Virtual Simulator for the Taking and Evaluation of Psychometric Tests to Obtain a Driver's License

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Abstract. This article describes the development of a virtual reality application that allows the application of psychometric tests to drivers, both professional and non-professional, who obtain their driver's license for the first time or are in the process of renewing or changing the category of their license; these implemented evaluations are aimed at measuring the reactions of drivers, as various audio-visual stimuli are applied in a more user-friendly manner. These implemented tests were developed in function of the traditional tests, that is to say complying with the objectives to be measured and evaluated; these evaluations have been developed with a Unity 3D graphic engine able to simulate the practical driving tests, to obtain results a numerical calculation software is used that presents graphs and statistics of the results obtained. The application is very attractive and allows users to perform their evaluations in a way that is close to reality, the tasks to be developed are performed with equipment that are very common for the user such as the steering wheel and pedals.

Keywords: Virtual reality · Psychometric tests · Drive test

1 Introduction

Traffic accidents can be understood as: "an event, general involuntary, generated at least by a moving vehicle, which causes damage to persons and property involved in it" [1]; human factors are the cause of the highest percentage of accidents having 77% according to the ANT (National Traffic Agency), due to circumstances how: reckless maneuvers, omission by the driver, speeding, physical health, loss of motor skills and reaction [2], these failures are not detected at the time of acquiring a license since drivers choose to pay third parties to perform psychosensometric tests to obtain their driver's license.

In several countries tests are carried out to evaluate the abilities of the driver at the time of controlling a vehicle, these tests are called psychosensometric, the characteristics that are evaluated of the person are his sensory abilities, his motor capacity, and his cognitive and psychological dexterity. Dividing the previous ones in activities such

L. T. De Paolis and P. Bourdot (Eds.): AVR 2019, LNCS 11613, pp. 138–149, 2019.
https://doi.org/10.1007/978-3-030-25965-5_11

as: *(i) multiple reactions under alert and non-alert conditions*, which measures the average reaction time and precision of response to different stimuli when the driver is in a condition of alert or permanent attention; *(ii) concentrated attention and vigilant resistance to monotony*, which measures concentration and the deterioration or decrease of aptitude conditions due to monotony; *(iii) eye-hand coordination*, which measures visio-perceptive-motor coordination, using both hands simultaneously; *(iv) speed perception and movement estimation*, which measures impulsivity in the face of unnecessary risks that generate accidents; and finally *(v) braking instruction and decision making*, which measures the capacity of the driver to brake in the face of an alert and non-alert condition [3].

In order to manoeuvre a motor vehicle, it is essential that the driver has technical training, as well as possessing certain qualities that are worthwhile and that guarantee the responsible driving of the motor vehicle.

The document enabling the driving of a car is the driver's license (different categories), to obtain or renew this document must submit certain tests, which can be performed efficiently in applications based on (VR) that thanks to the advancement of technology, and the combination of different areas such as electronics, mechanics and computing, have great potential [4] and aim to simulate the real world with virtual environments (VR) that have been applied in areas such as: medicine; for anatomy and surgery training [5]; aerospace engineering, for maintenance and repairing activities [6]; graphic design, for product design and manufacturing [7], in the automotive industry where the development of virtual environments has been found, mainly oriented to the following fields: *(i) Design where VR* can be used for the diagramming and evaluation of concepts during an early stage of the development process [8]; *(ii) Virtual Prototyping (VP)*, in VR it is possible to replicate physical models that allow the reduction of cost and time derived from omitting the construction of physical models; *(iii) Virtual Manufacturing (VM*) encompasses the processes of modeling, simulation and optimization of critical operations in a process related to automotive engineering; *(iv) Training in maintenance* tasks and automotive service [9] and skills improvement in immersive 3D environments [10]; *(v) Virtual Assembly (VA)* facilitates the assembly and disassembly of virtual objects, supplementing the training process.

