ASSESSING SIM RACING SOFTWARE FOR LOW-COST DRIVING SIMULATOR TO ROAD GEOMETRIC RESEARCH

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ABSTRACT

In last years, driving simulators have had an increasing use in researching highway geometric design. However, research simulators have high costs. A possible solution to avoid these costs is using videogame simulators. Videogame racing simulators have achieved high quality with a moderate cost. Some of these games include very detailed models that describe very accurately the performance of the simulated vehicles. In addition, they provide very realistic images of the car, the highway and their surroundings.

With the aim of using them as research tools, several of the most popular games have been analysed. Two of them have been selected: rFactor2 and Assetto Corsa. Also, a 3D model of a section of an actual highway has been made and adapted to be used by the aforementioned games. Some tests have been conducted using a custom computer system, and the modelled highway section, with both game simulators. From these tests results, both sim racing software can be used to build a low cost driving simulator useful for road geometric design research.

1. INTRODUCTION

Driving simulators are designed to reproduce situations that occur in actual vehicle driving. Numerous studies establish the usefulness of driving simulators in research on road geometric design, traffic studies, and driver training.

Driving simulation research has a series of advantages compared to research based on actual driving. One of the most important advantages is the capability to create virtual environments with fully controllable parameters that would be challenging and expensive in actual driving (Olstam et al. 2008).

Another advantage of simulators is the relative ease of collecting data about driving parameters. In addition to the speed and acceleration values, which are not difficult to measure in actual driving, there are other parameters such as the position of the vehicle within the lane, the stopping distance from a stop line, or the fixation point of the driver's gaze, which are relatively easy to measure in a simulator and more difficult to measure in actual driving tests (De Winter *et al.*, 2012).

Driving simulators can be classified according to the type of vehicle they simulate: passenger cars, trucks, motorcycles, machinery and others. A distinction must also be made between simulators intended to be driven by one person or those intended to simulate autonomous vehicles. This paper talks about driving simulators for passenger cars driven by a person, which will be called driving simulators.

The use of driving simulators for research dates back to the second half of the last century (Fox, 1960). Currently, driving simulators use computerized systems. Their use has increased in recent years, favoured by the increase in computers' power and the improvement in the quality of image display systems.

Despite this development, the price of a driving simulation system for research on road geometric design is still too high for many research departments at universities. In the low range, a primary research simulator can cost between 30000 and 100000 euros. The most advanced models have complete systems for reproducing accelerations and require a hangar for their installation. Their cost can reach several million euros (BMW Group, 2020).

Allen *et al.* (1995) studied the characteristics that a simulation system based on a personal computer should have to serve as a low-cost simulator for research. The composition of a simulation system remains the same as when Allen *et al.* analyzed it.

However, some of the necessary components have improved performance and availability. A simulator requires various hardware and software components. Also, it is necessary to establish the characteristics of the simulated vehicle and the information necessary to reproduce the scenario in which the simulation takes place.

The simulator hardware includes the reproduction of the driving cabin, the reproduction systems of the images, sounds and accelerations, and the computers that control the entire system. The cockpit is where the driver sits and includes the controls to operate the simulated vehicle. The most basic controls are those to change the direction and speed of the vehicle.

The computer keyboard can be used for these functions in the most straightforward simulators, although today, it is common to have a steering wheel and pedals for the accelerator, brake, and clutch.

The cabin can include other additional controls, such as the gear lever or the handbrake, for example. Automakers sometimes use simulators to test the ease of use of new controls. Most complex simulators reproduce the interior of the vehicle completely. According to Mecheri *et al*. (2017), the absence of a cockpit in the simulator causes drivers to underestimate the vehicle's distance to the right edge of the road. In curves to the right, drivers move further from the centre of the road. This is not the case when turning to the left.

Leaving aside the possible influence that non-driving factors may have on driving, such as the driver's state of mind, the drivers take their actions based on the perceptions they receive through their senses. Of these senses, the one with the most influence is sight, although hearing and the perception of accelerations are also important.

According to Sivak (1996), most of the information used by drivers is visual. In a driving simulator, the image reproduction system consists of one or more screens that reproduce images with a certain cadence measured in frames per second (fps). The images span a certain width of the field of view (FOV). The FOV presented to the users of the simulator greatly influences their driving performance (Shahar *et al.*, 2010). There may be some additional screen to simulate what the driver would see through the rearview mirrors, for the instrument panels' presentation, to control the simulator software or to display the telemetry parameters. In some cases, virtual reality glasses are used instead of screens.

