Unity-based Simulation Scenarios to Study Driving Performance

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Abstract: In this paper, we present two 3D driving simulation scenarios and a vehicle model developed to analyze driving efficiency and safety. The scenarios include different roads, traffic, and events so that drivers can acquire driving competences and their performance can be tested. They were developed with Unity game engine, which allows to create 2D and 3D games and applications and to export them to many different platforms. The first scenario is urban with varied roads, crossroads controlled by traffic lights, and roundabouts. The second scenario is interurban with different road sections connected by roundabouts. The vehicle engine has been modeled setting the dependency between engine torque and rpm and the dependency of each gear and speed on fuel consumption. Automatic or manual gear shifting can be selected. During a simulation, the speed, rpm, gear, consumption, and traffic offences are showed in real time and stored in files for further processing. Seven people drove in the scenarios and their stored data enabled us to analyze differences in driving performance between them. The simulator was ranked positively by all the participants regarding ease of interaction, similarity to real driving, and usefulness for driving learning.

1 INTRODUCTION

Event simulation is being increasingly used in many fields. With the advance of technology, it is more feasible to create very realistic environments that let users an easy immersion in the simulators, achieving best results in their use. These simulators can speed up the process of acquisition of basic skills and are configured as tools of great learning potential in many fields.

Particularly, driving simulators achieve driver learning and reeducation of drivers through the inclusion of varied routes and situations where safety can be compromised depending on the driver behavior. Many companies such as Renault are investing large amounts of money in driving simulators (Munir et al, 2017). Simulation can let future drivers get used to many situations that take place rarely but that can result in traffic accidents, such as landslides, animals in the middle of the road, or a previous accident. The development of simulation environments is important not only for their utility to drivers but also because it allows to recover data that can be analyzed to study different aspects that have influence on traffic safety. This data can also be used to discover shortages in the education and abilities of drivers that can lead to dangerous situations. Simulators can help to maintain the decreasing trend in the rate of traffic casualties present in the last years in the European Union. 26 out of the 28 EU countries have decreased the number of traffic casualties with respect to 2010 (Mobility Transport. European Comission, 2018).

In this work, two driving simulation scenarios with different road sections and events and a vehicle model to analyze the driving efficiency and safety are presented. The scenarios and the vehicle model have been developed with the Unity game engine (Unity, 2018). Unity is one of the most used engines in low budget projects and allows to develop 2D and 3D games and graphical applications. Besides, it is possible to export the applications to 27 different platforms including PC, mobile, and console ones. An important feature of the last version of Unity is its integration with virtual reality platforms such as Oculus Rift.

The driving simulator that integrates the two scenarios shows in real time and stores in files for further processing, not only information about the driver vehicle (position, speed, rpm (revolutions per

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minute), gear, and fuel consumption), but also the traffic offences committed during simulation. This information can be used to analyze the different simulations fulfilled by the drivers so that conclusions can be drawn about their driving competence.

The rest of the paper is organized as follows. Section 2 presents the state of the art on driving simulators. Afterwards, Section 3 explains the developed driving simulation scenarios and user's vehicle. Section 4 details the obtained experimental results and, finally, Section 5 draws the main conclusions about the presented work.

2 DRIVING SIMULATORS

A simulator is a hardware and software configure-tion in which, through calculation algorithms, the behavior of a particular process or physical system is replicat-ed. In this process, the real situations are substituted by other artificially created that can serve to acquire competences that will be transferred later to a real life situation in an effective way. In the education field, simulators are means not only for concepts formation and knowledge building but also for the application of them to new contexts that people, for several reasons, cannot have access to from the methodological context where their learning is developed. Simulators have educational advantages such as the providing of open learning environments based on real models and that users adopt an active role, turning themselves into the builders of learning from their own experience. To name some examples, simulation has been applied to fields so different as power engineering (Zimmerman et al., 2011) and spine surgery (Ryu et al., 2017) education with satisfactory results.

All the formerly mentioned is clearly applicable to driving simulators. Although there are driving simulators aimed to the learning of future drivers (DriveSim, 2018) from which the user can learn to drive from scratch, most of these simulators aim to entertain leaving aside the development of competences towards responsible driving. A large number of users, including race drivers, highlight that these types of simulators usually provide a very realistic experience and very detailed circuits that lets them know and adapt to new competitions, in a way that the routes are known before doing them for real (iRacing, 2018). Simulators such as iRacing, Project Cars, Gran Turismo, or Forza Motosport are recognized worldwide for their fidelity in the representation of racing vehicles' behavior. Concerning these kind of simulators, (Stinchcombe et al., 2017) found a statistically significant association between video game experience and risk-taking behaviors (large values of speed and crashes) when the participants had to drive in a scenario developed specifically to assess a particular skill such as handling. As a consequence, simulators for learning and assessing safe and efficient driving should be carefully designed to reinforce proper driving behaviors through the provision of feedback.

