Evaluation of Driving Education Methods in a Driving Simulator

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Abstract

This paper presents the development of a realistic driving simulator and its use in the study of driving education methods. In this study, a large set of persons without driving license will be used. Each person will be submitted to a driving course that may include driving lessons in a real car and / or in the driving simulator. The realism used in the simulation can be adjusted between the classical non-interactive, film based training and the full realism achieved by our driving simulator. Each driving education method will be evaluated by comparing driver's competence before and after the applied course.

We expect to determine the influence of the simulation realism in the learning process, and to understand how and when the driving simulator should be used for better performance in the education process.

1. Introduction

The large number of accidents and dead occurred due to traffic circulation in public ways is one of the most concerning problems of today societies. It has been commonly accepted that one method to reduce these losses is the improvement in driver's education and selection. To do so, and due to recent advances and spread of image generation systems, interactive driving simulators are being more and more used in driving education tasks.

It is commonly accepted that the use of driving simulators presents some advantages over the traditional methods of drive learning. Because of their virtual nature, the risk of damage due to incompetent driving is null. This usually allows a reduction in the cost of driving lessons or a longer and richer training but imposes a very hard limit to the cost of a driving simulator. According to professionals in the area of driving education, to explore its advantages in driving education use, a driving simulator must not be much more expensive than real vehicle.

Although the recent advances in computing and image generation systems, to keep the cost of a driving simulator compatible with the education uses, many simplifications must be done. For example, reductions in field of view, image resolution, vehicle's dynamic behavior and scenario reactivity are common in today educational driving simulators.

This paper presents the development of a realistic driving simulator and its use in the study of driving education methods. This study will be done using data acquired from a large set of persons without driving license. Each person will be submitted to a driving course that may include driving lessons in a real car and / or in the driving simulator. The realism used in the simulation will be adjusted between the classical non-interactive, film based training and the full realism that can be achieved by our driving simulator. Each driving education method will be evaluated by comparing driver's competence before and after the applied course.

As results of this study, we expect to determine the influence of the simulation realism over the learning process, and to understand how and when the driving simulator should be used to maximize the driving education's productivity.

The state of the art in the field is summarized in Section 2. Section 3 discusses the use of driving simulators in driving training and driver's evaluation. Section 4 presents a short description of DriS, its goals and applications. The study, being prepared, about driving education methods and its evaluation is detailed in section 5.

2. Related work

Driving simulators are hi-complex real-time, imersive systems *[1][10]*. The improvement in realism and the validation of their performance are the major concerns in development of any scientific driving simulator *[3][4][12]*.

The usability of simulators in training and in evaluation of human performance is already studied and generally accepted under several restrictions *[14][9]*. In driving education, it is today common to find the use of driving simulators either with training or with evaluation proposes. Some experiences are known that analyze discrepancies between human driving in real and in simulated environment *[11][13]*, but no studies are know that evaluate how these discrepancies affect the driving education process.

3. Driving Simulators

In the last years, we assisted a tremendous development in computing and image generation technology that allowed the proliferation of VR systems with acceptable quality for some education purposes. Even thought, the development and maintenance of a realistic driving simulator is still a very expensive task. So, to keep the cost of a driving simulator compatible with the education uses, many simplifications must be done.

For example, most driving simulators used for driver education present only a narrow filed of view. This reduction clearly degrades the perception of the surrounding environment by the human driver and also limits the amount of information that he must receive and process. Also, the generation of the backward images presented in mirrors is crucial, for instance, for training overtaking maneuvers.

The image resolution used in today driving simulators is always poorer than the one obtained by the direct observation of the real world. This results in a different driver behavior due to the lack of obstacle perception. It is known that, when approaching an obstacle, a driver breaks sooner in a driving simulator than in a real car *[13]*.

Reductions in vehicle's dynamic behavior and scenario reactivity are also common in today educational driving simulators.

All these, and other simplifications affect human driver reactions but, it is accepted that they do not invalidate the data we can get from the simulated driving task and the knowledge acquired from training. It is known that, when correctly used, even a simplified driving simulator can be useful either in driver performance analyses as in driving education. A big challenge that is proposed to every driving educator is the choice of how and when to use driving simulator in order to maximize the education productivity. This choice implies a selection of simulation realism and its trade off with the simulator cost. Then a selection of training exercises must be made but this selection is usually limited by the realism achieved by the possibly available driving simulator. Because a simulated training is still far from completely substitute a real experience, decisions must also be taken on how these two kind training should interact.

