Design of a Modular Beam Control System for Vehicles

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Abstract

High intensity beams enable the drivers to survey a large portion of the road ahead of them at night. These beams are meant for use when there aren't many vehicles around. However, a lot of drivers make use of these beams while driving because of the convenience of having a larger field of view. These beams often result in momentary partial blindness for drivers in the oncoming lane, causing them to become floundered. In such a state, they tend to lose control and cause accidents. In this paper, we propose a novel method to curb such happenings by automating the high beam and low beam settings of a vehicle. For the purpose of this study, we used a custom prototype, which is also discussed in detail. The solution we propose, if developed into a product, would be available as an add-on module, and if implemented appropriately, will reduce the accidents due to headlight glare by an exponential factor.

Keywords

Accidents, Automation, Automobile, Glare reduction, Headlight, High beam, Image processing modular, Road safety.

As opposed to the norm, a vast majority of people prefer to drive with a high beam on, since it gives them a wider field of view. This however, compromises the vision of drivers either directly in front of the vehicle or of those in the opposite lane. Though organizations seem divided on their opinions on the fact whether headlight glare at night is a major cause of accidents, but one cannot escape the fact that the numbers are still significant. Big names in the automobile industry such as Mercedes Benz have come up with technologies to limit the issue.

However, these technologies are, at present, only being offered in high-end cars. With our idea, we wish to make this solution available for most vehicles. The intention is to make the design modular so that the system can be installed on all sorts of automobiles with little to no adjustment (Fig. 1).

The prototype we used for this work involves the use of the Silicon-on-Chip (SoC) computer Raspberry Pi 3B, relay module, camera module Pi-Cam V1, 12-to-5V DC-DC convertor and other peripherals. The SoC was programmed using the python programming language on Terminal Window of Ubuntu Operating System. Also, the OpenCV and NumPy libraries were extensively used.

In the literature survey done, several papers countered the problem in their own ways, the highlights of some of the papers can be summarized as, one paper presented the idea that because there are a lot obstacles or countenance on the road so why should the headlight have a static two-way system so the author gave it an extra angle by controlling the angle of lights themselves (De, 2014). Another paper talked about rather than just using a camera to procure a 2-D image it would use sensors to create a better understanding of the road ahead and around and then use Cartesian coordinates to better calculate the "Mahalanobis Distance", and some further statistical analyzation would choose the direction of the headlight (Gavriilidis et al., 2012). Another paper presented the road simulation work don on Simulink and Lab-View which is one of the most important works done
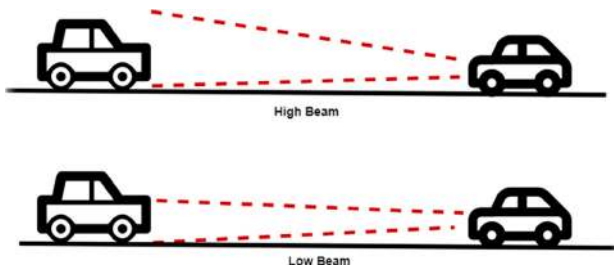
Figure 1: Representation of high and low beam profiles.

till date by using Google 3D warehouse, and multiple algorithms such as 'relevant traffic selection', 'risk estimation', 'pitching' & 'deactivation' (Tideman and Janssen, 2010).

Algorithm

The intensity profile of light coming from the opposite vehicle can be roughly thought of as a closed contour. Lesser the distance of the oncoming vehicle from ours, greater will be the area of contour as perceived by us, and vice-versa. So, we can say that distance and area of intensity contour share an inverse relationship. In order to obtain the intensity profile contour, we first use a camera to capture the image of the oncoming vehicle. We know that an image is nothing but a collection of various pixel values. By using thresholding features, it is possible to isolate those pixels which have high intensity, in our case, the pixels corresponding to light (will have high pixel values). Thus, we get a localized estimate of the oncoming vehicle's position.

The originally captured image and the thresholded image are fed into an AND logic pixel-by-pixel. The resulting image is a black and white image such that white represents the light profile and black represents other unnecessary data or noises. The area of all the different contours in white are found. Of these, the largest area value is used to manipulate the control signal to be sent as an output from our system.

The threshold values, wherever required in the process, were chosen using trial and error method so as to achieve an optimum performance. If the final area value exceeds the threshold value, the control signal sends a "0" value to the relay, which in turn sets the beam profile to "LOW". Once the vehicle passes and the area value goes below threshold, the beam profile is reset to "HIGH" again, if it was being used at all (Fig. 2).

