

VIRTUAL REALITY DEVICES IN DRIVING SIMULATORS: STATE OF THE ART AND ONGOING DEVELOPMENTS AT U.P.M.

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Figure 1: A driving simulator at the Virginia Campus of The George Washington University [2]

1.- INTRODUCTION

The advances in Virtual Reality (VR) have always run in parallel with the increase of the computational power in informatics, and more advanced and complex graphics systems in the display devices and rendering capabilities. Thus, simulating a real scene of the world using only graphics is becoming progressively easier, and the obtained results more realistic. Apart from that, another issue which has also facilitated the spreading of applications that use VR is the falling of the cost of the equipments and of the specific hardware needed.

One of the fields in which VR has become very important is in the development of driving simulators (DS). These systems provide a very useful tool for studying the reactions of the drivers without the necessity of using a real car in a possibly dangerous situation. Another helpful application of these systems is in training simulators for educational purposes. In fact, there are some DS which are utilized for rehabilitation of humans. Of course, the development of entertainment systems, like racing games, is another area of application very well known by the general public at present.

In all these systems, it is very important to obtain the greatest feeling of reality. For example, and for this purpose, it is very common to include a real car in the architecture. Graphics are presented typically by video projector systems on a big wall (like in Figure 1), providing a flat 2D representation of the environment which offers a limited perception of immersivity. In these scenarios, the reactions of

drivers are analyzed and assessed, with the purpose of gathering statistical information about the human behaviour and reactions. The importance of this information is huge, and the conclusions that are achieved lead to meaningful clues to understand the human behaviour. However, it is clear that the limited perception of 3D immersivity in the environment must have an effect over the people that use the simulator, in the line of reacting in a different way than in the actual real situation, and most of the time this important fact is not taken into account in the reports.

With the previous idea in mind, we are currently working at the Universidad Politécnica de Madrid in the development of a DS which includes a stereo virtual reality model, that is, a system which is able to simulate the stereo vision of the human eyes, providing a very intensive feeling of immersivity into the virtual 3D world. The main objective is, then, the evaluation of the effect of the DS over the users depending on the level of immersivity that the simulator provides. The systems is currently under development, and so we provide here a brief report of its current status, and the main differences compared to other DS already available in the world.

2.- STATE OF THE ART

2.1.- Introduction to Driving Simulators

The first systems of DS appear in the early 70s [1]. The main cars constructor companies in USA took advantage of the technology developed by the U.S. air force in the military first flight simulators for building their own DS. Very quickly, this technology spread out to Europe, and many universities and research centers began developing new simulators.

Nowadays, there are two main branches of development about driving simulators around the world:

- DS for commercial purposes.
- DS for research and development functions.

The architectures of both types of simulators depend on the cost restrictions and the envisaged application. The implemented VR models are mainly limited by the available hardware in terms of computational cost and rendering capabilities.

Perhaps the most common architecture is based upon a real car, in front of a wide screen where virtual world is projected (Figure 1). Another line of work introduces a special platform in the scheme. This device is frequently a piece of vehicle cabin controlled by some electro motors which are able to move this cabin around three spatial dimensions. In this model, the screen can be inside the cabin, and it is usually composed by one or several ordinary display monitors. The third alternative, and usually the most expensive one, includes a real vehicle cabin inside a mobile platform (Figure 2). Some useful links with relevant information are provided in [4].

The following sections present the most important DS in the world, organized by continents, from which there is some detailed information available.

2.2.- USA simulators

The National Advanced Driving Simulator (NADS) at The University of Iowa is the world's most advanced ground vehicle simulator [3], following the third approach presented in the previous section. It consists of a large, 24-foot-diameter dome in which entire cars and the cabs of trucks and buses can

be mounted (Figure 2). At the same time, the motion subsystem, on which the dome is mounted, provides horizontal and longitudinal travel and rotation. The effect is that the driver feels acceleration, braking and steering cues as if the user were actually driving a real car. However, and as it can be seen in Figure 2(b), the display system is 2D, and obviously the depth perception of the driver is very limited. Surely, this affects to the driver reactions, as distance, speed and time are key issues while driving.

