

Development of a virtual reality driving experience of a Formula SAE-type vehicle

Desarrollo de una experiencia de manejo en realidad virtual de un vehículo tipo Formula SAE

SOLIS-ARRIAGA, Everth Rafael†, CORDERO-GURIDI, José de Jesús*, VELAZQUEZ-MENDEZ, Andrés and PÉREZ-REYES, Karol Josafat

Universidad Popular Autónoma del Estado de Puebla, México.

ID 1st Author: *Everth Rafael, Solis-Arriaga* / ORC ID: 0000-0002-1757-4997

ID 1st Co-author: *José de Jesús, Cordero-Guridi* / ORC ID: 0000-0001-5201-1906

ID 2nd Co-author: *Andrés, Velazquez-Mendez* / ORC ID: 0000-0002-3007-9632

ID 3rd Co-author: *Karol Josafat, Pérez-Reyes* / ORC ID: 0000-0002-9350-6830

DOI: 10.35429/JCS.2022.15.6.14.24

Received: January 20, 2022; Accepted June 30, 2022

Abstract

The objective of this work was to develop a virtual environment with the purpose of developing a driving experience in a FORMULA SAE type vehicle. The use of virtual reality has not only the purpose of entertainment, but also many more applications. From the different software tools for virtual reality, the use of the video game engine software Unity was essential. It is shown the development of a simulator that allows experiencing the movement of a Formula SAE-type vehicle through a simulated F1 track. To achieve this, we use a Formula SAE model designed by the UPAEP university. The results obtained showed different effects and sensations, including physiological effects such as dizziness depending on the variables of the simulator. However, it is a way to experience driving conditions in a Formula SAE-type vehicle. The simulator was validated by a group of engineering students and participants of the Formula SAE project, discovering results and findings from the simulation experience that allow the project to grow.

Virtual Reality, Formula SAE, Unity, Driving experience

Resumen

El objetivo de este trabajo fue desarrollar un ambiente virtual con el propósito de desarrollar una experiencia de manejo en vehículo tipo FORMULA SAE. El uso de la realidad virtual tiene no solamente el propósito de entretener si no que esta tiene muchas más aplicaciones. De las distintas herramientas de software para realidad virtual, el uso del software motor de videojuegos Unity fue fundamental. Se muestra el desarrollo de un simulador que permite experimentar el movimiento de un vehículo tipo Fórmula SAE a través de una pista simulada de F1. Para lograrlo, utilizamos un modelo de Formula SAE diseñado por la universidad UPAEP. Los resultados obtenidos mostraron diferentes efectos y sensaciones, entre ellos, efectos fisiológicos como mareos en dependencia de las variables del simulador. Sin embargo, es una manera de experimentar las condiciones de manejo en un vehículo tipo Formula SAE. El simulador fue validado por un grupo de estudiantes de ingeniería y participantes del proyecto Formula SAE, descubriendo resultados y hallazgos de la experiencia de simulación que permitan crecer el proyecto.

Realidad Virtual, Formula SAE, Unity, Experiencia de manejo

Citation: SOLIS-ARRIAGA, Everth Rafael, CORDERO-GURIDI, José de Jesús, VELAZQUEZ-MENDEZ, Andrés and PÉREZ-REYES, Karol Josafat. Development of a virtual reality driving experience of a Formula SAE-type vehicle. Journal Computational Simulation. 2022. 6-15:14-24.

* Correspondence to the author (E-mail: josejesus.cordero@upaep.mx)

† Researcher contributing as first author.

Introduction

The first conception of virtual reality was presented by Ivan Sutherland, who made a display that was placed on the user's head, which is considered the first virtual reality immersion, this first interaction with virtual reality had the characteristic of being able to show different images on the display, as well as knowing the position of the user's head [1]. For a system to be considered virtual reality, it must be able to digitally generate a three-dimensional environment in which the user feels present and in which they can interact intuitively and in real time with the objects they find within the system.

Technology has been constantly evolving in all aspects and the world of virtual reality has evolved in both software and hardware. A proof of that are the different applications and useful tools which satisfy current needs in different areas such as education, industry, music, medicine, architecture and virtual laboratories where it is possible to simulate the conditions of a real environment with visual content, tactile sensations and auditory stimuli, among others [3].

Currently there are different types of virtual reality hardware and software that help us to use the tools and applications in different ways such as the measurement and validation of parts, visualisation of different types of textures, providing different colours to parts, training in work simulations for company personnel and thus avoiding significant losses.

A great advantage of these softwares that allow us to develop and work with virtual reality is that different types of files can be imported from one platform to another, so that it is possible to work with different softwares at the same time and in this way work collaboratively with a work team, having as main advantage the reduction of time in the different developments of projects, works, etc.

The way in which virtual reality is transforming the way we perceive the world and how we perceive the virtual world has changed so much that sometimes it is difficult to differentiate virtual reality from reality. On the other hand, the use of virtual reality for research methods has also had a breakthrough.