In this context, with the development of several virtual environments in which the user performs the tests by means of the use of new devices that allow the stimuli and reactions [11] of the users to be better measured when interacting in immersive environments and thus simulate the driving of a motor vehicle, with easy-to-use devices that resemble reality, the idea is to replace the conventional way of performing the psychosensometric tests with scenarios in which real events that take place when driving are represented, the simulator is designed to assess the motor skills, dexterity and ability of a driver by using a haptic vehicle control device that performs the same function as the control controls on a real vehicle, so that by taking signals from the device the performance of the driver can be evaluated when performing a and determine whether or not a driver is fit to continue driving a motor vehicle.

This article is divided into 5 parts, the Introduction, in which the background and the importance of evaluating drivers prior to obtaining a driver's license are presented; in the second part, Formulation of the Problem, the problematic and general structure of the implemented system is described; in the third part is the Structure of the psychometric test simulator, a description of the hardware and software that make up the simulator is made, as well as the stages through which the tests will be carried out; the fourth part presents the experimental tests and results obtained, these tests were carried out in 4 scenarios in which the capacities of the driver in different scenarios and his performance during driving will be evaluated; and finally the fifth part, the Analysis of results in which the experience at the time of performing the driving tests is valued.

2 Problem Formulation

At the present time tests are carried out to obtain and renew the different types of driving license, these tests are: *(i) knowledge of traffic laws* and *(ii) psychometric tests aimed at measuring* the reactions of drivers to the application of various stimuli that are usually audio-visual, the aim of these tests is to see if the driver has physical, mental and coordination skills necessary to drive a car, depending on the type of license you want to obtain or renew, the tests are supplemented with a driving test with the respective vehicle of the category, specifically when the license are Type D, E and E1.

There are people who are not familiar with the equipment and instruments used in psychometric tests, due to the fact that there is no standardization of equipment in the different places enabled to obtain the license, as well as the management of the controls of the equipment is difficult for them. For this reason, one of the objectives of this article is the implementation of a simulator that allows to evaluate the reactions.

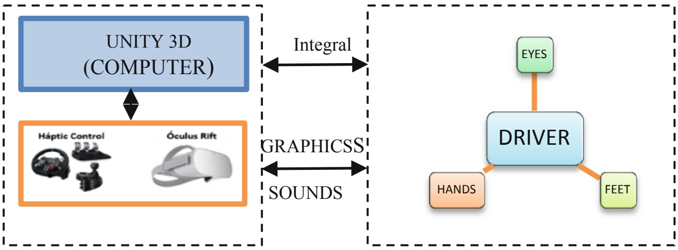

Fig. 1. Functioning of the system.

Figure 1 shows the block diagram of the overall system operation. The implemented application consists of two modules, oriented to measure: *(i) Mental capacity*, has as fundamental objective to examine if the individual has the capacity to respond to stimuli, to respond adequately with the environment, to maintain the sense of reality, reaction speed, orientation time - space, and decision making [12] *(ii) Integral motor coordination*, measures the capacity of the person to coordinate his movements and to control his own body to carry out specific actions. This series of tests includes: the aspirant's ability to perform precise and rapid actions using vision, hearing, upper and/or lower limbs [13], coordination of both hands, and coordination between acceleration and braking of a vehicle.

Figure 1 describes the interaction of the user (driver) with the proposed system, establishing as the main element of communication and feedback covering the two main actions within a virtual environment, observe and act.

The interaction between the user and the proposed system is established by means of a bilateral communication, that is to say, first through a graphical interface the implemented tests are shown that have as objective to measure the answers and reactions of the user; the user through the haptic control devices must comply with each one of the presented tests, and through a numerical calculation software the response curves and the weightings of the committed errors are obtained. The visual environment developed for this type of tests provides a comfortable environment for the user due to the immersion obtained when using virtual reality equipment and tools [14].

3 Structure of the Psychometric Test Simulator

This section describes the structure of the hardware and software implemented to simulate the practical driving tests interacting with the haptic devices and obtain the current level found by the user, the system consists of six stages as indicated in Fig. 2.

