Stereoscopic Programmable Automotive Headlights for Improved Safety Road

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Srinivasa Narasimhan (PI), Associate Professor
Robotics Institute, Carnegie Mellon University
https://orcid.org/0000-0003-0389-1921

Robert Tamburo (Co-PI), Project Scientist
Robotics Institute, Carnegie Mellon University
https://orcid.org/0000-0002-5636-9443

Srihari Shankar, Graduate Student
Electrical and Computer Engineering, Carnegie Mellon University

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1 Problem

Annual crash statistics continue to reveal the disturbing trend that driving at night is very dangerous despite nearly a century of automotive headlight development. Even with recent advances in adaptive headlight technology, the U.S. National Highway Safety Administration reports that more than half of the vehicle crashes and fatalities occur at night despite significantly less traffic during those [1]. Annually, more than three hundred thousand crashes and thousands of fatalities are caused by rain and snow at night [16]. Approximately thirty percent of drivers are stressed by glare from oncoming vehicle headlights causing hundreds of fatalities every year [14].

For the past 130 years, headlight development has been primarily geared towards developing headlights that can be electrically controlled, have a long working life, and are bright and energy efficient. The inventions of Halogen lamps, Xenon (HID) lamps [6][7] and the more recent LED [3][4] and Laser sources [11] have followed this research trend. These latest sources provide bright and comfortable color temperatures improving driving experiences. However, even with these new light sources the only control offered to the driver of a majority of vehicles is to switch between high- and low-beams.

Low-beams primarily illuminate the road a short range in front of the vehicle. On the other hand, high-beams have a wider angle and longer range. High-beams are useful in a variety of scenarios providing better visibility of narrow curvy roads and sidewalks and better visibility farther down the road crucial for high speed travel. At the same time, high-beams reduce the contrast significantly in the presence of fog and haze and cause bright flickering and distracting streaks during precipitation events. They also cause significant glare to other drivers, bicyclists, and pedestrians on the road. In many scenarios, for example, dark and narrow rural roads, bright headlights are required to safely see the driving environment (e.g., edge of the road, wildlife, pedestrians, etc.) especially when traveling at high speeds. Unfortunately, bright headlights also cause significant glare to other drivers, bicyclists, and pedestrians on the road. During rain and snowstorms, they also cause distracting bright flickering streaks. Thus, a headlight that adapts to the environment can be critical to improving driver safety during poor visibility conditions.

2 Approach and Methodology

Our programmable headlight overcomes some of the functional and performance limitations of standard headlights by being versatile, i.e., capable of being programmed to perform many different types of tasks to increase safety for all drivers on the road [2]. With previous support from the T-SET UTC, we have developed a single headlight prototype capable of operating at highway speeds. We have also developed several application algorithms and demonstrated them on the road.

Our headlight design consists of four main components; an image sensor, processing unit, spatial light modulator (SLM), and beam splitter. The *imaging sensor* observes the road environment in front of the vehicle. Additional sensors such as RADAR or LIDAR can be incorporated into the design to complement the camera. The *processor* analyzes image data from the sensor and controls the headlight beam via a spatial light modulator. The *spatial light modulator* (e.g., digital micro-mirror device, liquid crystal display, liquid crystal on silicon, etc.) modifies the beam from a light source by varying the intensity over space and time in two dimensions. We use a digital micro-mirror device (DMD) because its high working frequency and small pixel size permit high-speed modulation and fine illumination control, which makes it possible for our headlight to react to many types of objects during situations encountered on the road Fig. 1.

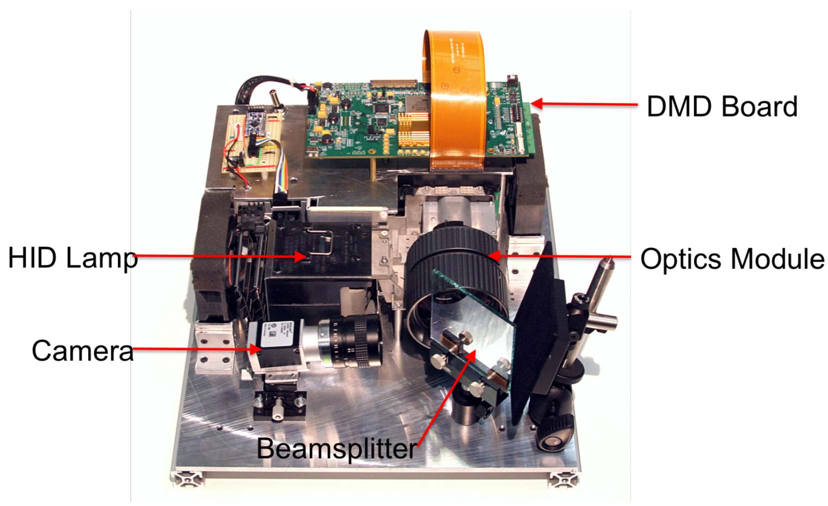

Figure 1: Prototype of our programmable automotive headlight design.