Now, virtual reality is used in laboratories, research, and industrial applications that allow the operator to feel, touch and see a product or service and generate sensations very similar to those of real life.

Virtual reality has applications that have supported the development and implementation of Industry 4.0, as well as Education 4.0. On the education side, it allows the simulation of environments where participants possess exceptional characteristics without risks to their safety or the need for large investments or for participants to share the same geographical location. On the other hand, participants can have abilities such as flying, occupying an object as a virtual body or observing the environment from perspectives that would not be possible in the real world [2]. It should be noted that one of the main applications of virtual reality within the automotive area can be driving simulations, vehicle design, testing environment, among others. The environments that can be created through virtual reality allow both students and professionals to have an immersive experience when visualising models and interacting with them. Using virtual reality software and hardware which has motion sensors, wall sensors and controls for interaction.

Figure 1 shows the schematization of a virtual reality application and evaluation strategy, where Checa, D., Martínez, K., Osornio-Rios, R. A., & Bustillo, A. developed a methodology where initially the instructions were shown, where the user is shown the objective and the needs of the work. Afterwards, the interface is shown, where it is connected to the virtual reality device, to the virtual reality controls and to the sensors for the execution of the programme. Next, we had the simulation, where we could observe an environment related to the interaction work, dynamic simulations, etc. Finally, the evaluation was obtained, whereby means of surveys to different users an analysis for the work and to be able to execute an optimal evaluation was made known.

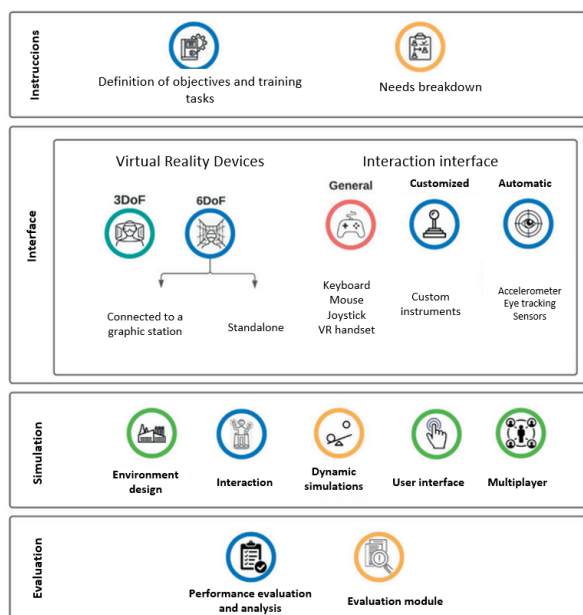


Figure 1 Proposed strategy for the design of Immersive Virtual Reality applications in the prevention of occupational hazards

Source: [5] www.revistadyna.com

Description of the method

The Society of Automotive Engineers (SAE) unveils the Formula SAE (FSAE) which is a competition where students with the help of teachers imagine, plan, manufacture and compete with their FSAE vehicle to demonstrate the creativity and engineering skills developed and put them to the test with other teams even from other countries because the FSAE competition is known around the world [4]. Drivers in FSAE as in any other competition must be subjected to different tests, in this case, driving experience can cause different physiological effects.



Figure 2 Formula SAE competition

Source: [6]

<https://www.avontyres.com/es-es/cuidado-de-neumaticos/fuente-de%20datos-tecnicos/aplicación-neumático-de-competicion/SAE-Formula-Student/>

This work was developed as follows: the method description section focuses mainly on the conceptualisation, the rules used in the work, as well as previous actions necessary for the correct execution of the programme. Finally, the series of steps explained in detail in order to complete the work in Unity. The next section contains our results and the answers obtained by a certain number of participants. Finally, in the final section are the conclusions reached after testing the simulator.

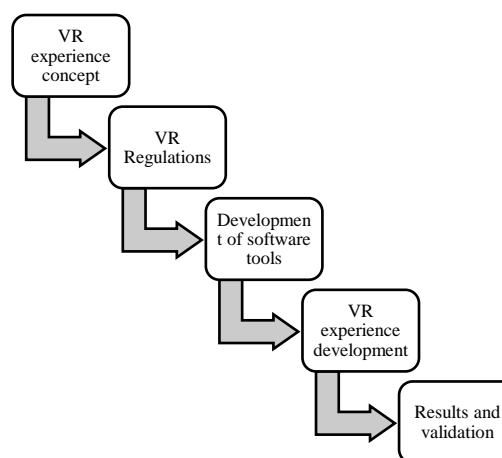


Figure 3 VR experience development method

In order to be able to carry out this work, a research of the standards related to virtual reality was carried out, so that it was possible to carry out this work, and also to have a better understanding of this virtual reality work.