The threshold values may vary with the camera being used, as parameters such as lens size, aperture, pixel density, width and depth of image etc. may vary.
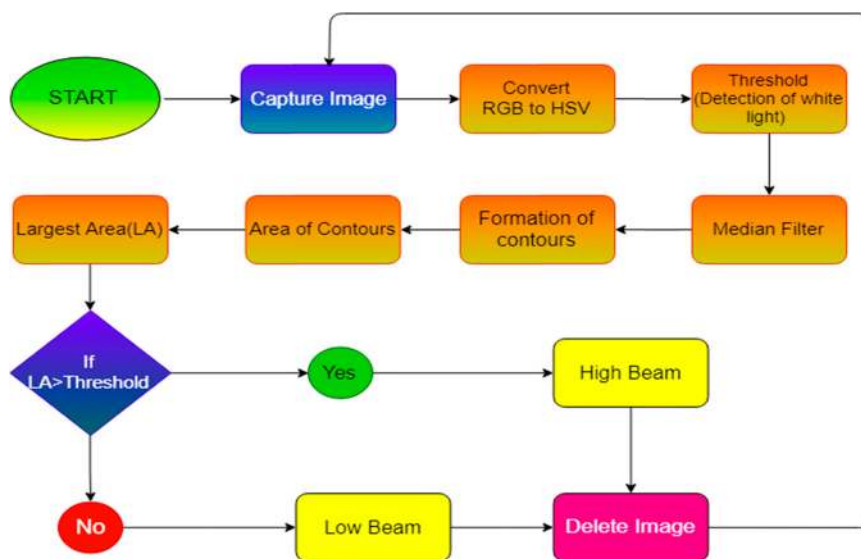

Figure 2: Algorithm for beam control of vehicles.

Implementation

The camera used when in working mode captures images at 32frames/sec, so as to keep all the possibilities in check. The images are fed directly to the code that is permanently rooted into the SoC. The main idea is that headlight should go into the dipper mode on its own, quickly enough so as to be able to handle critical situations. Images are not stored permanently into the memory. Once the processing is done, the images are simultaneously deleted so that there isn't any load of memory allocation. The images fed into the computer will have a threshold value in case the driver hasn't automatically shifted to the dipper system so as to decrease the glare for the vehicle in the front.

From the array of images, the area of white/yellow/blue light is calculated and the threshold is set as required. In order to reduce external noises in the image and to avoid unnecessary data being captured, we made use of a median filter.

The same battery that powers the vehicle's ignition, air conditioning and other electronics is used as a primary source of power for the module as well. The 12-to-5V convertor steps down the primary voltage (assuming our vehicle has a primary battery of 12V; may vary from 12–15V) to a value that can be fed into our SoC (in our case, a 5V signal for the Raspberry Pi board). Through the SoC, the camera, relay boards and cooling fan also get powered.

This product will especially be useful in case the vehicles in the oncoming lane are too huge in comparison to ours. For example, consider an 18-wheeler which not only has its headlights placed at a height, but also directly pointed towards the oncoming traffic's windscreens. A lot of accidents happen because smaller vehicle drivers lose control due to the enormous amount of glare from such trucks. Another case where this product would prove helpful is when the road has sharp blind turns wherein the drivers are met with sudden glare the moment they make a turn. Thus, overall safety of the vehicle is improved.

Results and Discussion

Following are some of the results that were obtained using the algorithm that we wrote. Here we can see the original image and image after implementation of the algorithm, which is a black and white image, a white region of the image indicates, light coming from the vehicle and we calculate the area of that white region. Figure 3(A), Figure 4(A) and Figure 5(A) are the images
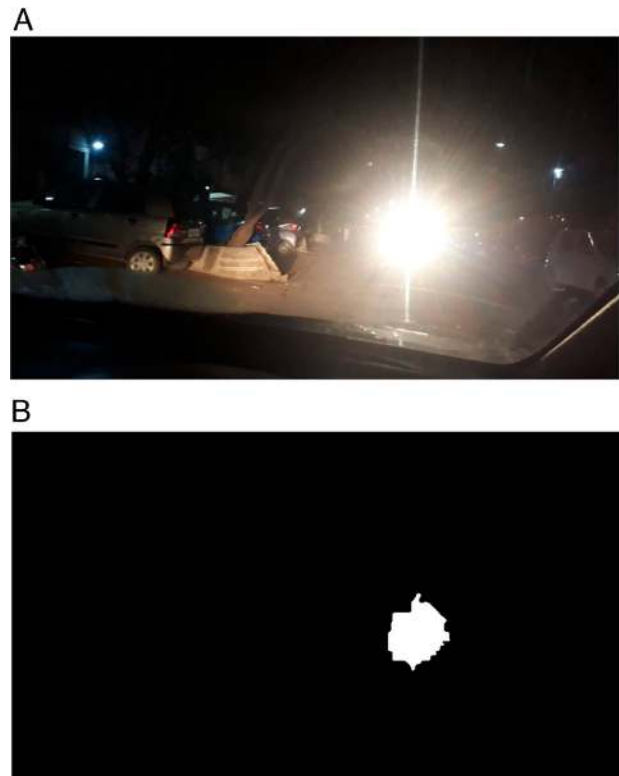
Figure 3: (A) Image captured from less than 50m. (B) Processed Image of Less Than 50m with Area Value of 7773.5.

