Application of real-time lighting simulation for intelligent front-lighting studies

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RESUME

Des études ont été menées dans la cadre de la conduite de nuit [4,7]. Afin d'améliorer la conduite nocturne, le Département Eclairage de VALEO et RENAULT étudient et développent de nouveaux systèmes d'éclairage intelligents. Les éclairages frontaux ont ainsi été étudiés de manière à améliorer l'illumination de la route, plus particulièrement dans les virages, à travers deux stratégies de contrôle simulées. La première est basée sur les informations du véhicule telles que la vitesse et l'angle au volant. Elle permet d'ajuster l'orientation des faisceaux dans les situations de virage. La seconde approche utilise les données de navigation pour déterminer à l'avance la géométrie de la route. La direction des faisceaux est corrigée en conséquence et permet ainsi au conducteur de mieux apprécier les courbures de la route.

Les deux stratégies d'éclairage ont été intégrées dans un des simulateurs de conduite RENAULT spécialement dédié à la simulation d'éclairage [3]. Le simulateur comporte un environnement de conduite classique, un générateur d'images pour une restitution réaliste de l'éclairage des faisceaux sur la route et un générateur de son. Un ensemble de logiciels permettent de générer un trafic routier réaliste, de créer des scénarios et de visualiser en temps réel des données issues de la simulation.

Des développements logiciels spécifiques ont été réalisés pour intégrer dans le simulateur Renault les stratégies d'éclairages développées par Valeo. Les deux stratégies ont été comparées en temps réel sur le simulateur. Ce dernier a permis de réduire les coûts et les délais de développements nécessaires à la construction de prototypes. De nombreuses heures de mises au point sur véhicule réel et d'essais de nuit ont été ainsi évitées.

ABSTRACT

Road safety studies have been carried out in night time visibility conditions [4,7]. To help night time driving, VALEO Lighting Department and RENAULT are studying and developing new intelligent lighting systems. Lighting strategies for front lighting systems have been explored to better control the illumination of the road, especially in curves. Two different adaptive strategies have been realised : the first one consists in studying specific vehicle parameters like the car speed and the steering wheel angle to adjust front-lighting performance on curves. The second one, based on navigation data and the vehicle speed, determines easily the shape of the road in advance. Additional beam correction is then supplied to help drivers better negotiate the curves of the road.

Both strategies have been integrated in a Renault automobile driving simulator dedicated to real-time lighting simulation [3]. The driving simulator includes a driver cockpit, an image generator providing realistic restitution of headlight distribution, a sound generator, realistic traffic and user-friendly man-machine interfaces to define car and headlight data as well as test scenarii.
Specific software developments were carried out to perform the integration of adaptive front-lighting strategies in the simulator environment. A system that detects curves in the graphical database was created to simulate a navigation system. The comparison between strategies is then easily handled by switching from one to the other in real-time driving conditions.

The driving simulator allows to reduce significantly developments costs for building prototypes. It also enables to save hours of tuning and testing on physical vehicles at night. Therefore, the driving simulator appears as a cost- and time-saving tool for the development of new headlamp systems.

1. INTRODUCTION

Night-time driving with conventional headlamps is particularly unsafe : only 25% of the driving is done at night but 55% of the driving fatalities occur during this period [4,7]. In order to reduce these road traffic hazards, developments are carried out in *the Valeo Lighting Systems Branch* at the request of *the Renault Lighting Department* aiming at dynamically directing additional headlamps according to the behaviour vehicle, environmental and road conditions. The lighting simulator of *Renault Simulation and Virtual Reality Research Group* was then used to tune and test lighting control strategies. It enabled to reduce development costs and delays while enhancing the quality of the new front-lighting strategies.

2. VALEO'S ADAPTIVE LIGHTING CONTROL STRATEGIES

Car lighting today

For efficient lighting respecting road traffic safety, the headlamps must provide the best possible performances and avoid at the same time glares for the oncoming drivers.

Performance improvement has been achieved thanks to the source and the optical unit :
- Halogen bulbs provide 30% more light than previous generation.
- Clear lens complex shape allows the use of 80 % of the light that was previously wasted on shields and bezels.

