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Development of a road safety simulator applying state-of-the-art technology with mixed reality

Desarrollo de un simulador de seguridad vial aplicando tecnología de vanguardia con realidad mixta

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Abstract: The project developed a road safety simulator in Cúcuta, using mixed reality and advanced technology such as Unreal Engine 4.27 and Oculus Quest 2. The objective is to improve drivers' skills and reduce accidents by teaching the proper use of traffic lights. A five-stage waterfall methodology was followed: requirements, design, implementation, verification and maintenance. The simulator integrates multimedia tools such as 3D Max 2022 and rendering engines such as Corona Render 9 and Arnold. It offers a high-level interactive experience and seeks to raise awareness among drivers about the importance of respecting traffic signals. This initiative combines cutting-edge technology with pedagogical strategies to promote road safety and reduce accidents in the city.

Keywords: Traffic lights, road safety, mixed reality.

Resumen: El proyecto desarrolló un simulador de seguridad vial en Cúcuta, utilizando realidad mixta y tecnología avanzada como Unreal Engine 4.27 y Oculus Quest 2. El objetivo es mejorar las habilidades de los conductores y reducir accidentes al enseñar el uso adecuado de los semáforos. Se siguió la metodología de cascada en cinco etapas: requisitos, diseño, implementación, verificación y mantenimiento. El simulador integra herramientas multimedia como 3D Max 2022 y motores de renderización como Corona Render 9 y Arnold. Ofrece una experiencia interactiva de alto nivel y busca sensibilizar a los conductores sobre la importancia de respetar las señales de tránsito. Esta iniciativa combina tecnología de vanguardia con estrategias pedagógicas para promover la seguridad vial y reducir accidentes en la ciudad.

Palabras clave: Semaforización, seguridad vial, realidad mixta.

1. INTRODUCTION

In all countries of the world, the vehicle fleet has become a social issue in the citizenship to improve mobility, it is also essential in the daily transfer of people to their workplaces and back to their homes, as well as in the transport of food or raw materials. This leads to address important issues such as vehicular mobility and safety from the protection and care of pedestrians. It is evident the need to carry out a series of processes, among which traffic lights stand out. The main function of a traffic light in the management of an intersection is to allow the passage of different groups of vehicles and/or pedestrians alternately. This system is used to allow different users to cross the intersection with the least possible inconvenience, danger and delay
[1] The existence of traffic lights is vital for efficient mobility in increasingly populated cities with growing traffic problems [2].

This is intended to ensure the proper functioning of traffic, as well as to reduce the accident rate in terms of vehicular mobility. Although the implementation of traffic lights in Colombia is lagging behind in terms of technology and adaptability compared to other countries. This is due to the fact that traffic lights are sometimes programmed without adequately considering important groups of people who do not use motor vehicles, such as pedestrians, cyclists and people with disabilities. This may be due to overestimation of vehicular traffic or limited allocation of resources for this purpose. However, it is important to note that the first steps towards the modernization of traffic lights have been taken, especially in the main cities of the country [3].

On the other hand, the city of Cúcuta located in the Department of Norte de Santander in Colombia, a city in which there are failures with respect to the proper functioning of the traffic lights. These problems range from the lack of electronic devices, programmed obsolescence, and electronic failures in some places where the implementation of these devices is necessary due to the high vehicular traffic [4].

The above brings with it consequences that are defined in their entirety, such as the increase in traffic accidents, due to the irregularities that occur. This gave rise to the creation of a

strategy based on the use of information technologies that promotes the awareness of pedestrians and drivers with respect to the correct use of traffic lights, respect and correct use of the vehicle by the driver with respect to speed, actions such as stopping or moving forward at the times indicated by the green, red or orange traffic light, in order to contribute to the reduction of accidents.

Ana Isabel López-Gestal, [19] et promotes virtual reality and road safety from a literature review to a digital literature review" by Manuel Gómez-Marco, et al.

Diaz [5] states that; "crashes occurring on roads where there are pedestrian walkways greater than 1 m wide and traffic lights at the intersection were less likely to be of these severities. In addition, if the road is a collector road or if the speed limit is higher than 40 km/h, the probability of a fatality increases". This statement makes it clear that there are areas of high danger due to the frequent violation of traffic rules by drivers and pedestrians in the main cities of the country.

Taking up again the announcements of the main media of the city, some new traffic lights collapse in the city of Cúcuta. [6] It states that: "A serious situation is being registered in some traffic lights in the city of Cúcuta where the new traffic lights have been turned off for a week. The fact that has generated the concern of the citizenship lies in the silence maintained by the responsible concession, as well as the controller and beyond this the accidents that are beginning to be registered in the roads of the city."