Different standards were used in the development of this project:

- ISO/IEC TR 23842-1:2020 [2] Information technology for learning, education and training-Human factor guidelines for virtual reality content-Part 1: Considerations when using VR content; in this standard we see the considerations that should be taken for the appropriate and effective use of VR in different areas, such as education, learning and training.
- ISO/IEC TR 23842-2:2020 [3] Information technology for learning, education, and training-Human factor guidelines for virtual reality content-Part 2: Considerations when making VR content; where we see the considerations for making VR content in different areas such as education, entertainment and learning.

- ISO/IEC TR 18040:2019 [4] Information technology-Computer graphics, image processing and environmental data representation-Live actor and entity representation in mixed and augmented reality (MAR); this standard provides a reference model for Mixed Augmented Reality (MAR) applications, furthermore, it manages and controls learning, education and entertainment (LAE) in a MAR environment, on the other hand, it integrates LAE in a 2D/3D visual environment in a VR environment and can provide an exchange format needed to transfer and store data between MAR applications.

The following figure shows a diagram of the process developed to generate a simulation of a driving experience.

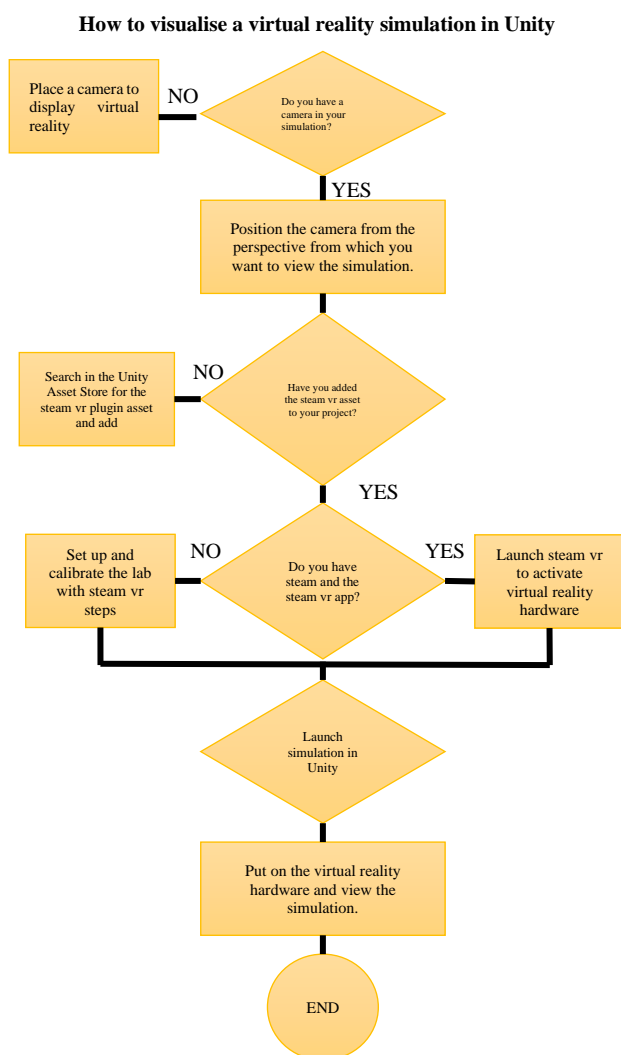


Figure 4 Unity flowchart

Model development

For this work it was of utmost importance to take into account the types of files that were going to be used, this was because not all files are compatible with the software used for this work, in this case the software used were Blender and Unity. The Blender software was used to be able to texture and colour the CAD model and Unity was used to make the simulation in virtual reality, in this scenario the type of file that these softwares have in common is ".FBX", which is ideal for 3D models.

In order to change the file type of the CAD model, i.e., the Formula SAE type vehicle model, a dedicated software was used, since the CAD model had an extension ".STP", which is not compatible with the software used in this work, this dedicated software is called CAD Exchanger, in which the CAD model was imported with the extension ".STP" (figure 5). STP" (figure 5) and then the desired file type was selected, in this case the file type ".FBX" (figure 6), once the CAD model was obtained with the desired extension the model was exported from the CAD Exchanger software and in this way it was possible to work with the CAD model correctly in the Blender and Unity programs.

