Headlight Intensity Controller Design using Wireless Sensors (HIC-WSN)

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ABSTRACT

Many factors are considered when analyzing automobile transportation in order to increase safety. One of the most prominent factors for night-time travel is temporary blindness due to elevated headlight intensity. While headlight intensity provides better visual acuity, it inversely affects oncoming traffic. This problem is compounded when both drivers are using a higher headlight intensity setting. Also, higher speed due to decreased traffic levels at night increases the severity of accidents. In order to eliminate accidents due to temporary driver blindness, a wireless sensor network (WSN) based controller is devised to quickly transmit sensor data between cars. Low latency allows quicker headlight intensity adjustment to minimize temporary blindness.

1. INTRODUCTION

Roughly one third of all traffic accidents happen after dark, even though there is considerably less traffic at night than during the day. Accidents during the hours of darkness also result in a particularly high proportion of fatalities (the risk of getting killed in an accident at night is almost twice as high as during the day).

Significant safety benefits are gained from continuously adapting the vehicle's illumination range to the traffic situation and immediate surroundings [1]. Drivers not only see more clearly but are also less tired and much more relaxed. As the light intensity varies continuously, there is no abrupt switch from high beam to dipped headlamps.

The increase in number of road vehicles has outpaced the improvements and developments on the road resulting into unsafe road travel. In a conventional car today, drivers would still be required to drive the vehicle at night without any assistance by the system. The traffic moves at higher speeds along the highways and freeways at night. Earlier work on headlight intensity control [2]-[5] focuses on the control system and design of a smart controller using fuzzy logic. Some of the patents that reflect developments in this area are given in [6]-[8]. In this work, we present headlight intensity controller design for vehicles to provide optimal illumination in the event of different road and weather conditions.

Certain applications of WSN may call for strict security protocols, while others may not require any security at all. Low-latency data retrieval may not be required in network deployment designs due to high energy cost. Besides cost, energy efficiency is typically the most important design parameter for network design. Energy efficiency is an important factor in designing Low-Powered WSN due to the impact of network downtime for maintenance.

We aim to develop the hardware system using WSN to control the head light intensity in this paper. The design and development is focused on using the on board MCU and light sensor to communicate wirelessly.

We look at the WSN as a powerful wireless communication mechanism that is cost effective monitoring and controlling solution. WSN is suitable for diverse applications like; military, structural health monitoring, agriculture, machine health monitoring, and environmental monitoring like; green house monitoring, forest fire detection, landslide detection etc. The monitoring requirements from this application demand design focusing on network uptime, data retrieval speed, security, cost, and other parameters.

2. METHODOLOGY

The sensors in WSN capture any real time data, WSN are event driven systems. The nature of WSN is generally data centric due to the hardware and application restrictions. In data centric architectures, information of the network flows towards a central processing point that behaves as a gateway of the network, usually called base station. Fig.1 shows the design scheme of the headlight intensity controller. The sensor board in use is a MemSIC MDA100CB, which contains an onboard photo resistor interfaced to the ADC of the Atmel Atmega 1281. Sensor captures the oncoming headlight intensity data at a predetermined sampling rate selected by the user.

The onboard processor filters and identifies the oncoming vehicle. In other words, the processor reads the intensity of the oncoming vehicle. In response, the controller modifies vehicles own headlight intensity.

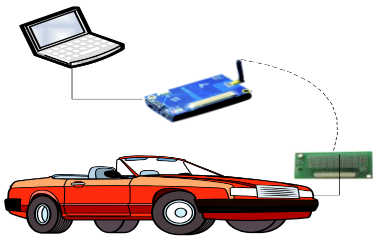


Fig.1. Schematic of WSN controller

This process of updating the intensity continues until the oncoming vehicle passes by. This wireless radio board transmits the captured light intensity data to the base station. Both the sensing node and base station contain a Memsic Iris XM2110 radio board. The base station also contains a MIB520 USB interface board. This allows the board to connect to the laptop and log the data to the PostgreSQL database.

a. Headlight Intensity Controller Overview

In order to reach a light intensity equilibrium that balances with optimum visibility and safety, very low latency must be achieved with data collection, headlight intensity adjustment, and re-sampling. A low cost microprocessor capable of achieving this sampling rate and ADC resolution is used in conjunction with a photo resistor. The ADC data is processed and compared to the optimum safe value determined through existing experimental data, and then the output port of the microprocessor adjusts the voltage level going to the headlight. This process is repeated on both vehicles until equilibrium is established sufficiently close to the determined optimum safe value.

3. DESIGN ISSUES

In order for the designed system to work, the proposed controller is expected to be an integral part of all vehicles due to the requirement of the oncoming vehicle to reciprocate headlight intensity sampling, adjustment, and re sampling. The terms used in the design are defined next.