4. DriS - Driving Simulator

A description of our driving simulator (DriS) can be found in [2]. Its main core runs on a SGI Onyx Reality Engine 2 graphical workstation (Figure 1). This workstation holds the scene database, and performs the simulation and the image synthesis tasks. It is connected to the sound PC and to the cockpit PC by local area network. Communications are implemented synchronously with the rendering process, using a socket library.

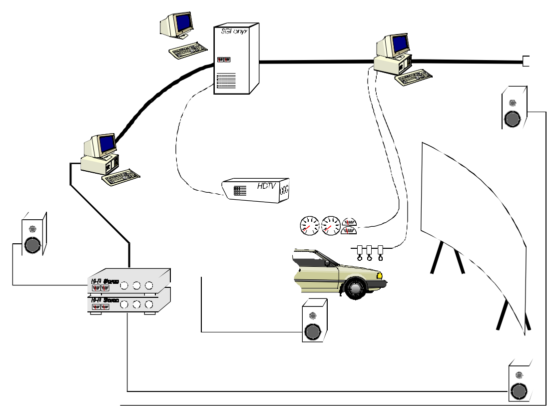

Figure 1: DriS driving simulator.

In DriS, the driver sees a realistic image either in a large screen display or in a HMD. The generated image is applied to a large flat screen (3.40mx2.00m) by a video projector. Typical experiments are usually performed with resolution of 1280x1024, with an image update of 20 images per second, and a frame rate of 60 frames per second *[15]*.

High quality audio information is also supplied in either stereo sound with headphones or in multi-channel surround sound using loudspeakers, and an additional channel for the typical sound of the vehicle *[6]*.

DriS is being developed by a large team of researchers from several institutions and different scientific areas. The development team includes experts in computer systems, image analysis, computer graphics, road and traffic engineering and psychology. Their main goals are the study of driver behavior and road analyses under conditions that are difficult or even impossible to reproduce:

- risk situations

- accident
- new roads
- new managing systems
- new road signals
- new vehicle models

4.1. Applications of DriS

In [7], Noriega and others presented a study of vehicle's motion detection with concurrent self motion with three kinds of road pavement:

- concrete pavement
- bituminous pavement
- bituminous pavement with chromatic bands

The DriS driving simulator allowed an easy preparation of the stimulus presented to each one of the 106 persons with driving license that participated in this study. It was concluded that the pavement with chromatic bands produces a higher number of wrong detections of vehicle's motion, while differences in image contrast were considered not relevant.

A new study is now running to evaluate the influence of external publicity panels (outdoors) in driving performance and several others are being prepared *[5]*. One of most important studies is the evaluation of driving education methods that is detailed in this paper.

5. Evaluation of Driving Education Methods

This section presents the study of driving education methods that is now being prepared. This study will be done using data acquired from a large set of persons without driving license. Each person will be submitted to a driving course that may include driving lessons in a real car and / or in the driving simulator. The realism used in the simulation will be adjusted between the classical non-interactive, film based training and the full realism that can be achieved by our driving simulator. Each driving education method will be evaluated by comparing driver's competence before and after the applied course.

5.1. Driving Environment

A driving simulator will be used (DriS), and the virtual environment will try to reproduce a typical street from Porto. For this propose, we choused some well-known streets and avenues from Porto located in the Foz do Douro area. This area is traditionally one of the most used areas in Porto for driving lesson purposes.

Roads were modeled using real field dimensions and buildings were finished using photographic textures taken from some choused streets:

- *Avenida do Brasil*
- *Avenida de Montevideu*
- Passeio Alegre.

Figure 2 presents a view of a modeled road. Several autonomous vehicles were added to compose the environment traffic. These vehicles are driven by virtual drivers that try to emulate human drivers *[8]*.

Figure 2. View of a modeled road.

5.2. Methodology

This study will be done using data acquired from a large set of persons (subjects) without driving license. Each person will be submitted to a driving course that may include driving lessons in a real car and / or in the driving simulator. The realism used in the simulation will be adjusted between the classical non-interactive, film based training and the full realism that can be achieved by our driving simulator. Each driving education method will be evaluated by comparing driver's competence before and after the applied course.

