SAE TECHNICAL
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980007

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Reprinted From: Automotive Lighting Technology
(SP-1323)

SAE The Engineering Society For Advancing Mobility Land Sea Air and Space® INTERNATIONAL

International Congress and Exposition
Detroit, Michigan
February 23-26, 1998

400 Commonwealth Drive, Warrendale, PA 15096-0001 U.S.A. Tel: (724) 776-4841 Fax: (724) 776-5760

ISSN 0148-7191

Printed in USA

90-1203B/PG

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ABSTRACT

A new light concept called Adaptive Light Control (ALC) is developed with the aim to improve night time traffic safety. ALC improves the headlamp illumination by means of continuous adaption of the headlamps according to the current driving situation and current environment. In order to ensure rapid prototyping and early testing the step from offline to online (real-time) simulation of light distributions in the driving simulator has been successfully done. This realtime simulation enabled the interactive development of new light distributions in different driving situations and driving environments. The solutions are directly ported to real vehicels to allow further testing with natural road conditions.

In this paper, results of the development of movable headlamps are presented. These headlamps are controlled by means of path prediction based on vehicle dynamics and route vectors of the navigation system. A comparison of static and dynamic light distributions is illustrated and an outline of the basic concept of the Adaptive Light Control system is given.

INTRODUCTION

For decades, car headlamp systems have basically remained unchanged. The driver can select high or dipped headlights and perhaps switch on fog-lamps if necessary. These systems, of course, have become many times more powerful with the light bulbs of yesteryear replaced by halogen lamps and, ultimately, by xenon headlights, which are three times as powerful. Due to specially cut lenses, projection headlamps, and computer-calculated reflectors, utilization of light quantity has also been increased by thirty to seventy percent. But the headlamp system as such has remained essentially unchanged. The possibility to direct the available light dynamically into the direction where it is actually needed has remained a wish. In recent years, however, there has been a considerable amount of interest in improving the light quality of automotive headlamps to improve night-time driving safety. A few technical realizations using turnable reflectors have been presented in the past (e.g. Ref. 1,2), and subsequent investigations now prove that different driving situations require different light distributions to obtain an optimal illumination (see Ref. 3-8). In addition, viewing strategies of the driver -especially during curve negotiation - are an important issue for the design of dynamic light distributions (Ref. 9)

In the following sections we will give an outline of the interactive environment for developing new lighting systems using real-time simulation of light distributions in the driving simulator and the first version of ALC with moveable headlamps in real vehicles.

INTERACTIVE ENVIRONMENT FOR NEW LIGHTING SYSTEMS

Normally, a headlamp is first designed and then its characteristics are tested and optimized in practice. Due to the difficulty and costs of developing appropriate automotive headlamps, a lot of work has been done in light simulation. Usually static light distributions for specific situations have been modelled in an offline simulation, with a CPU-time from 10 seconds up to minutes per frame (e.g. Ref. 10). Until now, a real-time simulation of (dynamic) light distributions did not exist, and hence, a tool to evaluate light distributions adapted to different driving situations or influenced by different weather conditions has not been available.

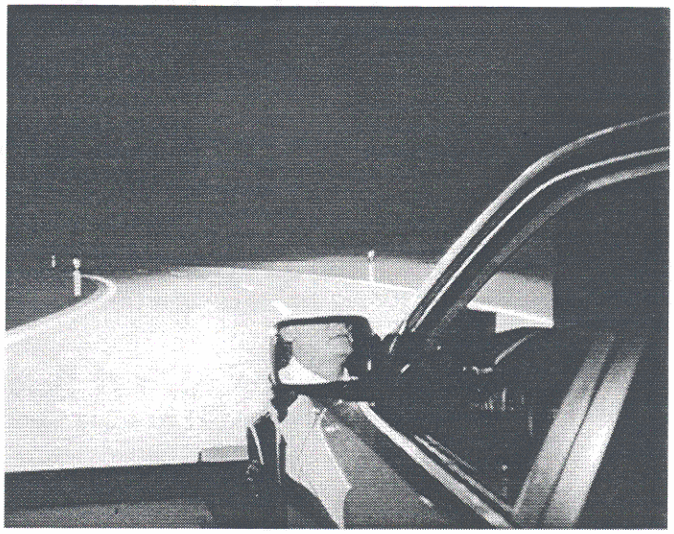

Fig. 1: The headlamp system in the driving simulator

By combining high-performance computers and specially developed lighting software with a real-time kernel, an environment is realized which allows online simulation of light distributions and, therefore, interactive development of lighting systems. The simulation produces a series of images (30-60 frames/second) that is projected onto a screen and enables one to drive interactively in the simulator with modelled light distributions, as illustrated in Fig. 1.