María Dolores Pérez-López, et [18] generates the premise of the effectiveness of VR in the driver education of high school students. The results show that VR has a positive impact on participants' knowledge, attitudes and driving skills.

On the other hand, "obsolete" traffic lights like the ones in Cúcuta cause deaths, highlighting that the city of Cúcuta is the third in the country with an increase in deaths due to traffic accidents, according to the Road Safety Agency; with good traffic lights, correctly arranged and working properly, lives can be saved on the roads. The statement was made by the director of the National Road Safety Agency, Alejandro Maya" [7].

The term "Educational Digital Object (EDO)" is also recognized by the LOM.es v.1 0. application profile as "Digital Educational Material" or "Digital Didactic Object" and defined as "An educational digital object (EDO), digital educational material

(MED) or digital didactic object (DDO) is a digital educational content whose ultimate purpose is user learning and which, in itself, constitutes or may come to constitute, through its integration with other simpler objects, a multimedia educational material" [8].

The simulator is the main occupation of the students, which makes it a very important activity, since it stimulates and facilitates greater development in different areas such as psychomotor, cognitive and affective-social. In addition, the game in the process of teaching and learning of students has formative purposes and also contributes to the development of their creative abilities, so it is considered an effective means for the understanding of reality.

Tomalá [9] states that: "The game can be one of the ways to enjoy leisure time, as a form of entertainment. Although the game has specific rules (whichever of them is practiced), its difference with sport lies in the fact that the latter not only has clear rules but is practiced within a sports institution and requires perseverance, teamwork and serious goal setting" (p. 32). (p. 32).
According to the RAE [10] virtual reality is the "Representation of scenes or images of objects produced by a computer system, which gives the sensation of their real existence."

The term Virtual Reality is common to describe a content that can be played through digital devices such as virtual reality glasses or smartphones [11]. Currently, the application of virtual reality is involved in fields such as medicine or engineering. With advances in screen resolution and the integration of sensors and gyroscopes, the use of this technology has expanded significantly. Moreover, it is now possible to access it with minimal investment, such as through the use of a smartphone and Google Cardboard. [12].
Araya Brenes & Rojas Vargas [13] conclude in their work that virtual reality helps in teaching of road safety education, by making better use of virtual experiences.

Taking into account the above, by means of a road safety simulator that allows to go through the main streets of Cúcuta where there is more traffic congestion in the hours with a higher rate of traffic, the process of raising awareness of drivers on the proper use of traffic lights in the city of Cúcuta is being carried out, in order to increase the skills of drivers, raise awareness about the importance of respecting traffic lights in the city and thus contribute to the reduction of traffic accidents, in a pedagogical and didactic way.

Maria Dolores Perez-Lopez, et al. [17] enunciates the potential of VR as a tool for road safety awareness and training and how it can promote road culturalization in the community.

2. METHODOLOGY

The methodological model selected for the project is the Waterfall Model, so called because of the orderly sequence of phases in software development that seem to flow from one to the next in a natural way, was presented in 1970. This methodological approach establishes a strict structure in the stages of the software development process, so that each phase begins after the previous phase has concluded [14].

The benefits of this methodology become evident when there is no need to implement immediately, allowing adequate time to develop each phase. It is relevant to note that, in order to minimize risk, it is essential that the requirements are very well defined and have been formally established in the initial phase of the project [15].

3. RESULTS AND ANALYSIS

The results obtained as a result of the methodological sequence established through stages are described below.

3.1. Requirements, design, implementation, verification and maintenance phase.

a. This stage describes the workflows performed by the system, which range from the mechanics of starting the system to the mechanics of starting the system simulator, in which it bifurcates into two response systems; in the first instance, the activation of the geospatial location of the VR goggles, to have range delimitations for more ease of use of the simulator.

b. Secondly, the mechanics of starting the simulator with VR glasses, which allow a similarity of geospatial training almost identical to reality.

3.2. Site Identification

According to the workflow requirements of the city of Cúcuta, Norte de Santander, which will be simulated, as well as the different elements that compose them, strategic points were also chosen, such as the light source, where there is great vehicular congestion during the hours of high vehicular flow, as shown in Figure 1.