Halogen Renault Scenic

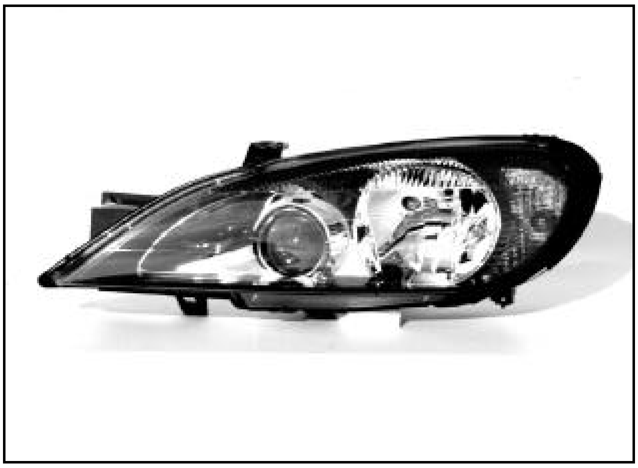
Since ten years, Xenon lighting has been pushing the performance into a new range : doubled flux and beam width, 30 % increased range, day-light colour rendering and 40% reduction of electrical consumption.

According to the European Xenon 1996 regulation, the vehicles must be equipped with headlamp cleaning devices and automatic levelling that modify the light beam in order to compensate situations where it could be glaring (heavy weights at the rear of the vehicle…). Latest generation of levelling are acting in real time and therefore may reduce the glares during accelerations.

The first Renault Xenon headlamp has been installed in the Safrane in early 1997.

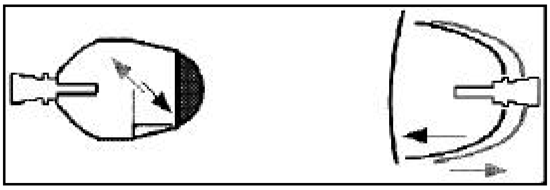
Halogen lighting

Xenon lighting



Xenon Nissan Primera

Bi-function systems allow the same performance for low beam and high beam with only one Xenon bulb, through a relative mechanical movement of the bulb to and from the optical surface.

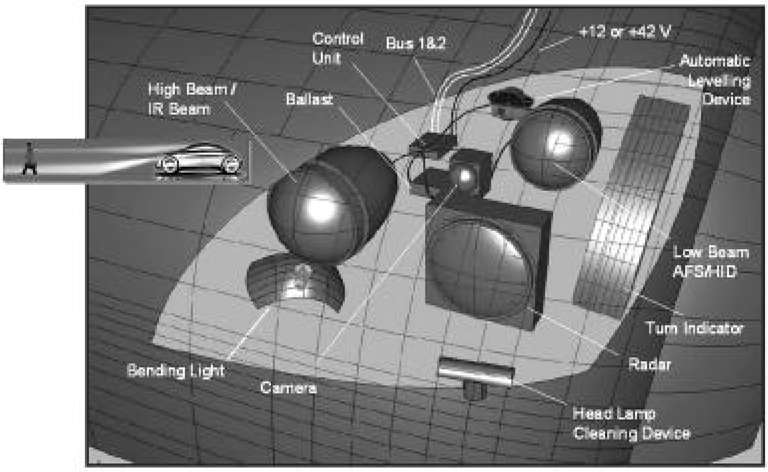


Bi-function mechanical system

Further improvements

Many researches are going on in the field of lighting improvement. They usually take advantage of the future availability of information networks at the vehicle front end.

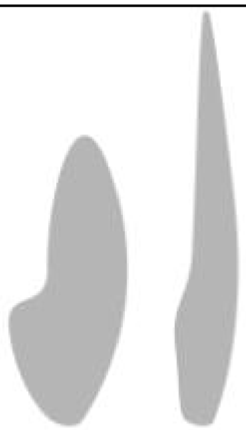
- Infra Red lighting may give a clear image of the dark part of the road,
- Additional optical surfaces or modified low beams may perform as suggested by the “Adaptive Front lighting Systems“ future regulation (see below),
- CCD camera may be used in order to replace levelling sensors,
- Automatic Cruise Control radar antennas may benefit from the Xenon levelling,
- …



Future optical block

Adaptive Front lighting Systems (A.F.S.)

