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Concept of an Intelligent Adaptive Vehicle Front-Lighting Assistance System

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***Abstract*— for many of the drivers, the keys to a car are the keys to independence, but for some of them they are also the "key" to serious injuries. In Europe, road accidents are considered as one of the main causes of death of people under 45 years of age. They number about 1,700,000 accidents, causing over 40,000 deaths and more than 1,300,000 injuries each year[1]. More than 23% of these traffic fatalities had occurred due to bad visual acuity at night as well as adverse weather and road conditions. This paper presents a concept of an intelligent front-lighting system, which can adapt its light distribution according to the changes in the traffic conditions. This system tends to achieve an optimal illumination of the traffic space by avoiding glaring the other road participants and creating the conditions for an optimal visual perception to the driver.**

I. Introduction

The investigations of the European Road Safety Action Programme 2003-2010 show that the high number of car crashes can be reduced by 50% through three approaches:

1) Encouraging users to behave in a safe manner, through training, penalty and harsher policing.

2) Improving road infrastructure.

3) Making vehicles safer through improved active and passive safety measures and technology.

The focus of this contribution lays on some aspects of the third approach, and more preciously of the improvement of the driver's visibility conditions.

A. Safety and Lighting Technology

Good vision is very essential for driving safely. The investigations show that more than 90% of the information that humans perceive is perceived by vision. In typical traffic situations the contrast sensitivity and visual acuity as well as the speed of perception and danger recognition are strongly dependent on the ambient light distribution. We all experience, due to daytime, weather conditions, etc., changes in our vision indicators that may be a concern, and that may include difficulty of reading signs or identifying objects at short distances, difficulty of seeing lane and pavement markings, other vehicles, and pedestrians, and as well as difficulty of seeing at night due to the glare of other vehicles' headlamps. One of the most important tasks of modern automotive lighting technology is to support human perception at night and under adverse weather conditions. Nowadays, headlamps allow the driver to choose between dipped beams, main beams and fog lights depending on his judgment of the traffic situation and environmental conditions. Since these conditions change permanently, the driver's attention is required for adapting the light distribution. An ideal lighting system would perform this adaptation automatically, taking into account information on the present traffic and environment situation as well as information on the drivers' individual vision performance [2].

B. Light Based Driver Assistance Systems (LBDAS)

One emphasis within the development of safety- DAS for increasing the active safety of a vehicle is put on the area of lighting technology. False or missing adaptation of driving speed to visibility is one of the main parameters that cause failure or accidents. To improve safety, the automotive industry is looking into other ways of providing the driver with a clear picture of the road ahead. New developments like the Adaptive Front-Lighting System (AFS) can improve the illumination of the road in front of the vehicle by offering the driver an optimal light pattern in nearly every situation. The AFS headlamps split the low-beam function into four different light distributions: a country light, a town light, a motorway light and an adverse weather light [3]. Furthermore, dynamic and static bend lighting enables better illumination of curves and crossings.

Fig. 1. Examples of adaptive light distribution (source: Hella KG)town light (top left), dynamic bend light (top right), static bend light (bottom left), motorway light (bottom right)

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Another LBDAS is Brake-Force-Display system, which indicates the following cars how much the own car decelerates. This is realised by the help of an adaptive brake light with illumination areas varying in size. The following cars can thus react faster on hard braking maneuvers; therefore, the danger of collisions is reduced.

The proposed development in this paper aims to introduce a system that generates an optimal light distribution that prevents the glaring of other road users (glare-free high-beam) and marks hazard potentials. This merges the automotive front-lighting technologies with other driver assistance systems that aid the driver to avoid dangerous situations such as lane departure warning, night vision or automatic collision avoidance concepts. The main difference to other driver assistance systems lies in the fact that here, all information is presented in the outside of the car. The driver is not distracted from the surroundings, e.g. by any additional display, but acquires the important information very naturally.

Figure 2. Glare-free high-beam light distribution

II. SYSTEM CONSTRUCTION

A simplified form of the system construction is shown in figure 3. The system is shaped according to the flow of information. Firstly, both internal and external sensors are needed to monitor the vehicle states and the environment in the vicinity of the vehicle. Then the acquired information must be processed. Among others, this involves disciplines such as object recognition to gain the necessary knowledge about the vehicle's surrounding and driving dynamics calculations to take into account the vehicle's state. In the central information processing, all the data collected by the sensor systems is analyzed, sorted and interpreted in order to gain knowledge about the environment in the vicinity of the vehicle and the vehicle states. Merging all-important data from these areas gives us the system's internal representation of the current situation. Then an appropriate strategy has to be chosen for the given situation. The strategy includes information on which objects to blind out or mark and how to do so (Figure 2). Finally, the chosen strategy is applied to the projected situation and the desired light distribution is calculated.