Event: Two vehicles approaching each other in opposite direction at a specified speed noticing each other from specified distance defines an Event.

Onset of the Event T_1: When the two vehicles are at a distance $D = D_{th}$, it defines Onset of the Event (occurrence of event).

End of the event T_2: The time instant when the two vehicles cross each other.

Threshold Intensity, I_{th}: Minimum headlight intensity that enables the driver to clearly see (permissible intensity (normal).

An event occurs when an oncoming vehicle comes within range of the photo resistor measuring headlight intensity and exceeds the reference value of intensity. At a time only one event is detected by the controller. The event may be followed by another event if there are number of vehicles on one lane with only one vehicle on the other lane carrying traffic in the opposite direction.

Fig. 2 depicts the pseudo code for the controller. As given in Fig. 2, T_1 and T_2 indicate the times at which the event occurs and ends respectively. $T = (T_2 - T_1)$ indicates total time elapsed during the event. I_1 depicts intensity of vehicle 1 (my vehicle), I_2 depicts intensity of vehicle 2 (oncoming).

```
double t1;                                  //time WSN begins sensing incoming light data
double t2;                                  //time WSN finishes sensing incoming
                                            //light data, vehicles pass
double intensity1,intensity2;               //headlight intensity values measured by WSN
const double intensityDatum = 250;          //defined intensity datum/threshold value
const double decrIntensity = 5;             //amount to incrementally decrease intensity
double te = t1 - t2;                        //MCU must operate faster than te

if (intensity1 > intensityDatum)            //event begins
{
   if ((intensity1-intensity2) != 0)
      intensity1 = intensity1-decrIntensity;
   else;
}

if (intensity1 < intensityDatum);
```

Fig.2. Pseudo code for the controller

Fig.3 shows three situations of an event namely, event onset, event ongoing, and event over. The onset of event activates the controller. While the event is occurring the controller generates output that modifies the headlight intensity. When the event is over, the controller returns back the normal headlight intensity value to the headlights. The duration for which the controller sends updated intensity values depends on the speed of the vehicle V(x). Since the normal intensity level is specific to a model and make, controller declaring end of event resumes the normal intensity level.

For a fleet of vehicles moving at a fixed speed V(y) along the single lane road would mean there would be series of events occurring, that demand almost instantaneous switching between the events E_1 (end of event 1) and E_2 (onset of event 2) etc.

This value is the basis for adjustments of the vehicle's headlight intensity value. Once a safe value has been reached for the duration of the event the system returns to normal operating headlight intensity. The period of time for adjustment must be nearly instantaneous in order to be effective. The experiment deployed one sensing node placed in the line of sight of the driver side of the dashboard such that it received the blind spot with the sensor board facing parallel to the windshield.

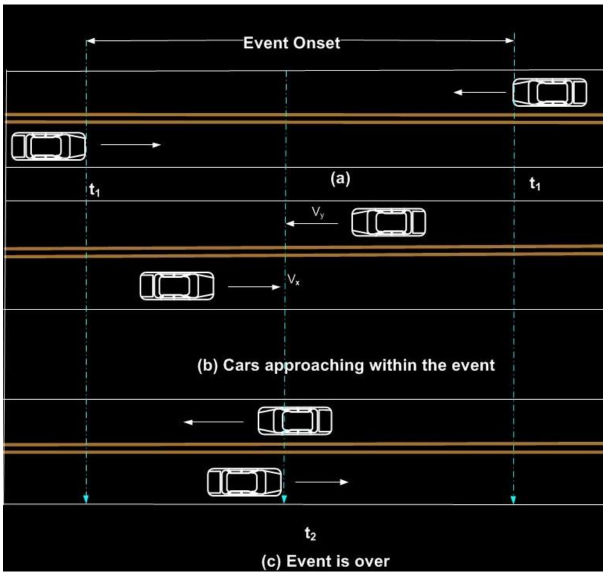


Fig.3. Event occurrence

The raw data in Fig. 4 shows that intensity of the light increases whenever a vehicle passes by. This increase in light intensity is dependent on the headlight intensity of the oncoming vehicle and is evident from the peaks in the graph. However, the graph also shows undesired light captured from the environment like street lights etc., (noise).