Some authors have pointed out that virtual reality glasses do not provide significant advantages and, on the other hand, increase dizziness problems in simulator users (Kemeny and Panerai, 2003; De Winter *et al.*, 2007, 2009)

One or more speakers reproduce the sounds that the driver heard while driving. The sounds include the engine's noise, the friction of the wheels with the road, the sound produced by other vehicles, the wind, or others.

In most elemental systems, there is no mechanism available to reproduce accelerations. Current models of steering wheels usually include vibration systems, called force feedback, which reproduce the sensations that the driver perceives through the steering wheel while driving, due to impacts with irregularities in the road, due to collisions, wheel slippage or other reasons. More complete systems may include actuators that move the seat in rhythm with the vehicle's supposed movement.

The simulator software runs on one or more computers. It controls all the hardware. The software is in charge of managing the vehicle's controls, performing the calculations related to the physical dynamics of the movement, generating the images and sounds, and maintaining the general operation of the system.

The simulation uses a virtual scenario containing all the information related to the road, its surroundings, the weather, and the traffic of other vehicles and pedestrians. This virtual scenario, together with the physical parameters that define all the scenario elements, constitutes the simulation's data.

One of the factors that most affect the economic cost and consumption of the simulator's resources is the reproduction's fidelity. Trying to replicate the world in all its details is impossible and inefficient.

Furthermore, it is unnecessary to achieve the research objectives. Modelling involves abstraction. The model must extract the aspects of the world that are important so that the tests' results have the required validity. Some authors claim that it is essential that the operation of the vehicle, the visual representation and the behaviour of the objects in the environment are as realistic as possible (Olstam *et al.*, 2008; Allen *et al.*, 2010). Other authors think that greater fidelity does not always positively affect the result. It depends on the objectives that the simulation wants to achieve (De Winter *et al.*, 2009; Tichon and Wallis, 2010)

The video game industry has become one of the leading entertainment industries. The expression 'sim racing' refers to virtual motor racing competitions based on driving simulation games. This expression highlights the difference with the arcade type driving games, which leave aside the driving simulation aspects a bit to delve into other different objectives. There are two hardware platforms for this software: consoles and personal computers (PC). Consoles offer the advantage of immediacy; it is only necessary to turn on the console and start playing. Computers need more preparations, but they also offer the most significant possibilities in terms of customization and modification of games to adapt them to research objectives. Some of the sim racing games simulate circuit car racing, such as Assetto Corsa, rFactor 2, iRacing, Automobilista, Project Cars 2 and F1 2020. Others simulate rallies, such as Dirt Rally, Collin McRae Rally or Richard Burns Rally. There are also others geared towards truck driving, such as Euro Truck Simulator. Currently, almost all have versions available for consoles and PC. They also usually include the ability to compete with other players over the Internet.

Sim racing has undergone significant development in recent years, leading to championships in which professional motorsports drivers participate. Often such tournaments are even televised and lead to significant cash flows from prizes and advertising. This has led large car manufacturers to develop content for such events, providing realistic models of their vehicles, for example. Currently, the main simulation games reproduce the racing circuits with maximum fidelity, using models extracted using LIDAR techniques that reproduce even the most minor details of the track or its surroundings. All this has resulted in some of the existing games reaching very high standards for the quality of the graphics and the fidelity of the reproduction of the physics of the vehicle movement. The widespread use of sim racing video games has led some researchers to question whether their use by young people may have an influence on how they drive actual vehicles in the future (Ruscio, 2018).

Parallel to the development of the sim racing games industry, an industry of hardware components for such games has been developed, including all the components necessary to reproduce the vehicle's cockpit: seats, steering wheels, pedals, gear stick, motion platforms and others. This development has led to lower prices for these components.