Fig. 1. *MoodBoard of the visual conceptualization of the city o f Cúcuta, Norte de Santander.*
Source: *Own.*

3.2.1. Definition Phase (MoodBoard, Brainstorming)

In this first step, a concrete analysis was made to determine the most visited places by users, in addition to which are the locations with the highest vehicular flow in the midday schedule, taking as a premise that it is lunchtime for most users who work and move to their places of residence or nearby restaurants, therefore this place was chosen as the epicenter of the simulator, in addition, the engine called Unreal Engine version 4.27 was used; which was made the most reliable structuring with respect to the previous image.
As shown in Fig. 1, a moodboard was made, in which the zones that are close to the central point to be highlighted in the simulator are defined.
The traffic signal elements, a road and psychological verification is made to determine the degree of importance that drivers obey, and to determine if the locations in which they are implemented comply with the minimum standards of road safety.

3.2.2. Design Phase (3D wiframe construction in the 3D Modeling engine)

The initial prototype is the initial affectation of the proposed 3D modeling, in the modeling engine called 3D Max Version 2022, with the installation of the Corona render engine render 9 and Arnold, to have a preview of how the simulator would look in the future; therefore, in Fig. 2, the first phase of the simulator is presented.

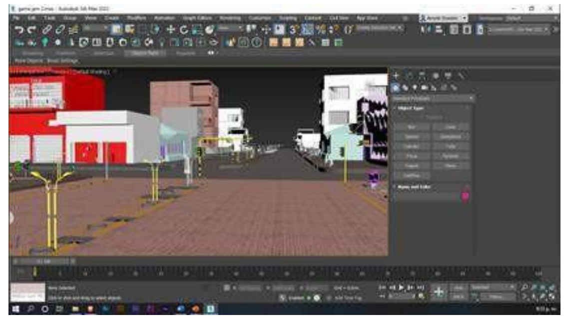

Fig. 2. *Preliminary phase of the Road Safety Simulator.*
Source: *Own elaboration*

As shown in Fig 2, the wiframe is very important phase because it shows directly which elements are going to be used in the resource, in this case in the simulator, as in turn, if the elements that were implemented made a reliable function and also conformed to the parameters of road mobility and also if it had the necessary visualization so that the user who goes in the automotive can understand the message and said this perform the action to follow to avoid some kind of coalition or road traffic accident once it is visualized, shows the initial phase of the modeling in preliminary phase, which was adapted to the sizes that were standardized in the construction to real scale, in addition the types of materials that have each element of the area were incorporated, to have the greatest similarity of the elements to the visualization in real time, to have a greater impact dl simulator and be able to teach accurately what you want to impart.

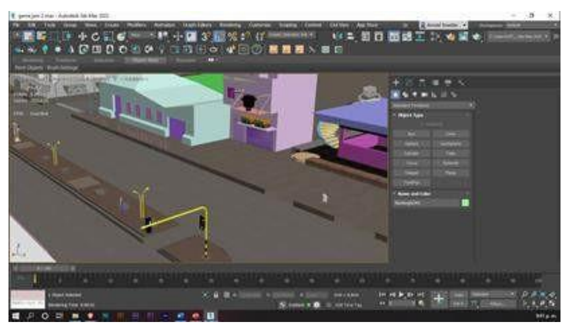

Fig. 3. *Preliminary phase of the Road Safety Simulator.*
Source: *Own elaboration*

Fig. 3, It shows a visualization of wiframe in second preliminary phase where some textures are implemented that allow to see the visualization of how the distance of them and the realism that represents in addition equidistant models were prepared for the construction of the vegetative part and the traffic signs in which allusion is made to the part of the zero avenue mainly in the luminous source where it is the origin of the project of the simulator. The measurements of the streets, buildings and vegetation were also verified in order

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to have a more direct visualization of how the structure of the 3D digital environment is perceived in the real environment and to visualize the similarity between the two so that the user has a perspective that he is navigating in the city of Cúcuta Norte de Santander without feeling that he is navigating in virtuality, In addition, it presents a lower diagonal plane, to show in a simple way and provide a slightly more detailed visualization of the elements shown in the 3D modeling, also simplified, to make easier the handling and usability of the 3D modeling program called 3D Max version 2022.

