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Automatic Road Networks Generation Dedicated to Night-Time Driving Simulation

S. Espié
Institut National de REcherche sur les Transports et leur Sécurité
2, Av. du Gal Malleret-Joinville, 94114 ARCUEIL Cedex, France
Phone: +33 1 47 40 70 23 Fax: +33 1 45 47 56 06
Email: espie@inrets.fr

E. Follin, G. Gallée, D. Ganieux, J-M. Hespert
OKTAL, 55, Rue Thiers, 92100 BOULOGNE, France
Phone: +33 4 42 37 18 88 Fax: +33 4 42 24 23 72
Email: jean-michel.hespert@oktal.fr

ABSTRACT

Nowadays, driving simulation is used for more and more complex studies, mostly linked with safety and comfort. Absence of risk, reproducibility of situations and strict control over experimental parameters: these advantages make the use of a simulator crucial to study driving in night-time conditions. The development of adaptive front-lighting system is a field where driving simulators have been lately used.

Since the preparation of experimentation requires to iteratively improve the database according to the expected scenario, the process of generating road networks database has to be as easy as possible, with the constraint that the result matches the required photometric and perceptive quality.

To suit night-time simulation, 3D databases must meet some strict requirements: database must be finely tessellated, all polygons must have a similar size once projected on screen, and, in order to get a satisfying refresh rate, the number of computed polygons per image must stay acceptable. Moreover, texture used in such a database must be properly set to match the particular night-time conditions.

In order to satisfy all the constraints, INRETS and OKTAL have set up processes to easily generate or regenerate 3D database even when modifying parameters such as: road description, transverse profiles, longitudinal profiles and crossroads. At the core of this process are algorithms based upon transverses profiles application, automatic texture application and automatic levels of detail generation and usage. These developments concern projects aiming to improve the use of innovative lighting technologies, as well as those studying, for example, the visibility of pedestrians in night conditions.

INTRODUCTION

Driving simulators are for conducting Studies related to human factors is nowadays of current use. The tool allows studying without risks situations which can sometimes be complex. Reproducibility of the situations and strict control over experimental parameters make driving simulators irreplaceable.

Unfortunately various technological limitations restrict the situations where the tool can be scientifically used: e.g., focusing only on visual restitution, display devices and images rendering.

Regarding display devices, limitations concern at least resolution, luminance and contrast. Despite some technological improvements (e.g. DLP projectors), progresses are slow and current state is far from satisfying. The developments of HDTV push the market, but even for this application the request are far from our specific quality requirements.

Concerning images rendering, limitations concern mostly the calculation in "real-time" of traffic situations in specific meteorological conditions. The physical fidelity of the proposed images is of high importance as far as the conducted experiments are related to perception mechanisms (which is tightly coupled to both safety and comfort aspects of driving). Fortunately, pushed by the SOHO game market, serious technological improvements are under progress in the field of graphic engines.

Night-time driving is a risky situation any there is a need in research for a better understanding of the perception mechanism and to propose driver support systems like augmented reality devices or adaptive front-lighting systems.

French National Institute for Transport and Safety Research (INRETS) and OKTAL company have been collaborating for many years for simplifying the production of the various databases needed for running experiments using simulators and for allowing "real time" rendering of traffic situations in various meteorological conditions (7, 2, 3). Évariste réseau (Evariste Network) software is the result of this collaboration.

In this paper we will describe our latest developments related to generation and regeneration of databases for driving simulation. We will particularly focus on the creation of 3D-road network database suited for night-time experiments.