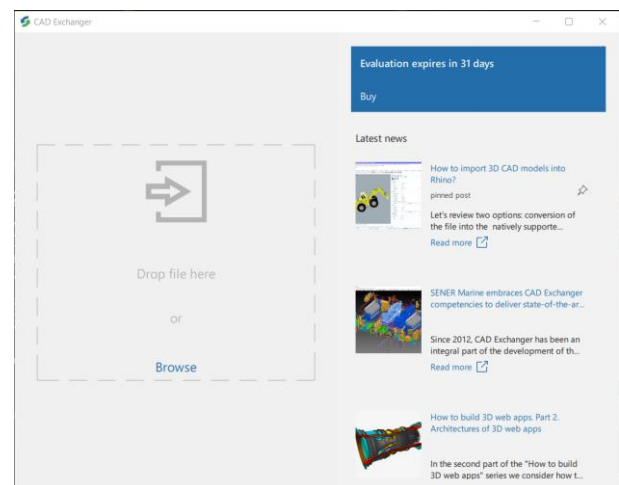


Figure 5 Import model into CAD Exchanger

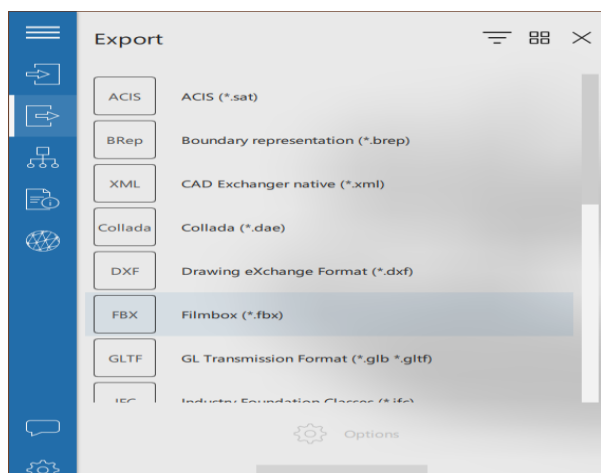


Figure 6 Select the desired file type in CAD Exchanger

Adjusting the coordinate axis

The coordinate axis is different in CAD modelling software than in software for texturing and simulation, which is why an adjustment of the coordinate system was made so that the CAD model used in the simulation would be consistent with the simulation environment. To make this adjustment, the Blender software was used, which allows us to change the coordinate system of the CAD model and in this way a correct orientation of the CAD model was obtained in Unity.

For the UP orientation in the modelling software is usually the Z coordinate, and this was changed to the Y coordinate and then in the FORWARD option was placed Z (figure 7), as it is the one that orients the model correctly.

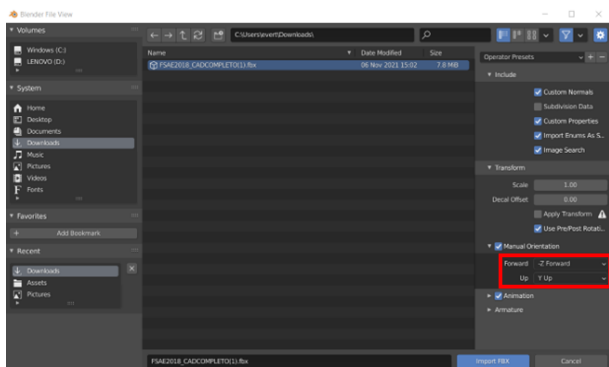


Figure 7 Coordinate adjustment

Assignment of materials and textures

Texturing is important for this work, as in this way it was possible to give greater realism to the simulation, as well as making it possible to improve the immersion experience in virtual reality, so texturing the CAD model of the SAE formula vehicle helped to improve the simulator experience.

The texturing was started by exporting the CAD model of the SAE formula vehicle in Blender software, as this software was used to select the colours of the CAD model, as well as the textures of the model.

The texturing was started in the Layout tab of Blender and within this tab the Material Properties tool was used.

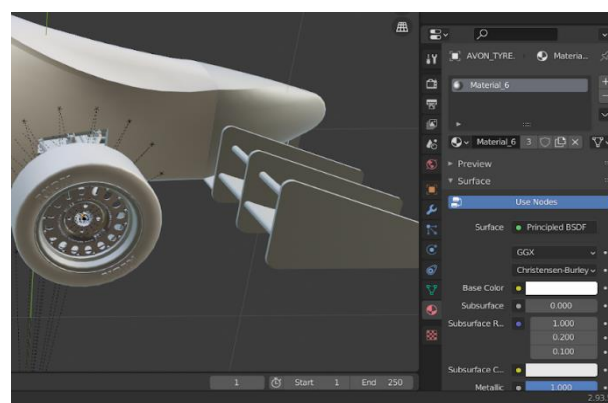


Figure 8 Material properties in blender

The surface to be textured was selected from the CAD model. In this case, the texturing began with the SAE formula vehicle tyres, as well as the rims, to which a chrome texture was assigned.

Subsequently, a wheel with colours and textures was obtained as shown in the following image, so to finish the complete texturing of the CAD model of the SAE formula vehicle, this logic was continued for the other textures.



Figure 9 Assigning colours and textures to the Formula SAE 3D model

Import file to Unity

The CAD model of the Blender software was exported and saved with the extension ".FBX", so that Unity could support the 3D model of the vehicle type formula SAE, later in Unity the CAD model was imported in the Assets tab and then in New Asset (Figure 10), then the CAD model file with the extension of ". FBX", the file was selected and once the import of the CAD model file was finished, the 3D model was placed in the Unity scene and in this way the 3D model of the vehicle type formula SAE textured in the Unity software was obtained.

