wrist and they sent the hand’s position to the application.

Using the gloves, the users can grab the virtual steering wheel like they would in real life and drive the car accordingly.

Figure 6. Manus VR.

IV. Tests And Results

To analyze the virtual experience and the game mechanics, 20 people tested the application and gave feedback. The subjects had ages between 15 and 30 years and 12 people had no prior virtual reality experience.

After the first tests, the users complained about a Leap Motion problem. When they wanted to grab the lever to accelerate or brake, they couldn’t control the car anymore because the hand which interacts with the virtual steering wheel disappears as it is not in the field of view anymore. Sometimes this will result in an immediate car crash. The cause was identified as: the lever and the steering wheel are not in the field of view of the Leap Motion at the same time. To change the speed, the user must look at the lever and when they do this, the hand of the steering wheel is disappearing from the scene.

To solve this, it was required to detect when the virtual hands are no longer interacting with the virtual objects. If the interaction with the steering wheel is stopped, the car is braking. The lever functionality was removed for the Leap Motion scene and it was replaced with two hand gestures. These gestures can be made within the field of view of Leap Motion with one hand. With this, the user can control the car and the acceleration at the same time.

In virtual reality, users accused symptoms similar to motion sickness when they are driving the car and when a car crash occurs. When the user drives the virtual car, their physical body remains in the same position, but they are moving in the virtual space. Due to the contradicting feedback received, the body tries to adapt causing a shift in the user's perception of balance that physically manifests similar to motion sickness. This was identified as cybersickness [4]. The worst experience that the users had was when the car leaves the track and it rolls over while the user was trapped like in a real accident. This was associated with cybersickness as well.

To address the cybersickness concerns, when the car leaves the track it stops from moving and its position and rotation are frozen for one second until the respawn occurs to prevent the car from rolling over. To further reduce cybersickness, the car is not behaving like a normal car would. The virtual car's "gravity" [5] is disabled and the car has a property named "kinematic" [5] to prevent unwanted collisions or other forces that could affect the car.

As a conclusion of our testing sessions, Table I displays the average completion time of the track, the number of crashes and the number of brakes / each control device.

TABLE I. TESTING RESULTS

Devices	**Metrics monitored**		
	Average Time	***Total crashes***	***Total Brakes***
HTC Vive Controller	01:41	51	49
Leap Motion	02:16	75	46
Manus VR	02:18	67	79

V. CONCLUSIONS

The paper presented an experimental application, a virtual reality driving simulator and the first set of tests that were conducted in order to identify and assess user experience parameters, expectations and performance.

The HTC Vive Controllers scored the fastest finishing time and the least number of crashes. The users were impressed by the good tracking and how easy it was to interact with the virtual environment.

Using Leap Motion was challenging because the users complained about the lack of physical feedback. It had the lowest number of brakes because using gestures to brake the car was unnatural so they preferred to crash the car and reset the position.

For most users, the Manus VR was the favorite device because having gloves with haptic feedback by vibration was very intuitive and easy to adapt to. The average finish time was not as good as expected, but the users interacted more naturally with the lever to accelerate and brake the car.

ACKNOWLEDGMENT

This work is supported through the DiFiCIL project (contract no. 69/08.09.2016, ID P_37_771, web: http://dificil.grants.ulbsibiu.ro), co-funded by ERDF through the Competitiveness Operational Programme 2014-2020.

REFERENCES

[1] HTC Vive Controllers. Available: https://www.vive.com.

[2] Leap Motion. Available: https://www.leapmotion.com.

[3] Manus VR. Available: https://manus-vr.com.

[4] LaViola, J. J. Jr., "A discussion of cybersickness in virtual environments," in SIGCHI Bulletin, vol. 32, pp. 1-3, Jan. 2000.

[5] Gravity and Kinematic. Available: https://unity.com.

[6] M. T. Chan, C. W. Chan, and C. Gelowitz, "Development of a car racing simulator game using artificial intelligence techniques," Int. J. Comput. Games Technol., vol. 2015, Nov. 2015.

[7] S. Ameur, A. B. Khalifa, and M. S. Bouhlel, "A Comprehensive Leap Motion Database for Hand Gesture Recognition," International Conference on Sciences of Electronics Technologies of Information and Telecommunications (SETIT), pp. 514-519, Dec. 2016.

[8] D. Herumurti, R. R. Hariadi, A. Yuniarti, I. Kuswardayan, W. N. Khotimah, F. A. Putra, S. Arifiani, "The overtaking car simulation using the technology of virtual reality," in Jurnal Ilmiah Kursor, vol. 9, No. 3, pp. 95-102, Jul. 2018.

[9] P. Skalski, R. Tamborini, A. K. Shelton, M. Buncher, and P. Lindmark, "Mapping the road to fun: Natural video game controllers, presence, and game enjoyment," New Media & Society, 13(2), pp. 224-242, Mar. 2011.