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DESIGN AND IMPLEMENTATION OF FUZZY SYSTEM FOR SAFE (NIGHT CASE) VEHICLE DRIVING

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Abstract

The vehicles headlight high beam plays a major role at night driving. While driving there may be annoying situations that forces the driver to be absent-minded, so a clear perception of the road and upcoming obstacles in it not possible, then drivers generally switch ON headlight high beam while driving at night times. However, if the driver forgets to do that then accident occurs. Vehicle intelligent safety embedded systems are useful for keeping the safety of the driver and passengers from accidents, such systems as Lane departure warning. In this paper, a system designed to switch gradually (ON/OFF) the high beam of a vehicle headlight bulb depending on two parameters; vehicle speed and the status of light intensity surrounding the vehicle. This paper develops a low-cost controller based a fuzzy logic designed in embedded system such as Arduino. The system is based on Fuzzy Logic Control (FLC), where the measured vehicle speed and the vehicle surrounding light module acts as inputs to FLC, the vehicle headlight high beam status represents the output of the system. FLC utilized successfully in various applications; it is generally used in complex control systems because of its great performance when using non-linear applications, unlike weak performance conventional controllers. An Arduino based ATmega328 microcontroller utilized for real time controlling this system with speed measuring and light intensity sensors. The feasibility of the proposed method is verified based on the results of the experiments with different case study.

Keywords: Embedded system, Fuzzy logic, Optical speed sensor, Vehicle headlight bulb control, Vehicle safe driving.

1. Introduction

There are many things to do before starting to drive a vehicle, such as; use of a seatbelt, setting vehicle controls (choose radio station, adjust the seat, adjust heat etc.), but unfortunately; most drivers almost forget to do one or more of these things before driving and they start to do them after driving, then accidents happen. Sometimes, there are things must be done while driving, such as; obeying speed limits, turning on signals to make intension to the other drivers when turning and even controlling headlight high beam at some cases under specific low light intensities.

The existence of smart safety (stand-alone) systems is very important and required strongly in vehicles. Some vehicle safety systems use the light intensity as an input to the headlight switching system, where after detecting the low light intensity of day/night case the headlight is switched ON/OFF automatically. However, in some night cases or low light intensity situations and with a high-speed acceleration of the vehicle, another system related to (surrounding light intensity and vehicle speed) is required to switch (ON/OFF) the high beam of the headlight automatically [1, 2]. The switching (ON/OFF) process of the high beam is required to be smooth and gradual, so a fading ON/OFF circuit or a (light dimmer circuit) is required to accomplish this process and avoid switching ON/OFF the high beam suddenly. This is better to avoid harming other drivers' eyes when switching ON the high beam suddenly.

This paper designs automatically controlled system that controls the headlight high beam glare in vehicles. The system designed to operate as a stand-alone system (operates automatically without driver's intrusion), but it may be optional and used by the driver itself (manually). The designed system based on two entries (Vehicle Speed and surrounding Light Intensity). Optical speed sensor used to measure vehicle speed [3, 4], and a Light Independent Resistor (LDR) to sense the amount of light intensity, which is measured in LX SI unit. An Arduino UNO microcontroller is used to control all over the system. The microcontroller receives data from the optical speed sensor and the LDR, and then under some rules based on fuzzy logic the headlight high beam is controlled. When a vehicle speed exceeds a specific threshold and under low intensities of surrounding light, the headlight high beam operates gradually from OFF status to Bright GLOW status passing through DIM, GLOW statuses.

According to above, fuzzy logic controller is the best tool to manage the non-linear factors mentioned to control the high beam of the headlight bulb depending on vehicle speed and surrounding light intensity.

So, in this paper a design of a smart stand-alone automatic switcher, for vehicle's high beam headlight bulb is presented. The switching operation depends on the speed of the vehicle and the surrounding light intensity, i.e. the smart switcher turns the high beam headlight ON gradually as fade option and turns OFF gradually as a dim option, whenever the speed of the vehicle exceeds a specific threshold. This produces a far vision of the road while driving fast at night, without the need to switch-ON the high beam bulbs manually by the driver, leading to less possibility of accidents, which caused by a short vision of road.