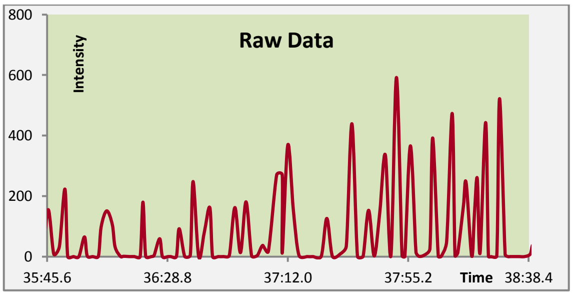


Fig. 4. Headlight intensity raw data

The raw data given in Fig. 4 can be analyzed to find the following parameters;

- Distance between two consecutive vehicles
- Speed of the oncoming vehicles and
- Total number of vehicles

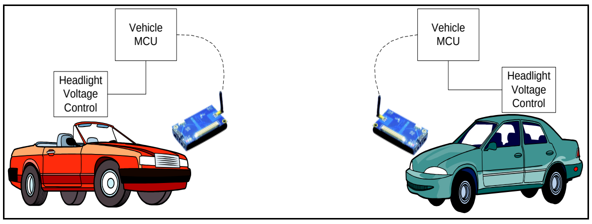


Fig.5. Experimental Set up

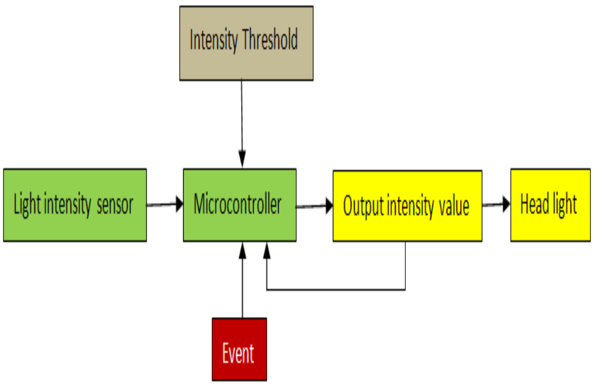
Fig. 5 depicts the experimental set up employed for picking up real time light intensity data on a single lane road with speed limits of 30 mph at night time. We purposely picked up a road with no light except the headlight and less traffic to evaluate the effectiveness of the controller. Real time data was collected for 15 minutes on a single lane road with minimal ambient noise. During this time number of vehicles that passed by were noted. The gateway and base station sat in the passenger seat.

The controller is effective only if it provides the modified values of the intensity before the next vehicle enters the event or the vehicle resumes its reference value immediately after the event is over.

In order to account for noise in the network, threshold values must be chosen to prevent extraneous headlight intensity adjustments. The oncoming traffic light data is clearly distinguishable from ambient light in the graph of the photo resistor data.

4. IMPLEMENTATION

Fig. 6 depicts the block schematic of the proposed controller.



Such a system is implemented using photo resistors interfaced to microcontroller via ADC. The microcontroller generates an interrupt when the real-time value of the light intensity is greater than the reference value. The interrupts initiates a control mechanism to modify the light intensity of the vehicle at a rate such that the blind spot does not occur. The reduction in the intensity of the headlight of the vehicle continues until the event is over, following which the reference value of the headlight intensity is resumed.

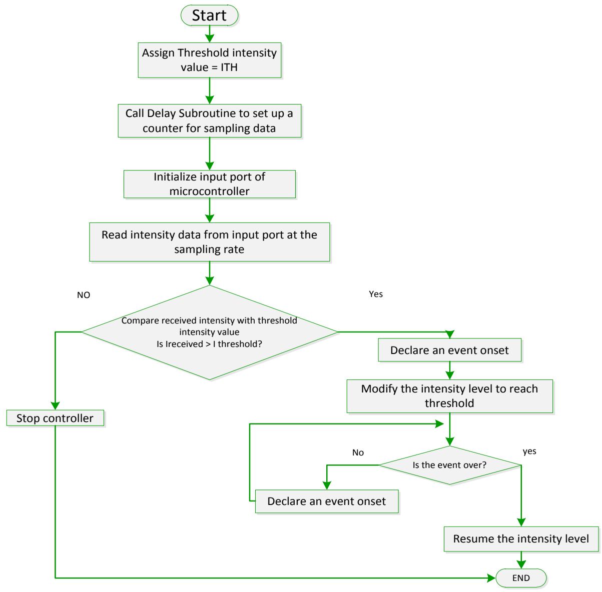


Fig. 6. Flow chart of the proposed controller

Following pseudo code displays this implementation. This system is aimed to be developed as an embedded IC into the headlight. The hardware used in experimentation is the Memsic IRIS XM-2110 radio board, MIB-520 programming board, and the MDA-100CB sensor board.

