Driver Assistance Systems Based on Image Sensors

Image sensors have a good chance of becoming established alongside radar and laser-based sensor systems. They facilitate the optical detection of objects and features in traffic space which can be detected only with great difficulty or not at all using other physical sensor principles, putting them in a position to provide effective support for assistance systems of the next generation. This article by Hella KG Hueck & Co. explains the sensor characteristics as well as possible future applications in some detail.

1 Introduction

The importance and the share of automotive safety systems on the one hand and systems providing more comfort and convenience on the other will significantly increase in the next few years. Sensors for measuring data in the vehicle environment are the first links in the signal processing chain in all such systems. This results in two new challenges: the measurement of physical parameters outside the vehicle...
system and, often inevitably linked with this, the use of innovative sensor concepts. With the aid of image-producing sensor technology and mechanical sight, pictorial features describing the infrastructure can be detected in traffic space. Optical sensors from Hella already used in standard vehicle models, such as rain or light sensors, form the optimum basis for integrative and functional expansion through future image sensor concepts. Expertise in the field of optics, synergies within electronic and software development as well as a thorough understanding of integrative questions are essential pre-requisites for survival in the automotive product market of future optical-image-producing systems.

Figure 1 illustrates the basic topology of future driver assistance systems. A distinction is made between the long-distance range > 100 m covered by 77 GHz radar or infrared lidar systems for functions such as Adaptive Cruise Control (ACC), the mid-range up to 50m and beyond covered by image-processing methods for functions such as Lane Departure Warning or night vision, and a close-up range covered by 24 GHz radar or infrared scanners for functions such as stop & go, automatic emergency brake, pre-crash, recognition of the blind angle and parking assistance.

Figure 2 classifies the image sensor applications according to customer functions, complexity and possible moment of use: the entry functions are comparatively easy and cover conveniences requirements. After this the driver assistance functions develop into safety-related networked functions, on the one hand increasing the complexity of the algorithms and on the other making the data fusion of several measuring principles necessary.

2 Lane Tracking: One of the First Applications of Image Sensors in Driver Assistance Systems

The first image sensor applications in passenger vehicles are rear-view camera, night vision and lane tracking. Whereas with the first two of these image reproduction for the driver and ergonomic marginal conditions are at the fore, the last mentioned feature manages without image representation. In this last case, image analysis and the transparent application for the driver with regard to the function are at the fore.

Figure 3 illustrates the most important features of a lane tracking system:

- The sensor captures the environment in front of the vehicle. Accuracy and stability in a wide range of different light and weather conditions are the most important features of the image quality. These are mainly determined by optical and image sensor chips.
- Integration in the vehicle. Optimum fulfilment of the customer function with aesthetic integration and a structure and connection technology which is as reliable as it is economical are the main design objectives.
- The algorithms of image processing mainly characterise the application. These will be explained in the following in more detail.
- The interface to the driver completes the customer function. It is here that the largest share of customer-related differentiation can be found.

3 Sensor Features

For applications with a view forwards, the obvious place to install such sensors is behind the wiped area of the windscreen. On the sensor side, there is a lens unit and design measures to reduce stray light situated in front of a CMOS image sensor chip. Primary design parameters determined by the application(s) are mainly the alignment of the optical axis, the horizontal and vertical aperture angle and the sensor resolution. The spectral sensitivity of the image sensor, the high variability of the spectral distribution of the light in the environment to be recorded (sunlight, artificial light at night) as well as the transmission behaviour of the windscreen must all be taken into consideration for the optical design. Depending on the sensitivity of the sensor and the aperture chosen, sufficient exposure must also be ensured at night.

Figure 4 and Figure 5. The type of dipped beam light source used for illumination of the scenario (halogen or gas discharge bulb) has a decisive influence on sensor exposure due to its different spectral distribution. Situations at night in particular make it clear that the performance of a driver assistance application based on image sensors is determined by the limitations with regard to the prevailing visible conditions. Thus, for example, the viewing distance for lane tracking at night without an additional IR light source is limited to the range achieved by the dipped beam light. Furthermore, detection of neighbouring lane markings in the dark in scenarios with more than one lane often causes problems, resulting in limited performance when changing lanes and putting the search areas for image processing into practice. On the other hand, some conditions for feature detection are better at night, since the retro-reflecting property of the markings at least supplies good image contrasts and prevents the occurrence of shadow situations. One point often discussed in connection with the physical radiation properties of sensors for automotive use is the demand for sufficient dynamics. Since extreme exposure situations can often occur extremely quickly (for example, shadow situations in a tree-lined avenue at high vehicle speed), the required high grey value dynamics must be related to each individual image frame. Last but not least, the whole camera unit is subject to great temperature influences, which result in fading images in the image sensor chip and material expansion with corresponding optical effects in the imaging unit.

Figure 6. A sturdily designed image processing system can tolerate such effects up to a given limit depending on the application involved, since the image has been intended for pure image processing and does not have to fulfill the visual requirements of a human observer.

4 Lane Departure Warning

Unintentional lane departure is one of the most common causes of fatal accidents. The reasons for this vary, and include distraction of the driver and excess speed, to give only two examples. A system that detects the position of the vehicle in relation to the lane markings and compares this with the expected driver intention, which can be determined by means of changes in steering angle, activation of the indicator light and brake pedal, can provide additional information to the driver in critical situations and give a warning. Such lane departure warning systems are already available in the commercial vehicle sector and will enter the passenger car sector in the next few years. Initially, such systems will primarily be used in well-structured scenarios with those road markings already available. White lane markings as pictorial patterns allow reproducible and advantageous recognition using appropriate image processing operators. This requirement of solid feature recognition must not be underestimated, and guarantees successful image processing in a wide range of different lighting and weather conditions. Edge-based image processing operators measure the positions of the lane markings at different viewing distances. Figure 7. These are entered into a model-based tracking using a Kalman filter process.