2. Literature Review

Stand-alone vehicle safety conventional systems vary according to their usages, such as; Smart seatbelt system, where some of these systems prevent vehicle starting ON unless the driver wear the seat belt [5]. Collision avoidance system, in order to minimize collision accidents, modern collision avoidance systems operate using laser sensors and a special Controller Area Network (CAN) controller with wireless media [6]. Road lane departure detection and warning system using a digital camera and video processing to detect road edges to make a decision if a vehicle departs its lane and gives an alert [7]. Real time blind spot warning system using camera vision analysis for motorcycle and vehicle detection in day/night time conditions to reduce accidents caused by the blind spot of side mirrors [8]. Integrated Vehicle Tire Pressure Monitoring System (IVTM) designed for warning the driver when a difference is occurring in the pressure, a special sensor fixed in the wheel checks the tire pressure and sends information wirelessly to the Vehicle Control Unit (CU). The CU identifies too low or too high pressure and changing the tire pressure. The system can distinguish whether the falling pressure is caused by tire leak or normal pressure variations [9]. The airbag system, collision dangerous analysis is accomplished fast to decide whether airbag to be opened or not to avoid accidents [10], and Anti-Lock Braking System (ABS), headlights, turn signals, etc.

On the other hand, for non-conventional systems, the FLC is adopted to the systems that have complexity nonlinear models and hard decision making cases. Vehicle Adaptive Cruise Control (ACC) system utilized fuzzy logic controller for an intelligent strategy based on the throttle or braking pedals with a combination between ACC system and (Stop/Go) system [11]. Vehicle driver drowsiness warning system used image-processing technique based fuzzy logic to determine driver fatigue level according to the period in which the driver closes his/her eyes then the system warns the driver [12]. Machine learning approaches used with fuzzy systems for decision-making, such as cell phone selection process under FLC and neuro-fuzzy system for personal usage, depending on seven inputs provided to decide the user decision [13]. Monitoring Driver’s Situational Awareness (DSA) with an intelligent Fuzzy-based Driver Monitoring System (FDMS) for safe driving, based on two sub-fuzzy systems, considers many inputs such as; vehicle’s environment temperature, noise level and heart rate to the first sub-fuzzy system and respiratory rate as an input to the second sub-fuzzy system, the system informs the driver and provides assistant [14]. Another approach used smartphone sensors (accelerometer, gyroscope and magnetometer) to analyse driver’s behaviours and its driving manoeuvres like (lane changes, left or right turns and U-turns) then a decision made under the base of Neuro-Fuzzy model for driver’s behaviour classification by obtaining patterns for these behaviours [15, 16].

More important vehicle safety systems are like the Adaptive Headlight Controller (AHC) system in which a digital images are processed continuously regulates the high beam when driving in the darkness. In lower light intensity in darkness at night hours may cause accidents with another vehicle or even for pedestrians comparing with daytime hours because of lack of use or incorrect use to the headlamp by the driver [1, 2].

3. Materials and Methodology

In this work, an automatic switch is designed utilizing vehicle speed measuring technique and Fuzzy logic controller, which are explained as follows:

3.1. RPM and speed measuring

Speedometers are used to measure vehicle speed. In general, there are two main types of speedometers; electronic and mechanical speedometers. Talking about electronic speedometers, they utilize speed sensors which are fixed on the speed gearbox or on the crank shaft, and they consist of a toothed metal disk, when a vehicle starts to move from standstill, then the disk rotates and pulses are generated from a magnetic coil, then these frequent pulses are used to measure vehicle speed.

In general, an encoder is a term used with transducers that generate a coded reading of a measurement; a shaft encoder is a digital encoder that is used for measuring angular displacement and velocities, it is of two types: Incremental and Absolute. The output of the Incremental encoder is a pulsed signal that is generated when a motion is occurred. The parts that construct this encoder are a (disk) that has equally spaced and identical windows, a Light Emitted Diode (LED) for a light beam generation and a photo-sensor that picks the light generated from the LED, Fig. 1.[3, 4].