The subjects set is being formed using people that meet all the following requirements:

- have not driving license
- want to have driving license
- are, preferable, between 16 and 22 years old
- have not visual or physics deficiencies

The study will be performed in two identical experiments. The preliminary experiment will be used to select the course curriculums that will be used in the final experiment. The preliminary experiment is now starting and will take about 9 months long.

Each subject will first be evaluated in driving performance terms and assigned randomly into one of 4 groups (Figure 3). Some effort must be done in order to achieve groups with the same amount of subjects and with similar driving and intellectual skills. We plan to use near 20 persons in the preliminary experiment and about 200 in the final one.

Then a different driving course will be applied to each subject group.

Course 1 will be a traditional driving course, performed at several driving schools and with different driving teachers. In Portugal the minimum curriculum of a driving course includes 25 hours practical lessons but it is known that this minimum is sometimes not needed to achieve the required driving competence. In our study, the final evaluation will take place after 15 hours of practical driving lessons.

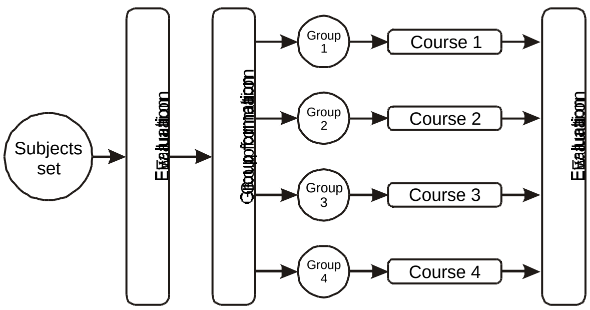

Figure 3: Experiment workflow.

Course 2 will consist of 30 hours of driving lessons using an interactive driving simulator. Lessons will be supervised by a driving teacher and will include simulated driving practice under several conditions of:

- traffic intensity,
- traffic velocity,
- own vehicle characteristics

Course 3 will consist of 40 hours of driving lessons using a non-interactive driving simulator. Lessons will be supervised by a driving teacher and will include simulated driving practice under several conditions of:

- traffic intensity,
- traffic velocity,
- own vehicle characteristics

5.3. Evaluations

Initial and final driving performance evaluations will be done using data acquired from the simulated driving in a realistic driving simulator.

Each subject will be asked to follow a previous route, in order to adapt to the simulator. Then, in the experimental route, the driver will follow a first road without other vehicles, a second one with low traffic intensity, and a third with high traffic intensity.

During the experimental route, several driving parameters will be measured and stored for further analyses.

Measures can be divided into three groups: measures reported by the driver, a rating scale of mental effort (RSME); physiological measures, eye movements (with a NAC eye tracking recorder); and performance measures.

The rating scale of mental effort will be monitored from several electro-magnetic sensors located in the subject's head, using dedicated specialized equipment (Figure 4) that produces a graphical output printed in paper.

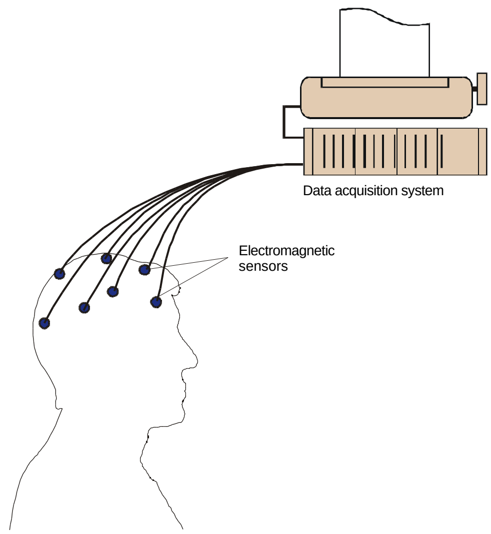

Figure 4. Mental effort acquisition system

Eye movements will be recorded in video using a dedicated optical tracking located near subject's head that detects the subject's retinal position (Figure 5). This data is related to the viewing direction and it is very important because it permits to determine attention and distraction rates.