The European working group A.F.S is preparing a regulation change for the years 2003-2005 in order to allow new improved beam patterns for the low beam lighting.
The main proposed improvements are **:**



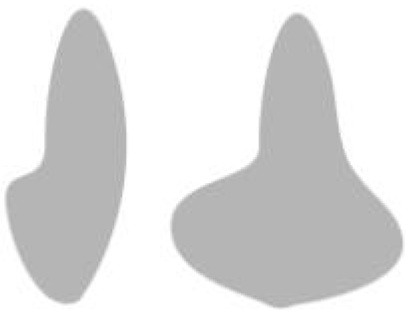
“**Motorway Light**”

The lower the vehicle speed, the closer and wider is the light requirement. A navigation system may help to insure that the oncoming drivers cannot be glared (highways with central separation…), otherwise, the range must prudently be increased.

“**Adverse weather light**”

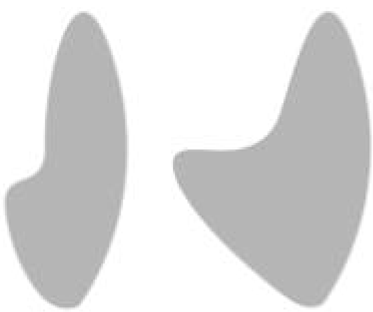
Following road reflectivity and weather condition, the beam pattern may be improved by :

- reducing the light that may glare the oncoming drivers after a reflection on the wet road,
- increasing the road side lighting.



“**Town light**”

The purpose is mainly to increase the lateral light when the car is under city lighting conditions, and allow nearly perpendicular pedestrian and cyclist identification (without glaring) at crossings.
A navigation system is required for an efficient automatic anticipation of the crossings.



“**Bending light**”

The light is following the direction changes of the road. This function is more detailed in paragraph 2.4.

A.F.S bending light (or curve-lighting) discussion.

This function may be optically provided by the mean of :
- Increasing the flux of static additional lights.
- Changing the angle of the main low-beams.
- Changing dynamically the angle of additional lights.

Although all 3 solutions are different, the last one consists partially in a mixing of the two others. It has been therefore decided to focus on it.

Curve-lighting strategy based upon car information

The minimum information required to perform curve-lighting is the steering angle.
When the vehicle speed is low, the usual steering angle is important, and generally not critic under a reasonable value.

When the car speed is high, the usual steering angle is low and meaningless for small values. Moreover, any quick small change of the light distribution could perturb the driver.
Therefore, the rotation angle of the additional lights is function of the steering angle, the vehicle speed, and the set up of different parameters like :

- The steering angle threshold versus vehicle speed.
- Possibly a minimum angle versus vehicle speed.

Curve-lighting strategy based upon availability of navigation information

It has been shown that the driver tries to anticipate his or her trajectory by looking roughly at the location where the vehicle would be on the road if he or she had to operate a braking down to the stop position.

It may happen that this location is not synchronous with the steering angle :
- The observed point is too far from the car.
- A long curve is followed by a short one.
- The road direction ahead is changing very quickly, as mountain curves…

For such cases, an anticipated orientation of the additional lights is possible if a navigation system (GPS, cartography and final destination) provides enough details about the road 100 to 200 meters ahead. Some of these parameters are :
- If a series of turns has been detected, the distance between the end of the current turn and the beginning of the next one.
- The angle, direction, spatial position and curvature of the current or next turns.
- …

3. RENAULT'S DRIVING SIMULATION

In traditional process, the development of a new vehicle headlight system requires the manufacturing of several prototypes. Night tests are essential to assess a new system and modify it accordingly. Several iterations are thus necessary before obtaining a headlight system that suits car company specifications. In order to reduce both development costs and delays, but also to maximise the quality of the headlamp control strategies, the *Renault* driving simulator dedicated to headlamp studies was used. The following paragraphs give an overview of Renault's driving simulation activities with a brief description of the dedicated software, developed by Renault.

