An Instructional Aid System for Driving Schools Based on Visual Simulation

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Abstract

The recent development of lower cost 3D graphics systems has led to a rising interest in the use of visual simulation techniques for driver education, training and evaluation. So far, the most common approach has been to develop an active driving environment, in which the student, trainee or tested subject is able to drive him/herself through a set of driving situations. These 'driving simulators' may be useful to introduce or check practical driving skills. However, they have some limitations, especially when they are seen from the point of view of small driving schools and other possible applications like traffic education in primary or secondary schools. The major problem with driving simulators is related to their cost, still too high for most schools. A second question that still needs some answers refers to the validity and utility of the knowledge acquired by using these simulators and its relation to the skills required in a real driving task.

A different approach to the use of visual simulation in driving education contexts, that does not exclude the former one, is described in this paper. SIVAS ('system for driver education based on visual simulation') is a set of computer programs that allow the designers to create the three-dimensional scenery and dynamics of typical driving situations, and the driving school teacher to use these situations as a flexible, interactive and powerful tool for teaching. The system extends the features of existing audiovisual teaching materials such as videotapes, slides and multimedia programs. The teacher's program uses inexpensive equipment; a personal computer and a television screen.

Introduction

Driving simulation is a growing field and its applications are now spread in the areas of vehicle design and road infrastructure testing and research in road safety (see a discussion in (Aaronson, 1994), but also in learning and training domains, especially regarding military vehicles and heavy trucks (Boidin, 1997). The large number of traffic accidents in many European countries and the social concern existing about this fact and, in general, about road safety matters, lead us to think about the possibility of using driving simulators as a system to improve the learning and testing processes of professional and non-professional drivers

In some countries, this idea has been taken seriously, resulting in a small number of driving simulation products, in which the beginner can drive a simulated vehicle by him/herself, acquiring skills that may include basic steering, maneuvering, and tactical and operational driving (Kergall, 1994). However, the introduction of an interactive driving simulation application in driving schools conveys a series of problems, from the need of changing legal regulations to the validity of the motor and cognitive skills that have been acquired.

The University of Valencia has been developing in recent years several types of driving simulation applications (Bayarri 1996a,b), and the inadequacy of conventional driving simulation to be used in driving schools has been detected and discussed with teachers and associations in this area. That was the reason why the authors focused in the development of a new application model for interactive driving simulation oriented to be used in instructional contexts related to road safety and specifically in driving schools. The tool that has been development is not a driving simulator in the usual sense, but could be better described as an interactive simulator of driving situations that the teacher can use as a flexible educational material to expose and develop the instructional contents.

System architecture

The basic idea of the SIVAS system (SIVAS stands for *SIstema de formación Vial Asistido por Simulación*) is to design and use in an interactive context a set of short animation sequences which present educational contents related to the driving task and road safety. The driving school teacher uses a computer program able to show these animations in a very easy to use and friendly environment. The program functionality is devised to complement, or even substitute, conventional teaching materials like overheads, slides, videotapes and interactive CDs.

The whole system can be seen as a set of three independent programs (see figure 1). The first program, the scene designer, is a 3D graphics modeling tool including special functions for road generation. The files created by this program are loaded by a second tool, the driving 'situation' designer, in which the behavior of any number of vehicles participating in the situation can be specified as trajectories. A set of situations can be combined in a 'lesson' file. The lesson files are used by the teacher in the SIVAS player to present the driving situations to the students with different levels of interaction.

If desired, each situation can be seen in the player in the same way that a static video recording. But the novelty of SIVAS with respect to previous systems is that the animation images are not pre-recorded, but generated in real time, so that the teacher can also move to any time in the sequence very quickly, change the point of view to any of the participating vehicles and show in optional auxiliary windows additional views from any vehicle in any direction, including the rear view mirrors.

