Image quality for driving simulation experiments

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Abstract: *The databases which are currently used in driving simulators do not take lighting into account in a realistic way. First, the visualization of surfaces use photographic textures. These textures are modified by computer graphics designers in order to visually match with a specific lighting environment, without photometric or colorimetric control of any kind. For instance, a database build from daytime pictures will need contrast, brightness and color modifications for a night-time simulation with road lighting. Secondly, the textures are stored as pixel intensities, instead of physical units, which yelds display dependant rendering. Yet, color and contrast fidelity would make driving simulators useful for many new applications, specially for road safety, which involves visibility issues (driving through fog, for instance). This motivation led us to test if current lighting computation techniques could be used in real time applications. Realistic rendering of contrasts and colors is a fast evolving topic in the field of computer graphics. Physical modeling of light transport, using the radiosity method for instance, is a standard approach to get realistic rendering in synthetic images. Such computations would improve the realism of driving simulators. Unfortunately, the algorithms are far from compatible with real time. This is due to high computation times, but also to the geometric representation of the surfaces, which need to be meshed (like in finite element methods). It leads to amounts of polygons that cannot be handled by current rendering technologies. In this paper, we propose a methodology allowing the use of lighting calculation techniques as a pre-process of database rendering on driving simulators. Our goal is to allow contrasts and colors to quantitatively match real world values, so as to use driving simulation in visibility and lighting evaluation experiments, and to increase the use of driving simulation for road safety studies. The presented methodology was applied on a database of the Fourvieres tunnel (Lyon, France).*

The *Laboratoire Central des Ponts et Chaussées* (LCPC), together with OKTAL S.A., are working since 2000 to build virtual databases with photometric and colorimetric realism. Our purpose is to reproduce the visual environment of the real scenes in driving simulations, in order to ensure the representativity of the drivers behavior. Presently a methodology has been build, gathering tools and know-how concerning the production and visualization of virtual databases (OKTAL), lighting computation and visual perception (LCPC). It was tested on a database of the Fourvières tunnel, in Lyon (France) [1].

I. Visual realism in real-time simulations

1.1 Motivations

The LCPC develops computation and visualization tools that are used in road safety applications: road visiblity (in fog for instance), road lighting installation. Image synthesis is useful, for this purpose, if the observers face a visual stimulus which is close to what they would face while driving for real. This is an essential condition if one wants the observers behave the same way as they would behave on the road.

For real time visualization, the images of a virtual database need to be synthetized with a sufficient frequency (between 30 and 60 Hz). The main restrictions to the quality of real time databases is due to the hardware: image computation and image display (monitor, screen, helmet). These limits lead to minimize the scene geometry, to map textures, to use a very simple lighting model, etc. The simulated situations are limited to daytime, night and closed areas being difficult to render with a good accuracy.

The ever increasing computation speed and memory space now allow to apply some rendering techniques to real time virtual reality. In our case, a model simplification is necessary, together with a new design of standard algorithms. Our goal is to improve the rendering quality of virtual reality databases, in terms of lighting environment and visual perception, in order to allow night driving simulations with road lighting or in tunnels, and to increase the field of interactive visualization in railway or driving simulators, and for road and city projects.

Fig. 1 :Real-time database :
entering the Fourvières tunnel.

1.2 Virtual database and driving simulation

In order to reach frequencies used for real time display, one needs to use all the hardware capacities. Therefore, the Open GL library is commonly used [2], as well as Performer. But the lighting model available with Open GL is poor: direct lighting only, point or directional light sources, “ambiant” light, etc. The geometrical scene is made of many surfaces, which are mapped with material textures. These textures are designed by infographists, so that the final image is the result of an artistic and creative work.

If we want to control the visual properties of the displayed images, a lot of problems arise. Fidelity of the contrasts with respect to the actual scene, color fidelity, screen calibration, luminance dynamics, texture definition, etc. We focus in this paper on what we consider to be the main problem: the faithful restitution of contrast and color.

Physical modeling of light propagation is a standard solution in order to get realistic rendering in synthetic images. The LCPC uses a radiosity approach [3] in order to evaluate lighting installations in roads and urban areas [4]. The main idea is to divide the geometric scene in small parts, and to compute the relevant physical quantities for each of the patches: illuminance[1], luminance[2], chromaticity[3]. These computations allow to improve the image quality, on a calibrated screen. The realism of these images would strongly increase the credibility of a driving simulator, because luminances, colors and contrasts of these images are consistent with what would occur on the real scene. Unfortunately, this kind of computation cannot be performed in real time, first because of the computation time, but also because of the large amount of patches, which cannot be handled by the current state of the art in image display.