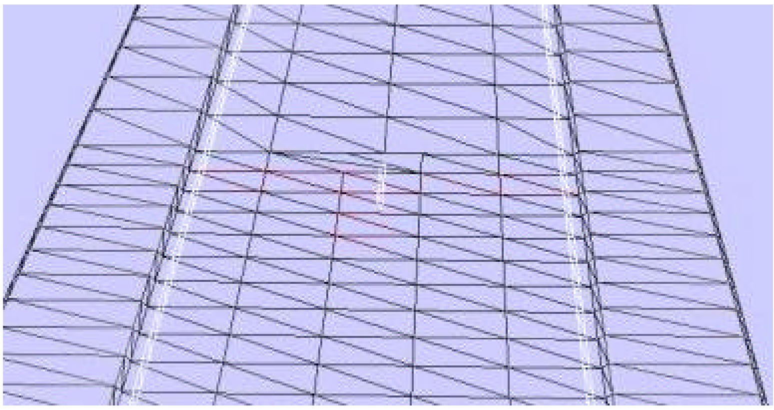
NIGHT-TIME RENDERING

For night-time situations, illumination is only provided by many artificial light sources, with a main contribution from the headlights of the simulated vehicle. It means that the illumination of the environment must be computed interactively, using a lighting module which can take into account the photometric properties of the headlights (12).

A driving simulator equipped with night-time rendering can be used for headlight studies. Thus, a projector can be assessed even before having a physical prototype (4, 5, 9, 10, 11, 13). It can also be used for human factors studies, e.g. for studies related to perception (visibility of pedestrians in night conditions) or to perception mechanism (visibility distances, speed perception).

The nigth-time rendering algorithm, developed by OKTAL, is based upon a multipass rendering method using Open GL and Open GL Performer libraries. It works both on IRIX and Linux Operating Systems, but the rendering is nowadays more accurate on a SGI Onyx machine. It can be combined with the special effects library (fog, blooming and glaring effects of adverse traffic, ...) designed within the French PREDIT VOIR (Optimized Visualisation of Road & rail Infrastructure) project (6, 8).

Due to the use of portable rendering librairies, and in order to achieve good quality results, some constraints must be applied on the visual database (12). The lighting pass must be performed using a conveniently defined road sampling level-of detail. In fact, since lighting calculations are done at each vertex in the database, the results depend on the database sampling. On the one hand, the use of a low sampling gives good image frequency but bad accuracy. On the other hand, the use of high sampling implies a large collection of polygons, which result in slowing down image frequency. A compromise solution relies upon the definition of level of details (LOD) on the road. Levels of detail provide more or less precise polygon description of the road, as illustrated in figure 1.



2nd LOD: triangles are wider and larger.

1st LOD: triangles are small enough for a good lighting simulation.

Figure 1: road with various LOD

DATABASES CREATION

In order to use a driving simulator, we need to define a relevant synthetic environment which consists in (at least):

1. A logical representation of the roads for the traffic simulation,
2. A physical representation of the roads for the dynamics model and, possibly, additional modules (sound…),
3. A 3D database for the visual module.

These data must be correlated in order to simulate a "consistent world" (cf. Figure 2).