In the last years, driving simulators have been used in many research studies for a wide variety of purposes. With them, drivers' reaction to different situations, which cannot be replicated in a real road, can be evaluated (Bham et al., 2010). Their suitability to assess the behavior of drivers and as a means to learn safe and efficient driving skills has been shown. (Sullman et al., 2015) showed the potential of the training in efficient driving skills with a simulator for bus drivers. (Jamson et al., 2015) studied with a simulator the tradeoff between driving efficiency and safety using systems embedded in the vehicle to advise the driver about the use of the throttle pedal. They showed that efficiency can be improved using these systems. Simulators were also used to compare younger and older driver performance (Stinchcombe et al., 2010) and to correlate driver cognitive measures and driving performance (Yamin et al., 2016). (Hooft van Huysduynen et al., 2018) used the Multidimensional Driving Style Inventory (MDSI) to study the relation between self-reported driving style and the driving behavior in a simulator, concluding that there is a modest correlation between them.

In driving simulators, scenarios to analyze the level of driving efficiency and safety, the relation between them, and the results produced as a function of them can be included. When a person sees itself in a real driving environment such as a city with heavy traffic or a complex junction, he may think that he will be unable to face that challenge. Particularly, there are people suffering from amaxophobia, characterized by the fear of vehicles or travelling in a vehicle (Gossling, 2017). Driving simulators enable users to face many of these problems in a virtual environment without endangering the user or other drivers. Simulators enable the users to face problems and to obtain driving skills to overcome these problems, in such a way that these skills can be applied when they face similar situations in a real environment. The users can also get used to the vehicle controls through simulations, manipulating them with the steering wheel, pedals, and gear lever similarly to in a real vehicle. For that purpose, different types of peripherals can be used, from controls to complete driving cabin, including devices such as Logitech G27. Obviously, simulators enable users to repeat simulations in a scenario and to face certain events many times. Besides, it is possible to simulate real situations that would be practically impossible to do voluntarily in a real environment. Situations such as a vehicle stopped in the middle of a road or a pedestrian crossing a road unexpectedly are events that can be replicated in a simulator easily. This will enable simulator users to be better prepared for unusual situations that can find in the future. Simulators can also be used to do studies about how certain agents, such as fatigue, physical or psychological state of the driver, medicine, drugs, or alcohol consumption or age, can influence driving capacity significantly. Moreover, they can be used to study the influence of Advanced Driver Assistance Systems (ADAS) (Gonçalves et al., 2014), or of the presence of children in the vehicle (Olaverri-Monreal et al., 2014), on driving performance easily and without danger. Lastly, it is important to mention that simulators can gather data in a simple way. Thus, users can have access to information of the fulfilled simulations and observe their evolution. This enables drivers to see their mistakes and committed traffic offences and what aspects they should improve to avoid them in the future.

3 DEVELOPED DRIVING SIMULATION SCENARIOS AND USER'S VEHICLE

We have developed two 3D driving simulation scenarios using the Unity game engine with a view to covering a wide range of environments and situations that drivers should know to react properly. We have also modeled the user's vehicle. As a peripheral input module, we have selected the Logitech G27 device, which includes steering wheel, clutch, brake, and throttle pedals, and gear lever.

3.1 Urban Scenario

The first scenario is urban. We have used the Road & Traffic System plugin from the Unity Asset Store to create the road sections and to include the traffic. This plugin can be used to create dynamic traffic networks in roads with one, two, and three lanes per direction, crossroads controlled by traffic lights, and roundabouts.

Pedestrians were included in the scenario. They use a 3D model of a person with its linked skeleton and animations that once applied to the 3D model make it behave with the intended motion. There are three different animations: Idle (standing still pedestrian), Walk Forward (pedestrian walking forward) and Hit (pedestrian being hit by a vehicle).

The driver is guided in the crossroads and roundabouts to follow an established route. Fig. 1 shows a schematic view of the scenario where sections with different lanes, 4-legged and T crossroads and roundabouts (green circles) can be observed. Fig. 2 shows images from this scenario. In these images, the vision of the rear view mirror at the top center, the current gear at the bottom center, and the rpm meter and speedometer at the bottom right of them can be seen.

