A STUDY OF VISION BASED VEHICLE INTELLIGENT FRONT LIGHT SYSTEM

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Abstract—Vehicle intelligent front light system is one of the advanced driver assistance systems. Vision based intelligent front light system is currently the research focus in this field. The purpose of this paper is to present a comprehensive survey of the vehicle front light system development and the latest vision based key technologies and proposals. By analyzing the significant disadvantages of traditional intelligent light systems, some possible improvement proposals and algorithms for lane, vehicle lamp recognition and track are provided. This survey shows that the Matrix-LED system could make the system more flexible and more effective and vision based vehicle intelligent front light system can improve the driving environment for the ego driver and other road users at night.

Keywords—Vehicle intelligent front light, Matrix-LED, Lane recognition, Light detection.

I. INTRODUCTION

ADAS (Advanced Driver Assistance System) which acts as an assistance for the driver while driving has been a popular research focus of many car manufacturers, universities, research institutes and companies. Many kinds of ADAS systems such as ACC (Autonomous cruise control), CACC (Cooperative Adaptive Cruise Control), LDW (Lane departure warning), FCW (forward collision warning) [36], BSS (Blind Spot Information System), AFS (Adaptive Front-lighting System), PCW (Pedestrian Collision Warning), V2X (Vehicle to X), Start/Stop system have been presented. With the assistance of these new systems, both the inside and outside driving environment would be greatly improved. Nowadays, many of them are already adopted by vehicles and some are being tested in the real road conditions. However, only the general functions of them have been realized. There are still many key technologies which need to be ameliorated. Among these various kinds of intelligent technologies, the intelligent front-lighting system which aims to improve the illumination conditions and reduce the accident rate at night is the main topic of this paper. The paper can be divided into five sections. Section one explains the general background and introductions of intelligent technologies of front-lighting systems. Section two details the development of intelligent front lights. Section three and section four present the main proposals and algorithms of lane and light detection track respectively. And conclusions about the survey of vehicle intelligent front light system are made in section five.

II. DEVELOPMENT OF INTELLIGENT FRONT LIGHTS

The vehicle lamp has been developed from the original incandescent lamp to halogen lamp and HID (high intensity discharge lamp) during the 20th century. Nowadays, halogen lamp and high intensity discharge lamp have been widely utilized in all kinds of vehicles. Meanwhile, as the LED (Light-Emitting Diode) vehicle lamp matures, it is increasingly being used. Because LED lamp has energy saving, flexibility, high efficiency characteristics, choosing it as vehicle front-light lamp is a trend. At the same time, the intelligent lighting system has been changed from static illumination to AFS and up to various kinds of intelligent lighting control systems. The AFS adjusts the movement of traditional
front lamps both in horizontal and vertical levels. The illuminated areas in front could be changed automatically according to the vehicle conditions. The lamps adaptively adjust the horizontal illumination area to the left/right front area of the roads while turning left/right and revise the vertical lighting level while the vehicle is in ramp road. In general, the traditional AFS has experienced three generations, the static curved road illumination, the combination of following lighting and static curved road illumination, and the multi-function illumination which includes the basic mode, curve road mode, highway mode, town mode, village mode and rainy day mode. At the very beginning, the AFS captures various kinds of driving conditions such as vehicle speed, steering wheel angle, front/rear axle loads, ambient light intensity, visibility and the road conditions (dry, wet, fog), etc. Due to the limitations of these sensors, this kind of AFS has some main shortages. In some situations, the light distribution of the front lamps will not be spread on the street, where the driver needs. As seen in figure 1, at the beginning of a curve because the AFS only starts horizontal distribution adjustment 1 or 2 seconds after entering the curve, the beam shines straightly forward rather than to bend along the curve [1]. In this short period, the curve area is not well illuminated and the driver could not well concentrate on the curve, which is dangerous and may cause uncomfortable to the driver. Also, as shown in figure 2, in the end of a curve, because the steering wheel is not yet back to the middle position, the beam still bends into the left side while the lane in front is already straight or extending to the right [1]. In this scenario, there is response lag as well.