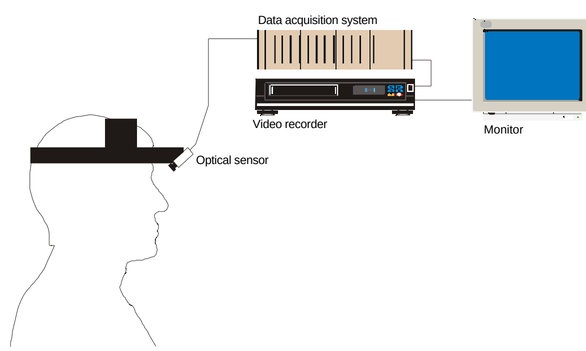

Figure 5. Eye movements recorder equipment

Both RSME and NAC equipment are synchronized with the simulation experiment by a developed interface module (Figure 6).

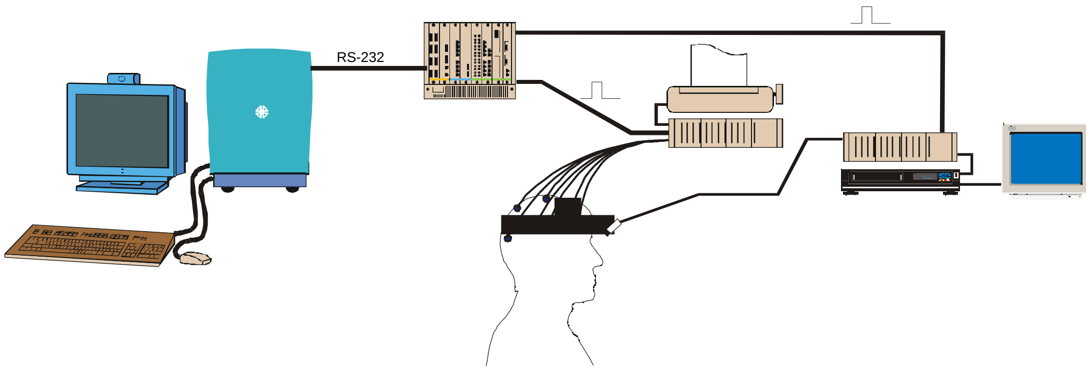

Figure 6. Synchronizing the acquisition equipment with simulation experiment

This module receives information about the simulation stage from the graphical workstation through a standard serial connection (RS-232) and outputs the required synchronization signals. The synchronization allows specialists to relate the outputted data with the simulated traffic events.

Learning measures will be the performance measures: the number of errors committed

- reaction times
- time-to-line crossing
- control of the driving path
- driving speed
- number of collisions

These measures are obtained by processing the information that the simulator reports in real-time.

This study reflects the relation between the driving simulator use and learning process in these courses. The performance results from these initial courses are presumed to be different from each other, even with the specified differences in course duration. An adaptation of each course curriculums must be done using information from the results of this preliminary experience. This adaptation is important because performance results from different courses can only be compared if they have some similarities.

The final experiment of this study will use the same methods but with differences on the number of used subjects, the number of groups and courses, and the curriculums of the driving courses.

A second study will be done on the validation of driving learning assessment. Driving teachers and experts will be asked to analyze video records from the first study (images recorded from the driver point of view), and to score the drivers performance with an evaluation sheet used at driving schools. The objective data from learning measures gathered at the first study will be then matched with the subjective evaluation from experts. This second study will allow us to analyze the value of subjective reports from driving teachers on topics such as vehicle control, skills of learning drivers in unexpected situations, learning improvement along driving sessions and agreement of experts in the assessment of driving skills.

As results of these studies, we expect to determine the influence of the simulation realism over the learning process, and to understand how and when the driving simulator should be used to maximize the driving education's productivity.

6. Conclusions

This paper shortly presented the architecture of DriS, a realistic driving simulator. DriS integrates a typical cockpit of a real car, a SGI Onyx Reality Engine 2 graphical workstation and a large projection screen. It also uses a PC for sound generation, and another PC to control and monitor cockpit sensors and signals. DriS is being developed to study driver behavior, road performance and driving education methods.

Experiments being prepared to the evaluation of driving education methods were also presented. These experiments will use data acquired from a large set of persons without driving license. Each person will be submitted to a driving course that may include driving lessons in a real car and / or in the driving simulator. The realism used in the simulation will be adjusted between the classical non-interactive, film based training and the full realism achieved by our driving simulator. Each driving education method will be evaluated by comparing driver's competence before and after the applied course.

We expect these experiences will allow concluding about the required level of realism that a driving simulator must achieve in order to be used in driving education processes and to understand how and when the driving simulator should be used for better performance in the education process.

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