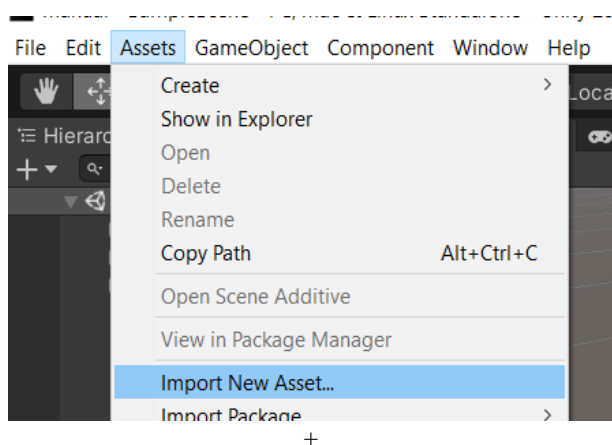


Figure 10 Insert 3D model of Formula SAE in Unity with the extension .FBX

Inserting and adjusting the camera in the 3D model

The main objective of the camera is to give a real perception inside the environment, so it was placed in a way to obtain a realistic perspective and coherent with the environment of the unity scene.

The camera with the name "Main camera" was placed inside the single-seater to obtain a realistic perspective in the simulation, to place the camera inside the single-seater in the Hierarchy tab the 3D model of the vehicle type formula SAE was looked for and it was placed inside the "Main camera" of the 3D model (figure 11), in this case the name is "fsae", once the camera was placed in the 3D model only an adjustment was made to obtain the perspective that was needed (figure 12).

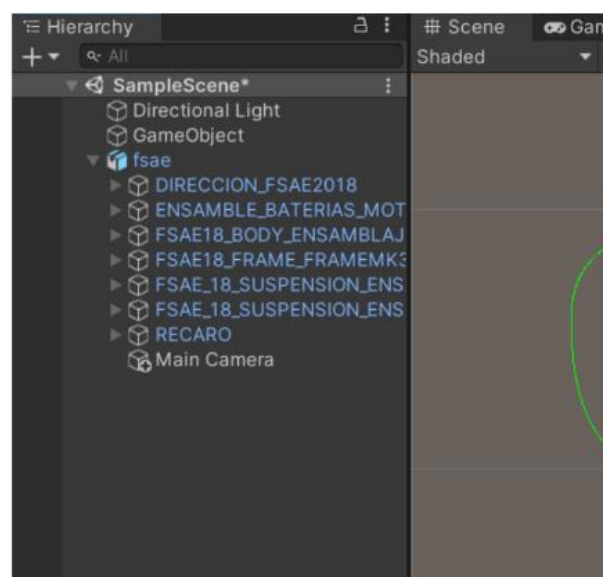


Figure 11 Insert "Main Camera" inside the "fsae" section

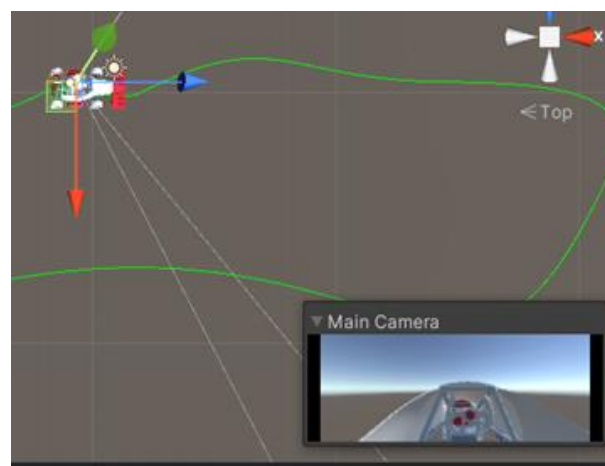


Figure 12 Camera placed inside Formula SA

Track development in Unity

For the vehicle track, data similar to a Formula competition track was considered. Based on the choice of this vehicle category, table 1 shows the general dimensions of the track considered for the simulation.

Characteristics	Value
Track length	1.5 km
Length of track	60 Seg
Overall vehicle dimension	Length 2790 mm Height 1200 mm Width 1360 cm

Table 1 Overall dimensions of the virtual track

An asset called "Béizer Path Creator" was downloaded from the Unity Asset Store, which was necessary to create the circuit to be followed by the 3D model.

The circuit of the SAE formula vehicle was started by right clicking on the "Hierarchy" tab and then selecting the "Create Empty" option (figure 13) and then naming it "GameObject".

"GameObject" was selected in order to click on the tab with the name "Add Component", then a window was displayed and "Script" was selected and then "Path Creation", finally, the option "Path Creator" was clicked (figure 14).

Subsequently, a circuit guide was displayed in the Unity scene for the SAE formula vehicle (figure 15). Then the coordinates of the displayed guide were adjusted to fit the circuit to the desired shape with the following command "Ctrl + Shift + Click". Finally, the path guide was closed with the option "close path" to have the path set (figure 16).