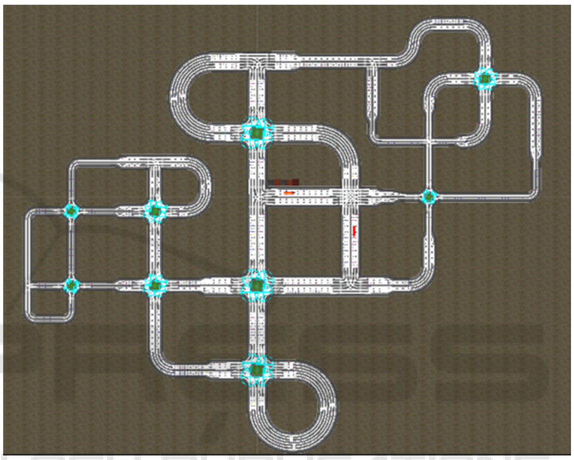


Figure 1: Schematic view of the urban scenario.

(a)

(b)

Figure 2: Urban scenario images.

3.2 Interurban Scenario

The second scenario is interurban with road sections between 0.5 and 2.5 kilometers long interconnected with 2-lane and 3-lane roundabouts. Roundabouts are very common in roads throughout the world as they have replaced traditional 4-legged crossroads (Nikitin et al., 2017) to improve traffic flow and safety. The road sections are also of 2 types: some have one lane per direction and others have two lanes per direction. Fig. 3 shows a schematic view of the scenario. Similarly to the first scenario, drivers are guided with signs informing, while approaching a roundabout, about the exit they have to take. The pedestrians were also included similarly to the first scenario. The traffic vehicles were included by applying two scripts to them, one for the car as a whole and one for each wheel without using the Road & Traffic System to control their behavior so that adaptation to interurban traffic can be better achieved. Each vehicle has to know if there are other vehicles in the surroundings to change its speed or lane accordingly. Fig. 4 shows some images from the scenario. Fig. 4(c) shows an image where the scenario projected on a screen and the Logitech G27 steering wheel can be observed.

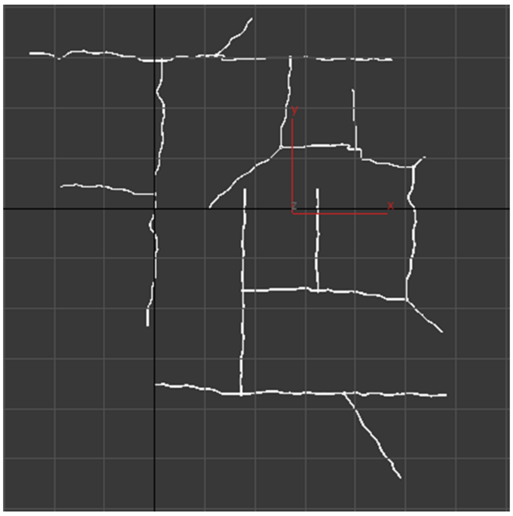


Figure 3: Schematic view of the interurban scenario.

(a)

(b)

(c)

Figure 4: Interurban scenario images.

3.3 User's Vehicle

Regarding the engine modeling of the user's vehicle (with internal combustion engine), the dependency between the engine torque and horsepower and rpm were set as shown in Fig. 5. Other factors to compute the overall force of the engine have to be set, such as differential ratio, gear ratio (per each gear) and wheel rpm. To compute the fuel consumption, its dependency on the current gear and speed was set as shown in Fig. 6. It is possible to select manual or automatic gear shifting before the beginning of a simulation. There are several cameras that can be selected by the user to change the field of view. One camera is outside the vehicle as shown in Fig. 4(c). Other camera is inside the vehicle, as shown in Figs. 4(a) and 4(b), to have a view similar to the driver in a real vehicle. With this view, the vision of the rear view mirror of a vehicle is included. Besides, the user can turn the view left or right pressing particular buttons on the steering wheel. While Fig. 4(a) shows the frontal view inside a car while approaching a roundabout, Figs. 7(a) and 7(b) show the view turning left and the view turning right that a user had in nearby places during a simulation, respectively.

In each route in a scenario, the simulator stores for further processing the position (x, y, and z coordinates), the current and average speed, covered distance, rpm, current gear, and current, average, and total fuel consumption every second.

