

# HEADLAMP-BASED VISION SYSTEM AND THE VISION TASK

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## ABSTRACT

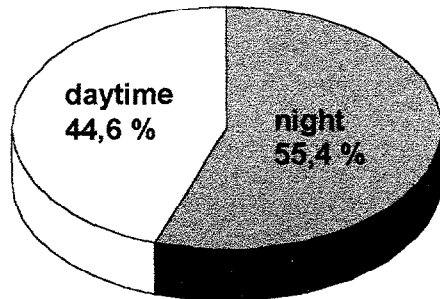
Today the driver's eyes collect all visual information on traffic flow and accident prevention. The intricate physiology of the human eye and the visual cortex is fit to discern vision noise from visual information sufficiently to guide a vehicle through traffic - in almost all cases.

The study of the performance of the vision system under disfavoured conditions exposes the limits. It provides immediate input to vision assistance. For example, it clarifies design criteria for more comfortable, hence safer, vehicle lighting systems. It assists the introduction of first, primitive vision functions in headlamps.

The paper details the study of visual performance, defines the resolution conditions for existing active safety devices and shows first examples of vision system applications in automotive headlamps.

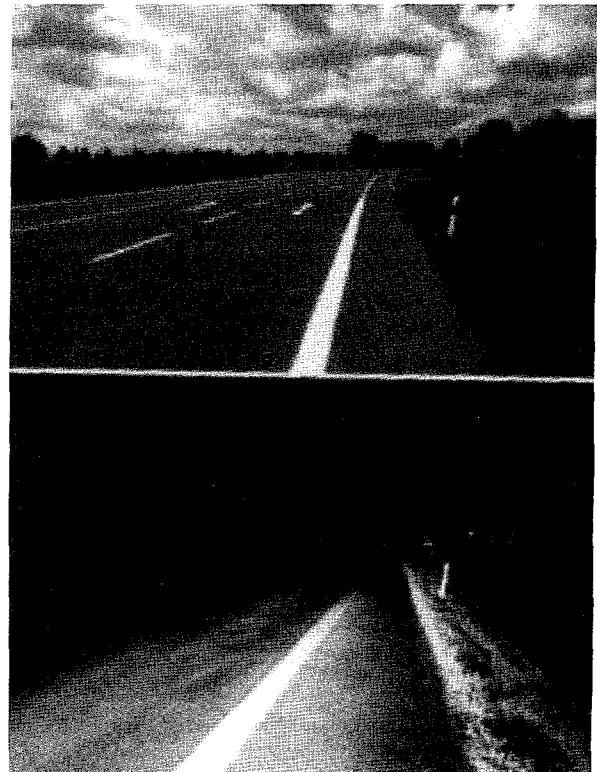
## INTRODUCTION

In recent years, the number of sensors in motor vehicles has increased rapidly. The most important examples are pressure, acceleration and temperature sensors. The information these sensors supply is, however, almost exclusively concerned with the condition of the vehicle itself, but not with the surrounding environment, let alone with the traffic situation. This task is still entirely that of the driver. The only exceptions to date are sensors for outdoor temperature to warn drivers of potentially icy road conditions, as well as recently developed rain sensors to control the windscreen wipers for him. Sensors for ambient brightness are soon to come, which will serve the purpose of turning on the running lights when darkness falls.



**Figure 1.** Proportion of fatalities for day and night in Japan 1993.

84 % of the ambient information drivers have to sense and process in order to drive a vehicle safely through traffic is visual in nature [1], i. e. is input through the eyes. The human eye, and above all the subsequent information processing in the brain, is well-adapted to this task, although the system is sometimes ill-equipped to handle conditions of poor visibility, as seen in accident statistics. In Germany, for instance, about half of the accidents (49.6 %) in 1993 occurred at night [2]; in Australia, the percentage of night accidents was 43.8 % in 1995 [3] and in Japan 55.4 % [4] - see figure 1. To understand the significance of these figures, it must be remembered that only about 20 - 25 % of total driving time is at night. The comparison in figure 2 demonstrates that the cause of this disparity is to be found in the lack of information due to poor visibility. In addition to the examples of visibility hindrances listed there, darkness and rain, fog and snowfall also play important roles.



**Figure 2.** Comparison of vision conditions in daylight and at night.

The above examples make it clear that, at least under certain conditions, the driver of a motor vehicle can use some assistance and support to master the task of gathering sufficient information about ambient road and traffic conditions.