We propose a methodology which allows to includes realistic lighting computations in a real time database. The present paper shows the feasibility of the method, which was tested on a full database.

2. Method

2.1 Architecture

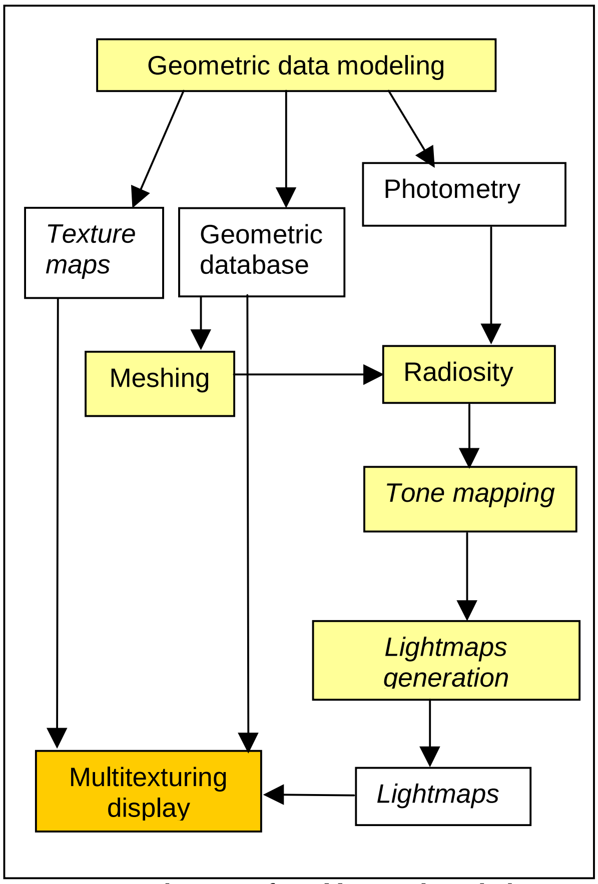

Fig. 2 : Architecture for adding realistic lighting computation to a real time database.

We consider the lighting computation as a pre-process. Then, in a second step, the result of the lighting computation is transformed in such a way that makes it usable by a standard real time display process. An integrated software has been build described on Fig. 2. Starting from the initial database, a meshing of the geometric database is performed in order to compute the radiative transfer with the help of photometric data, also added to the database. In the end, the meshing is replaced by lightmap textures. This leads to a new

[1] The illuminance is the amount of light lighting a given surface. It is given in lux.
[2] The luminance is the amount of light emited by a light source or by a surface, and reaching an observer. It is given in candela by square meters (cd/m^2).
[3] The chromaticity is a physical quantity which describes the color.

virtual database, with the same complexity as the initial one, but with a realistic characteristics.

2.2 Database preparation

In order to compute properly the light propagation, we transform the database in two ways. First, the surfaces of the database are completed with photometric information: the light reflection behavior of every surface, which depends on the light wavelength. The light propagation model needs also to specify the location of the light sources, and spectral and directional information, describing the quantity and quality of the light emitted by the sources. This is done with available information from a paper description of the lighting project, or from standard specifications issued by the *Association Française d'Eclairage* [5].

In a second step, each surface of the database is meshed in order to compute the illuminance received from the light sources, and then the reflections between patches. The size of the mesh depends on the visual importance of the surface, because the accuracy of the final result differs from one surface to another. For instance, it is more important to get a good accuracy on the road than on the ceiling of a tunnel.

2.3 Lighting computation

The light propagation computation is separated in two steps. The direct lighting step consists in computing the amount of light reaching every patch of the mesh, and coming from every light source[4]. The indirect lighting step consists in computing all the reflected light, from any patch to any other patch. This second step is especially necessary in closed areas like tunnels and city narrow streets, where some surfaces (the ceiling of a tunnel, for instance) receive no direct lighting, but can be seen by the drivers because of indirect lighting. This step is very time-consuming.