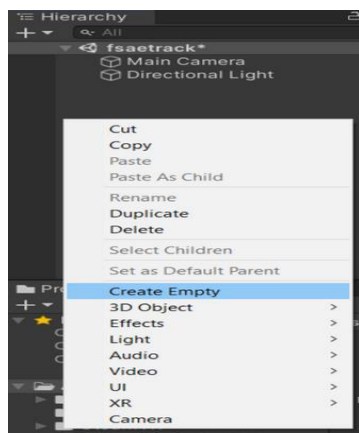


Figure 13 Create empty of "GameObject"

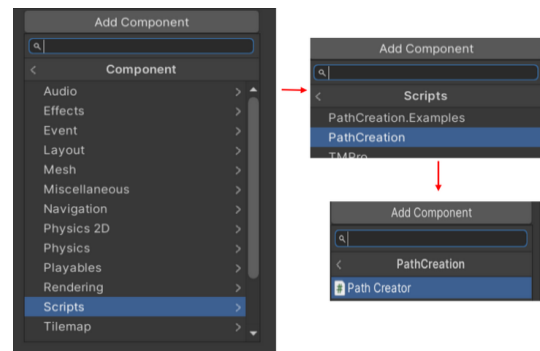


Figure 14 Script, path creation and path creator

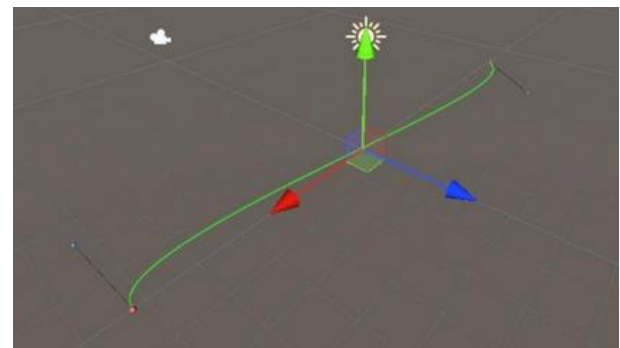


Figure 15 Path guide

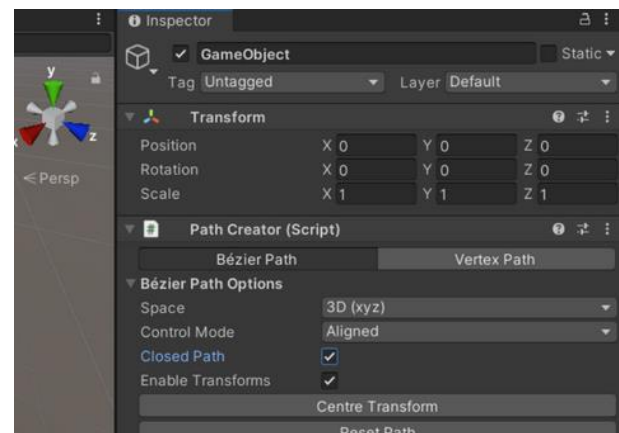


Figure 16 Close path

Development of simulation environment

Again with the help of "Unity Asset Store" an environment was downloaded for the scene according to the needs of this work, in this case a formula 1 type race track was required. In this case the most outstanding asset and similar to the dimensions proposed was "Austria Racetrack Formula 1" (Figure 17).

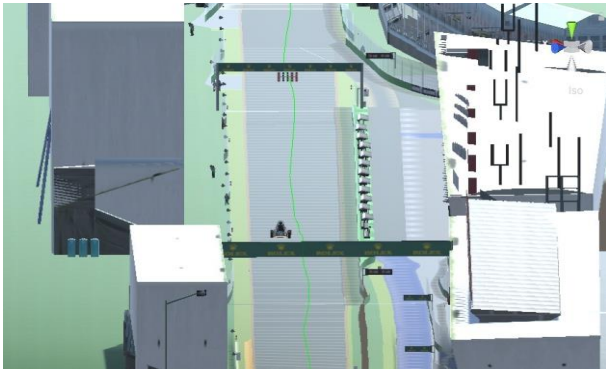


Figure 17 Environment Austria racetrack Formula 1

The content was imported into Unity, and we found it in the assets area, then clicked on "Prefabs" and finally selected "Austria" and placed it in the operations tree (figure 18).

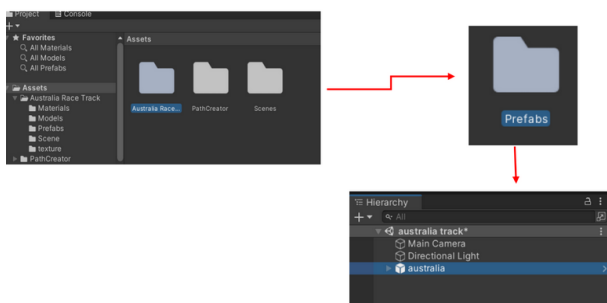


Figure 18 Place GP Austria as environment

Adjust time and speed

A time and speed adjustment was made in order to achieve the best possible immersion in virtual reality, so the speed at which the CAD model moves in the circuit was adjusted to give the user the feeling of speed and the time was adjusted so that the user was not in prolonged sessions with the virtual reality viewer, so it was left with a time of 1'30". This was carried out in the "Follower (script)" section of the Formula Sae and finally in the "Speed" option it was modified (figure 19).