Figure;1. Beginning of a curve and end of a curve

Additionally, the traditional AFS focuses on the low beam adjustment and considers less on the glare of the high beam to other road users. In order to overcome the curve response lag disadvantages, AFS combines GPS (Global Positioning System) to form the prediction AFS, which can predict various kinds of driving conditions ahead. In this way, the system could realize different kinds of illumination area distributions and precisely provide better illumination for the driver. And, in order to improve the utilization of high beam and avoid glaring other road users, some kinds of proposals have been presented to avoid glaring other vehicle drivers in front. The AHC (Adaptive Headlamp Controller) is a system which can detect the front vehicles and automatically switch between high beam and low beam according to the front vehicle information. If there is a vehicle in front, the low beam is switched on. And if there is no vehicle in front, the high beam is switched on. In this way, the driver operation fatigue could be avoided, the high beam usage in crowded roads could be increased and the driver safety is improved. However, as described in figure 3, when the high beam is deactivated, there is a dark area between the cut-off line of the ego vehicle lights and the front vehicle [1]. The obstacles in this area are not effectively illuminated and can be missed.
Also, there are some other kinds of prediction AFSs which use vision or infrared sensors to detect the obstacles and pedestrians at the crossroads and corners. But due to the low accuracy of GPS in the intensive building areas and the complex of distinguishing pedestrians, vehicles and obstacles, these kinds of AFSs have not been widely used. Nowadays, many car makers and auto parts manufacturers have quoted the traditional kinds of AFSs in their mid-class and high-class vehicles. And prediction AFS is the hot research topic for them. The leading companies include BMW, Mercedes-Benz, Audi, Opel, Volkswagen, Hella, Bosch, Valeo, Denso, Koito and Viston. Meanwhile, BMW, Mercedes-Benz, Audi, Opel, and Volkswagen are developing the Matrix-LED based intelligent front-light lamps [5], which can be seen in the latest Auto shows worldwide. Combination of AFS and Matrix-LED is the development trend of intelligent front lighting system in the future. By using Matrix-LED lamps, the beams can be generated as a single main beam or separated beams. When the camera behind the windshield detects other vehicles in front, the relevant LEDs could be statically switched off or the beams that are responsible for these areas should rotate some degrees to avoid glaring the drivers in the front vehicles. In this way, the main beam could be much more energy efficient. And the illuminated areas in every kind of driving condition would be more perfect, which could enhance driver safety and comfort. Audi adopts the continuous illumination distance function in the Audi A8 2010 model. This auto model utilizes a new camera to identify the brightness ahead, detect and classify the head lights and rear lights of the front traffic and recognize the distance between ego vehicle and the front vehicle, thus to continuously adjust the illumination area between low beam and high beam according to this distance. In this way, without glaring other vehicle drivers, the illuminated area could be as large as possible if permitted. If there is no vehicle in front, the illumination area could be increased to the high beam mode. And if other cars are near to the ego car, the area will be in the low beam mode. In the latest 2014 model, as seen in figure 4, a new Matrix-LED based front lighting system is to be presented. The horizontal illuminated areas can be separated by switching on/off or dimming different LED lamps to form different light shapes as showed in figure 4. It can also be connected with the GPS to perform different kinds of illumination modes according to the road conditions.

Figure 3. Dark area between high-low beams
Opel's Astra series of auto models apply the Matrix-LED showed in figure 4 as the front head lamp. Also, the ambient brightness is detected by the camera behind the wind shield. And the brightness, shape and area of the front light can be automatically adjusted accordingly. If the vehicle enters into a tunnel, the front light will be switched on. When a car is oncoming, the lamps irradiated on the front car will be dimmed and lowered and the other lamps will be kept at the same bright level. The pedestrians and animals could also be recognized as well. After passing, the front light is illuminated as large and bright as possible. In this proposal, all the matrix areas in front could be fully range adjusted. This Matrix-LED technology might be implemented in all Opel auto models in 2015.