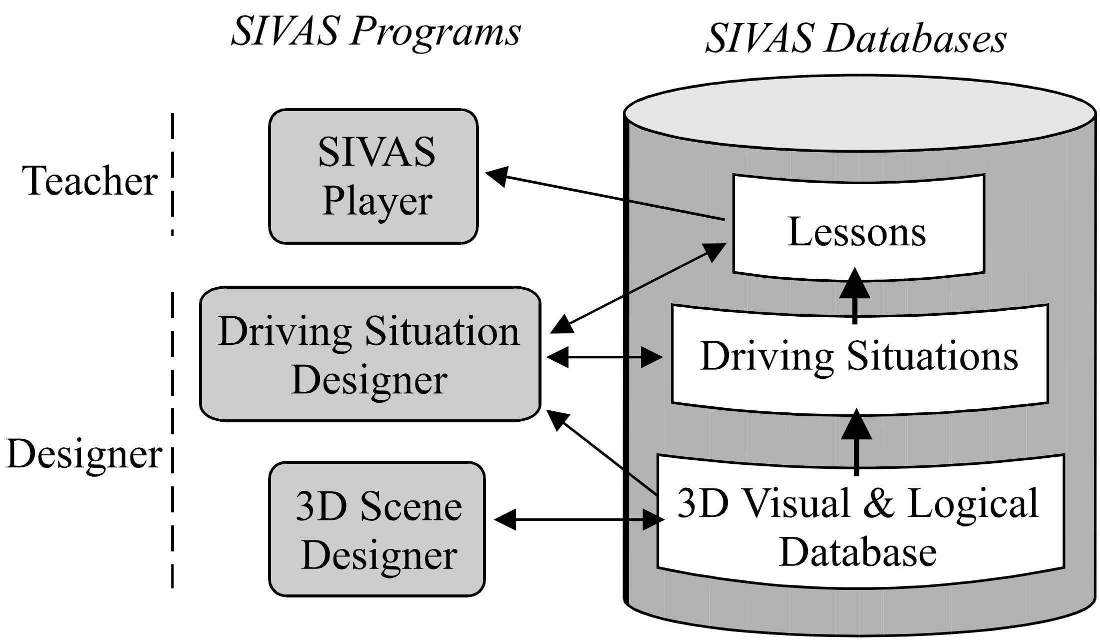

Figure 1: Architecture of the SIVAS system

The 3D Scene Designer

The generation of a 3D scene is necessary to provide input data to the real-time 3D graphics system of any simulation application, but also other types of data required to simulate the dynamic elements of the scenario, like vehicles or traffic lights, which require additional information like accurate surface description and road network topology (which part is connected to which other), forming what has been called 'correlated data structures' (Evans 1994).

The cost of generating such a complex database is too high if the designer uses conventional 3D modeling packages (that in any case, would only provide a part of the required description). A very few commercial tools, like Multigen's one, offer a road design module, but their limitations are strong, and most simulator researchers [9] and providers [8] have developed their own tools. One of such tools was created by the authors including automatic generation of buildings, terrain and other decoration elements jointly with the road visual and topological information in a correlated database [6].

The data structure that is used in the 3D Scene Designer is based on the combination of logical nodes, representing the intersections and road segments, and visual nodes that contain the data required for real-time visualization of the scene objects. Spatial relations among the logical elements are also represented in this data structure, so that it combines the hierarchical functionality (grouping, level of detail selection) required by standard visualization libraries like IRIS Performer and the additional information levels needed to generate a correlated database for driving simulation (see figure 2).

The basic layout of the road network is created and edited by means of control points but, as the road generation module is inserted in a general-purpose 3D tool, we are also able to edit detailed polygon, material or texture properties, so that further details can be added and objects not directly supported by the road function can be integrated in the scene. An intermediate stage in the design of a complex environment can be seen in figure 3.

The 3D road designer provides functions to keep the geometric constraints affecting the road segments and intersections, so that when a control point is moved, not only the directly controlled object is modified, but also others involved in that change. In this way the user of the tool is not required to keep by hand the consistency of the different elements.

The polygons that will, in the end, be used to visualize the scene, are generated by using sampling criteria (for instance, based on the road curvature), and a proper level of detail selection structure based on distance ranges is created.

The Driving Situation Designer

This software module reads the 3D scene description generated by the 3D Designer and is used to create a description of the dynamics of a driving situation that is considered to have educational interest. Each situation or animation sequence will usually involve some vehicles that move and perform other changes (e.g. in their lights).

The technical approach followed to describe this vehicle behavior is based on the generation of trajectories, and the association of any change in the vehicles to these trajectories. It is clear that in this way the entire situation is completely predefined, and conventional interactive driving is not possible, since the behavior of all vehicles is fixed once their trajectories are defined. This restriction does not diminish the utility of the SIVAS system, since it is not intended to provide an interactive driving environment, but an interactive interface to explore a predefined 3D animation.

In this sense, the situation designer can be seen as an specific computer animation tool (Snibbe, 1995). The conventional animation tools use parametric curves (Splines, Bezier curves or NURBS) to describe the motion of the objects. These curves have the advantage of been controllable by means of a few points. But the drawback of this kind of parametric curves is that do not allow an analytic computation of the relation between the arc length (the distance on the curve) and the time (Guenter, 1994), making difficult to perform the simulation of the object movement.