There have been experiences in using Sim Racing games for research. Weinberg and Harsham (2009) built a driving simulator using commercial components for the video game industry to reproduce the cockpit. The simulator seat was equipped with a motion platform that allowed to reproduce the vibrations and inclinations experienced during driving due to potholes, acceleration, braking and others. As software for the simulation they used rFactor software (Studio 397 and Image Space Incorporated, 2005). For the creation of the scenarios they used the program Bob’s Track Buider (Pywell, 2007). To obtain the telemetry they used plugins from the rFactor game as well as plugins developed by themselves. The result was a simulator that they claim was comparable to a mid-range research simulator and at significantly lower cost. Tiu et al. (2020) analyzed the possibility of using a sim racing game to analyze the driving ability of people who had suffered a stroke. The authors of the study point out several advantages in using sim racing games compared to research simulators: they have a considerably lower cost, provide a wide range of telemetry values and offer greater realism of the images and the operation of the vehicle. One of the drawbacks noted in the study is the difficulty in reproducing real traffic situations with more than one vehicle.

Using a simulator based on a sim racing game for research has advantages and disadvantages compared to using a simulator specifically designed for research. About the cost of the hardware (computers) and the vehicle cockpit, all things being equal, the cost is the same.

However, the cost of simulation software, as already mentioned, is much higher in research simulators. While a simulation software for research can cost between 30000 and 100000 euros, the software cost to create a simulator based on a sim racing game, including all the additional software necessary for creating scenarios and the management of the telemetry, rounds the 100 euros. Another advantage of sim racing games is the realism of the vehicle physics. In general, the realism achieved in the physics of vehicle operation in the latest versions of sim racing programs is superior to that of commercial research simulators (excluding the specific simulators available to large car manufacturers). The quality of the graphics and the scenarios realism is also generally superior to that of the research simulators. However, research simulators have specific tools that make it easy to incorporate the road geometry. In sim racing games, it is necessary developing specific tools or use more artisanal procedures. The simulation of the traffic of other vehicles and pedestrians is possible and relatively easy to incorporate in the research simulators. In sim racing games, it is not possible, or it is not easy.

In general, simulation software has two critical components in simulation: the graphics engine and the physics engine. The physics engine manages the controls inputs, performs the necessary calculations, updates the vehicle and other objects positions and passes the information to the graphics engine, which is responsible for generating the images that appear on the screens. Both the graphics engine and the physics engine use 3D scene data and vehicle data.

The creation of the 3D model of the scenario in which the simulation is to take place is the most time-consuming task in the tests carried out with a driving simulator (Dols *et al.*, 2016; Dols *et al.*, 2021). The possible components of this scenario are:

- Road:
    1. Geometry: Alignment, profile and cross-section
    2. Pavement: physical and visual characteristics of the road pavement
    3. Traffic sign and road marking
    4. Infrastructure associated with the road: guard-rails, lighting columns and other elements
- Environment:
    1. Area of the terrain that is visible while driving
    2. Constructions, vegetation and other elements whose presence may affect driving
- Traffic: other vehicles, pedestrians or animals that may affect the behaviour of drivers
- Weather: wind, rain, snow, fog or other weather effects
- Sound effects

Depending on the type of experiment and the level of fidelity desired, each element needs greater or lesser detail. The simulation software also needs to know the vehicle characteristics in the simulation to reproduce its behaviour.

2. MATERIALS AND METHODS

The start-up of the simulator consists of the acquisition, assembly and configuration of the hardware and software. Then, for each test, the 3D model of the road and its environment must be created in the appropriate data format for use in the selected simulation software.

With this, it is now possible to test by conducting road trips with different drivers while recording telemetry data. Finally, the data from the routes telemetry is analyzed to conclude the research. Below is the description of these phases as they have been carried out in this research work.

2.1 Hardware

The hardware used during this research has been the following:

- Computer: HP Prpdesk, Intel i7, 64 bits, 3.4 GHz, 8 Gb RAM
- Graphic card: NVIDIA GeForce GT 730 2 Gb RAM

- Screen: HP 2009V
- Steering wheel: Thrustmaster T300 RS – GT Edition
- Pedals: 3 metal pedals (accelerator, brake and clutch)

As gearshift stick, the steering wheel's paddles were used, one of them to upshift and the other to downshift.

2.2 Software selection

The first part of this research work consisted of selecting the sim racing games to assess their suitability for use as support software for a driving simulator applicable to the research. For this, the main sim racing programs has been explored and analyzed their fundamental characteristic. A survey was conducted among regular users of sim racing games to obtain additional information about the reviewed games. The survey asks about the graphics quality, the realism of the physics of the vehicle movement and some other questions. The survey obtained 54 valid responses. Figure 1 shows a graph with the results of the survey.