taken from less than 50m, between 50–100m and 100–300m respectively, and Figure 3(A), Figure 4(A) and figure 5(A) shows the output when these images are given as an input to our algorithm, also gives us the area value. With the help of these area values, we can determine the threshold value.

Given below are the images of our setup. Figure 5(A) represents side-view of high-beam profile of lamp when there is no vehicle coming from other side and Figure 5(B) represents side-view of the low-beam profile of lamp when there is a vehicle coming from another side. Whereas Figure 6(A) represents top-view of high-beam profile of lamp when there is no vehicle coming from other side and Figure 6(B) represents side-view of the low-beam profile of lamp when there is a vehicle coming from another side. In Figure 6(A) and Figure 6(B) we can see a red led, that is the camera which is sensing the oncoming vehicle or light source, our SoC reads the area value and sends a signal to the circuit to switch from high beam to low beam.
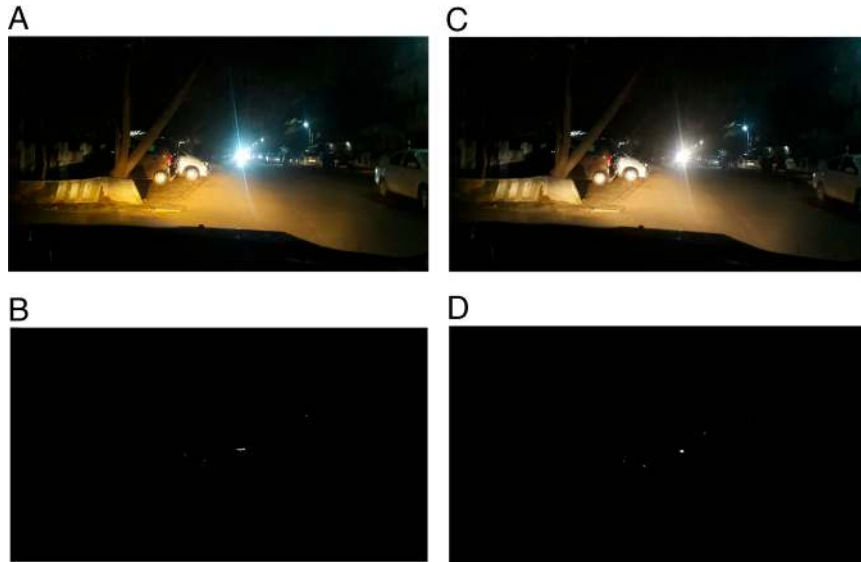
Figure 4: (A) Image captured from less Than 50–100 m. (B) Processed Image of Less Than 50–100 m with Area Value of 30. (A) Image Captured from Less Than 100–300 m. (B) Processed Image of Less Than 50–100 m with Area Value of 25.
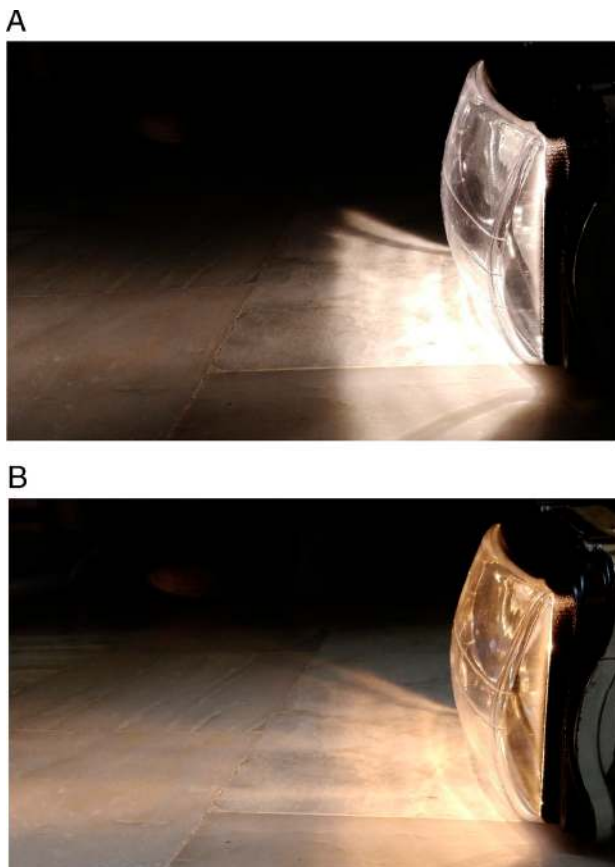