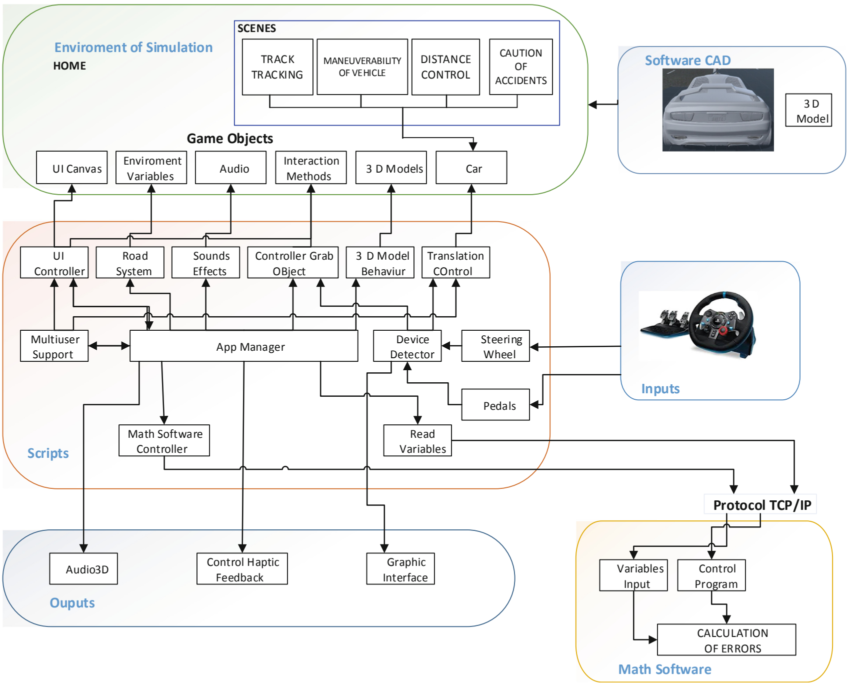

Fig. 2. Hardware structure and system software

The environment of simulation, contains the 3D environments of the graphical interface that allow to simulate a real driving environment, the characteristics of the environment are previously assigned as the climate, gravity, season, driving route, and other physical properties that simulate the real environment, where it incorporates a 3D land vehicle incorporated from the Assets of Unity with the main driving simulation task, there are four scenarios in which you can perform the simulation: *(i) Tracking*, contains a simulation path in which a guide line has been drawn by which the user must follow, avoiding moving away from it until completing the path previously drawn, *(ii) Maneuverability of vehicle*, in this scene the user must avoid the obstacles located in the simulation road and collect the largest amount of coins that are in the provided circuit, *(iii) Distance control*, contains a vehicle that starts automatically and the user in his simulated vehicle must always maintain the same distance that has been assigned to him before starting the circuit, *(iv) Caution of accidents*, in this last scenario the user demonstrates his ability to avoid accidents with pedestrians who unexpectedly cross the tracks by pressing the brake pedal of the simulated vehicle found in haptic devices; The interface allows us to observe the physical variables that the terrestrial vehicle possesses: speed, direction, position and skid.

The set of Scripts contains the code that allows the bidirectional communication between the haptic devices and the graphic engine, between the mathematical software and the graphic engine in real time. To interact with the input device is used proprietary library (SDK), which allows to establish communication with the equipment to obtain data of the variables of speed and direction of the vehicle and make it sent to the mathematical software through TCP/IP protocol client-server structure, where it has been established to the simulation software of the environment as server and the mathematical software as client, using two different ports for sending and receiving data thus avoiding collision of them, allowing the transmission of data obtained in the haptic devices to the mathematical software and vice versa is in real time.

The CAD software allows the simulation of a real vehicle with all its corresponding dynamics, as well as the structure of the objects that have been implemented in simulation scenarios such as trees, stands, flowerbeds, roads, green areas, etc., to have a completely immersive environment where the user has a realistic experience.