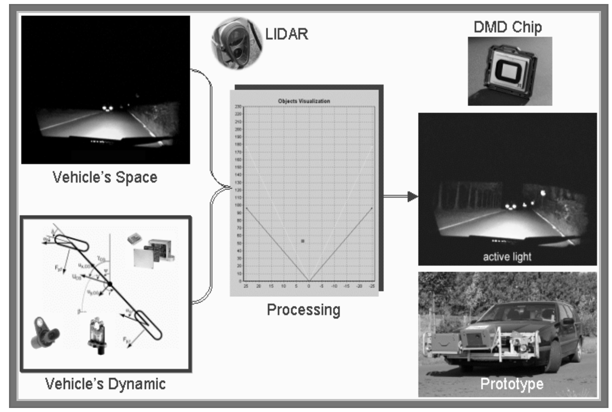

Fig. 3. System Structure

A. Vehicle's Sensors

Sensors are widely used at many places in the vehicles and play as a corner stone for all the driver assistance systems [4]. The vehicle's sensors can be classified as internal and external sensors. There are many applications for the internal sensors for example, engines have a set of sensors to measure various engine parameters; there are sensors used in the air conditioning unit, anti-lock brakes, power steering, exhaust units, transmission unit, suspension system, anti-skid mechanisms, safety systems, distance sensing, and navigational systems. On the other side, the external sensors or remote-sensors are used to detect the presence of the objects close to the vehicle and to give information about the vehicle's traffic space. The remote sensor is any device that collects data about real-world conditions. The processing computer receives data from the sensor as input, makes a decision, and sends commands to vehicle subsystems to help prevent an accident, mitigate its severity, or protect the vehicle occupants. Intelligent safety systems will require different types of sensors for different applications, and in some cases, multiple sensor types for the same application. Figure 4 shows some examples for different types of state of the art remote-sensors. Currently, three remote-sensors are being under investigation to implement the proposed system.

1) Vision- and image-based sensor

Cameras play an important role in intelligent safety systems. Rear view enhancement is a common implementation of a vision-enabled application. A high-resolution vision camera assists a driver in parking and backing up by providing a clear view of the area otherwise not visible directly or in the mirrors. What the automotive industry needs are automotive-specific cameras that meet the requirements for automotive safety [5].

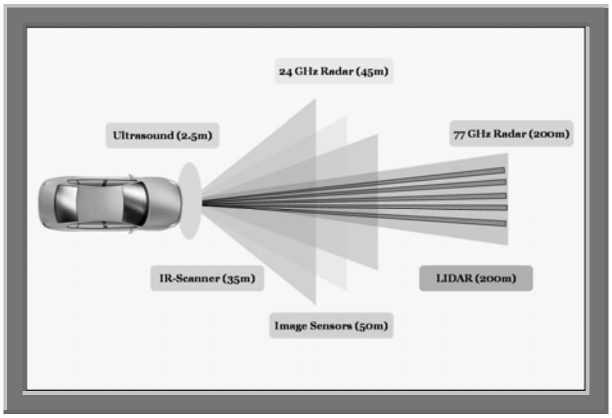

Fig. 4. Remote-Sensors

Unlike traditional cameras that use film to capture and store an image, digital cameras use a solid-state device called an image sensor. These fingernail-sized silicon chips contain millions of photosensitive diodes called photosites. In the brief flickering instant that the shutter is open, each photosite records the intensity or brightness of the light that falls on it by accumulating a charge; the more light, the higher the charge. The brightness recorded by each photosite is then stored as a set of numbers that can then be used to set the color and brightness of the image's dots. The digitized image can then be processed, displayed and searched for recognizable features using a model-specific filter. Maximum-response locations are used as the initial search points for the model-matching process, possibly supported by other features such as shape, symmetry or the use of a bounding box. In principle, image-processing techniques are being be used to give information about the presence of objects at close ranges, i.e. less than 0.3 m and up to 50 m.

2) Micro-wave RADAR sensor

RADAR is an acronym of RAdio Detection And Ranging. The radar device emits a microwave signal and detects the arrival of the reflected signal. Target objects reflect the microwave, and the elapsed time between emission and return is a function of the distance of the object from the radar device. The speed and direction of a moving object can be determined by analysing the shift in the frequency of the microwave signal (Doppler Effect). The use of microwave radar sensors for obstacle detection in the near vicinity around the vehicle has advantages in special situations like bad weather, poor visibility or harsh environmental impacts like ice, snow or dust coverage. Two microwave sensor technologies have been investigated and become well accepted and established in the automotive industry. 77-GHz technology has been developed to cover a long-range observation area in front of the vehicle up to a maximum range of 180 m at a narrow opening angle [6].

