Automotive Adaptive Front Light Systems for Road Safety

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Abstract: Road safety is a growing concern. The Adaptive Front-Lighting System (AFS) is one part of the Active safety system. AFS system aims at automatically adjusting the headlight beam to illuminate the road as much as possible without causing any discomfort to the driver and oncoming drivers. The proposed system “Automotive Adaptive Front Light System for Road Safety” focuses on building a prototype of adaptive front lighting system that improves the night time illumination of the curved roads to the driver and reduce the glare for the oncoming drivers. In this proposed system, unlike the traditional AFS which uses steering wheel angle for the headlamp’s horizontal adjustment, a camera is used as image sensor to detect, capture the details of the curved road ahead of the vehicle and adjust the headlights horizontally to illuminate the curved road. As a result, a suitable light beam with improved road illumination is obtained for the curved roads. To prevent glaring to the driver of the oncoming vehicle, vertical adjustment of the headlights is required. Ultrasonic sensor is used to detect any oncoming vehicle and adjust the headlights vertically. Thus, it prevents glaring to the driver of the oncoming or the front vehicle and make driving more comfortable. The horizontal or vertical movement of the headlamps is done by using stepper motors unlike the present AFS systems which uses the servo motors. As a result cost of the overall system is reduced. But at higher loads step-loss or stall of the motor can occur. Using an encoder or additional sensors to detect the step-loss or stall in the stepper motor increasing the complexity and cost. So a sensor-less closed loop algorithm is designed in this proposed system to detect the step-loss and stall in the motor.

Keywords: AFS, Camera Based Image Sensor, Ultrasonic Sensor, Stepper Motor, Step Loss and Stall Detection.

I. INTRODUCTION

As the automobile industry developed over the years, there was a great increase in the number of vehicles resulting in the increase in the number of road accidents. Road accidents at night time are more serious and result in more fatalities. In the research, it was found that approximately 60% - 70% fatal vehicle - pedestrian accidents take place at night time. Poor visibility or improper illumination of the roads at road corners, curves and of surrounding area results in accidents. The main cause of most of the accidents occurring at night time is generally the driver fails to see the obstacle or the pedestrian and react in time or apply brakes in time. With the increase in human age the light requirement to the eyes also increases. A youngsters or an adults eye requires more light compared to a child to do a same task. Therefore, proper illumination is a very important task.

The headlights are very important and play major role in the driver’s visibility and safe driving. Headlight assembly in automobiles serves two major functions a) housing the headlights and b) projecting the light with a standard pattern by reflectors so as not to cause glare. The fixed head lighting create blind spots at the road corners while turning and it also limits the driver’s sight to the emitted light beam range. Based on this problem, the AFS system was developed. Adaptive front-lighting system (AFS) is an active driving safety enhancing system which can automatically change or adjust headlights for different external conditions or factors such as road conditions, driving conditions and weather conditions etc. AFS relies on transducers, electronic sensors and actuators, unlike earlier directional headlamp systems that used the steering angle or other mechanical linkages.

Headlights with AFS illuminate the curve of the road when the vehicle is turning at the curved road. Comparison of headlamp light distribution patterns with AFS and without AFS shows that the headlamp without the AFS do not make the full curved road illuminated which blocks the driver from detecting any pedestrian in the way of the vehicle. The headlamp with AFS is able to illuminate the curved road fully which as a result does not block the driver from detecting the pedestrian in the way of the vehicle. The driver will be able to detect the obstruction before time so that accidents can e be avoided.

This paper proposes an automatic adaptive front-lighting system based on camera sensor which is better than the traditional AFS which were dependent on the steering wheels for the adjustment of the headlights. This new kind of AFS uses image recognition technology to gather the curved road or corner details in advance from a certain distance. Then it adjusts angles of the headlights in advance based on the details obtained by the camera sensor. This will lead to proper illumination of the curved road surface. This way, it can adapt to curved road condition in advance through camera sensor without any need for the calculation based on the steering wheel angle sensor. Another main drawback of headlights is glaring. Glaring is the discomfort caused by bright light of the headlight temporarily. The proposed system uses ultrasonic sensors to detect the oncoming vehicle and then adjust the headlamp vertically to prevent glaring. As a result, the new AFS system is able to prevent the glaring to oncoming drivers and improve the road illumination at curved roads in advance automatically unlike the traditional AFS system. The control the horizontal or vertical movement of the headlights, servo motors are used presently. In this paper, stepper motors are used
instead of servo motors. Using stepper motors reduced the cost of the overall systems as servo motors are costly compared to stepper motors. But the major advantage of servo motors is it contain inbuilt feedback mechanism for motor positioning and motor positioning is an important criteria of AFS. In this proposed system this advantage of servo motor is added into the stepper motor by designing a sensor-less algorithm which operates in closed loop.