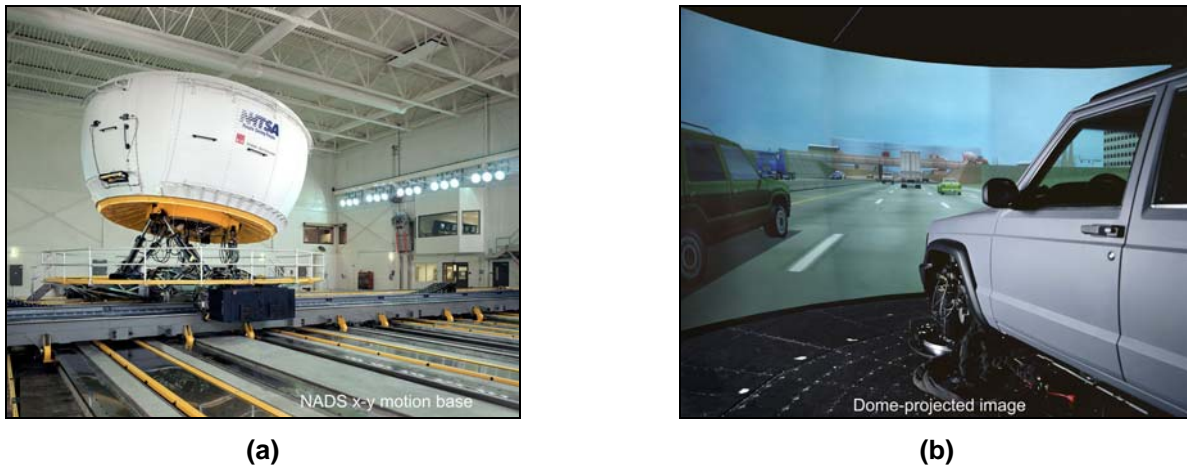


Figure 2 - NADS: Motion device (a) and projected display inside the dome (b)

The University of Minnesota has developed another DS called VESTR (Virtual Environment for Surface Transportation Research), enclosed in the HumanFIRST Program [5]. Differently from the model before, this DS has not any movement in the cabin in spite of the fact that it is formed by a real car too. From the display point of view there is also another difference, as it is composed by five different video projectors which are displayed in five jointed LCD panels (Figure 3). Although the displays partially “surround” the driver, there is also a flat 2D perception of the environment, and so the systems lacks in the same limitations of providing actual 3D depth and distance information to the driver.



Figure 3: Driving simulator of HumanFIRST Program

Another different line of work can be found at the ARMLab [6], where the development of a virtual driving simulator with *haptic feedback* is proposed. This particular effect consists of providing the

sense of touch by including kinesthetic information. This model is used with the aim of helping in telerehabilitation. In this way, virtual prototyping of automotive interiors are implemented at the University of Michigan [7]. This is not exactly a DS like the previous models, but we think it is worth mentioning and must be included in this revision of current available implementation, as it provides a new and interesting capability that contributes to the enhancement of immersivity. Currently, the main uses of this DS are the design and evaluation of human factors and ergonomic issues, which are very expensive to obtain with physical prototypes.

2.3.- European simulators

There are also very important DS in Europe. One of the first labs to develop an advanced motion system [1], allowing multiple degrees of freedom in the simulation, was the Swedish National Road and Transport Research Institute (VTI) [8], and its simulator is perfectly comparable with the American NADS.

Nowadays, another important DS is found in UK, at the Transport Research Laboratories (TRL). Its simulator [9] offers a variety of validated test scenarios, and it works in studies about effects of drugs and energy drinks in conduction, motorway roadworks and speed management systems among others applications. Moreover, researchers at the University of Leeds have developed a static base driving simulator for using in the research of transport safety, telematics and driver behaviour [10]. Another interesting branch is related to Figure 4: the Truck Driver Training Simulator (TDTS) located in UK too [11] and depending on the Department of Transport. A dynamic truck cabin plus a wide display screen formed this simulator. At Politechnika Warszawaska (Poland) another truck DS (this time with a static cabin) is installed too [12].



Figure 4: Truck Driver Training Simulator

Finally, there are many other interesting projects in Europe about DS, such as: project EVA at Labor Fahrzeug-Simulation (Germany) [13], the FTM (Lehrstuhl für Fahrzeugtechnik München) driving simulator (Germany) [14], and SIM2 at INRETS (Institut National De Recherche Sur Les Transports Et Leur Securite) (France) [15].

2.4.- Rest of the world simulators

Asiatic continent has some important centers which develop their own DS, as the simulator at Nakamura & Yamane Lab (University of Tokyo) [16] (which can be seen in Figure 5), and a more complete model of DS at the Vehicle Control Laboratory at Kookmin University [17].



Figure 5: A driving simulator at Nakamura & Yamane Lab (Japan) [16]

3.- DEVELOPMENT AT UPM

None of the systems introduced before provide a true feeling of immersivity in the scene. For improving this aspect, the Universidad Politécnica de Madrid is currently working on a basic model of DS which introduces a 3D virtual world using two channels of graphics (stereo vision) with a suitable gap between themselves, thus providing a video signal for each eye, and simulating the natural way of seeing. The main objective is to provide a natural perception of depth and distance to the driver, and to evaluate and assess the differences to other systems that use non-stereo 2D displays. The amount of work still to be done is huge, as the system is still in its initial status, with stereo system capabilities (described in detailed in the following paragraphs) and a rudimentary set of steering wheel and pedals. This set will be enhanced in the following future, with a piece of vehicle cabin controlled by electro motors able to move the cabin around three spatial directions.