The horizontal axis indicates the quality of the graphics for each game, and the vertical axis indicates the realism of the vehicle dynamic. The program that got the best rating from users for its physics was Richard Burns (RB) Rally. Top rated for graphics quality were Assetto Corsa and Assetto Corsa Competizione. They both score very highly when it comes to physics.

Not all games allow for incorporating actual roads or for using ordinary tourist vehicles. Programs that do not allow such modifications are not helpful for the type of research intended. It is also needed to extract the telemetry of the tests to analyze speeds, trajectories, and other data.

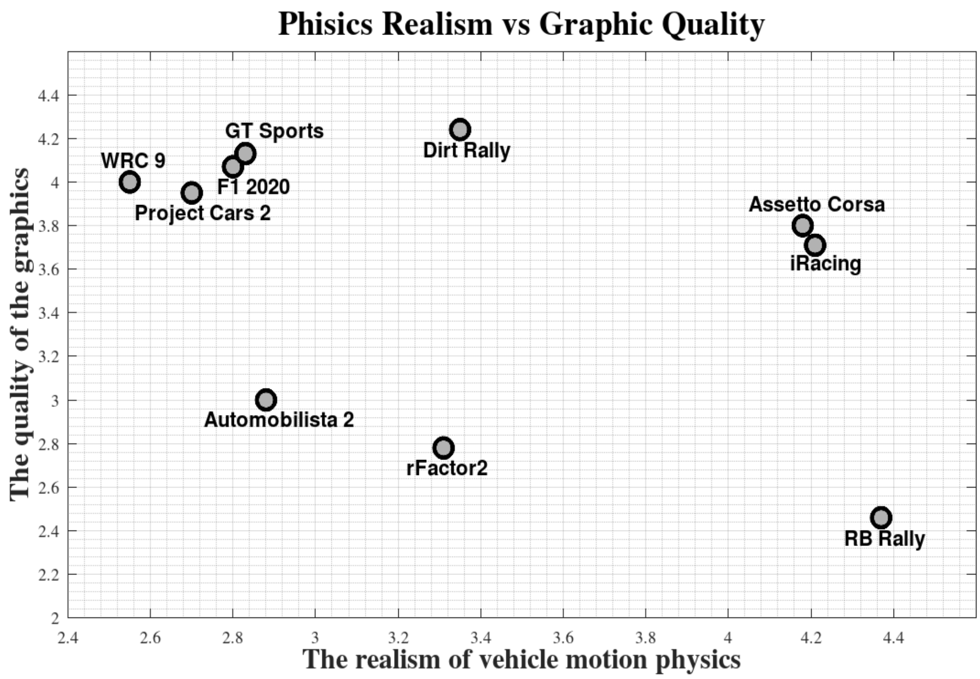

Figure 1 – Summary of survey results about sim racing games: image quality vs physics

Among the sim racing games analyzed, only three meet the conditions to incorporate actual roads, use passenger cars, and allow extracting and analyzing the telemetry: Assetto Corsa, RB Rally and rFactor2. All three have high-quality graphics and very realistic physics. RB Rally is no longer in development, so the decision was to use Assetto Corsa and rFactor2 for research tests (Studio 397 and Image Space Incorporated, 2012; Kunos Simulazioni, 2013).

Sim racing games come with presets adapted to sporty driving. For use in road research, it is convenient to adjust some parameters to increase the realism of driving of a passenger car. One of them is the turning of the steering wheel. In racing cars, a particular turn of the steering wheel produces a more significant turn of the wheels than in passenger cars.

Another parameter that is important to adjust is the driver point of view. The two games selected allow to set the position of the driver seat. The width of the FOV is also essential; an improper setting produces an unrealistic driving feel.

2.3 3D model development

For each road to test, developing a 3D model in the appropriate data format for the chosen simulation software is necessary. 3D modelling software is an adequate tool to create these models. 3DS Max and Blender are examples of this type of software. Modelling software can export their models to the FBX format, but each sim racing game uses its specific format for the 3D model. Some software is needed to convert the 3D model (in FBX format) to the specific format of the sim racing game.

When generating the FBX files, 3D objects and materials need specific parameters to define their characteristics so that later the physics and graphics can be interpreted appropriately by the sim racing game. Each of the games has a different way of defining these parameters.