DRIVING SIMULATOR - The heart of the driving simulator is comprised of several high-performance supercomputers operating in conjunction with specially developed lighting software. The vision simulation is performed by 2 closely coupled graphic engines with a 2-pipe and a 1-pipe machine, respectively. The graphic is equipped with two multi-channel options, six raster managers (16 MB) and 12 CPUs. Several graphical databases are implemented including textures for trees, buildings, signs, and cars.

ONLINE MANIPULATION OF LIGHT DISTRIBUTIONS

The light distribution is simulated not only in real-time but is also changable online and can be checked immediately. Fig. 2 shows the shape of cut-off illumination of the road that is integrated with the lighting software in the driving simulation (Ref. 10). Fig. 3 shows the isolux diagram at road level for the same distribution. With these light distributions, as an example, the following issues could be addressed:

- Cut-off line simulation
- Dynamic headlamp levelling
- Evaluation of light distributions (different light distributions)
- Changes of the distributions (e.g. low beam and low beam with spot)
- Movable headlamps with curve illumination

LIGHT COURSE AND DRIVING SIMULATION

LIGHT COURSE - To test different light distributions a specially designed light course was developed. The driving simulator light course contains a closed course with many different curves and includes a crossing. The radius of curvature of the bends varies between 25 and 150 m. The width of the road is 7 m with a center line and beacons every 50m. Decorated with buildings, bushes, trees, pedestrians and traffic signs, it provides a photorealistic appearance.

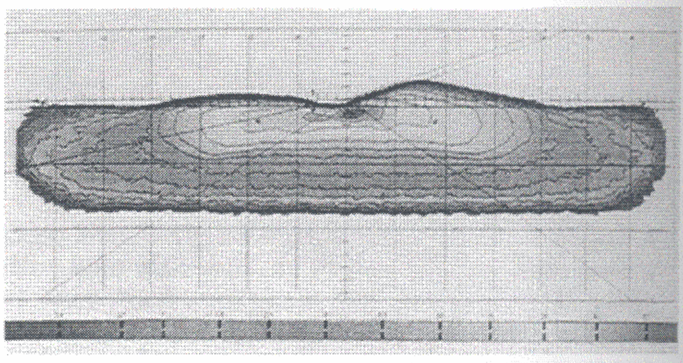

Fig. 2: Integrated light distribution in the driving simulator

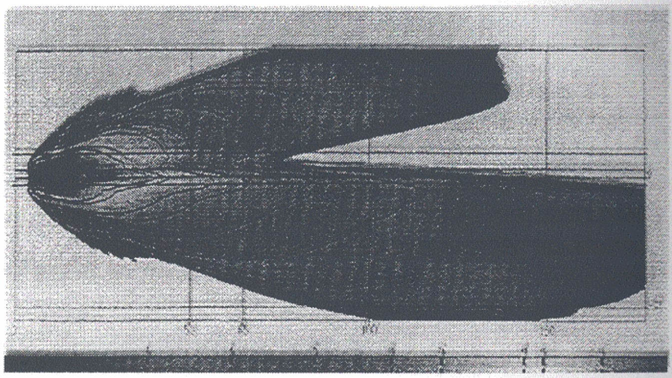

Fig. 3: Isolux diagram at road level

CONCEPT OF ADAPTIVE LIGHT CONTROL (ALC)

During night-time driving it is more demanding to keep the vehicle within the lane boundaries. The automotive lighting equipment illuminates the driver's viewing field and has to deliver the appropriate information for lane keeping under many different driving situations.

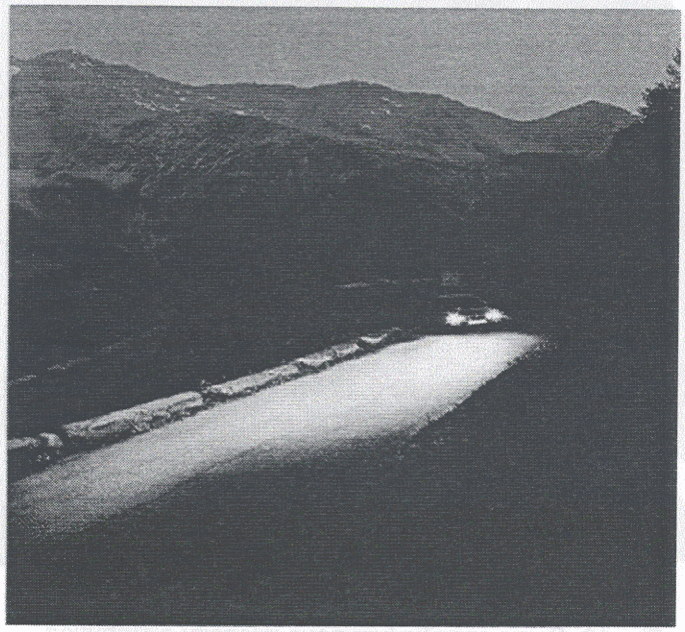

Fig. 5: Driving situation with Adaptive Light Control

Regarding the driver's needs for visual information about the road ahead, present headlight technology insufficiently lights up bends in the road ahead. The advantage of using Adaptive Light Control is shown in Fig. 5, where one observes a country road lit correctly. Instead of illuminating some fields or trees, the available light is directed dynamically in the direction where it is actually needed, enhancing the visual information for the driver.