It must be taken into account that the main objective of the UPM simulator is not to build the best simulator in the world, but to evaluate and assess the differences in perception and reaction of drivers depending on the level of immersivity. For such purpose, the realism of the environment is important. To achieve different level of immersivity, our system is able to display graphics both in 2D and 3D. For a better understanding of the display system, the following sections provide some detailed information of the two devices that have currently deployed and installed:

- A very basic projection method: a pair of stereoscopic 3D glasses (Figure 6), and

- A more complex environment, composed by two projectors, a wide screen, and a pair of polarized glasses (Figure 8(a)).

3.1 On the usage of 3D devices

Many critics have been done to systems that make use of glasses for simulators, claiming about the uncomfortability of the device for the driver, and the possible effects to his reactions. In our work, we have verified that people usually feels strange the first time that put on the glasses. But we have also checked that, after some few minutes, the driver gets used to the 3D perception of the environment, and the determination and estimation of distances and depth gets very much improved.

From our preliminary tests, we have concluded the following points:

- The adaptation set-up time varies from person to person, ranging from just a few seconds to two or three minutes.
- The maximum peak of stimulus seems to be reached after four or five minutes, when the human visual system is completely adapted to the new environment (both eye focus and brain visual neuron net). In this situation the driver can make use of the system for some time, until some visual fatigue appears.
- The human visual systems seems to have some difficulties to continue working in the 3D environment after 15 to 20 minutes. The effect is similar to the difficulties that some people experiment in 2D display DS, where some lost of stability is detected, and feeling of light sickness arises.

All the previous conclusions clearly confirm the actual possibility to research the differences in reactions and behaviour of drivers in simulators with 2D and 3D displays, and we expect to provide more detailed and practical information in the following months, once our simulator is more complete.

The following sections present our 3D systems.

3.2.- Basic stereo system

The first system we are currently using is formed by a special hardware which is plugged into the output of the graphics card adapter of a personal computer (Figure 6 and Figure 7(a)). The outputs of this device are plugged into a monitor and a pair of stereoscopic 3D glasses. These glasses are synchronized with the stereo channels, providing the desired 3D effect. Moreover, a steering wheel plus an accelerator and a brake pedal are added to the system.

The main advantage of this architecture is that the cost requirements are very low and, which is better, a low cost development and mobile 3D platform is achieved. An example using this model can be seen in Figure 7(b).

Nevertheless, this simple hardware does not supply a real stereo vision. The operation of this device consists of dividing the video of the graphics card adapter into two equal signals separate a fixed distance (disparity), simulating the vision of each eye. However, this is not a reliable sensation because that disparity depends on the depth of the observed object, and the hardware is not able to extract this information from the computer.



Figure 6: 3D glasses



(a)



(b)

Figure 7: Simple system with 3D glasses (a) and an example of using (b)

3.2.- Stereo projection system



Figure 8: Stereo projection system (a) and their output monitors (b)

The stereo sensation can be greatly improved if a better projection system is used. The more expensive this system is, the better 3D sensation is obtained. This way, we are working with two video projectors (Figure 8(a)) which display two different signals in a wide screen (Figure 9). In the control computer, these signals can be observed separately (Figure 8(b)). This display method is able to supply a real stereo vision, because its hardware analyzes the depth information of the virtual world and the separation between the two video signals (the disparity) is appropriate.



Figure 9: Driving simulator scene

Using these projectors with the steering wheel and a pair of appropriated polarized glasses a very immersive scene is obtained (Figure 9), where user can interact with the driving simulator and it is involved inside the virtual world.

4.- CONCLUSIONS

Most of the better DS in the world make use of 2D display systems that do not allow the driver to obtain the actual information of depth and distances to other object in the scene. Obviously, this limitation must have some implications in the reactions and behaviour of the driver, and these facts have not commonly been taken into account in the different reports about driver behavior obtained from DS and published in the literature.

At UPM, we are currently developing a system able to provide actual 3D perception of the environment. The preliminary tests confirm the actual possibility to research the differences in reactions and behaviour of drivers in simulators with 2D and 3D displays, and we expect to provide more detailed and practical information in the following months, once our simulator is more complete

The inclusion of the special hardware plus the 3D stereo world offer a high level of interaction and a very immersive atmosphere, more similar to reality than the rest of simulators. Moreover, in the future, real video using stereo cameras could be inserted in this architecture, offering the possibility to make use of the so called augmented reality, which includes real video and synthetic graphics to provide interaction.

5.- REFERENCES AND LINKS

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