Several simulators have been developed by the Renault Research Department since 1989. A dynamic simulator that enhances driving realism thanks to coherent visual and kinaesthetic stimuli was recently built in answer to the emergence of new research and development needs. Dynamic control systems (Adaptive Cruise Control), assessment of man-machine interfaces can be quoted as examples. The *Driving Simulation and Virtual Reality Group* also developed several static simulator to deal with lighting simulations, as presented in the followings.

The SCANeR© II comprehensive driving simulation software system

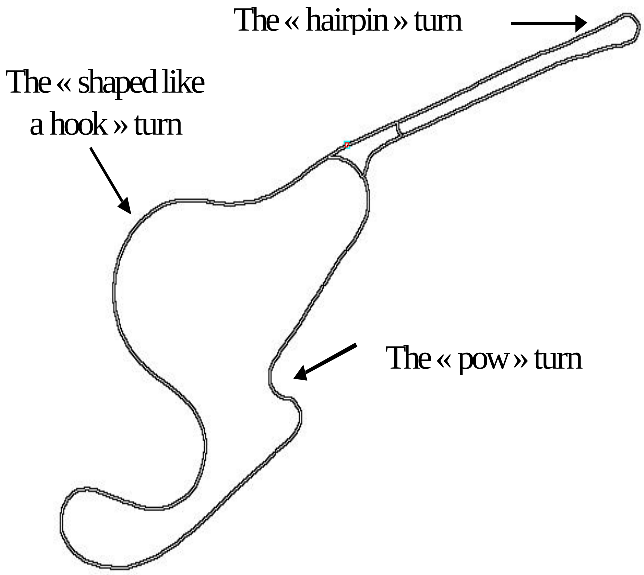
Renault's simulators are based on commercial hardware and use SCANeR© II driving simulation software package. SCANeR© II is a set of distributed, multi-platform application software allowing the user to build a vehicle simulation. SCANeR© II brings tools, from database creation to real-time interactive simulation, to replay and post-processing. Traffic generation is at the heart of SCANeR© II with a comprehensive traffic generation engine handling all types of infrastructures. An intuitive graphical interface allows to set-up traffic conditions to fit the application. The dynamics model is based on multi-body analysis and real-word measurements. It is interfaced with an advanced road surface definition based on Bézier patches and including variable adherence, noise and road-type factors. Beyond the accurate driving simulation environment SCANeR© II provides supervision and analysis tools. The experimenter has a view of the vehicle and simulation through real-time update of dials and maps. The modules described above correspond to distinct functional units that use a common communication protocol in the SCANeR© II software architecture.

A driving simulator for headlamp studies

Renault, Research Department has developed a real-time lighting simulation software able to render high precision visual aspects of a light beam on the road in real-time, thanks to computer generated images. This software, integrated in SCANeR© II, accepts photometrical and colour data characterising the projector. This data is issued from measures taken on an existing projector or from computations based on CAD projector models. Thus, a projector can be assessed even before having a physical prototype.

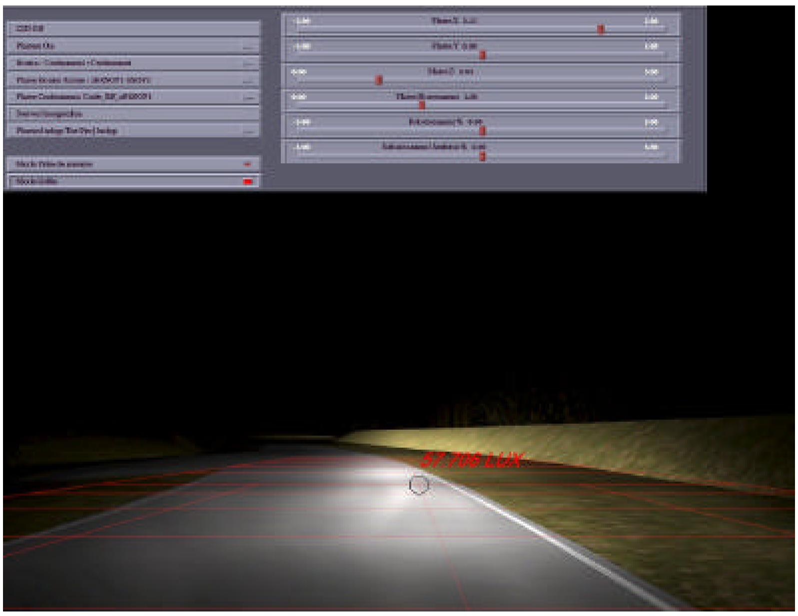
The driver is seated in the simulator drive station. He or she drives through a virtual environment.
The virtual environment is the reproduction of the Aubevoye Renault's test track. This test track is usually used for night tests. It includes short turns like the "hairpin" and "pow" ones, but also long turns like the "shaped like a hook" bend. A precise definition of the road in terms of polygon was necessary to obtain a realistic lighting rendering.