3.2.3 Prototype Test Modeling Phase (Construction of 3D models in Autodesk 3D Max 2022 software)

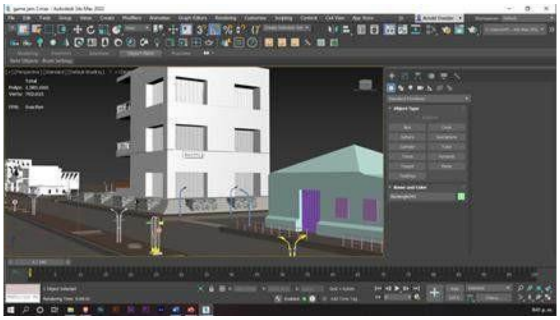

Fig. 4. *Types of structures Av. 0.*
Source: *Own elaboration*

As referenced in Fig. 4, the structural visualization is made in real time to see the visualization of how it would be implemented in the real world, also structured different structures both digital and programmatic to give a deeper and more reliable visualization to the real version, also made a digital metric study to understand if the structure with which it is being implemented in the 3D model has a similar fidelity to the real one also topographic studies were made to determine the geo spatial location of each of the elements and also make some corrections and also with due permission to structure some proposals for the different elements. In this case, the 3D max. tool was implemented for the architectural elaboration of the simulator. In addition, a Google Maps window was used to understand the geo-spatial and topographic location of the elements, as well as photographic elements and videos were used to understand the environment of the simulator.

In addition, it shows one of the tallest structures of Avenue 0, and demonstrates the comparison of scales, with references to the other models, and is in a demonstration material of imperfections in which, it shows what kind of errors the mesh has, to avoid any bad visualization of the simulator.

3.2.4. Testing phase in human implementation (approaching the users with the simulator for interactivity).

Fig. 5. *First phase test implementation and interaction with the simulator.*
Source: *Own elaboration*

The implementation of the first person approach was done as shown in Fig. 5, to see the results and the form of interactivity that had both the professor of Multimedia Engineering at the Simon Bolivar University, specializing in the creation and interactivity in Virtual Reality, The simulator interaction in this phase was implemented to see what scope you had, what sensation it generated in the user and also how was the implementation of knowledge in the user to understand if the different dynamics and interactivities that the simulator had, implemented and positively squeezed the user and also to receive a feedback in real time to receive a feedback in real time to see the results and the form of interactivity that had both the professor of Multimedia Engineering career at Simon Bolivar University, specializing in the creation and interactivity in Virtual Reality. receive feedback in real time to determine how the next phase of the simulator was going to continue with the proper feedback and how the 3D model could be improved with the proper road psychosocial and psychological implementations to have a greater impact without having to have any kind of impact on the user.

Fig. 6. *Second phase test implementation and interaction with the simulator.*
Source: *Own elaboration*

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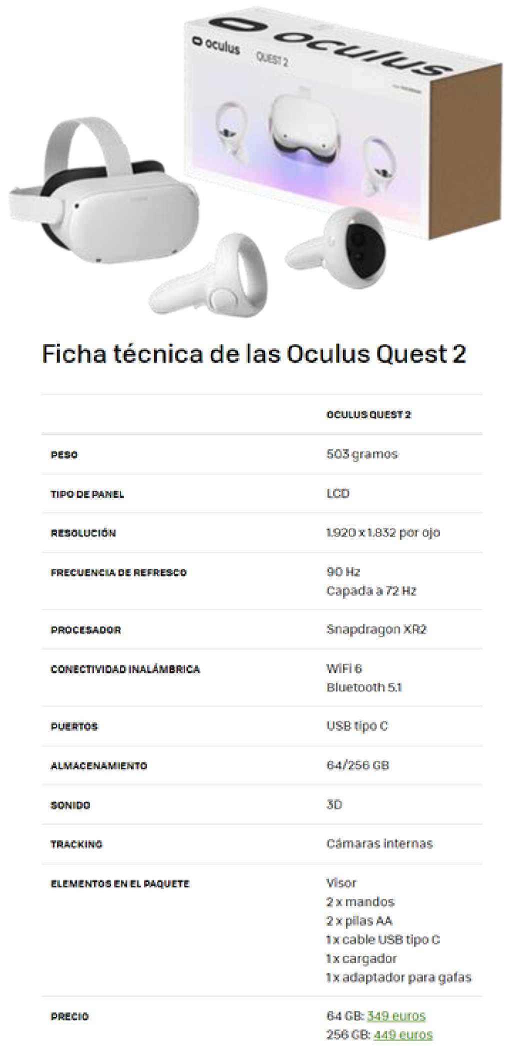
As shown (see Fig. 6), the use was implemented with a psychology student from Simon Bolivar University to see how was the psychological interactivity of the simulator towards the user in addition to simply using the controls of the Oculus Quest 2 glasses for greater interactivity with it also the psychology student had several uncertainties regarding the simulator because he did not know what to expect for that phase 2 was represented to have feedback from both the psychology student in psychosocial psychological perspective and the simulator to understand how it could be improved so as to provide more adequate information and detailed to the users without violating any kind of user's circumstances and also several feedbacks were made in the sense of the retroactivity of the knowledge of the simulator and also the function and functionality of the controls of the Oculus Quest 2 goggles.

