SAE TECHNICAL PAPER SERIES

980007

Adaptive Light Control – A New Light Concept Controlled by Vehicle Dynamics and Navigation

J.P. Löwenau, J.H. Bernasch, H.G. Rieker, P.J.Th. Venhovens, J.P. Huber, and W. Huhn
BMW AG Research and Development

F.M. Reich
Technical University Vienna

Reprinted From: Automotive Lighting Technology (SP-1323)

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

980007

Adaptive Light Control - A New Light Concept Controlled by Vehicle Dynamics and Navigation

J.P. Löwenau, J.H. Bernasch, H.G. Rieker, P.J.Th. Venhovens, J.P. Huber, W. Huhn
BMW AG Research and Development

F.M. Reich
Technical University Vienna

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.

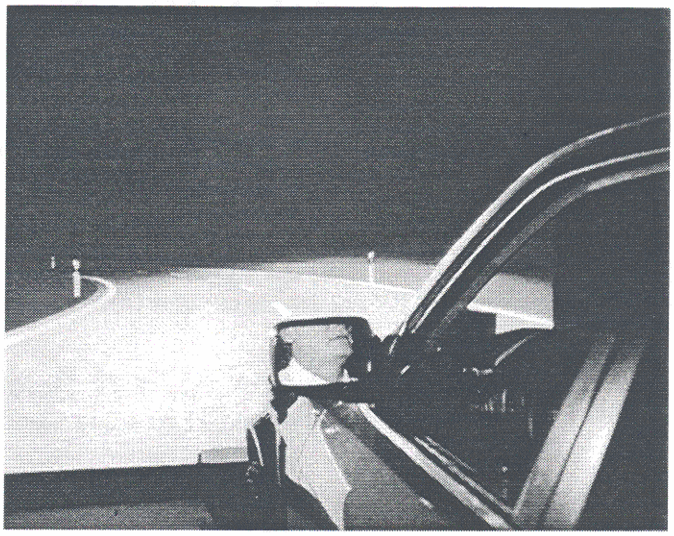

Fig. 1: The headlamp system in the driving simulator

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.

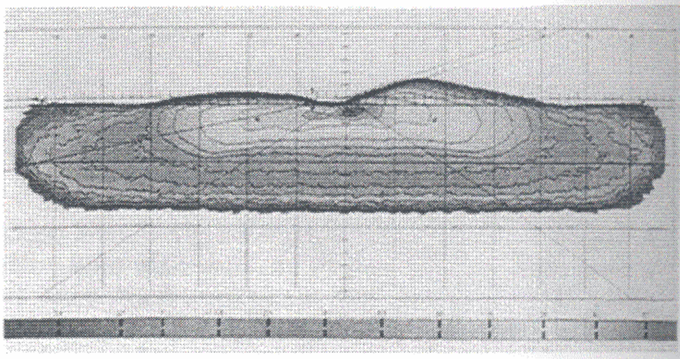

Fig. 2: Integrated light distribution in the driving simulator

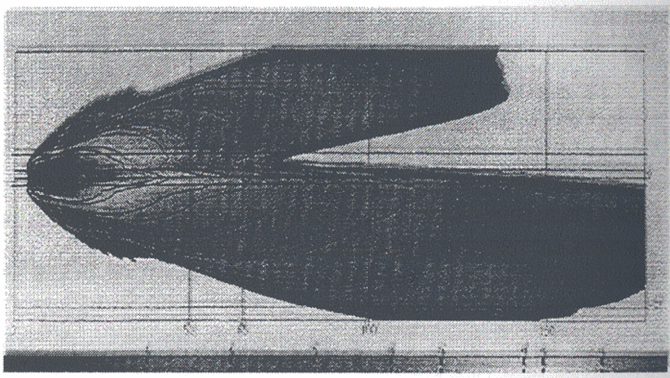

Fig. 3: Isolux diagram at road level

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.