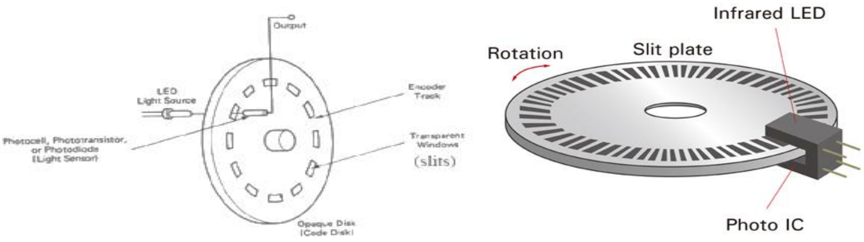


Fig. 1. Optical encoder schematic representation.

There are two methods for determining velocities by the incremental encoder, pulse-counting (frequency measurement) which is accurate for fast moving devices like motors and turbines with thousands of revolutions per minute:[17,18].

$$\mathrm{RPM} = \frac{(\mathrm{pulses}/\mathrm{s})\times(60\ \mathrm{s}/\mathrm{min})}{(\text{number of sensor pulses/revolution})} \tag{1}$$

In addition, pulse- timing which is accurate for slowly moving devices like shafts with less than 10 revolutions per minute.

$$\mathrm{RPM} = \frac{60}{pulse\ period \times pulses\ per\ revolution} \tag{2}$$

Speed calculated from RPM depends on vehicle wheel radius, so:

$$\mathrm{Speed}\ (\mathrm{km}/\mathrm{h}) = 2\times\pi\times r\times \mathrm{RPM}\times\left(\frac{60}{1000}\right) \tag{3}$$

3.2. System representation

The proposed system in this paper is used to control vehicle headlight bulb high beam depending on two parameters, the first parameter is related with vehicle speed, which is measured in (km/h), and the second parameter is related to (day/night) status. The construction of the proposed system, Fig. 2, with the following parts are:

- Arduino UNO based (ATmega328 microcontroller)
- HC-020K infrared pulse counter
- LDR (photocell resistor)
- 1 kΩ, 10 kΩ resistors

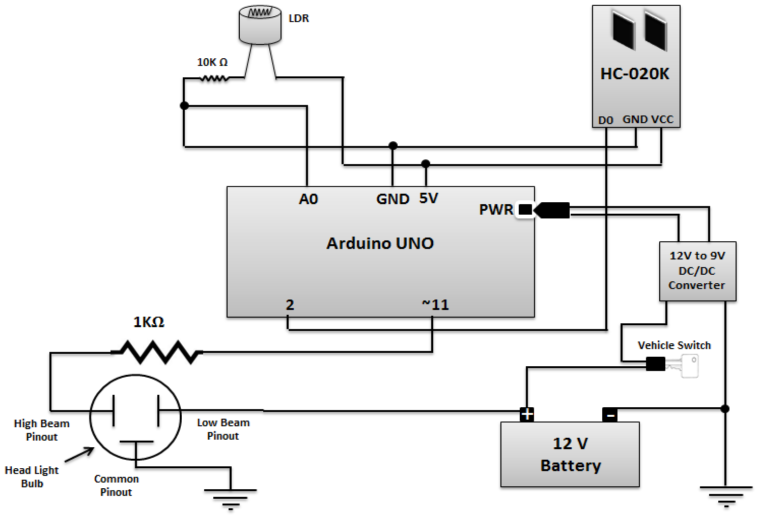


Fig. 2. The construction of the proposed system.

The operation of the system is described as follows; when the vehicle engine starts ON by the driver, the system is started ON too. In Fig. 2, Arduino gets data from both the HC-020K optical sensor (via digital pin 2) and from the LDR photocell (via analog pin A0) at the same time. Arduino starts to process the incoming data, and sense the status of headlight bulb high beam, after data manipulation the decision of switching ON/OFF the high beam of headlight bulb is made by Arduino kit itself (via PWM pin ~11).