Figure 5: (A) Side View of High-Beam Profile of Our Setup.

Conclusion

The system so developed was tested for various cases and showed promising results as discussed. A system which takes control of the night glare and the root of the problem that is the drivers who forget to change their light stance is radically useful on actual roads and highways. Our system is cheaper to manufacture compared to already existing designs by various brands of automobiles and has the flexibility of installation in any kind of vehicle. This design has the potential to improve safety while driving at night, providing drivers and passenger with peace of mind and making their travel more comfortable and less stressful.

Future Scope

When the car is running at a particular speed at night, there are obviously problems with night glare. So for that, when the system is running, we need to assume that the oncoming vehicles or a cluster of vehicles have the same or similar module which can communicate freely. This opens many new domains for research, especially when it comes to intercommunication between many such devices on the road which can improve their accuracy based on the live location of other vehicles in a localized area.

In place of conventional headlamps, strips of LEDs can be put to use so that specific sections of
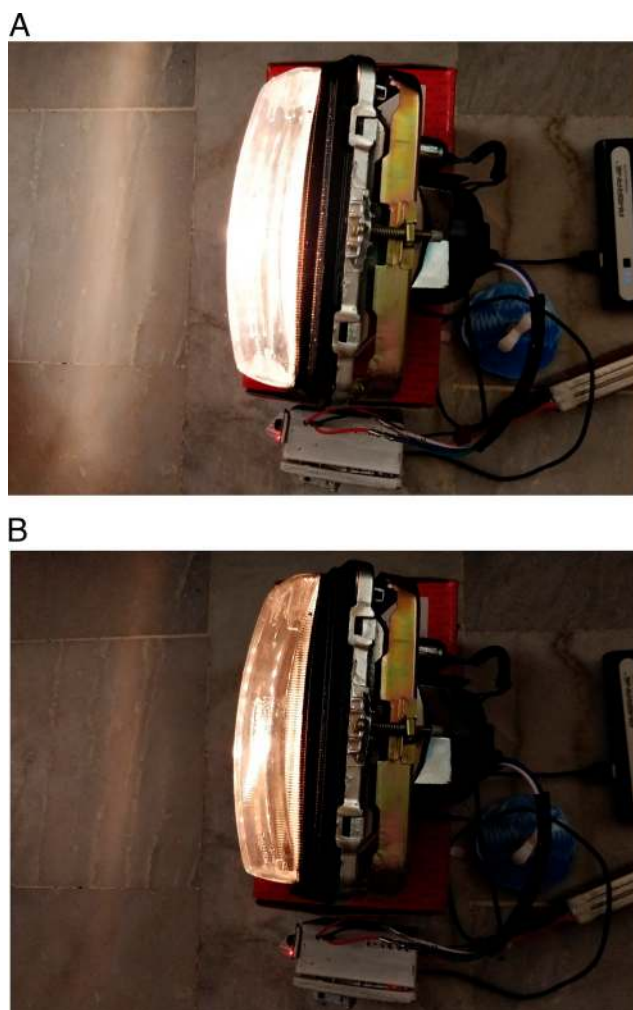
Figure 6: (A) Side View of High-Beam Profile of Our Setup. (B) Top View of Low-Beam Profile of Our Setup.

an area in front of the vehicle can be given variable intensity and direction of light so as to reduce glare while keeping the visibility optimum.

In addition to the methods we discussed, neural networks and machine learning algorithms can be incorporated into the module so that the error is reduced and better performance is achieved based on history of learning.

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