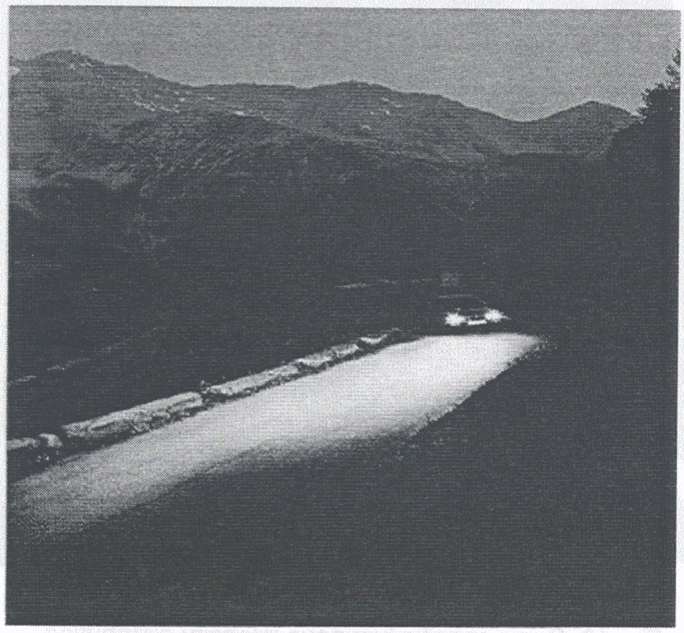

Fig. 5: Driving situation with Adaptive Light Control

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.

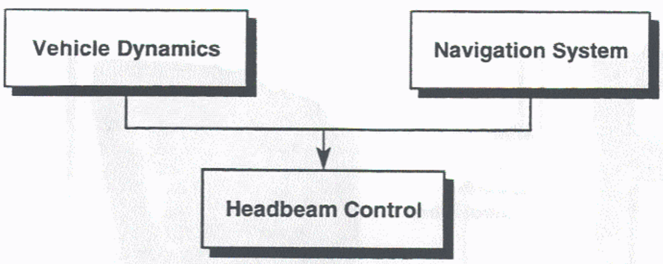

Fig. 6: Structure of Adaptive Light Control - ALC

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).

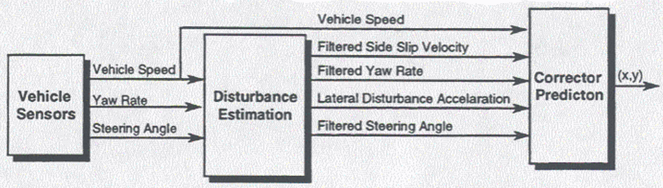

Fig. 7: Structure of the dynamic path prediction

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.

Fig. 9: Conventional luminous intensity distribution

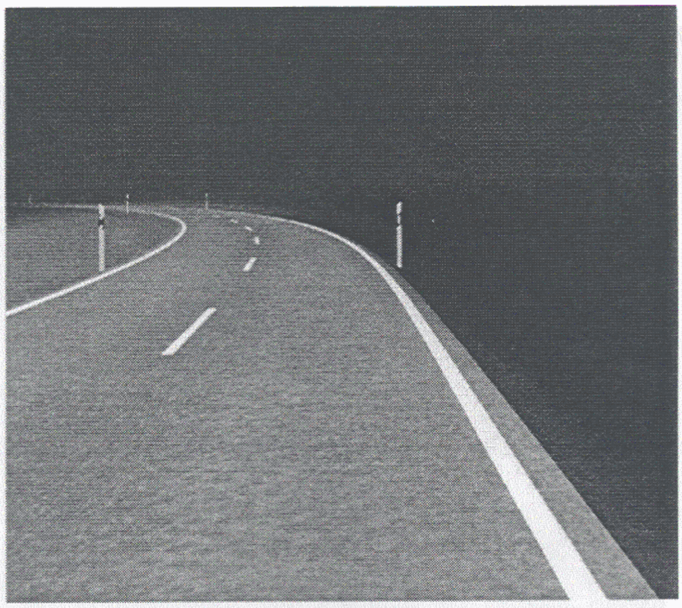

Fig. 10: Curve specific luminous intensity distribution

NAVIGATION DATABASE - In addition to the vehicle dynamic parameters, route vectors from the navigation system are used to control the movable headlamps. An electronic compass, two wheel sensors, and GPS data are the input of the navigation system (Fig. 11).

The navigation system permanently keeps track of the precise location of the car, and with its built-in digital road map (CD-ROM) it knows the road characteristics ahead. The system provides position accuracy of 10 to 30 m for country roads and cities.

SIMULATED NAVIGATION DATA - To be able to use the navigation system in the driving simulation the output data are simulated in a manner reflecting the characteristics known by the real system. Even a simulation of distorted or low quality data is possible and was included in the overall solution. A special protocol is used to provide the following information:

- current car position
- route data vectors of the scheduled route, with
  - reliability of the route data vectors,
  - current road class
  - on-map or off-map status.

These data are necessary to develop control strategies to produce light distributions for adaptive lighting situations depending on the items mentioned above.