### POTENTIALS FOR OBTAINING INFORMATION FROM THE AREA SURROUNDING THE VEHICLE

One idea would be to transmit such information to the vehicle in automatically evaluable form. Since such a method requires a standardized infrastructure external to the vehicle, it will not be feasible within the near future.

The only remaining possibility is to use independent systems in the vehicle to obtain the necessary information. Various sensor systems offer potential solutions. Radar devices are surely the most familiar. Radar systems are designed to provide information on distances. The scanning systems used to obtain a flat image are expensive and complex. On the other hand, radar devices are not dependent on optical visibility.

Lidar (light detection and ranging) devices function similarly to radar, the difference being that they function on the basis of light instead of high frequency and hyperfrequency electromagnetic waves. This means they are dependent on optical visibility, although the equipment is usually not as expensive as radar devices.

Video methods are of course dependent on optical visibility, too. The big advantages of such systems is that the way they obtain information is very similar to the way human vision works. On the other hand, exact distance information is much more difficult to obtain with such devices.

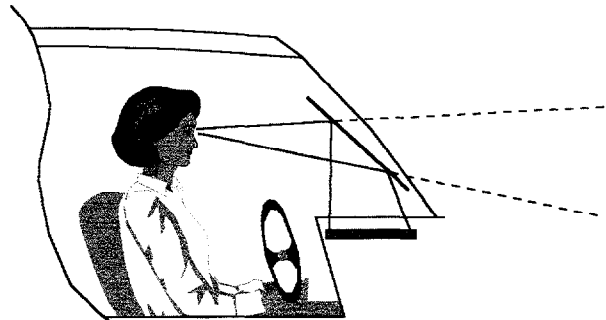
### UTILIZATION OF INFORMATION FROM THE AREA SURROUNDING THE VEHICLE

Utilizing information obtained from the area surrounding a vehicle represents a new technical field, so that it is important to begin by considering carefully what exactly should - and can - be done with such information. Such systems generally entail a problem inherent in the practically infinite number of potential constellations and input states. It is therefore impossible to check with 100 % certainty whether the system is reacting properly to all potential changes in the input parameters. Since the consequences of functional failures are considerable in terms of product liability laws, completely automated use of such functions, particularly in safety-relevant applications, will not be available for some time. The approach being taken at present is to design such systems as driver assistance systems, i. e. so that the driver can decide and react contrary to system recommendations at will. Full responsibility thus remains with the driver.

One example of such a driver assistance system is ACC (Adaptive Cruise Control) [5], series installation of which is

expected for 1999. In the initial version, it will be used with a radar sensor. The question has been raised as to whether drivers might be tempted to drive blindly through fog, trusting to the better "vision" of the radar system. This would be a case in which the driver relies entirely on the system, which is not in keeping with its design concept as a driver assistance system. This fact admittedly represents a risk factor.

Another approach draws the driver's attention to specific potential danger sources. During daylight hours, a head-up display could be used, correct control of which would have to take the driver's head position into account to ensure that the driver really sees the superimposed symbols in relation to the potentially dangerous object - see figure 3