BASIC STRUCTUR OF ALC - The newly developed movable headlamps are controlled by means of path prediction based on vehicle dynamics and route vectors of the navigation system (see Fig. 6). With the output of the path prediction model it is possible to control the movable headlamps appropriately.

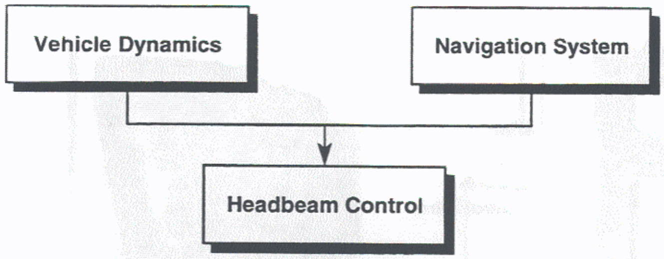

Fig. 6: Structure of Adaptive Light Control - ALC

DYNAMIC PATH PREDICTION - Fig. 7 shows the structure of the path prediction. The prediction consists of an estimation of the (lateral) disturbances (or accelerations) acting on the vehicle body and a prediction of the future path of the vehicle based on the current vehicle dynamic states in combination with a simple model of the vehicle. A filtering has been added such that the variations in the prediction of the future path, e.g. due to steering wheel motions, can be controlled (Ref. 11).

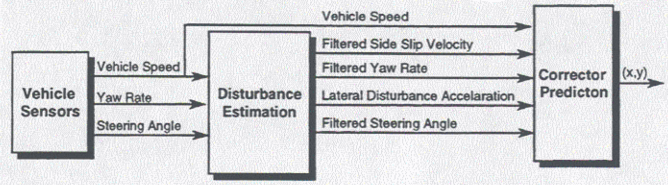

Fig. 7: Structure of the dynamic path prediction

DISTURBANCE ESTIMATION - The disturbance estimation is based on the afore-mentioned simple vehicle model. The disturbance estimation is necessary to avoid an undesired curvature of the path prediction due to the driver's counteracting steering motion in situations such as superelevated road surfaces or side wind.

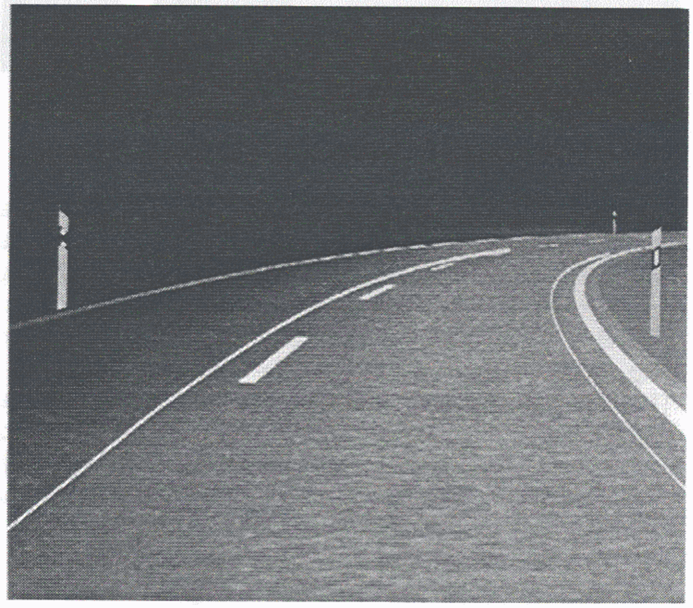

Fig. 8: Control of the headlamps with path prediction

The equations of the well known single track model are known from literature (see e.g. Ref. 12 and 13). Fig. 8 shows the movable headlamps controlled by the path prediction, which is identified by the two curved white lines.

Fig. 9 and Fig. 10 illustrate the differences between a conventional low distribution (light distribution mentioned above) and special curve specific distribution on a normal country road.

Experiments in the driving simulator have shown that the vehicle dynamics based path prediction used to control the headlamps is limited to a certain road geometry. It is insufficient when encountering s-curves, crossings, and other types of special road construction, because the driving dynamic does not know anything about the road geometry further ahead. Additional knowledge is necessary to overcome these deficiencies.

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