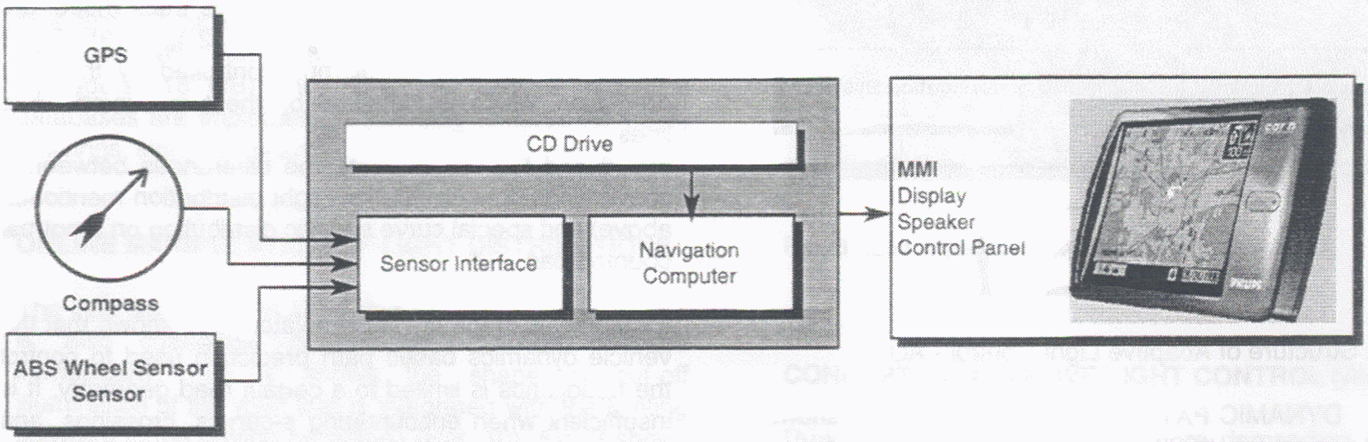

Fig. 11: Structural diagram of the navigation system

Fig.12: Visualization of path prediction and navi-data

DATA INTEGRATION - As a final step, the path prediction and the navigation data have to be coupled to ensure consistent control of the movable headlamps. Fig. 12 shows both, the path prediction from the driving dynamics (white lines left and right) and the vector of the simulated navigation system (white line in the middle).