Hence, it was necessary to develop two different models: one for Assetto Corsa and the other for rFactor2. The Assetto Corsa scenarios use the .kn5 format, which can be obtained from the corresponding FBX file using the KS Editor software (made by Assetto Corsa developers). This format includes the materials and the images of the textures used to display them. However, the rFactor2 scenarios use GMT format files for the geometry of the 3D meshes and the files. It stores the texture images in separate files.

Each of the programs has a set of files where the physics of the materials is defined. Figure 2 shows the workflow used from creating the 3D model for the two sim racing games.

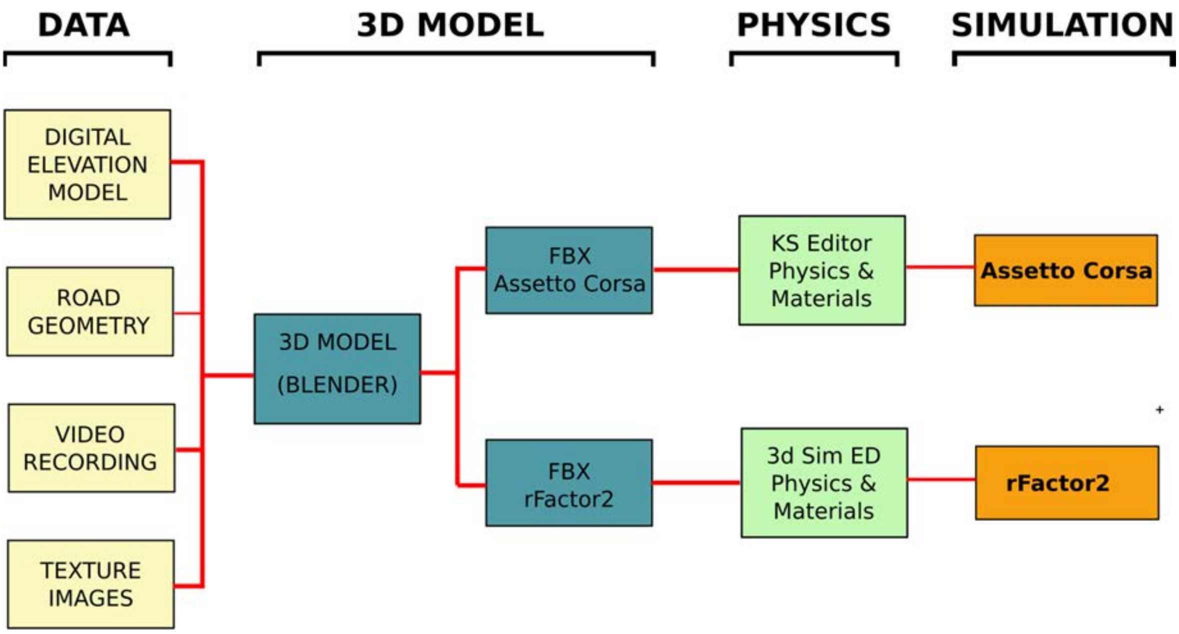

Figure 2 – Workflow for creating simulations using the sim racing games rFactor2 and Assetto Corsa.

This research work studied a 6 km long section of the two-lane rural highway M-607, located between Colmenar Viejo and Cerceda (Madrid). The section chosen is located between stations 36 and 42. The lane width is 3.5 m and the shoulder width is 2.5 m.

Digital elevation model (DEM) from the Spanish *Instituto Geográfico Nacional* (CNIG) was used in GIS format. A 12x3 km rectangle was used, which included the road area. The road centre line geometry was obtained from the definition of its alignments. Using GIS tools and scripts developed for this study, a file was generated with the X, Y, Z coordinates of the centre line points every 10 meters.

For 3D modelling, the Blender v2.91 software with the GIS plugin was used (Blender Foundation 2021, Lyszczarz, 2012). A script developed in Python by the authors was used, allowing reading an XYZ coordinate file and converting it into a 3D Blender curve to incorporate the road centre line in Blender (Higuera de Frutos, 2021). In order to achieve a more realistic 3D model (road markings, traffic signs, etc.) data recorded in the actual highway through RoadRecorder software was used (Higuera de Frutos, 2017). Images with free licenses were used for materials textures (roadway asphalt, shoulders, terrain, vegetation, guard-rails and traffic sign). The final model had 136,156 vertices, 249,947 edges, 118,796 tiles, and 197,039 triangles.

Figure 3 shows two details of the edition of the model with Blender software. The image on the left shows a general view of the scenario: the road mesh and the digital elevation model mesh with the mountains in the background. The image on the right shows a detail of a part of the model.