Math Software receives the data sent by the game engine to perform calculations and measure the current driving level that the user has according to the scenario in which it is, in Tracking is sent the current position of the vehicle to calculate which is the error it has according to the position of the line drawn to follow the driver, in the scene Maneuve-rability of vehicles is received the number of coins that has been collected and compared with a metric established to know its level, in distance control you receive the current position of the vehicle that has autonomous driving and the position of the vehicle that simulates driving and thus obtain the distance between them to then process these data and obtain an average of the distance that was maintained, and in caution of accident the games engine sends the acceleration and positions that was found the vehicle before stopping to calculate the reaction time that the driver had.

The Input consists of the haptic devices that are the steering wheel and the LOGITECH G29 simulation pedals, which allow sending speed and direction data to the video game engine according to the position they are in when running the simulation environment.

In the Exit it is obtained the real sound that emits a vehicle when being in movement, when it is in high speeds, low speeds and at the moment of crushing the brake, in addition a friendly environment of driving simulation is observed together with the feedback of the haptic device that allows a realistic immersion to the user in the simulation environment.

4 Experimental Tests and Results

The tests that were carried out in the 4 stages evaluate the capacity that a person has to obtain a driving license, for the experimental tests the virtual environments were carried out in Unity 3D 2018.2 and a kit of haptic devices was used such as: LOGITECH G29 steering wheel, pedalboard and gear lever, in addition a desktop computer with an AMD Ryzen 7 2700 Eight-Core processor, Ram memory of 32 GB, Óculus Rift.

Track Tracking

This test consists of a circuit to evaluate the capacity that the driver has for the hand-eye coordination by supplying the traditional Bimanual Coordination Test indicated in Fig. 3.

Fig. 3. Track tracking

First, the creation of a desired trajectory was carried out by means of points that must follow located in the center of the track, and then the trajectory described by the user will be obtained, thus obtaining the way to carry out an error calculation and the qualification at the end of the circuit indicated in Fig. 4.

In the virtual environment, you can see that the environment is familiar to a driver, with different traffic signals and a correct visualization of the road.

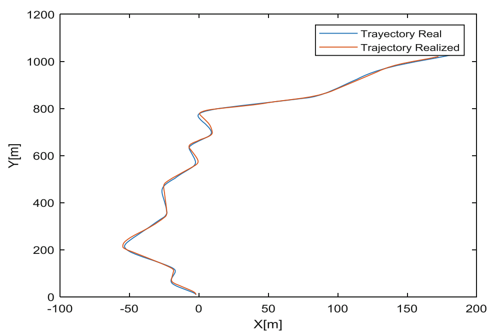

Fig. 4. Ideal route and the route described by the driver.

Analysis: The blue line describes the ideal trajectory that a driver should follow, while the red line represents the trajectory that was performed by a driver close to obtaining a driver's license.

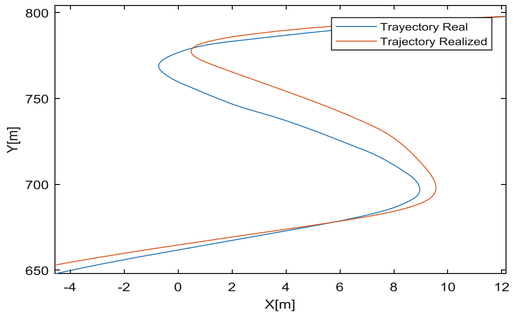

Fig. 5. Trajectory comparison. (Color figure online)

According to Fig. 5 there is no major difference between the ideal trajectory and the trajectory performed by the driver, demonstrating that the user has skills in this test.

Maneuverability of Vehicle

This test is designed to measure the ability to discriminate stimuli and the concentration capacity that a driver has on the road changing the usual way of Multiple Reactions test shown in Fig. 6, the circuit consists of several objects at different distances that the vehicle must dodge, but at the same time is trying to get the most coins that would come to become the desired trajectory.

Fig. 6. Maneuverability of vehicle.

The circuit was designed in a user-friendly way conformed by the different traffic signs and placing the obstacles in a visible way as well as the coins that must be acquired by the driver at the time of testing.

The last part of the test will calculate the error that the driver obtained when choosing a different trajectory than the desired number of coins that he obtained before finishing the circuit. The maximum number of coins that will be obtained in this circuit is 50 demonstrating 100% mastery in this test; the results obtained by the user indicate Fig. 7.