When the vehicle starts to move from standstill (0 km/h) to some slow speeds, or when the vehicle decreases its speed (below a specific threshold speed) and at high levels of surrounding light intensities, then the headlight bulb high beam remains OFF (if it is so) or it is switched OFF (if it was ON). At speeds more than the specific threshold speed and at low levels of surrounding light intensities, the headlight bulb high beam is switched ON (if it was OFF).

When light hits the photocell resistor, the photons of light excite the electron of the semiconductor that the LDR is made of and electricity conduction is occurred. The resistance of the photocell drops when it is placed in sunlight but when the LDR is placed in dark, the resistance increased. Fig. 3, elicits the characteristics of LDR.

In Fig. 3, it is obvious that as intensity of light increases gradually from low levels of illumination (approximately 0.1 LX) to higher levels of illumination (approximately 1000 LX), the resistance value of the photocell is reduced gradually. The resistance of the photocell at low levels of illumination is in its higher values (approximately near to 10^8 Ω) as shown in Fig. 3, and this indicates the (Dark) case of surrounding environment to the photocell. As a little increasing in light intensity values there will be a resistance drop in the photocell indicating the (Daylight) case of surrounding environment. As this increasing keeps continue to a higher levels (approximately 1000 LX) as it is obvious in Fig. 3, the resistance of the photocell drops to a very low values (approximately near to 10 Ω) and this indicates the (Sunlight) case of surrounding environment.

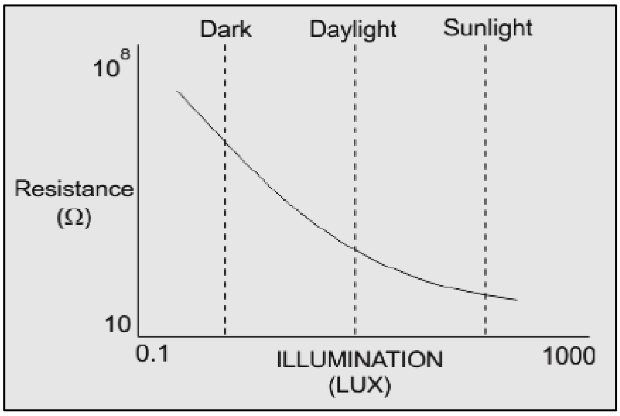


Fig. 3. Characteristics of LDR.

3.3. Fuzifier controller with creating system rules

The proposed system complexity increases when more than one parameter is to be analyzed to make a decision, since it becomes more difficult and impossible to make a precise statement about the system behavior. Fuzzy logic is the way to solve such problems and analyze them through a system that resembles human decisions, which can use appropriate data to find precise information. First, the description of fuzzy sets that represent the system action parameters should be done. As it is known that, the fuzzy logic uses linguistic variables instead of numeral variables to define its sets, so the definition of these variables is the first step to design the fuzzy logic system.

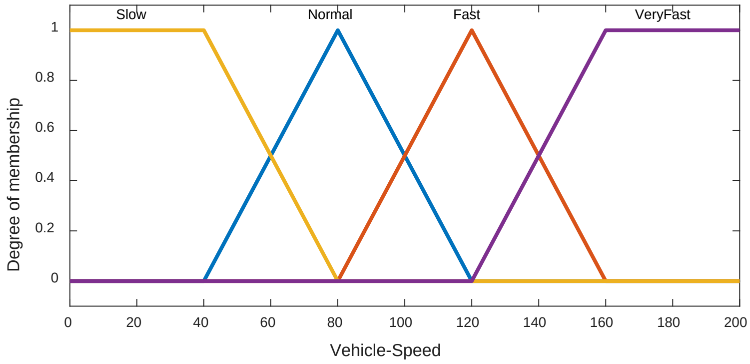
In our system, the linguistic variables distributed on three sets, two input sets represented as; Vehicle speed set (with four membership functions), Light intensity set (with three membership functions). In addition, one output set represented as; Vehicle headlight set (with four membership functions). Table 1 explains the memberships of these three sets.