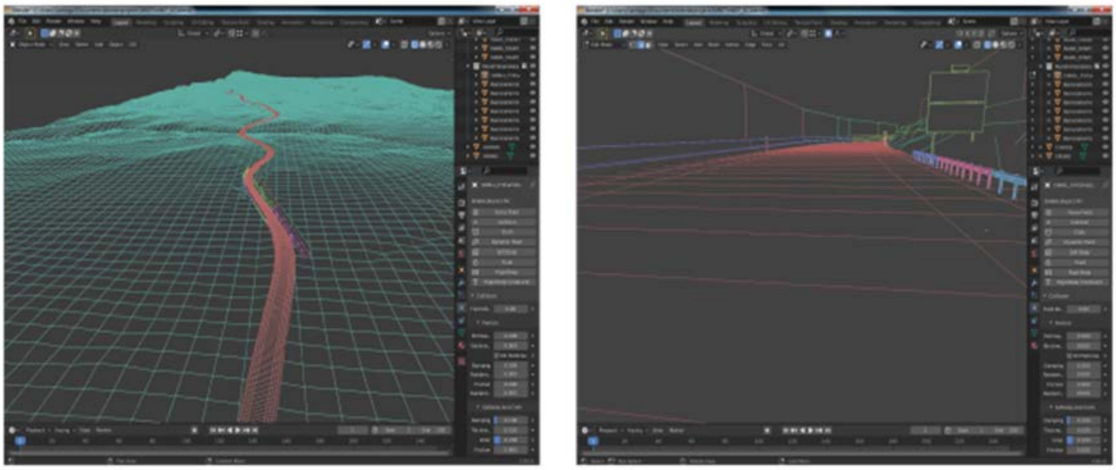

Figure 3 – Edition in Blender. The left image shows DEM and road meshes with mountains on the horizon. The right image shows the mesh detail in some area of the model

2.4 Materials and physics

The 3D model must follow certain conventions regarding the geometries and names of objects and materials. Together with specific parameters defined in the scenarios configuration files, these conventions allow the game engines to correctly interpret the way of visualizing the materials and interpreting the physics. Also, specific objects, called *spawn objects* by Assetto Corsa and *timing objects* by rFactor2, allow games to interpret the position where the simulation begins, the direction of the routes, and what telemetry sections record, among other functions. Each game has its objects and its way of interpreting them.

The lighting characteristics, the properties of the objects materials, and the shaders parameters determine the visual aspect. Each game has its shaders and its collection of parameters to define. Each object, for example, the road surface, uses several superimposed images (several image channels), which, when processed by the shaders, generate the final appearance. It is a complicated process that requires specific knowledge of computer image processing.

Some configuration files define the properties of the objects and their physical behaviour.

The primary interaction is between the vehicle tires and the roadway surface. The gravity force also affects all objects. It is also needed to define if the objects can collide or move in case of impacts. The game engine will interpret the driver actions on the controls and resolve collisions, friction or acceleration of the vehicle.

2.5 Telemetry

The physical parameters of the simulation can be monitored using data acquisition plugins and stored in telemetry files.

The most widely used telemetric data analysis program is Motec (MoTeC Pty Ltd, 2001), a professional system well known in all kinds of actual motorsport competitions. Assetto Corsa and rFactor2 can also use Motec. Each game allows installing a specific plugin to generate data logs that the Motec program can then interpret.

The telemetry files generated offer about one hundred parameters measured while driving every few milliseconds. The parameters include the instantaneous values of position, speeds, accelerations, vehicle inclination angles, engine operation values, parameters about the tires, temperatures, and many more. Also, Motec offers the possibility of generating formulas that, from the existing parameters, allow generating values not contemplated by default.

An interesting feature is generating the track followed by the vehicle from the lateral acceleration values. This option helps analyze the trajectory followed or generate the drawing of the road when the GPS position is not available.

For this study, Motec software was used in order to analyze vehicle telemetry of every test.

3. RESULTS AND DISCUSSION

Creating scenarios was laborious and required knowledge about 3D modelling and image processing, but the results were satisfactory. The generated scenarios can be used, with minor modifications, in either of the two simulators (Assetto Corsa and rFactor2). The imaging of the two simulators was very sophisticated, with highly realistic images. The process of creating scenarios and starting the simulations required a similar workload for both programs. Figure 4 shows the comparison between road actual video frame, the image generated by Blender, and the equivalent frames while driving in each of the simulators.