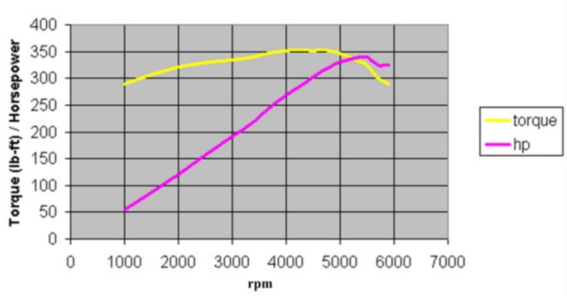


Figure 5: Graphs of the engine torque and horsepower as a function of rpm of the modeled vehicle.

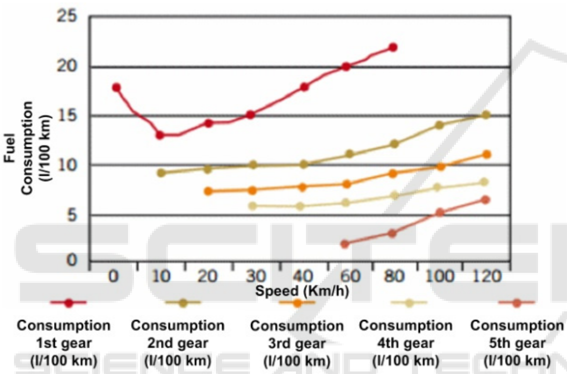
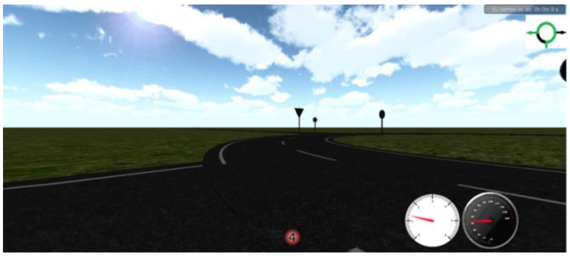


Figure 6: Graphs of the fuel consumption as a function of the current gear and speed of the modeled vehicle.

4 EXPERIMENTAL RESULTS

Seven people drove in the driving simulation scenarios ranging from 21 to 42 years old. The participants drove in the first scenario twice, firstly with automatic gear shifting and secondly with manual gear shifting to analyze the influence of the different gear shifting. They drove in the second scenario with manual gear shifting. Figs. 8 and 9 show the average speed and the average fuel consumption of the users in the three simulations, respectively. As expected, the average speed is much lower in the urban scenario, where there were small differences in the routes using automatic and manual gear shifting. Five out of the seven participants drove a bit faster with automatic gear shifting than manual gear shifting in the first scenario as they did not have to pay attention to the gear shifting. Regarding the fuel consumption, it was higher in the urban scenario as expected and five out of seven participants has a higher fuel consumption with manual gear shifting as they did not change gear as efficiently as using automatic change.



(a)

(b)

Figure 7: Interurban scenario images.

Figs. 10 and 11 show the rpm, standard deviation of rpm, and average consumption using manual gear shifting for the urban and interurban scenario, respectively. The standard deviation of rpm is much larger in the urban scenario as expected due to frequent stops in it. In both scenarios, there is a correlation between large values of rpm, the standard deviation of rpm and average consumption as economic driving implies soft driving trying to keep the value of rpm low and constant.

While User #1 had both the lowest value of standard deviation of rpm and average consumption in the urban scenario, he clearly decreased his driving performance in the interurban scenario comparatively as he had both the second largest value of standard deviation of rpm and average consumption in it. The rest of the users had comparative values of the standard deviation of rpm quite similar in the two scenarios. User #7 was the participant with the worst driving performance as he had the largest value of standard deviation of rpm and the third largest value of average consumption in the urban scenario and had both the largest value of standard deviation of rpm and average consumption in the interurban scenario.

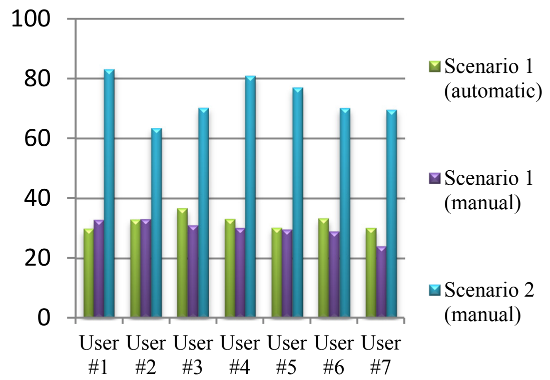


Figure 8: Average speed of the users in the simulations.