Fig. 5. RADAR sensor

3) LIDAR

The LIDAR (Light Detection And Ranging) sensor is a modern opto-electronic measuring technology based on the principle of measuring the time of flight. LIDAR is a low-cost alternative solution for the Radar Sensor. On the basis of the known propagation rate of light in the given medium, it is possible to calculate the distance to an object throughout the measurement of its runtime. A short infrared light pulse with a high peak pulse power is generated by a laser diode transmitted in the direction of the object. The distance to the recognized object and its speed can be calculated based on the runtime of the reflected signal. To achieve high lateral resolution and a wide horizontal opening angle, the LIDAR sensor has been designed as a multi-channel device. LIDAR has 16 horizontal channels cover 16° horizontally and 3° vertically. The practical detection range of the Lidar sensor is up to 150 m with resolution 0.1 m [7].

Figure 6. LIDAR sensor

B. *Advanced Headlamps*

Conventional headlamp modules do not fulfill the demands and prerequisites to generate assisting light functions. Therefore, new concepts have to be developed and evaluated. In the following section two active headlamp concepts will be presented and their functional principals will be explained.

1) *DMD (Digital Micro-mirror Device) Headlamp*

The core of a DMD headlamp is an array of micro aluminum mirrors that reflect the light of a high intensity light source.

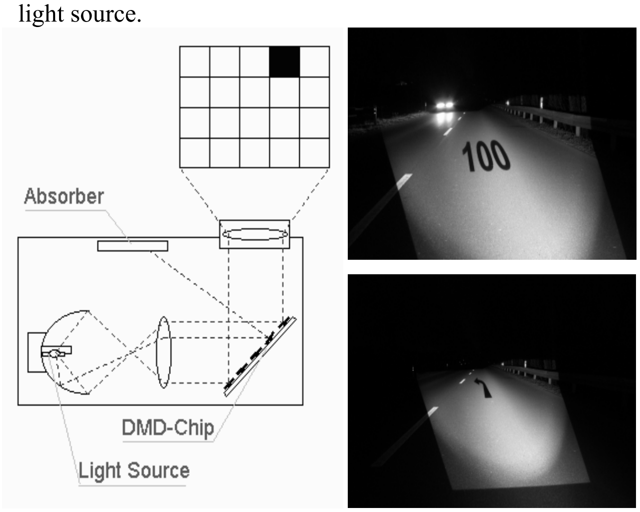

Fig. 7. Left: Working principle of a DMD headlamp. Right: Light distribution with display function.

Such a micro-mirror array is composed of hundreds of thousands of mirrors with an edge length of about 13 µm mounted on small hinges atop a CMOS device [8]. The individually addressable mirrors can be tilted between two positions. Either the light is directed through a projection lens to illuminate a target area or it is guided towards an absorbing surface (Figure 7). Therefore, a DMD device allows the generation of a picture consisting of light and dark pixels. Installing such a device as a headlamp not only allows the generation of a large variety of light distributions, it also permits the display of characters and symbols on the street, as shown in Figure 7.

2) *LED-Array Headlamp*

In contrast to DMD, the LED-array headlamp does not need moving elements to generate different light distributions. Instead, the light sources are addressed directly. The light distributions are generated by creating an image of a matrix of LED-chips. The possibility of individually controlling each LED-chip of the matrix allows the generation of different shapes of light. Activating or deactivating single LED-chips of the matrix can easily realize assisting light functions; for example a glare-free high-beam function could be generated by switching off one or several of the LED-chips that illuminate the area of the oncoming traffic.

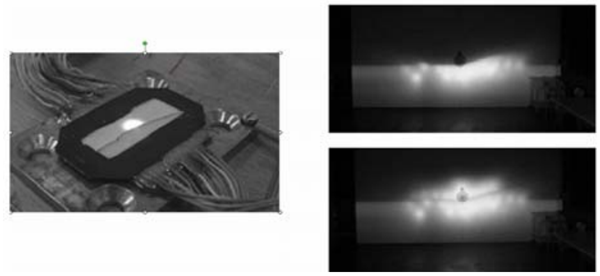

Fig. 8. Left: LED-array. Right: Exemplary low-beam and high-beam light distribution generated with the LED-array.

Using a PWM (Pulse Width Modulation) principal to drive the LED-chips makes it possible to produce different levels of brightness, which enable us to adjust the light intensity according to the road illumination. Activating single chips that contribute to the light distribution above the cut-off line could be used to realize a marking light function. Figure 8 depicts an LED-array prototype as well as a low-beam and high-beam light distribution generated with this array. The possibility of separately controlling the brightness of each LED-chip of the matrix allows the generation of driver-specific light distributions.

III. Conclusion

The concept of an active front-lighting driver assistance system has been presented, which produces an optimal adaptive light distribution without glaring the other road participants and marks probable hazard potential objects. Its functional structure and components have been shown and considerations about the sensors, the advanced headlamps have been developed.

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