To carry out the driving tests in the modelled section, five drivers aged between 50 and 60 years collaborate. All drivers had more than 20 years of actual vehicle driving experience.

Each of them did two test runs with each of the simulators on the M-607 road scene. Next, each driver made two tours in each simulator, and the system recorded the corresponding telemetries. Drivers did not found significant differences between the physics of vehicle operation. The driving sensations were realistic with both software.

Figure 4 – Top left: a video recording of the actual road. Top right: image generated by Blender. Bottom left: image from Assetto Corsa. Bottom right: image from rFactor2

Figure 5 shows an example of a report generated by Motec comparing the speed during the same driver trip, once using the rFactor2 simulator and the other time using the Assetto Corsa simulator. The upper part of the graph corresponds to the comparison of the speeds along the route. The black line represents the speeds during the ride with rFactor, and the blue line during the ride with Assetto Corsa. The vehicle speed values are similar. The lower part of the graph corresponds to the road track generated from the geographic coordinate data obtained by rFactor2.

4. CONCLUSIONS

The objective of this study was to analyze the possibility of using sim racing games as driving simulators in research work on road geometry. A comparison has been made between the two existing games that, in the authors' opinion, offer the best features for this purpose: rFactor2 and Assetto Corsa.

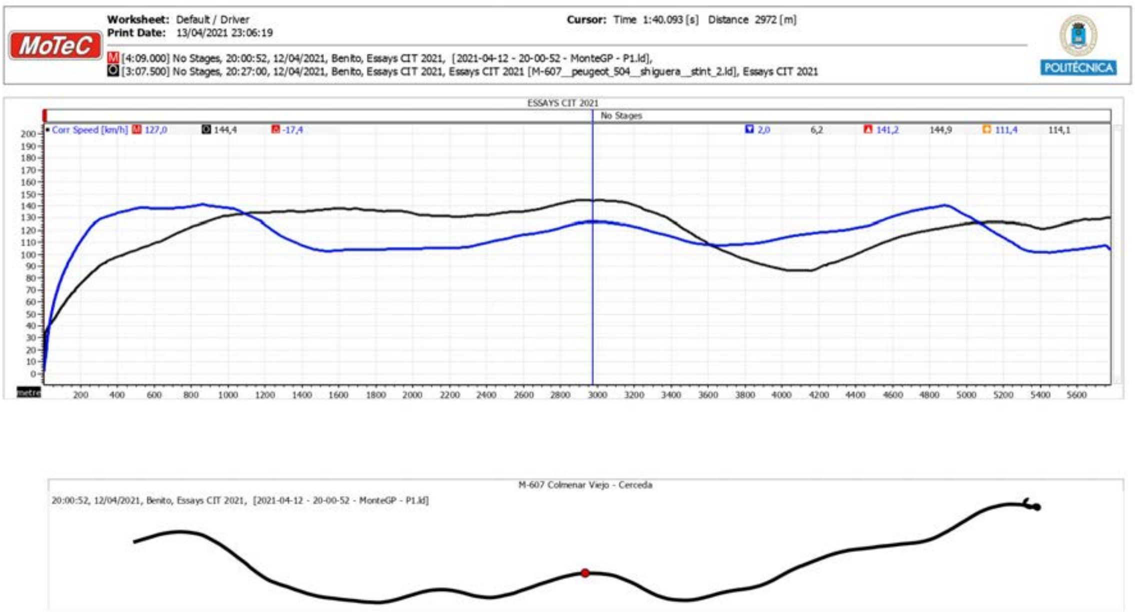

Figure 5 – Motec telemetry report. Comparison between the speed of the same driver in two different simulators ((Assetto Corsa and rFactor2). Up: speed (km/h). Down: road alignment (m)

The use of 3D design software (Blender), GIS information and road geometry to create the 3D scenarios was a time consuming task, but provided results with realistic images. During the driving tests, the drivers found no significant differences between the physics of the vehicles in the two games. Both software offered realistic driving sensations. The telemetries obtained (positions and speeds) had enough information for future research studies on vehicle speeds and road geometry. In next research works, the number of studied roads and the number of drivers will be increased.

In conclusion, both tested software can be used for building a low-cost driving simulator for road geometric research.

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