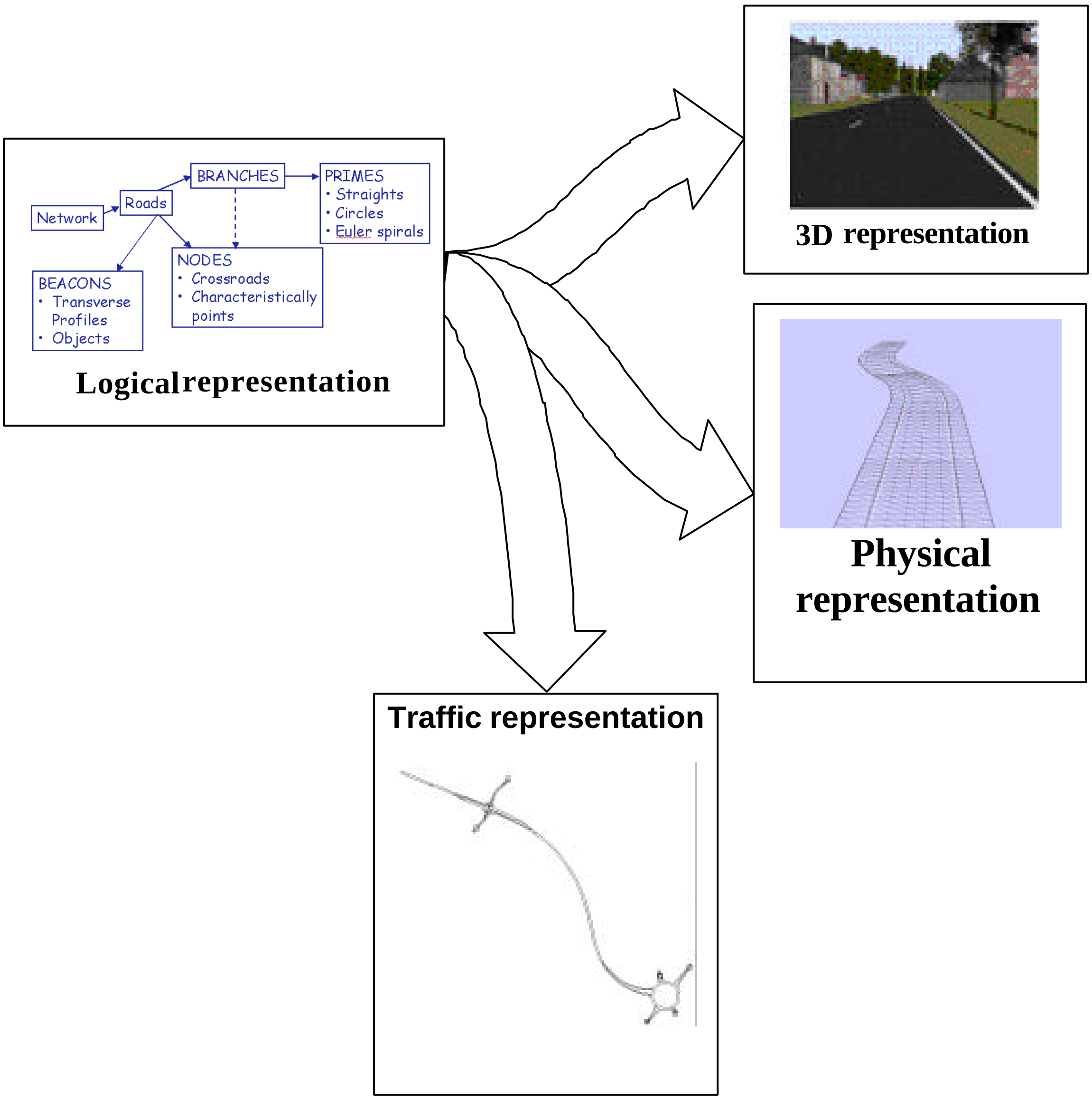


Figure 2: databases creation process

In the case of night simulation, and in order to let the OpenGL lighting algorithm compute the lighting on the roads with optimal results, a particular emphasis must be put on the 3D database construction. The database must be created with various levels of details and meet geometric constraints.

Each level of detail represents the same part of the road network; the use of the representation will depend on the distance between the car and the 3D object: the object from the most precise database is used for the first level of details. Lighting data must be set on the edges of the database to let the Open GL lighting algorithm compute the lighting on the roads.

The use of levels of details implies that each level must have strictly the same visual aspect in terms of texturing and lighting. As a matter of fact, the creation of a database dedicated to night-driving simulation involves a lot of work and control and is difficult to be achieved "by hand" with traditional tools.

An experimentation involves a lot of actors: experimentation customers (psychologists, road designers…), automotive simulator experts, computer graphic designers etc.. In the preparation of an experimentation, the specifications of the road network used for the experiment are modified, nearly at each meeting, to suit the customers' requests, simulator needs and database creation limitations. Thus, database modifications are very often needed, and the work required to improve the various databases and to ensure their coherency can be huge.

CONSTRAINTS FOR HEADLIGHT SIMULATION 3D DATABASES

Geometrical Constraints

The main constraints on 3D database are due to the rendering solution used for headlight simulation. The method is based upon multi-pass rendering and OpenGL lighting which is computed on vertices. Thus, to suit headlights simulation, and in order to obtain a good quality of rendering, 3D databases must meet some geometrical requirements:

1. Polygons must be small near the headlights: The lighting calculations are made using the vertices of the meshes of the 3D scene which implies to build narrow meshes near the lighting zone to get a realistic rendering. The nearer the light sources to the area, the narrower the meshes. Indeed, Real Time 3D representation is based upon computation of lighting on polygons vertices and interpolation inside triangles. This may lead to an unrealistic and too rough approximation if polygons are too big. This principle is particularly true when polygons are near the headlights or in lighting edge zones (cf. Figure 3).
2. All lighted polygons must have a similar size once projected on the screen: To ensure a continuous lighting interpolation, the size of every lighted polygon, whatever their distance from the headlights, must be computed to make them have a strongly similar size once projected on the screen.
3. To get a satisfying refresh rate, the number of computed polygons per image must be lower in night conditions than in day conditions: the multipass algorithm implies to compute at least as many scene rendering as the number of lighted headlights. That is why the rendering refresh rate for the same number of polygons and on the same computer is much better in day conditions than in night conditions.

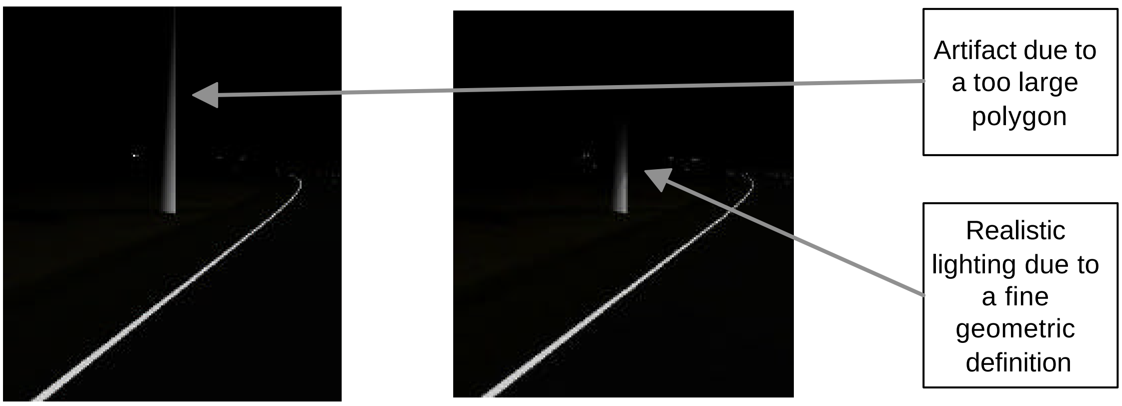


Figure 3: Triangle definition versus artefacts on lighting simulation (left: large polygons, right small polygons)

These first two constraints seem to contradict the third one. Therefore, a compromise must be found:

1. Use levels of details on the road in order to correlate the polygons density with the observer distance (assuming that the observer is close to the headlights) (cf. Figure 1).
2. Use the same level of details for the scenery objects.
3. Choose a maximum visibility distance between 500m and 1000m, depending on the road characteristics (more or less winding).

Materials constraints

Moreover, the database must fulfill materials specification:

1. Materials in use must have their specular and diffuse properties properly set to match the particular conditions of night-driving lighting and observation.
2. Lighting conditions of the pictures used as textures must match the particular conditions of night-driving lighting or be wiped off.

To meet these requirements, one may consider that the observer (i.e. the driver) position is close and constant relatively to the headlights

AUTOMATIC GENERATION PROCESS USING TRANSVERSE PROFILES

We have chosen to deal with geometric constraints by using different definitions of the same transverse profiles. Each definition corresponds to a specific level of detail. The automatic generation process will automatically use these definitions to produce the tessellation of the various levels of details. The given example shows a banked road; the pavement is 6 m wide. (cf figures 4 & 5).