A lot of work and research has been done in improving the headlights of vehicles so that the night time driving can become more safe and comfortable. In the earlier days headlights with acetylene oil were used and then electric headlights were developed. After this came the headlights with high and low beams. Then the halogen headlights were developed followed by the xenon lamps and the high intensity discharge (HID) systems and more recently the LEDS were introduced. The automatic systems for headlights developed and became available since the 1950s originally only on the luxury models. Beginning in the 2000s, there was a change in interest in the idea of moving the headlight beam in response not only to vehicular steering and suspension dynamics, but also to ambient weather and visibility conditions, vehicle speed, and road curvature. Manufacturers such as BMW, Skoda and Toyota have been working on AFS.

The work proposed by C K Chan, K. W. E. Cheng, S.L. Ho, and T. M. Fung [3] is based on the traditional AFS system which adjusts the headlights in horizontal direction according to the steering wheel angle, the pitch and adjusts the headlights by detecting the vehicle in front. They have also worked on the leveling of the beam according to the load in the vehicle. In the work of Yali Guo, Qinmu Wu and Honglei Wang [4] the motion models of headlights are established and turn angle of the headlights in horizontal and vertical direction can be calculated by mathematical equations the design of the system is put forward. Hardware and software of the intelligent headlamp control system is designed. Control algorithm uses the fuzzy control, and fuzzy controllers are designed. In [1], work aims to design and build a prototype of steerable headlights by adapting a conventional static headlamp. Literature [6] analyzed photometric characteristics of vehicles headlights when turning the corner, and developed a new kind of AFS (Adaptive Front Lighting System) based on CCD (charge – coupled device) which was better than traditional AFS. In [8], a closed loop operation for stepper motor was designed by using encoders and sensors. But this increases the overall cost and complexity of the system

II. SYSTEM OVERVIEW

The proposed AFS system consists of basically the sensor blocks, controller block and the actuator or stepper motor block. The sensor block provides the input to the system which is then processed by the controller and then the output is obtained in the form of actuator movement driven by the stepper driver.

![Figure 1: Basic Block Diagram of System](image)

In this paper, the proposed system focuses on adaptive front lighting systems using sensors which enhance driving safety at night time. When a vehicle is coming near to a curved road, the camera captures the condition of the road within its range. Image recognition and image processing is done on the captured image and details of the road curvature are obtained, that is, the slope of the white line on the road is obtained and sent to the controller unit. Then algorithm processing is done on the obtained slope of the white line by the controller. The processed information is sent to drive the motors and adjust the motors at the required angle. The lights are adjusted horizontally or there’s an angular movement of the lights according to the curve of the road. The motors are given a PWM input from controller to move accordingly towards left or right. Due to automatic horizontal adjustment of the headlights at the curved roads, obstacles can be detected in time and accidents can be avoided.

To prevent glaring, vertical adjustment of the headlights is required. Ultrasonic sensor is used to detect the vehicle in front. As a vehicle is sensed in the front, algorithm processing is done on the sensor output by the controller and then PWM obtained from controller is given to the motors as the input. The motors automatically move eventually headlights move accordingly at a certain angle upwards or downwards. Thus, this prevents glaring to the driver of the oncoming or the front vehicle and make driving more comfortable.

The vertical or horizontal adjustment of the headlights is done using stepper motors. At higher loads on stepper motors there may be step-loss eventually leading to stall of the stepper motor. To detect and avoid this, the driver used in this proposed system has Back EMF (bemf) output. Performing continuous load testing on the stepper motor and analyzing bemf value, a threshold value is defined above which there is a step-loss. Thus, the step-loss and stall is detected and accurate motor positioning is achieved.