Figure 19 Speed modification

Results

At the end of the development a scenario with a circuit according to the simulation was obtained, and the experience was immersive and everything had coherence, from the scenario to the formula car.

In the following images we can see how the formula car looks in the Unity scenario in a static way (figure 20) and in movement (figure 21).

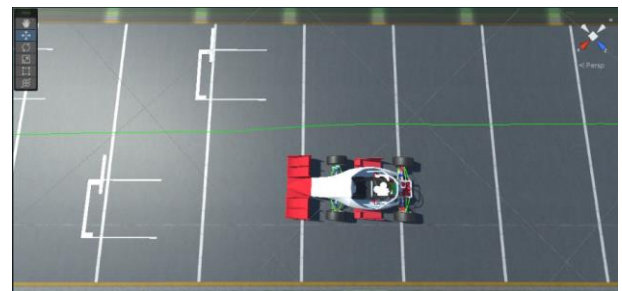


Figure 20 Formula SAE vehicle static on stage

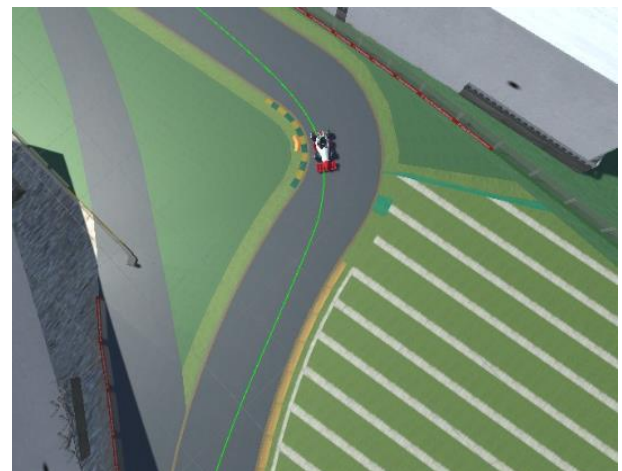


Figure 21 Formula SAE vehicle moving in the scenario

Two views were obtained from the virtual reality viewer, a static view (figure 22) and a moving view (figure 23) from the perspective inside the single-seater.



Figure 22 Perspective from inside the static single-seater

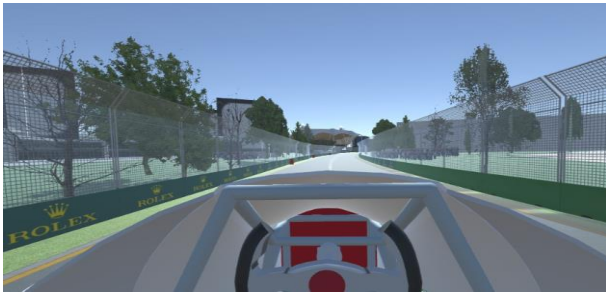


Figure 23 Perspective from inside the moving single-seater

Finally, in the real part, the simulator is shown in a simple way with only a chair for the user so that there is coherence between the virtual and real part, to match that the user is sitting in the car, and likewise a static view (Figure 24) and a moving view of the vehicle (Figure 25).



Figure 24 Real static simulator



Figure 25 Real simulator in motion

The sample consisted of 7 males and 5 females with an average age of 21.16 years. The instrument was validated by calculating Cronbach's alpha with a value equal to 0.715984. The questions related to the vehicle models, the track route and the immersive environment reported the lowest values, so future studies will consider improving the aspects of the models, the orientation of the vision in the environment and the use of sound. Table 2 shows the averages and standard deviations obtained from the sample studied.

Variable	Average	Standard Deviation
Facilities and equipment	4.9	0.34
Vehicle model	4.5	0.66
Simulation atmosphere	4.8	0.38
Simulation speed	4.6	0.58
Duration of the tour	4.8	0.41
Immersive handling experience	4.5	0.66
Physical integrity	5	0.20

Table 2 Statistics obtained from the sample

It is highlighted that the experience, the laboratory facilities and the physical integrity of the participant were the highest scoring variables, followed by the track design of the course, the driving sensation and the speed used in the simulator. There were comments on the absence of sound and the presence of dizziness when turning the head to observe elements of the environment. The latter element was important because participants indicated that as the speed of the simulator increased, the sensation of dizziness and vertigo increased, so that the exercise had to be stopped for some of the respondents. From the open-ended suggestions question, users raised opinions regarding interaction with the steering wheel, improved environmental imagery and the inclusion of sound to enhance the experience.