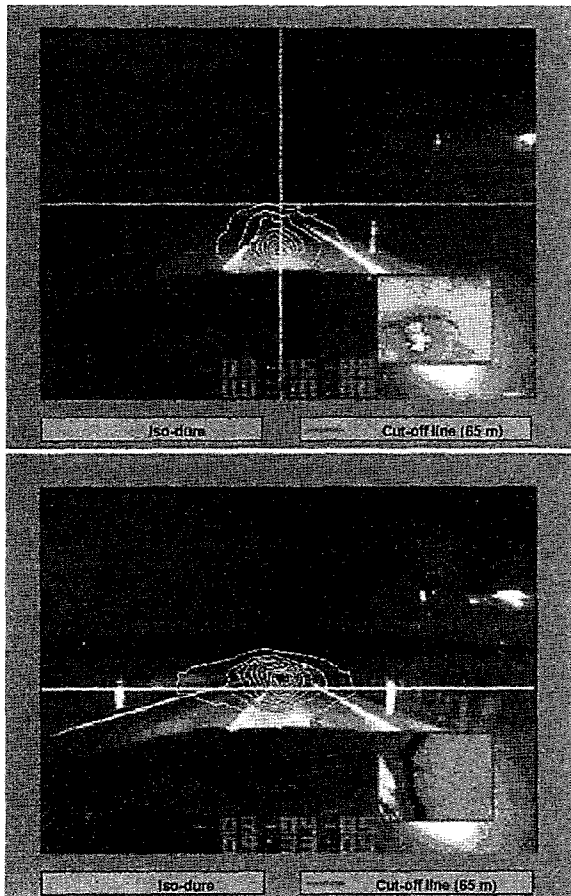


**Figure 3. Use of a head-up display for warning of potential dangers on the road.**

At night, a different method can be used: The attention of the driver can be drawn to specific points by means of light. Every driver is familiar with the effect of overly bright interior lighting distracting one's attention from what is going on outside the car at night. This effect is added to the reduction in object visibility resulting from diminished contrast. The headlamp light is predestined to influence the attention of the driver within the range that is particularly important for the operation of a motor vehicle.

## INFLUENCING VISUAL ATTENTION OF DRIVERS BY MEANS OF HEADLAMP LIGHT DISTRIBUTION

To achieve an active influencing of visual attention using headlamp light, it was first necessary to determine the principles on which the process is based. The corresponding studies were done by the "Auto, Sicht, Sicherheit" Research Group (ASS) in Cologne and Daimler Benz Forschung Fahrzeug, Abteilung Mensch und Fahrzeug in Berlin [6]. Figure 4 shows the influence of light distribution on the distribution of visual attention. Using headlamps with an emphasized close-range illumination area, as in the H4 system used here, a shift of vision towards the vehicle can be seen. The width of the 90 % area is also restricted on account of the "narrow" light distribution. Exactly the opposite can be seen in the case of the Xenon headlamp with its ellipsoid system and wide field of illumination at the cut-off line, whereby the 90 % area is substantially widened. The driver thus "scans" the more distant areas more intensely.



**Figure 4. Dependency of the visual attention on headlamp illumination distribution for H4 and xenon headlamps**

One can conclude from these results that the greatest light intensity will be applied where potential dangers could arise, and at a distance correlated with current driving speed. The future may bring the technical feasibility, and legal allowance, of light distribution that is freely adaptable to current road and traffic conditions, at which point these studies will require further refinement. At present, such unrestricted lighting practices are not yet in sight. Current considerations are therefore restricted to light distributions which, although fixed in themselves, are mobile in relation to the vehicle axes.

## CONTROL OF HEADLAMP LIGHT DISTRIBUTION

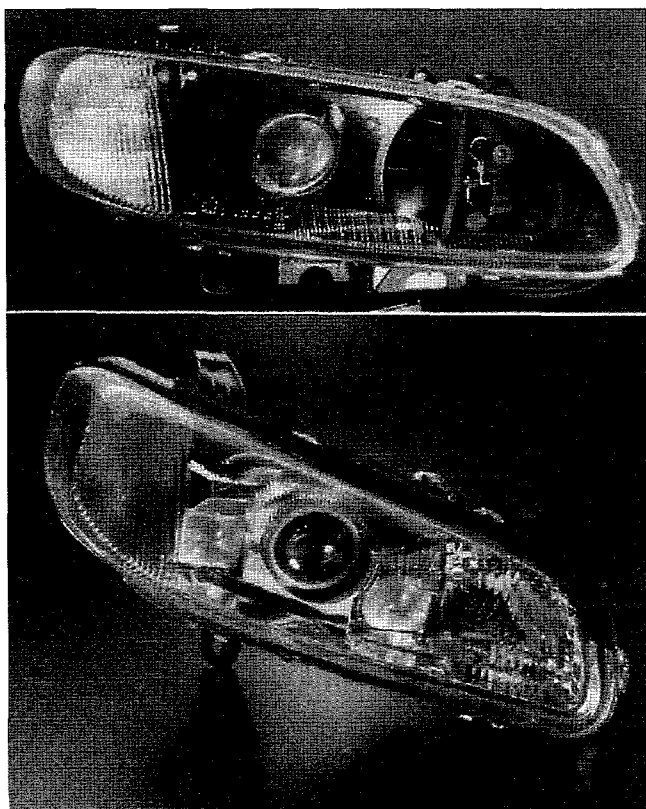
Control in relation to the vertical vehicle axis is a component of the dynamic cornering lighting [7] planned for AFS (Advanced Frontlighting System). Series production and use of such systems can be expected beginning in about the year 2003, since the regulations will have to be adapted to accommodate them. The current approach to control of dynamic cornering headlamps presupposes that the necessary information can be obtained with the aid of yaw and steering angle sensors. Testing of the corresponding prototype vehicles reveals the imperfection of the method, since these sensors can only provide a curve datum for the current vehicle position, whereas the headlamps illuminate the route in front of this. What is actually needed is data on the course of the road in front of the vehicle. Such information can be provided with the sensor systems mentioned earlier [8].