In the proposed system, TMS570PSFB61 microcontroller is controller (Figure 1) used which is part of the TMSx70 Platform family of microcontrollers.
designed for automotive applications. It has Dual ARM Cortex R-4 as a core processor. It included 1.25MB flash memory, 10 bit 20 channels ADC, serial interfaces, Enhanced High End Timers (NHET). These are few important features of TMS570PSFB61 microcontroller. The NHET is used for PWM signal generation. It is a dedicated processor so it doesn’t use the main controller CPU to generate PWM pulses.

Stepper Motors were selected as they are cost effective and a sensor less algorithm can be designed to get the feedback mechanism for motor positioning. NCV70522 is the stepper driver that is used to drive the stepper motor. It communicates with the controller through SPI. It has SPI control registers, SPI status registers and a SLA output. SLA output gives bemf value based on which the step-loss and stall is detected.

Ultrasonic sensors work on a principle similar to radar or sonar which evaluates attributes of a target by interpreting the echoes from radio or sound waves respectively. These generate high frequency sound waves.

III. SOFTWARE

A. Lane Detection and Slope Calculation:

This paper proposes an algorithm which is the combination of four important concepts:

1. Differentiating various curves (lanes) based on slope of curves. This helps in developing algorithm for tracking varying slopes of lane and develops efficient feedback system for proper localization in between roads.

2. Clustering of Hough lines to avoid confusion due to other lane type noises present on road.

3. Shadow, illumination correction and noise filters implemented on HSV color frame.

4. Feedback algorithm to continuously compare parameters (road texture) of current image frame with previous frame of image to decide boundaries in case of missing lanes and to detect the slope of change of the white line on the road.

B. Closed loop Control of the stepper motor:

This paper proposes a sensor-less algorithm to detect the stall of the motor. The NCV70522 ASIC has a SLA output. From this SLA pin we get bemf voltage value. The step loss or stall on the motor occurs because of the higher load on the motor. So apply different loads on the motor. By analyzing the different bemf values obtained at different load conditions, the threshold value of the bemf voltage to detect the stall of the motor will be decided. The value of the bemf voltage obtained from SLA pin is monitored continuously and if the voltage goes below threshold then the stall of the motor is detected.

Figure 2 shows the general flowchart that depicts the software flow of the whole AFS system. First the road image is captured and then the change in slope of the white line is calculated by performing image processing on the captured image. If there is change in slope of the white line then the controller initiates PWM generation for the control of stepper motor which eventually controls the headlights horizontally. Based on the Ultrasonic sensor output, if any oncoming vehicles are present, then the controller triggers the PWM generation and controls the stepper motor which will move the headlights vertically. Also parallel feedback of the bemf will be monitored so that no step loss or stall is occurring on the motor. If any has occurred then the motor has to be moved to the initial position.

Figure 2: Flowchart Depicting the AFS
IV. RESULTS

Figure 3: Lane Detection Output

Figure 3 shows the lane detection algorithm output. This result is one frame. When this frame is compared with the next frame and if there is change in the angle between the white line then controller generates PWM signals to drive the stepper motor accordingly in move in the horizontal direction based on the angle change of the white line.

Figure 4: SLA Output of The Stepper Motor

Figure 4 shows the SLA output obtained at the NCV70522 ASIC. We have bemf values at every zero crossings of the coil currents. We monitor this value continuously to detect the stall and step loss of the motor. Figure 5 shows SLA output obtained at the NCV70522 ASIC when the motor is stalled. It can be observed that the bemf voltage value is very less. So analyzing various bemf voltage values it is concluded that the threshold voltage is 0.4V.

Figure 5: SLA Output When There Is Stall

V. CONCLUSION

The existing conventional light systems do not provide illumination in the right direction on curve roads. Due to this constrain, a need to understand an alternative technology solution. This paper propose the new system which is based on camera as input sensor to adjust the horizontal rotation of headlamp and this newly proposed Adaptive front lighting system (AFS) helps to improve driver’s visibility at night time hence achieving enhance safety. Also stepper motor is used over servo motors to reduce the overall cost of the system. The future work mainly concentrates on to invent a comprehensive AFS system which can be suitable for complex road conditions including water corner, highway, rural road and urban road and so on. Also since camera is being used, this system can be further extended for IoT solutions. If the cars are interconnected and if cars can communicate between each other then the AFS enabled systems can communicate/alert to the cars without AFS which are coming behind about the curved roads, obstacles ahead.

VI. REFERENCES