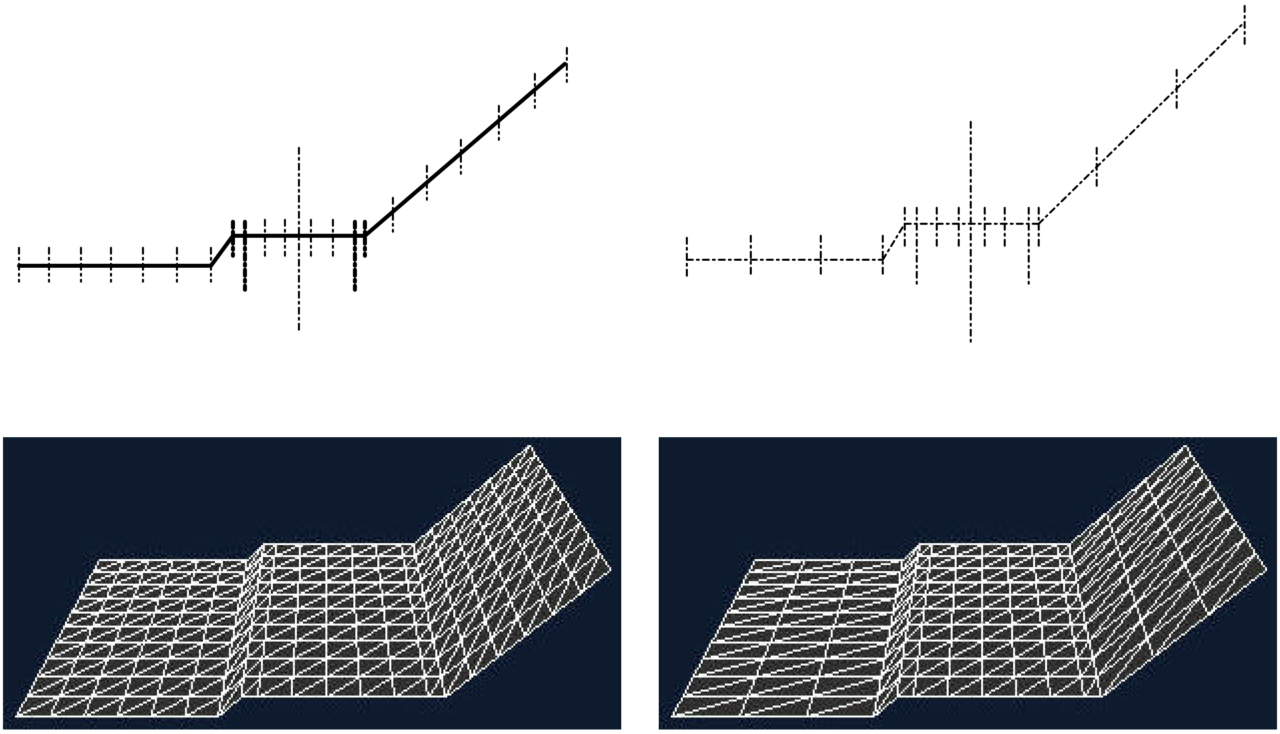


Figure 4: Transverse profile finest level (left: meshing 1 m) and fine level (right: meshing 1m + 2 m)