Control and steering of movements about the longitudinal axis is not important in automobiles, although it could make a significant contribution to motorcycle safety. A prototype developed by Hella demonstrated its performance capability in the Daimler Benz research vehicle F 300 Life-Jet [9], which was introduced to the public at the IAA 97.

Control about the transverse axis of the vehicle is already realized by automatic headlamp levellers today. Dynamic headlamp levellers - used particularly in combination with Xenon headlamps - compensate not only various load states, but pitching movement as well, for instance during acceleration and braking. A more precise analysis of the reactions of these systems reveals that the axle sensors currently used to obtain control information are only capable of determining the position of the vehicle in relation to the road in the area immediately adjacent to the vehicle, so that the headlamp ranges set near hilltops and dips are either too great or too small. Just as with the vertical axis, only sensors that see what is coming can provide perfect results.

## APPLICATION OF VISION SYSTEMS FOR HEADLAMP CONTROL

The problem of implementation of a sensor that sees what is coming, i. e. a vision system, to control headlamps would suggest use of a video camera in the headlamp itself. Firstly, this would result in a compact device; secondly, the optical axes of at least one headlamp and the camera would be nearly contiguous. Locating the vision system behind the windscreen, as has been repeatedly proposed, would have neither of these advantages. On the other hand, the requirements placed on the system with regard to temperature resistance and other environmental influences would be much tougher.

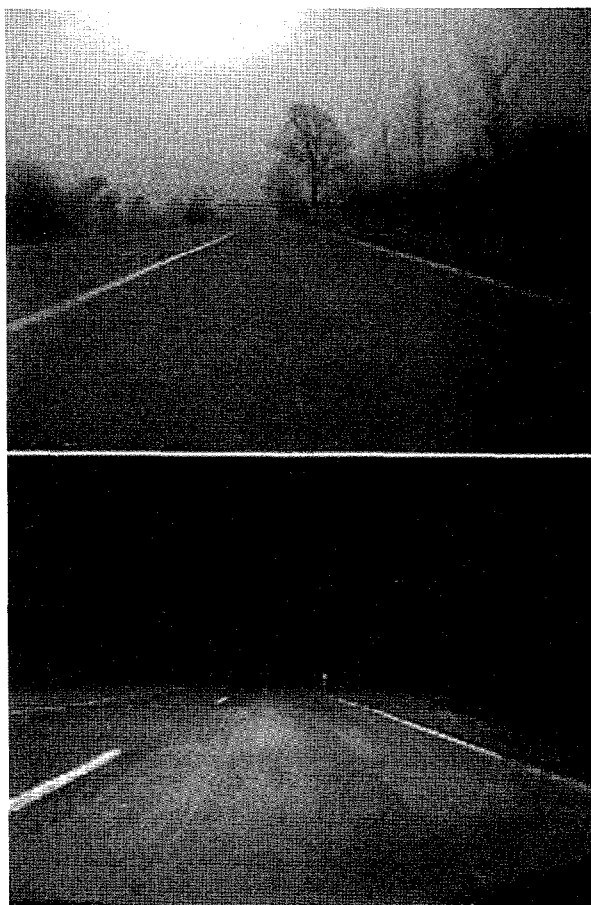


**Figure 5.** Hella's test bed for headlamp-based vision systems and a headlamp with Lidar sensor.

Figure 5 shows the system Hella constructed to test camera systems in the headlamp. Modern headlamp designs without optical lens patterns are favourable to such applications, although no experiential data is available on optical influences that were of little significance to date, influences that will have to be taken into account when installing the camera. Figure 6 shows images photographed by this camera on the road.

## FUTURE DEVELOPMENTS

The advantage of this headlamp-based vision system is that one and the same sensor can be used to obtain much more data, which can in turn be used for further tasks. Examples of this include drowsy / inattentive driver warning systems, lane deviation warning systems, vehicle distance warning systems and position-regulated speed control systems (ACC) [10].



**Figure 6.** Examples of video images taken with Hella's headlamp-based vision system.

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