Fig. 7. *Second phase test implementation and interaction with the simulator.*
Source: *Own elaboration*

We also took the perspective of another teacher with a focus on the design part to have a more visual and attractive structure for the user and also have an attraction that traps the user to continue learning with the simulator also many interactions were made regarding the teacher's feedback to have a much more youthful identity and more educational so that it does not have a loss that is taken as a leisure simulator but with an educational simulator in addition to that several structures in the graphical interface to make it more understandable, using design thinking to have a better assertion and that the user has a 100% attraction of the knowledge that you want to provide also designed a strategy to help the user to have ease of interaction with the information and make it easy to understand what you want to implement.



Ficha técnica de las Oculus Quest 2

	OCULUS QUEST 2
PESO	503 gramos
TIPO DE PANEL	LCD
RESOLUCIÓN	1.920 x 1.832 por ojo
FRECUENCIA DE REFRESCO	90 Hz Capada a 72 Hz
PROCESADOR	Snapdragon XR2
CONECTIVIDAD INALÁMBRICA	WiFi 6 Bluetooth 5.1
PUERTOS	USB tipo C
ALMACENAMIENTO	64/256 GB
SONIDO	3D
TRACKING	Cámaras internas
ELEMENTOS EN EL PAQUETE	Visor 2 x mandos 2 x pilas AA 1 x cable USB tipo C 1 x cargador 1 x adaptador para gafas
PRECIO	64 GB: 349 euros 256 GB: 449 euros

Fig. 8. *Second phase test implementation and interaction with the simulator.*
Source: *Own elaboration*

Tests were made with the Oculus Quest 2 glasses, as referenced in Fig 7. also a visualization of the technical information and the components that contained that element was made as shown in Fig 8 also the simulator was visualized in the Oculus Quest 2 glasses with the specification of in the first instance the refresh rate to see what image quality had also the verification was made that it had a broad spectrum wifi card which in this case has a wifi of 6 and a Bluetooth of 5.1 that allows a fast traceability of information without too much latency in addition, It has a 256 GB solid state storage also has internal and external cameras that allows a greater flow of information regarding the simulator and also represents a viewer in 4k quality for better quality and visualization of the simulator because the higher the quality of the viewer the more you can appreciate the details that the product has.

3.2.5. Third Prototyping Phase (Programmatic and vegetative resource implementation)

Fig. 9. *Second phase test implementation and interaction with the simulator.*
Source: *Own elaboration*

Fig. 10. *Second phase test implementation and interaction with the simulator.*
Source: *Own elaboration*

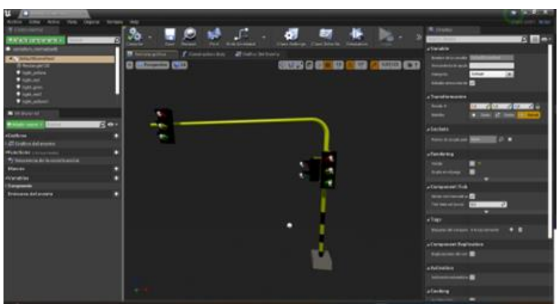


Fig. 11. *Second phase test implementation and interaction with the simulator.*
Source: *Own elaboration*

Fig. 12. *Second phase test implementation and interaction with the simulator.**Source:*** *Own elaboration*

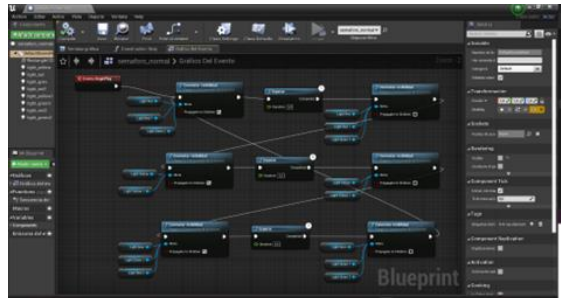


Fig. 13. *Second phase test implementation and interaction with the simulator.*
Source: *Own elaboration*