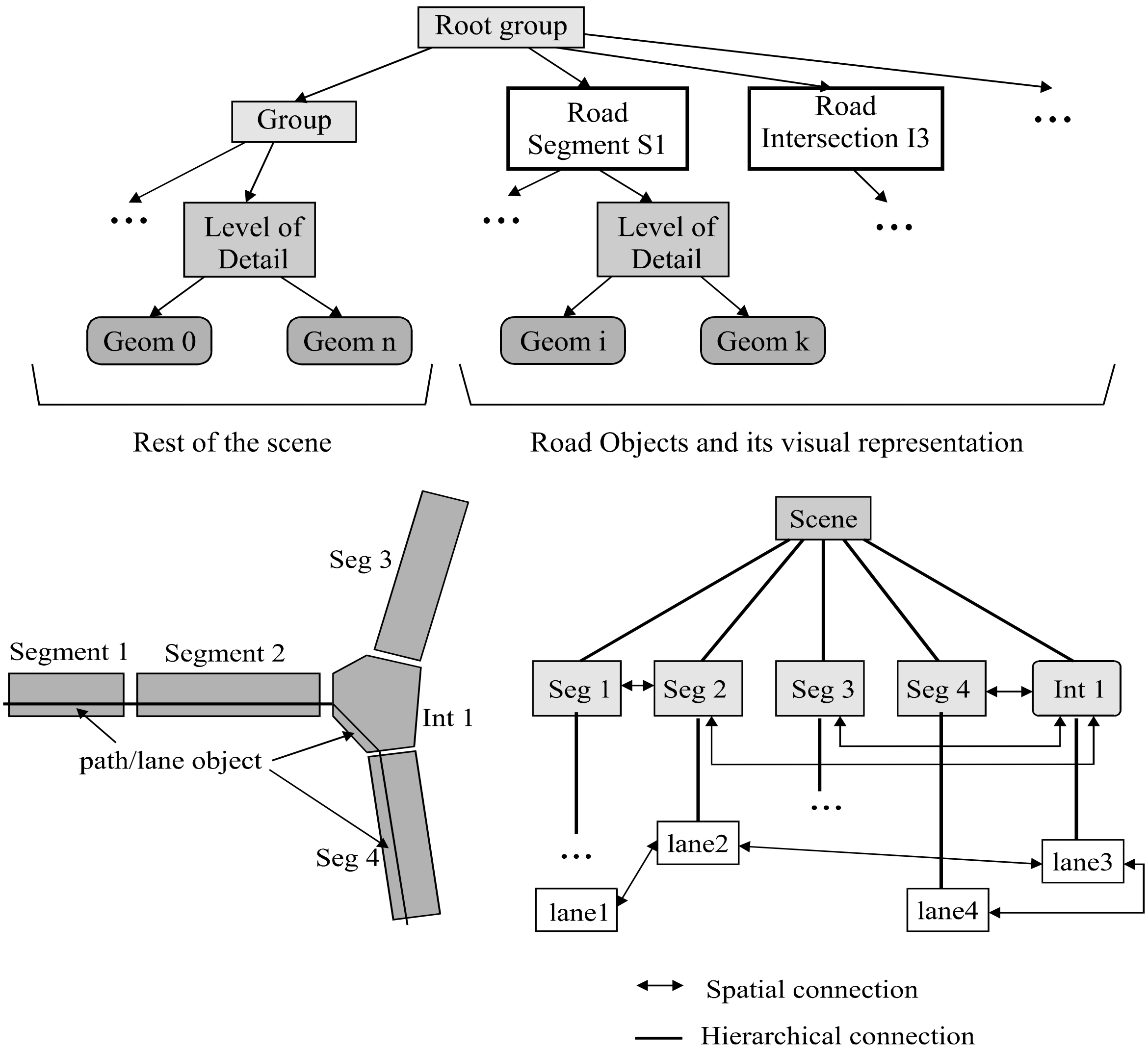

Figure 2: Data structures in the 3D Scene Designer

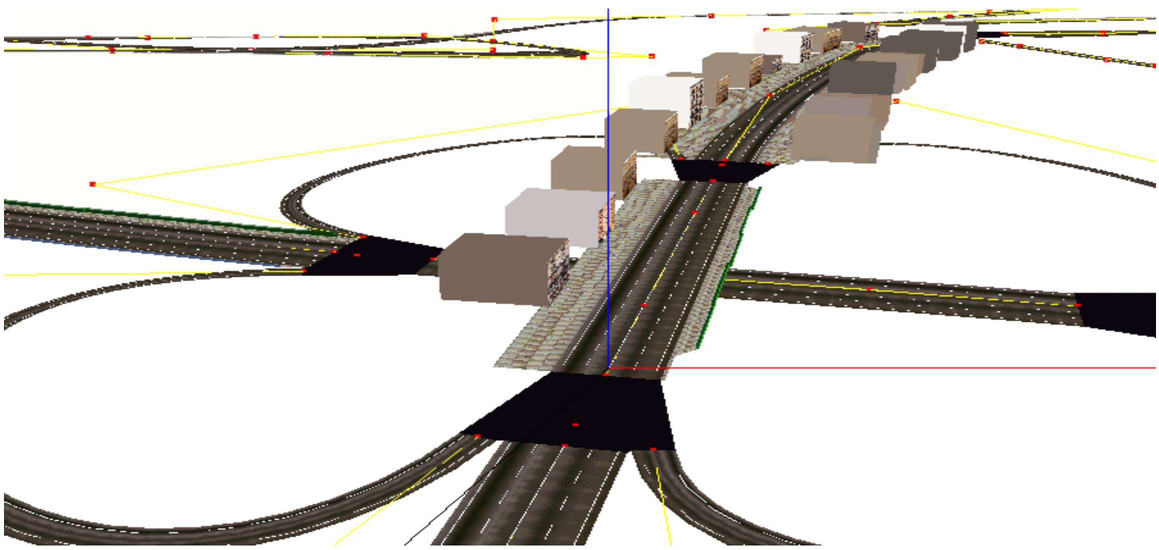

Figure 3: Intermediate result in the process of generating a complex 3D road database

Due to this limitation, a piecewise linear structure was chosen for the trajectories, allowing a simple and efficient position, orientation and speed interpolation in real-time. To define initially the trajectories the user of the tool only has to pick a sequence of points on the road surface. The tool then assigns speed values along the path using two different strategies: to make the speed proportional to the separation between points, or simply to keep it constant.

After this initial definition, trajectories can be modified by using two mechanism. On one hand, the points of the trajectory can be moved by clicking and dragging on the 3D window, and new points can be added to refine the definition. On the other hand, it is possible to open a second window in which the trajectories are represented in a time diagram (see figure 4). Moving the points in the time diagram allows a direct control on the speed of the vehicles at each point.

The segments that compose the animation sequence of each vehicle can be also used to specify the state of its lights and other dynamic variables. An animation preview function allows to visualize the situation to check whether it appears as it is intended to or not (see figure 5).

An independent module of the situation designer is in charge of grouping together a number of animation sequences that will be together in a lesson file, being this file the one that the teacher will load and manage with the player program. Of course, the distribution of situations into lessons must be done following instructional criteria.