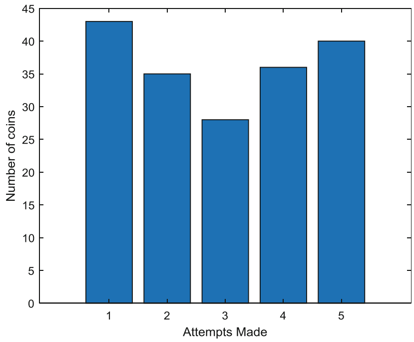

Fig. 7. Statistical data collected.

Analysis: Clearly the majority of drivers obtained a considerable amount of coins during the journey thus demonstrating their ability to drive a vehicle.

Distance Control
This circuit evaluates the time/space perception which is the user's ability to perceive speed and trajectories of a dynamic anticipation exercise and the ability to self-control replacing the Anticipation Test as shown in Fig. 8.

Fig. 8. Distance control.

This test coast of a vehicle that starts automatically at a standard distance that one vehicle must have from another, is followed by the user's vehicle which must maintain the distance that was initially assigned to it and its rating will depend on how close or far the vehicles are. This environment is composed of a circuit that has several curves that allow the driver's dexterity and prudence to be visualized, in the same way that the front of the vehicle can be clearly visualized.

Figure 9 indicates the distance obtained by the user according to the speed applied in the simulation.

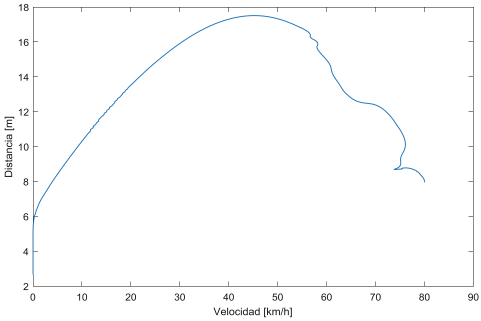

Fig. 9. Behaviour of the driver in the presence of another vehicle.

Analysis: A driver has control of his vehicle at lower speed, maintaining caution and distance from the front vehicle, when raising the speed the control decreases and can cause a collision.

Caution of Accidents

Figure 10 indicates the last test that evaluates the individual's capacity to react to external factors of the road, replacing the Braking Reaction Test. The test consists of presenting a mobile element with uniform displacement, in this case a pedestrian, an animal, a thing, etc. that will unexpectedly leave the environment, causing the driver to make the decision to brake quickly, softly or slowly, according to the distance that this external factor is found in the vehicle.

Fig. 10. Caution of accidents

This environment has a clear visualization of the imprudence that a pedestrian can eat when crossing the street, causing the driver to perform an unexpected maneuver depending on the distance at which he is.

Figure 11 shows the test performed by the user, who performed it at different speeds to see the reaction time of the vehicle.

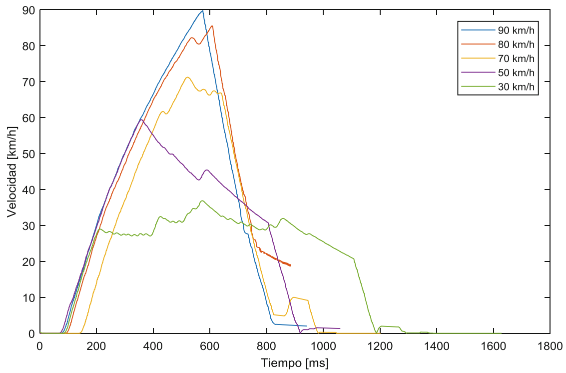

Fig. 11. Testing at different speeds.

Analysis: According to Fig. 11, the control of the vehicle before an external factor can be done at low speeds, avoiding a collision. At high speed, braking is sudden and there is no reliability to avoid collision.