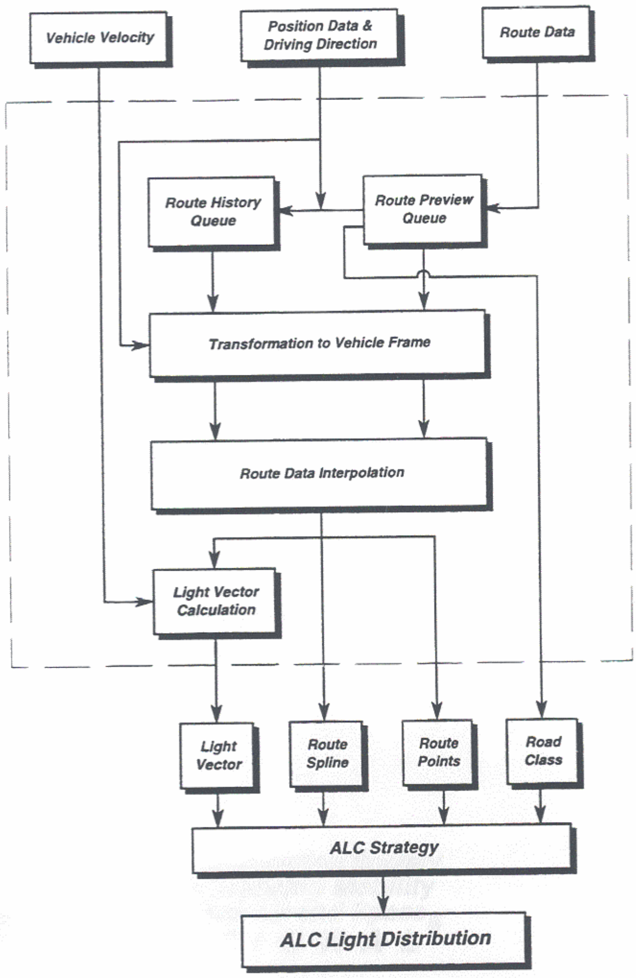

Fig.13: Interface of ALC and Navigation

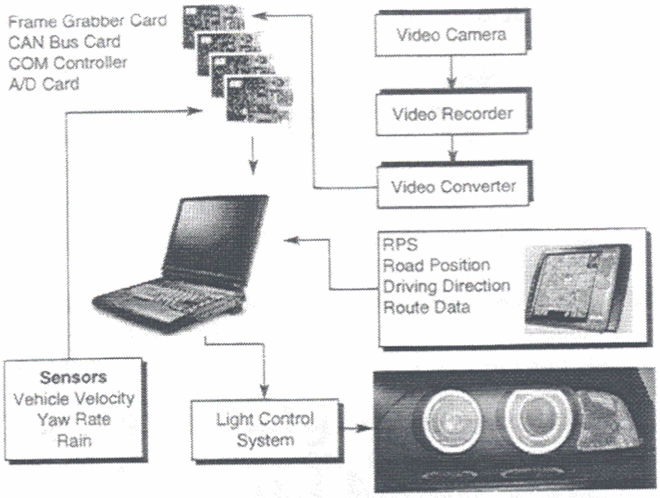

Fig.14: ALC-Hardware in the vehicle

With our modular program structure we are able to test, tune, and evaluate ALC strategies in the simulator. Figure 13 shows the program structure of ALC based on the navigation system.

For the development of ALC the components described in Fig. 14 are used. The ALC headlamp in Fig. 14 is designed to fit into existing series vehicles and to fullfil the ALC requirements.

RESULTS

Using special graphic algorithms a real-time simulation of light distributions with 30-60 frames/second has been achieved. Using this real-time simulation an adaptable light distribution for dynamic movable headlamps is developed for the light system Adaptive Light Control (ALC). The solution of ALC with control algorithms and lighting strategies has been realized at first in the driving simulator. It has been ported with minimal effort to real vehicles, the first hardware prototype of ALC is now under investigation. First experiments demonstrated the subjective advantage of ALC for the driver, it seems to serve as active guidance device for the driver by means of lighting up the scenery primarily in driving direction (eg. the road even in curves).

OUTLOOK

In this paper an outline of the environment for developing light distributions and movable headlamps in a driving simulator is presented. First results of experiments as well in the simulator as with real vehicles are very promising. In the near future the focus will be on lighting strategies and optimal control algorithms and on the interaction of eye movement behaviour and dynamic light patterns.

REFERENCES

1. Wada, K., Miyazawa, K., Yaki, S., Takahashi, K., Shibata, H. (1989) Steerable Forward Lighting System. SAE Technical Paper Series 890682, USA.

2. Kobashi, S., Hayakawa, M. (1991) Beam Controllable Headlighting System. SAE Technical Paper Series 910829, USA.

3. Braess, H-H., Reichart, G. (1995) Prometheus: Vision des intelligenten Automobils auf intelligenter Straße, ATZ 95/6.

4. Schmidt-Clausen, H.J., (1995/97) Progress in Automobil Lighting. PAL Conference, Technical University Darmstadt.

5. Huhn, W., Hege, G. (1995) High Intensity Discharge Headlamps(HID). SAE Technical Paper Series 950591, USA.

6. Hogrefe, H., Neumann, R. (1995) Adaptive Light Pattern - A New Way to Improve Light. SAE Technical Paper Series 970644, USA.

7. Damasky, J. (1995) Lichtechnische Entwicklung von Anforderungen an Kfz.-Scheinwerfer. Dissertation, TH Darmstadt.

8. AFS - Advanced Frontlighting Systems, (1996) Eureka Project No. 1403. Phase 1 - Feasibility Study, Final Report.

9. Bernasch, J.H., Bengler K., Löwenau, J.P., Scholles M. (1997) Comparison of Viewing Strategies during Curve Negotiation in Reality and in Simulation. *In Proceedings of the Driving Simulator Conference DSC '97,* Lyon, France

10. Bernasch, J., Haenel, S. (1995) The BMW Driving Simulator Used for the Development of a Driver-Biased Adaptive Cruise Control. *In Proceedings of the Driving Simulator Conference DSC '95.*, Sophia Antipolis, France.

11. Reich, F.M., Bernasch, J.H., Löwenau, J.P. (1996) Online Steering Dynamics in the BMW Driving Simulator. *IMAGE Conference 1996*, Scottsdale, Arizona, USA.

12. Mitschke, M. (1992). Dynamik der Kraftfahrzeuge, Band C: Fahrverhalten, Springer Verlag, Berlin.

13. Reich F. M., Venhovens P. J.Th., Bernasch J.H., Löwenau Jan P. (1997) Optimized Haptical, Acoustical and Visual Tuning with Different Vehicle Dynamic Models for the BMW Driving Simulator, IAVSD 15th Symposium Dynamics Of Vehicles on roads and tracks, Budapest, Hungary