Using the vehicle commands, the user can switch from low to high beam or fog lights. He or she can also modify in real-time the projector type or version.



Renault test track

A graphical user interface allows to modify in real-time various projector parameters such as position, pitch or colour. Photometrical measures can be taken on each point on the road. A grid is displayed on the road for this purpose. Finally, a top view of the track can be displayed, for a better assessment comparison of projector characteristics.


Renault lighting simulator screenshot

4. INTEGRATION AND COMPARISON OF THE VALEO LIGHTING STRATEGIES ON THE RENAULT'S DRIVING SIMULATOR

Two different curve-lighting systems were proposed by *Valeo*. Different types of parameters are necessary to their modules so that they can determine the direction of the vehicle on the road. Two strategies were studies : the first one uses information on the vehicle speed and the steering wheel angle ; the second one on the vehicle speed and the characteristics of the road.

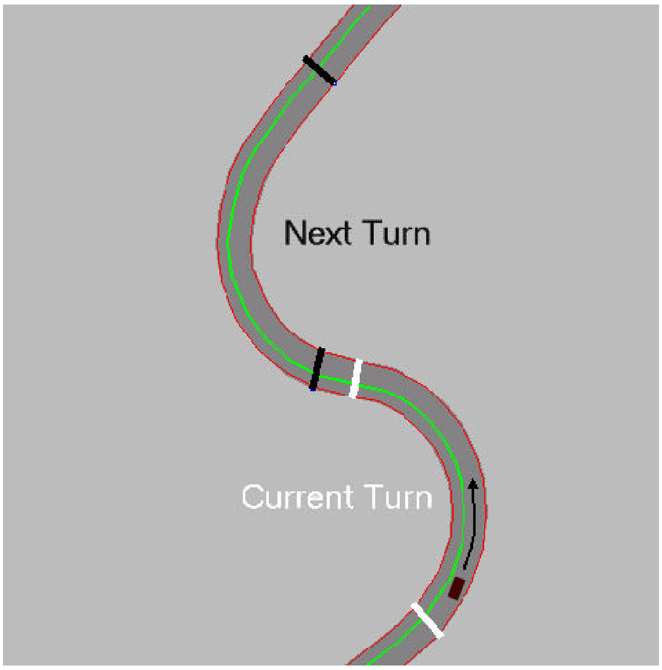
Simulation of a navigation system in the driving simulator

Vehicle parameters are handled by standard SCANeR© II software package and are provided to the lighting module through SCANeR© II network protocols . However a specific development became necessary to deal with the geometrical characteristics of the road for the navigation system. It was simulated in order to supply the control strategy with the required features.

A first study consisted in finding out one accurate criteria to decide whether a road is a bend or not. The curve radius of the road had to be analysed along the road way. It was decided that the user would define a 'curve radius threshold'. This approach allows the experimenter to decide bends to detect for a specific database. For the curve-lighting application applied on the Renault tests track of Aubevoye, the curve radius threshold was adjusted to recognise different bends such as the "hairpin" bend or the "shaped like a hook" turns. This application took also into account the possible inaccuracy of such an approach due to inexact sporadic curve radii along a real-life road.

The software was also modified so that not only the turn in which the vehicle is currently driving could be detected, but also the next turn the vehicle is getting closer to. In this way, situations that are taken into account in the second Valeo strategy such as series of consecutive turns could be handled in the simulator environment. However the system is still left unsure of which route to light when faced with intersections.