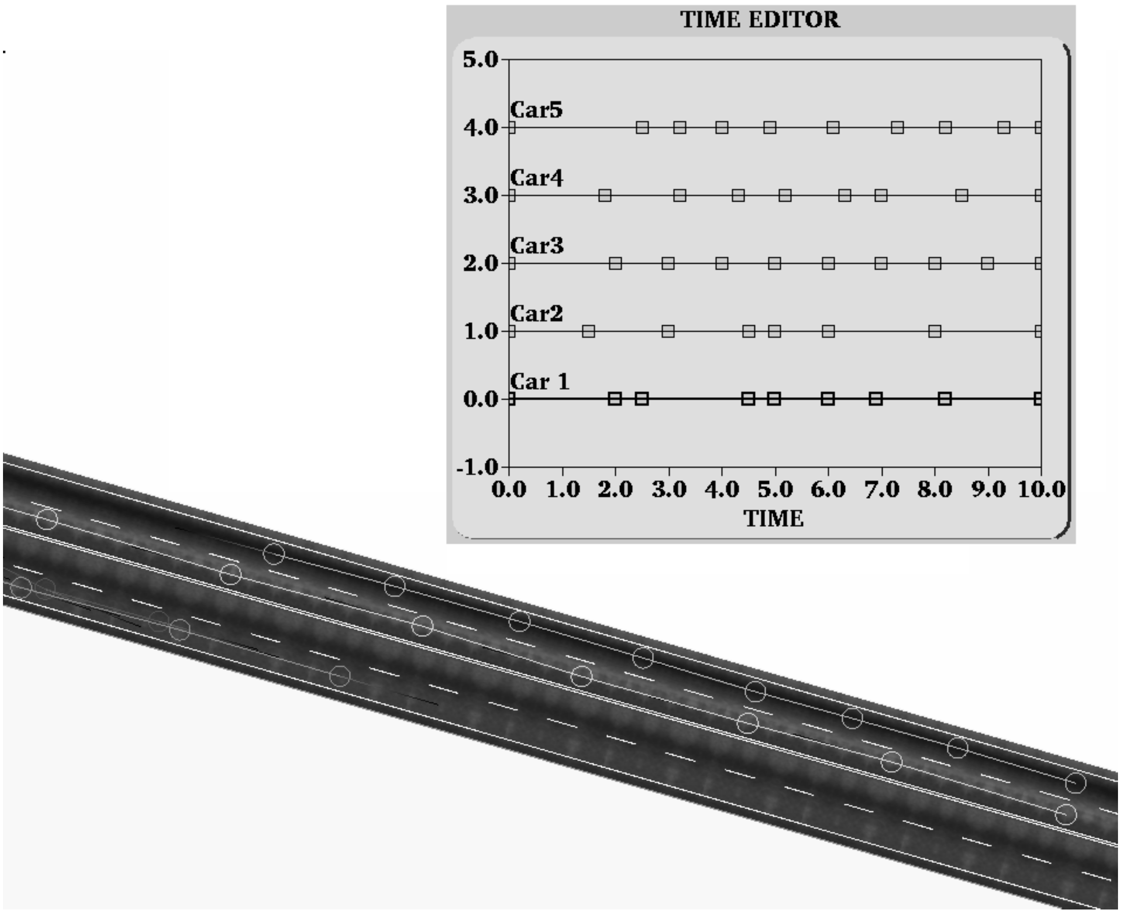

Figure 4: A top view of a road segment with the points defining different vehicle trajectories and, superimposed, the time control window of those trajectories

Figure 5: Animation previews in texture mode

The SIVAS Player

The player program access lesson files and follows the references to visual data and situation (vehicle trajectories) files to load all the data structures required to perform the simulation of the animation sequences.

The concepts of the SIVAS system, and specifically of the player user interface, have been developed after studying the educational methods of driving school teachers and discussed with providers of educational material and driver schools associations. One of the key guidelines found was to simplify as much as possible the interaction and distribute it in several levels, so that teacher that have little or no experience with computers can start using the tool very easily, and after go into the detailed control options.

That is also the reason why the flexible 3D navigation that a real-time graphics system is able to generate was reduced to a set of predefined viewpoints and viewing directions. In the first interaction level, the teacher has some options that allow to play the animation in the same way that a video sequence. In the lesson file, preferences about the default location of the viewpoint and the viewing direction would have been set. In a second level, the teacher can use a slider or scroll bar to go quickly through the animation (forward or backward) to an especially interesting point. This allows the professional to focus on relevant parts of the situation more easily than by using standard or digital video.

In a third level of interaction, the teacher can change, with the help of a configuration window, the default viewing point and direction, so that the animation can be seen from other vehicle or angle, or from a bird's eye view. It is possible also to combine (see figure 6) a main view with two auxiliary smaller views from different points. This option has been found very important to make emphasis in critical moments of those situations where more than one vehicle plays an active role or where it is required to compare the view of the driver and a more 'objective' view of the scene, like the one from the top.

The basic controls are grouped in a control bar, with a set of buttons that are quite similar to the ones found in video or music players, plus the time slider. The conventional mouse is replaced by a floating long-wire or wireless mouse that allows the teacher to stand in the classroom some meters away from the computer while explaining the driving situations.

Figure 6: View of the player window in the PC no-texture version. The control bar is seen below; a main view (bird's eye) and the right auxiliary window with a from view from the white car are shown

Application and conclusions

A prototype set of situations for testing the system in real driving school context was developed. The issue of passing maneuvers was chosen, since it involves several vehicles moving, different types of scene and emphasis in view points and directions. The player program with these situations was tested by a set of driving school teachers and the use they made of the system was recorded in video to perform further analysis.

It was found that the system could be used, even by people with no previous experience with computers, windows interfaces and the like. The methodology of usage varied significantly among the users, each one adapting to his/her own style the tool options. The system proved its flexibility and the possibility of easy integration in the educational environment.

From the technical point of view, a PC version of the player was developed as an inexpensive option. 3D graphics quality and performance depends on the PC model and additional graphics accelerators. A video output board provides the connection to a video player and TV installation that is common in driving schools.

The focus of the work is now in the tuning of the system from the comments provided by the teachers, the development of a full set of lessons and the integration with other types of material (texts, digital video).

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About the Authors

The authors are members of the Institute of Traffic and Road Safety, a multidisciplinary research Institute including computer engineers, traffic psychologist and medicine especialists; and of the Institute of Robotics, that includes a real-time graphics team. All of them complement this research position with teaching positions at the University of Valencia. Both institutes have been collaborating several years in the development and application of driving simulation techniques.