At the end of the computation, we obtain the photometric quantities that are relevant for the display of every patch: luminance and chromaticity, which lead to the color and luminance contrast information. The reason why we have to make all this computation in physical units is that the visual performances of observers is directly bound to the luminance contrast. Visibility experiments using these images may not lead to a representative behavior otherwise.

2.4 Display

[4] Not only the amount of light, but also its color distribution is taken into account.

For the visualization, we need to convert the computed physical data into RGB information. This step is device dependant; hence a display calibration is necessary in order to apply a correct transfer function.

Most display devices cannot manage to display the actual computed luminance, because of a technological limitation: it is easy to understand, for instance, that a usual PC monitor cannot dazzle the observer. There is no easy way to cope with this problem. The usual solution, called *tone mapping*, is to build a look-up table between the luminance we want to display and the luminance we actually display. The difficulty is to build this table without disturbing the visual performances. The best available solutions are based on psycho-visual data [6].

Lightmaps and texture maps

As it is not possible to display in real time the enormous amount of patches that are necessary for the computing steps, the result of this computation is stored into a *lightmap* texture, which replaces the initial texture designed by an infographist.

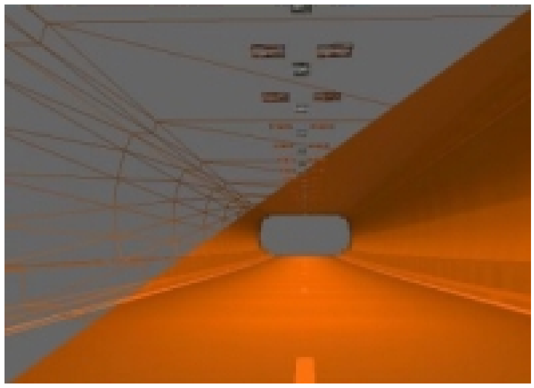

Fig. 3 : *Lightmaps of a tunnel section*

Fig. 4 : *Texture maps of a tunnel section*

For the computation, the surfaces optical properties are considered uniform. Thus, high spatial frequencies are not available in the lightmap textures. But they can be added with texture maps, properly normalized. This texture maps are build through a normalization of the

RGB components of the initial textures of the surfaces. The visualization of the database is finally achieved using both the *lightmaps* and the texture maps of every surface, with a multi-texturing technique.

3. Application: the Fourvières tunnel

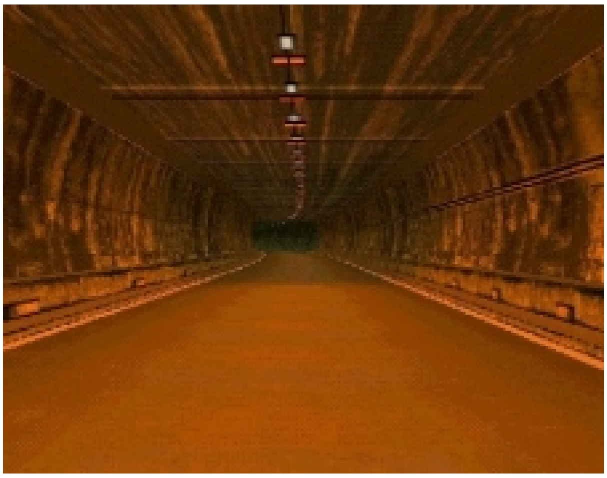

Fig. 5 : The Fourvières tunnel: entrance section

We have used an accurate geometric description of the Fourvières tunnel, together with a technical description of the actual lighting installation (provided by Philips Lighting). We have used the presented methodology to build a realistic database of the tunnel. It is 1800 meters long, with two lanes. According to road lighting regulations, the lighting decreases from the entrance area, reaches a low level in the main section, then increases until the end of the tunnel. Two kinds of light sources are used, fluorescent lamps all along, and sodium lamps in the starting and ending sections. The initial tunnel database was build by OKTAL for a real time display with 60 000 textured surfaces. The lighting computation used around 720 000 patches, and ended up into 8 megabytes of lightmaps. The monitor calibration was performed for a SGI GDM-4011P monitor at the LCPC.

Fig. 6 : The Fourvières tunnel: exit section

4. Conclusion

We have designed, implemented and tested a software which can be used to include photometric lighting computations into a virtual database designed for driving simulation. This tool must still face an industrialization process. We also want to improve some of the light propagation model properties (specularity, car lights [8], etc.) and select a proper *tone-mapping* algorithm [4].

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