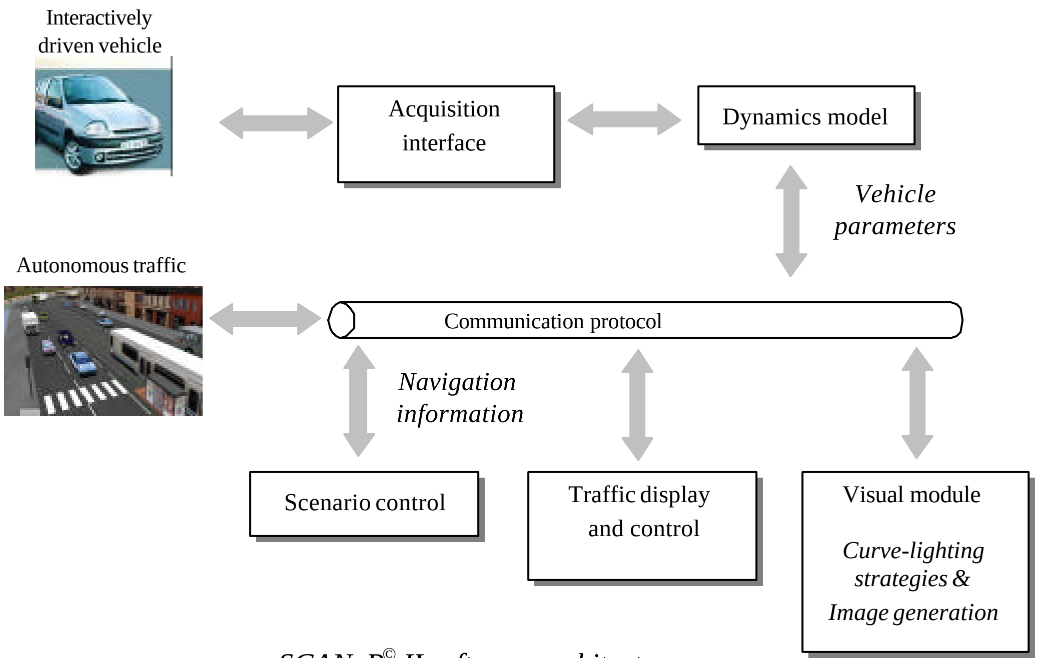
Finally, different functions were created to get the data concerning both the current and next turns to be able to feed the curve-lighting modules. Those functions were used to generate a scenario dedicated to curve-lighting in the SCANeR© II traffic interface. Thus the required information concerning road turns could be sent to the visual module in which the Valeo strategies had to be included.



Detection of current and next turns

Integration of the Valeo strategies in the lighting simulator environment

Software modules that deal specifically with the *Valeo* strategies were added to the visual module. Information related to the vehicle parameters and the navigation data were captured on the network and provided to the curve-lighting units. The rotation angles of the additional headlights were consequently calculated by the software and then supplied to the visual model to get the corresponding image generation.



SCANeR© II software architecture

In order to compare both approaches during an experiment without having to restart it, a specific software architecture was implemented to be able to switch from one strategy to the other using the vehicle 'warning' switch by the driver.

The tests and the tuning of both strategies were handled rapidly and efficiently thanks to the simulator environment and the facility to modify the mathematical formula in the software dedicated to the curve-lighting. Both strategies were then compared in real-time. Advantages and drawbacks were highlighted for each one of the two curve-lighting approaches during the experiments on the driving simulator in the Aubevoye test track.

5. CONCLUSION

A validation of the curve-bending strategies was carried out by lighting experts from *Renault* and *Valeo*. Both solutions introduced by *Valeo* showed specific advantages that are distinct from one strategy to the other. An improved curve-lighting strategy could hence take the advantage of the fact that the gains of both current approaches do not occur in the same road configuration. In this context, a new strategy combining the two separate adaptive systems is to be developed and studied thanks to the *Renault* lighting simulator.

The lighting simulator allowed to save cost on and headlight-systems prototypes, and on time that would have been necessary for the headlight tuning process. Besides, a better quality of the *Valeo* adaptive front-lighting systems was made possible thanks to a total control of the test environment.

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