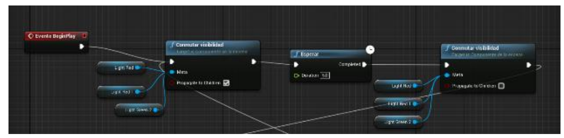


Fig. 14. *Second phase test implementation and interaction with the simulator.*
Source: *Own elaboration*

The third phase was done in which new zones were implemented in the 3D modeling part as shown in Figs. 9 and 10; In addition, the implementation began with the programming of the traffic lights with the use of lights and an artificial interest system as shown in Figs. 12, 13 and 14, to denote that when a traffic light is in green the others are in red so it was basically shown the implementation of the programming called blueprint that is a programming directly in nodes that is a structuring of higher quality and of more use because it allows a simpler structuring more orderly and easier to understand with the different implementations of the lights also created a small database to understand when the light is red the others are in green and thus constantly during the time that the simulator is running also to take into account several instances were created to store information to make it easier to understand the information that is being given also also implemented a timer to determine how long it will appear the yellow light red and green act which was implemented thanks to its with that information for artificial intelligence deduce how long it will last a light how long it will last another and so gradually,

3.2.6. Final Prototyping Phase (Implementation of all established resources)

Fig. 15. *Second phase test implementation and interaction with the simulator.*
Source: *Own elaboration*

Fig. 16. *Second phase test implementation and interaction with the simulator.*
Source: *Own elaboration*

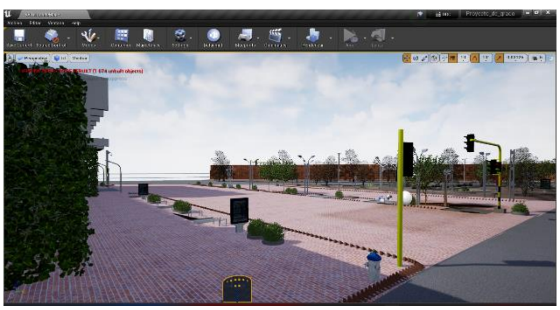


Fig. 17. *Second phase test implementation and interaction with the simulator.*
Source: *Own elaboration*

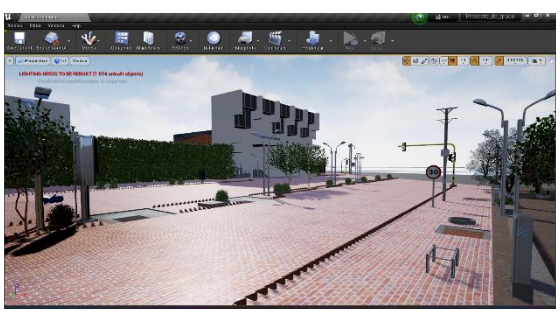


Fig. 18. *Second phase test implementation and interaction with the simulator.*
Source: *Own elaboration*

Fig. 19. *Second phase test implementation and interaction with the simulator.*
Source: *Own elaboration*

Fig. 20. *Second phase test implementation and interaction with the simulator.*
Source: *Own elaboration*

In the final prototyping all the necessary implementation was already established in the vegetation programming, structuring, modeling, texturing and sound environment as shown in Figs. 15, 16, 17, 18, 19 and 20; it is only the final presentation of how the implementation of all the elements as a whole is, in addition to the real-time visualization in aerial view of all the elements and the architectural structuring with the programming phase done.

4. CONCLUSIONS

The developed project presented a very great facilitation at the moment of applying it to the user because it allows an acquisition of knowledge almost 94% and it is also very feasible because it applies innovative technology and also cutting- edge technology that attracts the attention of users as well as having a high impact on it.

This case study presents the development and implementation of a VR experience for driver education. The results show that the experience was effective in improving participants' knowledge and skills [16].

The cascade methodology that was implemented in the developed project allows a more proper structuring and allows a more orderly structuring of the elements and also allows to demonstrate that each point that was made was done correctly because it is a methodology that does not allow to jump to the next phase without the previous peace is created correctly in all the proposed structuring, This allowed a very productive approach to the acquisition of road knowledge and allowed users to have a more fruitful approach to the use of virtual reality and also conceived the idea of having a greater understanding of road knowledge, road prevention and road safety.

Virtual reality presents two factors the innovation factor and the disconcerting factor because the user would not believe that it could be implemented for the educational part without losing the user's attention, but on the contrary, it would increase the user's attention to the information that is to be conveyed. In addition, there is a real physical touch in the virtual part, which makes it much more understandable what is to be conveyed in the user's mind.

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