The sensor board contains a photo resistor and a thermistor interfaced to the ADC. The IRIS XM-2110 contains 802.15.4 compatible radio operating at the 2.4 GHz band as well as an Atmel 1281 microcontroller. Channel selection is supported by altering the source code before compiling and programming via the MIB-520 board. A sensing program provided by MemSic was used for the baseline test. This program obtains a light sample via the photo resistor. The sampled light data is usually in analog form. 10 bit ADC on board converts the analog signal and the ADC values are read by the microcontroller. After the microcontroller processes the ADC data, it is then transmitted to the gateway. The gateway sends the data via USB to the host PC using the MIB-520 board. The host PC samples the data at 52.6 kb/s and then imports it into a PostgreSQL database. This database is parsed by the Moteview software and displayed graphically.

5. RESULTS

b. Filter output

Fig.7 shows filtered data that is free of noise. It also captures the information about number of vehicles crossing over the vehicle in the opposite lane in time domain.

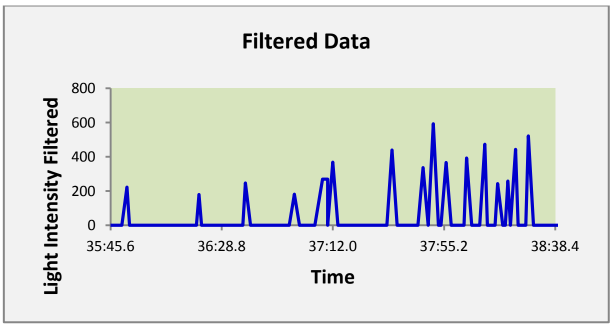


Fig. 7. Headlight intensity data filtered

c. Controller action and results

Fig.8 shows the output of the controller corresponding the filtered data of Fig. 5 in terms of maintaining threshold intensity level while the vehicles are in the event. Controller output provides equivalent analog output voltage to control the headlight intensity. After the event is over, controller resumes the output back to normal value (equivalent to low beam).

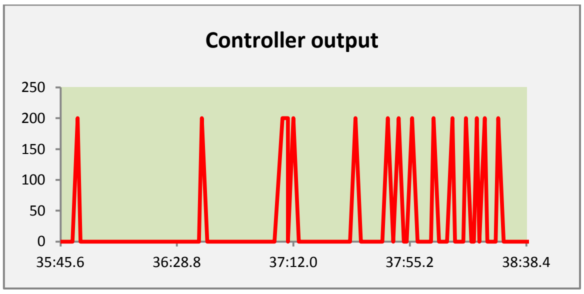


Fig. 8. The controller output describing Event

C. Additional Controller function

The controller also identifies number of vehicles passed by in a given time. Each time the controller defines an event, reduces its intensity gradually depending on the speed of the oncoming vehicle. The controller updation has a bearing on the speed of the oncoming vehicle. Controller action needs to be fast enough so that the intensity updation is achieved before reaching the blind spot during the crossover of two vehicles. If there is a fleet of vehicles approaching another vehicle in opposite direction, then the headlight intensity must be regained as soon as the vehicle crosses over, before it again activates for the next oncoming vehicle. In the experiment conducted, our vehicle drove north in one direction capturing light intensity of 8 vehicles and headed south along the same narrow dark road capturing another 8 vehicles in the opposite lane. In all, there were 16 vehicles and the data indicates the distribution of the vehicles as a function of their speed as they approached and crossed our vehicle one after another.

6. CONCLUSIONS

HIC-WSN greatly impacts the safety of drivers and their passengers. In this paper, WSN based controller is designed to modify the intensity of headlight of a vehicle to such a level that during vehicle cross over blind spot situation does not arise. This is achieved in real time while providing better vision sharpness for the driver. The preliminary results are confirming to the design concept sets a datum and optimizes the luminescence of the driver's and opposing driver's headlights enabling clear and restored light intensity once they cross by while traveling. This application is very useful for night drivers and potentially minimizes car accidents. Further steps to consolidating the design need to focus on real time controller.

Controller action needs further investigation since the electronics involved needs to be developed with real time performance and delay values well within permissible range.

Changing the intensity levels at a faster rate in response to an ongoing fleet may not be well received by the human eye. This issue needs further investigation. Alternately, keeping the intensity at low beam, the same code may be employed to control the fan beam of the headlight. Both the issues need further investigation. This will involve additional hardware to reduce the fan beam effectively.

7. FUTURE WORK

In order to further optimize our system, the next step in our research will be geared toward the analysis of the sampling rate of the microcontroller chosen versus the time constraint imposed by the event period. The rate at which the microcontroller may adjust the output based on the sampled light data critical to optimal operation. This is due to the relatively short event length or speed, as well as safety factors involved with visual impairment. This system also eliminates human error from the scenario, which in turn allows the driver to focus on safely navigating the road instead of manually adjusting headlight settings.

8. ACKNOWLEDGMENT

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9. REFERENCES

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