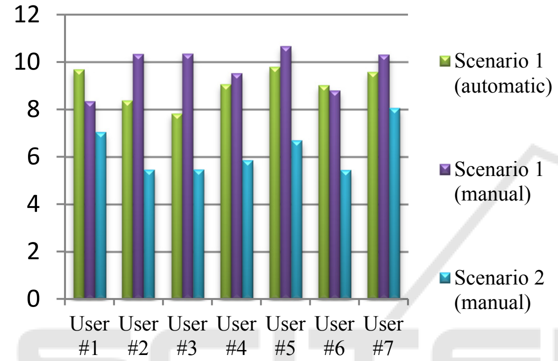


Figure 9: Average fuel consumption of the users in the simulations.

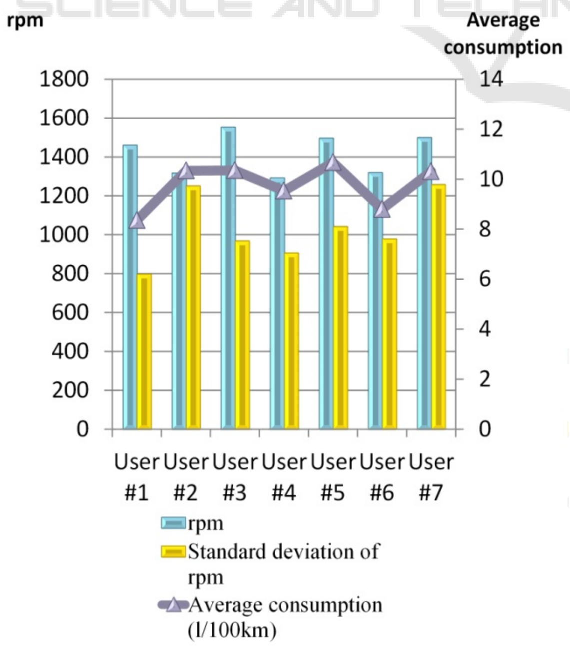


Figure 10: rpm, Standard deviation of rpm, and average consumption using manual gear shifting for the urban scenario.

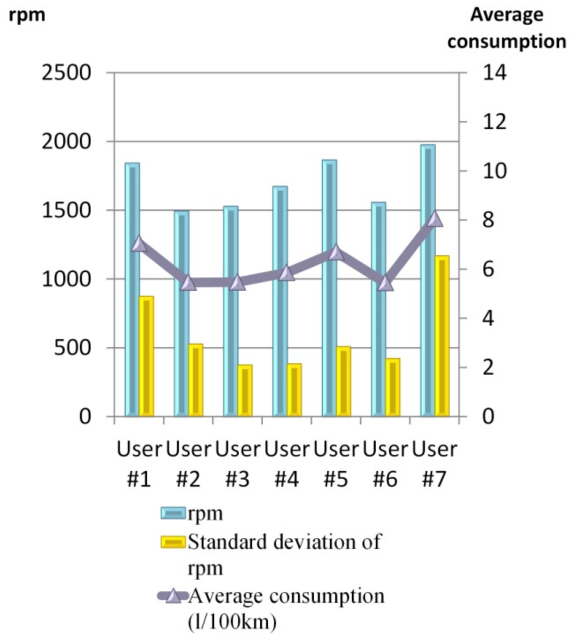


Figure 11: rpm, Standard deviation of rpm, and average consumption using manual gear shifting for the interurban scenario.

After using the simulator, the seven participants were asked about their experience driving in the scenarios. They were asked about the ease of interaction, the similarity to real driving, and the usefulness for driving learning, obtaining an average score (out of 10) of 8.5, 7.5, and 7, respectively.

5 CONCLUSIONS

In this paper, two driving simulation scenarios, which were developed with the Unity game engine, have been presented. The simulator makes it possible the acquisition of driving skills and the assessment of driver performance through the inclusion of varied road configurations, user's vehicle, traffic, and events so that the safety and efficiency are affected by the driver behavior. The continuous technological advances have enabled the development of low-cost simulators as the presented with realistic scenarios and events impossible to have in a real driving environment without endangering people or vehicles. People that took part in the experiments driving in the simulation scenarios highlighted the ease of interaction, realistic experience, and usefulness for driving learning of them. The data stored in the simulation will allow to carry out deep comparative analysis to associate the different drivers and their driving styles with their safety and efficiency level, and assess the evolution in the development of driving competence as more drivers will use the simulator.

The simulator can be extended to new scenarios and events and virtual reality devices. Oculus Rift virtual reality device is planned to be integrated in the simulator to achieve a more realistic and immersive driving experience together with new scenarios and different user's vehicles regarding size (bus, truck) and motor (electric).

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