III. LANE RECOGNITION AND TRACK

Based on the current technology level, the reliability of the vision detecting system in vehicle is mainly influenced by the factors such as shadows, weather, and intensity of the illumination. Specially, in night situations, the valid image is more difficult to fetch due to the front and rear lights of vehicles, reflections of constructions and wet roads, etc. The algorithm for the nighttime implementation would be much more complex and very challenging. Basically, according to different recognition algorithms, vision based lane recognition methods can be divided into region segmentation feature, model 3D vision multi sensor merging based methods etc.

Region segmentation based method usually the region segmentation based method evenly or non-evenly divides the interested region into several small rectangular windows. The interested windows that include lane information can be picked out as showed in figure according to the contrast information.
After that, the lane markings in each interested window can be linked together to generate the stepped lines. Thus the lane characteristics in the interested area of image can be described by these stepped lines so as to form the final lane markings in figure 5. This method could describe every kind of lane markings including straight lines and curves and has good flexibility. However, some artificial noises might be added during the region segmenting. Feature based method the feature based method may detect the lane markings by the start points of lane boundaries, the forward trend, the gray values, etc. Based on this information, the lane can be presented as some possible lane vectors. In these vectors, the vector that has the lowest distance from the former vector can be selected to best express the lane trend, so as to confirm the lane boundary. This means has lower calculation time and good real time performance, but can only be adopted in the optimal lane marking areas as it often fails when the interferences are bigger.

![Feature based lane marking detection](image)

Figure; 4. Feature based lane marking detection

Also, the Hough transform method could be used to pick out the straight lines from the preprocessed image so as to determine the final lane boundary. This method could largely reduce the processing time and increase the real time performance. But it does not work well in the shady or broken lane situations. Model based method cites parabola B-snake even triangle model to express different lanes. After detecting the basic edge of lanes, a model curve with to-be-determined parameters is provided to express the actual lanes. The parameters of this curve are adjusted to optimally match the lanes. The curve with the best parameters is the one that is picked out to describe the lane. But if the number of control points of the curve is big, the processing time might be quite long. 3D-vision based method All the above methods are based on the assumption that the road plane is flat. However, the road is not flat indeed. So some 3D-vision based methods which can detect the 3D models of lanes and calculate the parameters of them are recommended. Usually, the 3D-vision based method uses the stereoscopic sensors [6]. Both images of the stereoscopic sensors should be matched to generate the real global model of the road lane.

![Lane tracking](image)

Figure;5 lane tracking
If the 3D map of the road lane is constructed, tracking the lane would be much more convenient. Certainly, more processing time is needed and the algorithms might be much more complicated since the models are more complex and more additional parameters should be estimated. [7] Multi sensor merging based method Also, more sensors can be applied to the vision system to strengthen the performance of the lane detection. For example, with the help of GPS information, the road information can be firstly confirmed. And then the front lane mark trend could be predicted, which can be used to insure or modify the basic lane recognition result. In the near future, the communications between the ego vehicle and the surrounding environment would be implemented. In this case, the vehicle can get the front lane information from the infrastructures or from the front vehicle. The vehicles in a small area could calculate and share their information with others. In this way, the processing time of each vehicle might be largely reduced and the real time performance would be improved.

IV. CONCLUSIONS

In this paper, a comprehensive survey of vehicle intelligent headlight system development is presented. Many factors such as road geometry, road conditions (intense light, wet, fog) or glare from other light sources (vehicles, road and structure reflected lights, lights along the road) may cause reduced illumination range or uncomfortable feelings for the drivers in ego vehicle and other vehicles, which may lead to traffic accidents. An optimal vehicle intelligent headlight system should take as many parameters from the ego vehicle and the surround environment as possible into consideration and be able to adapt on many kinds of driving conditions to provide a maximum illumination area of the street for the driver, without glaring other road participants. By investigating the development of vehicle intelligent front lights, discussing some latest key technologies and algorithms of lane detection and vehicle light detection and providing some possible proposals we come to the conclusion that the Matrix-LED system could make the system more flexible and more effective and vision based vehicle intelligent front light system can improve the driving environment at night and. However, this kind of system is still a challenging task for many car makers and auto parts manufacturers.

REFERENCES