5 Usability Testing

Usability is generally measured using a series of observable and quantifiable indicators from which tangible results can be obtained beyond intuition. One of these tests consists of quantifying the level of satisfaction by means of a questionnaire in the form of one or several questions that collect the impressions that the user has perceived as to the ease or difficulty of the general use of the application. The people chosen to carry out the study are chosen at random, the objective is to analyse the way in which users interact with the application to be evaluated. For this test, different questions have been selected, which have as weighting a scale that goes from “1” to “5”, in which it is considered that 1 does not comply at all and 5 complies very satisfactorily (Table 1).

When tabulating the data it is observed that there is great acceptance in the use of the virtual tool, this tool is very intuitive and very easy to use. The evaluation of a virtual environment by users is important because it allows them to identify possible deficiencies and, at the same time, increase the use of headsets such as HTC VIVE, so that immersion in a virtual environment becomes an experience that facilitates learning and training in new tasks (Fig. 12).

Table 1. Representation of the results obtained

Questions	Weightings				
	1	2	3	4	5
Does the application meet its objective?		2	1	5	22
Were the instructions easy to follow during the test?			3	18	9
Is it efficient and intuitive?	2		10	12	6
Do you consider the interaction in virtual environments for driving tests to be friendly?		1	1	13	15
Were the devices used during the test easy to use?			7	12	11
Does experience in a virtual environment resemble driving tests in real life?		4	8	14	4

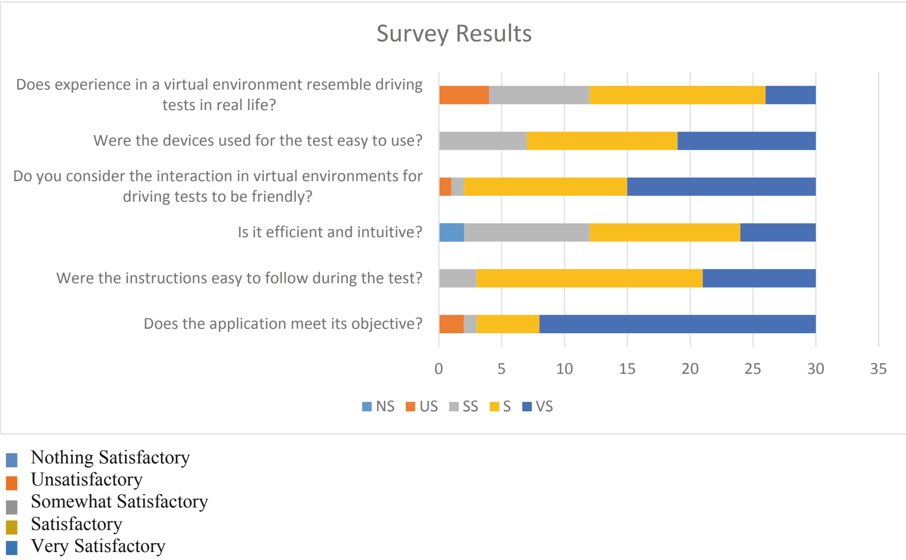

Fig. 12. Survey results

6 Conclusions

Virtual Reality tools are very flexible because they allow to build multiple scenarios according to the applications you want to give, by implementing virtual environments that resemble reality users can perform different psychometric tests in a more friendly way, by combining virtual applications with mathematical calculation software, different results are obtained that can be analyzed in order to observe the reactions of the users to the different audio-visual stimuli, as well as by means of the presentation of the results by means of curves, it is possible to analyze the driving behaviors that the drivers have in different circuits, and in this way it is possible to conclude whether or not the driver is able to obtain a driving license. These virtual tools combined with real or daily equipment are generally intuitive; however, it is convenient to validate the use of them either by direct observation or through surveys.

Acknowledgment. The authors would like to thank the Corporación Ecuatoriana para el Desarrollo de la Investigación y Academia – CEDIA for the financing given to research, development, and innovation, through the Grupos de Trabajo, GT, especially to the GT-eTURISMO; also to Universidad de las Fuerzas Armadas ESPE, Univer-sidad Técnica de Ambato, Escuela Superior Politécnica de Chimborazo, Universidad Nacional de Chimborazo, and Grupo de Investigación ARSI, for the support to develop this work.

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