We address the problem stated in Section 1 by designing and developing a stereoscopic programmable headlight. The addition of a second programmable headlight (i.e., camera) is advantageous because the distance to detected objects can be estimated to assist in classifying objects and reducing false positives in our current algorithms. Furthermore, three-dimensional computational methods such as reconstruction and scene understanding can be employed. More accurate algorithms for anti-glare high beams, seeing through rain and snow, and obstacle spotlighting will be developed. Algorithms for new applications such as dynamic beam forming and scene reconstruction will also be developed. We have built a prototype and developed software for the stereoscopic headlight system. A custom embedded solution was developed to reduce the cost, size, and energy consumption of the headlight.

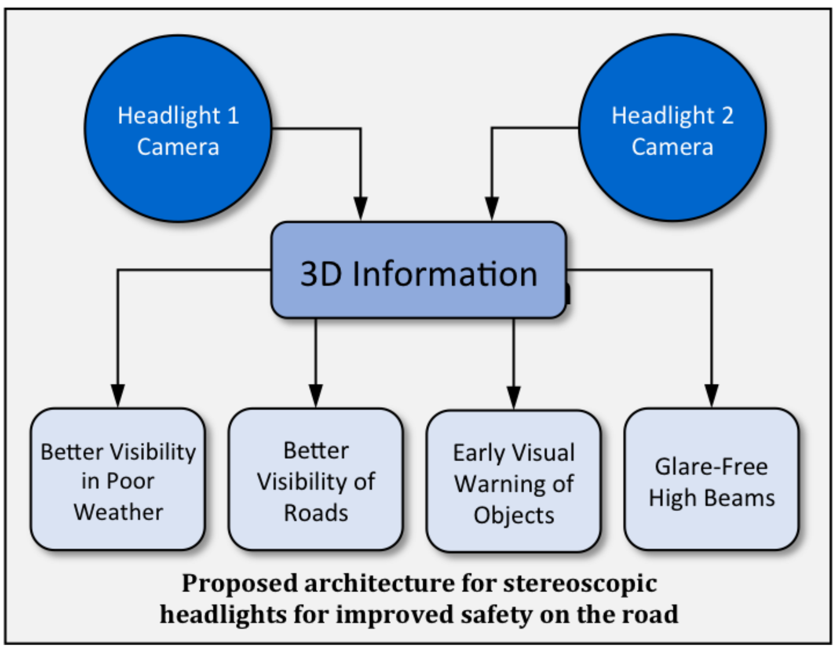

Figure 2: The images from each programmable headlight?s camera can be used to extract 3D information from objects and the scene. This information will be used to develop new algorithms for the above applications and algorithms for new application areas.

An overview of the stereoscopic headlight system is shown in Fig. 2. The images from both headlight are processed to calculate a depth map. The depth information is used in algorithms for various safety applications. An FPGA in each headlight performs rectifications. The FPGA in one headlight requests the rectified image from the other headlight and performs 3D reconstruction. This architecture is highly optimized permitting efficient image transfer and queuing over a gigabit ethernet connection. Further optimization to reduce bandwidth load was done by first processing images to detect objects generating a highly compressible image.

3 Findings and Conclusions

The headlight should not be a passive device that can be just completely switched on or off. It should be programmable to perform many different tasks to help the driver in various road environments. Our headlight design provides unprecedented light beam control over angle and time. Essentially, the full headlight beam can be split into hundreds of thousands of tiny little beams that can be turned on or off for very short durations (milliseconds). The flexibility and control of the headlight will allow us to perform numerous tasks for the first time: allowing drivers to use high beams without glaring any other driver on the road, allowing oncoming drivers to see the vehicle and road clearly despite the high beams, allowing drivers to see better in snow, and allowing better illumination so lanes, sidewalks and dividers can be clearly visible.

4 Recommendations

After more than a century of automotive headlight development, the industry is finally developing advanced headlights. However, the headlights are highly specialized towards specific tasks and not possible to update or upgrade. Future work should continue this momentum.

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