Conclusions

Throughout the development of this work it was possible to conclude that virtual reality has a high impact in different fields of work, on the other hand, it was possible to know all the approaches that nowadays virtual reality is considered, because it is in constant evolution and could be optimised by creating more sophisticated hardware and software so that the industry, whatever it is, generates more quality in its work and can observe a concept of a product or service in virtual reality before executing it physically, because it can fail to meet expectations or simply give a bad service in the simulation. The work presented contains similarities to that developed by Goedicke, D [7] who presents a driving experience simulator where participants can feel the sensations of driving a vehicle, including the consideration of physiological effects such as motion sickness. Under this consideration, Nascimento, A [8] considered virtual reality systems and simulators as an important tool in the development process of future technologies such as autonomous vehicles, in the main context of risk assurance in the design and support for the research and development process. It is important to mention that the simulator caused different sensations of motion sickness according to the programming of different speeds in it, so one of the future objectives will be related to the proper control of the physiological effects that the simulator causes, as well as the inclusion of greater controls for the user, sensations such as sound and the possibility of including telemetry to give greater fidelity with a driving experience of a Formula SAE type vehicle.

Acknowledgements

The authors would like to thank the Universidad Popular Autónoma del Estado de Puebla, for the use of the facilities and the facilities granted in the development of this work.

Funding

This work was fully financed by the Universidad Autónoma del Estado de Puebla A.C.

References

- [1] Ferreira, R. S., Xavier, R. A. C., & Ancioto, A. S. R. (2021). La realidad virtual como herramienta para la educación básica y profesional. *Revista Científica General José María Córdova*, 19(33), 223-241. <https://doi.org/10.21830/19006586.728> Retrieved from: <https://www.redalyc.org/journal/4762/476268269011/html/>
- [2] Gasca-Hurtado, G. P., Peña Pérez Negrón, A., Gómez-Álvarez, M. C., Plascencia-Osuna, Ó. A., & Calvo-Manzano Villalón, J. A. (2015). Realidad virtual como buena práctica para trabajo en equipo con estudiantes de ingeniería= Virtual Reality as good practice for teamwork with engineering students. *Revista Ibérica de Sistemas y Tecnologías de la Información*, (16), 76-91. <https://doi.org/10.17013/risti.e4.79-91>. Retrieved from: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://oa.upm.es/40285/1/INVE_MEM_2015_220172.pdf
- [3] Hernández-Chávez, M., Cortés-Caballero, J. M., Pérez-Martínez, Á. A., Hernández-Quintanar, L. F., Roa-Tort, K., Rivera-Fernández, J. D., & Fabila-Bustos, D. A. (2021). Development of virtual reality automotive lab for training in engineering students. *Sustainability*, 13(17), 9776. Disponible en <https://doi.org/10.3390/su13179776> Retrieved from: <https://www.mdpi.com/2071-1050/13/17/9776>
- [4] Sindhvani, R., Bhatnagar, A., Soni, A., Sisodia, A., Singh, P. L., Kaushik, V., ... & Phanden, R. K. (2021). Design and optimization of suspension for formula Society of Automotive Engineers (FSAE) vehicle. *Materials Today: Proceedings*, 38, 229-233. Disponible en <https://doi.org/10.1016/j.matpr.2020.07.077> Retrieved from: <https://www.sciencedirect.com/science/article/pii/S2214785320351671?via%3Dihub>

- [5] Checa, D., Martínez, K., Osornio-Rios, R. A., & Bustillo, A. (2021). [Imagen] Posibilidades de la realidad virtual en la reducción de accidentes laborales en la Industria 4.0. *DYNA-Ingeniería e Industria*, 96(6). Disponible en: <https://doi.org/10.6036/10241>. Retrieved from: <https://www.revistadyna.com/search/virtual-reality-opportunities-in-the-reduction-of-occupational-hazards-in-industry-40>
- [6] Competencia Fórmula Sae. (n.d.).[Imagen] www.avontyres.com. Retrieved April 5, 2022, from <https://www.avontyres.com/es-es/cuidado-de-neumaticos/fuente-de%20datos-tecnicos/aplicaci%C3%B3n-neum%C3%A1tico-de-competicion/SAE-Formula-Student/>.
- [7] Goedicke, D., Li, J., Evers, V., & Ju, W. (2018, April). Vr-oom: Virtual reality on-road driving simulation. In Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems (pp. 1-11). Disponible en: <https://doi.org/10.1145/3173574.3173739>. Retrieved from: <https://dl.acm.org/doi/10.1145/3173574.3173739>
- [8] Nascimento, A. M., Queiroz, A. C. M., Vismari, L. F., Bailenson, J. N., Cugnasca, P. S., Junior, J. B. C., & de Almeida, J. R. (2019, December). The role of virtual reality in autonomous vehicles' safety. In 2019 IEEE International Conference on Artificial Intelligence and Virtual Reality (AIVR) (pp. 50-507). IEEE. doi: 10.1109/AIVR46125.2019.00017. Retrieved from: <https://ieeexplore.ieee.org/document/8942308>.