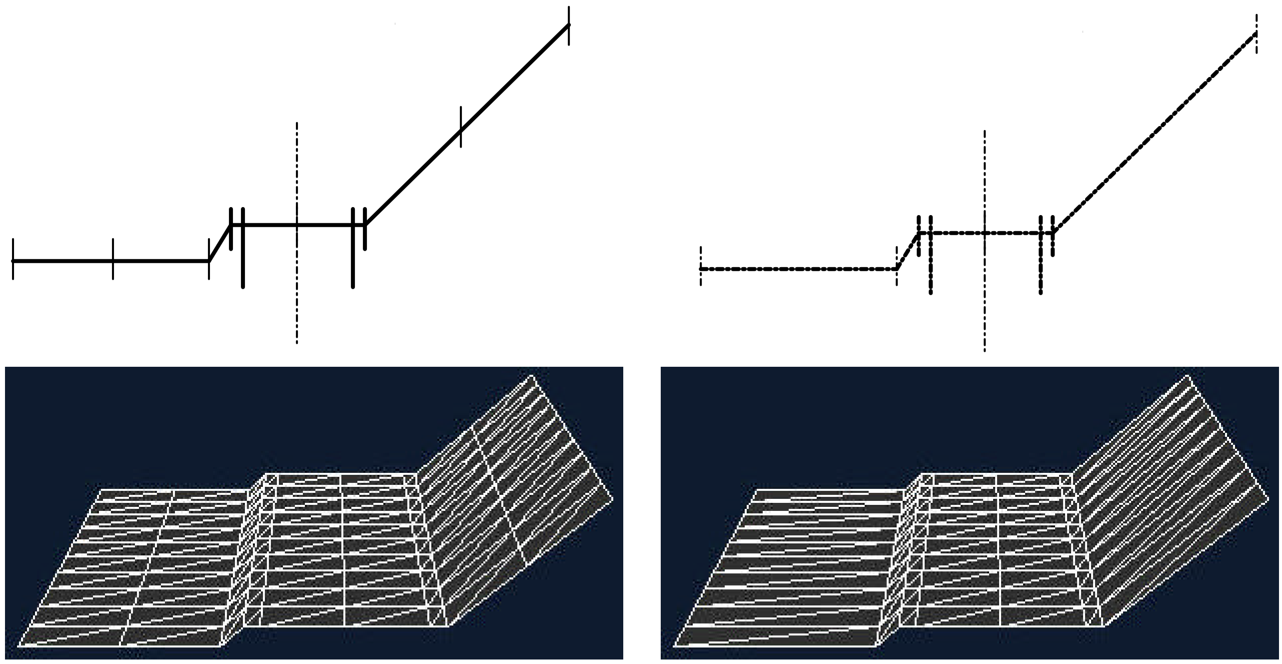


Figure 5: Transverse profile medium level (left: meshing 2.5 m + 3 m) and rough level (right: meshing 2.5 m + 6 m)

UTILITY OF AN AUTOMATIC GENERATION PROCESS

Finally, the creation of a synthetic environment for driving simulation is complex and can be very expensive. Moreover, the complexity of a night simulation 3D database increases the price and the delay. This reduces drastically the ability to build night-time driving experiments.

Facing the complexity of the data creation and the need of correlation between the different databases, we decided to develop a software solution to generate all the databases from a logical and topological description of the road network.

Our goal was to build a tool and specify a procedure to reduce manual work and time for the creation the databases. The EVARISTE tool allows various databases generation with a full respect of their coherency. It was designed to generate 3D databases using a simple description of the network. It consists in several modules which inter-operate. The various transverse profiles can be easily edited by using the EVARISTE transverse profile editor.

From a geometric description of the road network axes, a description of the transverse profiles and materials, and a description of the various elements which exist in the surrounding of the road network (road signs, trees, houses, ...), EVARISTE allows the user to construct automatically the various correlated databases.

A particular emphasis has been put on the 3D representations including automatic texture application and automatic cross-road calculation. One can reuse existing user-defined networks («tile» approach). Figure 6 & 7 show results for motorway and rural road. These images have been calculated within the E.U. CLARESCO project.

Figure 6: motorway night

Figure 7: rural road night

CONCLUSIONS

We have described the constraints of algorithms dedicated to automatic generation of night-time databases. The night-time rendering visual loop using these databases allows a high quality in terms of photometry. For various situations, provided that calibrated visual devices are used, and as far as geometrical and materials constraints are fulfilled, actual distances of visibility are rendered (1). However, limitations remain, particularly for high contrast situations.

In order to meet the requirements for rendering night-time situations, EVARISTE has been recently improved with a new module called "EVARISTE nuit / EVARISTE night vision" which is described in the current presentation. These algorithms allow an easy generation and regeneration of day-time and night-time correlated databases for car- or truck-driving simulator.

Since 1999, these tools have been used on driving simulator based upon SGI and, recently, on PC visual systems. Regarding the current results, SGI solution still provides the best rendering quality in terms of contrast and luminosity dynamics. Some limitations remain: frame rate performance and relative complexity of the generated databases.

Due to the latest improvements in PC graphic boards, it could be interesting to use the new shaders functionalities of these boards. These new functionalities will provide better performances in terms of frame rate with a small loose in photometry quality. Even with Open GL standard, we will lose the compatibility with the current graphics board and the current SGI Reality Engine. It is a new gap for visual rendering.

This kind of solution will be compatible with the day-time databases. Thus, we will be able to use the same databases in day-time and night-time. Since the day-time databases are lighter than the night-time ones, we will be able to drive in night time situations on wider road network.

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