Table 1. Membership functions sets.

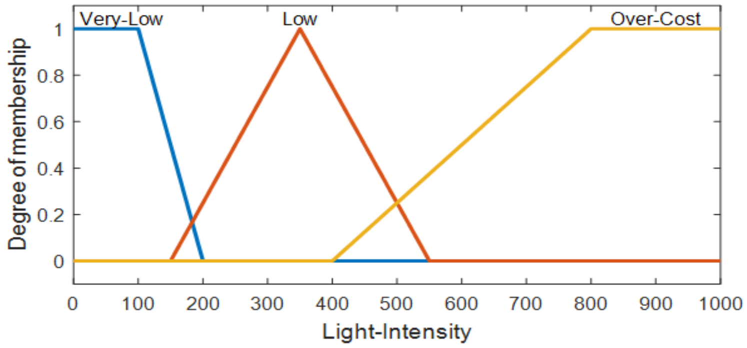
Input Variables		Output Variable
Vehicle Speed Set	**Light Intensity Set**	**Vehicle Headlight**
Slow	Very Low	Off
Normal	Low	Dim
Fast	Overcast	Glow
Very Fast	-	Bright Glow

Two Fuzzy logic models (Sugeno and Mamdani) are available, but the Sugeno is used since it is more accurate and more efficient computationally than Mamdani model, its output membership functions are either linear or constant, it is used with MISO (Multi Input Single Output) systems as our system is, finally, it is more flexible in system design.

Figure 4 shows the two input membership functions for the Fuzzy controller with their linguistic terms. For more simplicity, triangular membership function is used for both inputs (Vehicle-Speed and Light-Intensity), with a range of [0, 200] for Vehicle-Speed input measured in (km/h) and with range of [0, 1000] for Light-Intensity input measured in (LX), both representing universe of discourse for each input. Table 2 lists the linguistic terms and their ranges:



(a) Vehicle speed in (km/h)



(b) Light intensity in (LX)

Fig. 4. Input membership functions.

Table 2. Ranges of linguistic terms of the input membership functions.

Inputs	Linguistic Terms	Ranges
Vehicle Speed (km/h)	SLOW	0 → 80
	NORMAL	40 → 120
	FAST	80 → 160
	VERY FAST	120 → 200
Light Intensity (LX)	VERY-LOW	0 → 200
	LOW	150 → 550
	OVER-CAST	400 → 1000

4. Simulated Results and Discussions

Two inputs of data used in this paper; the first input extracted by speed sensor based infrared pulse counter considering the vehicle speed in (km/h) with four assigned functions (SLOW, NORMAL, FAST, VERY FAST) according to vehicle speed. The second input extracted by photoresistor considering light intensity in (LX) with three assigned functions (VERY LOW, LOW, OVERCAST) according to surrounding environment light intensity. Considering the quantities of related functions present in the controller assigned 12 rules, referring to the possibilities of combining the variables of each entry.

These rules are controlling vehicle headlight high beam according to the readings of speed sensor and light intensity sensor as shown in Table 3.

Table 3. Module rules.

Vehicle Speed / Light Intensity	SLOW	NORMAL	FAST	VERY FAST
VERY LOW	OFF	DIM	GLOW	BRIGHT GLOW
LOW	OFF	OFF	DIM	GLOW
OVERCAST	OFF	OFF	OFF	DIM

The graphical illustration of the rules for the vehicle headlight high beam control is elicited in Fig. 5, it shows the surface view of vehicle speed and surrounding light case changes which both control the case of vehicle headlight beam as shown with the Z-axis. The surface viewer elicits that as vehicle speed increases gradually and light intensity decreases to near of zero LX, the vehicle headlight operates gradually from (OFF to Bright Glow) case passing through the other cases of headlight statuses.

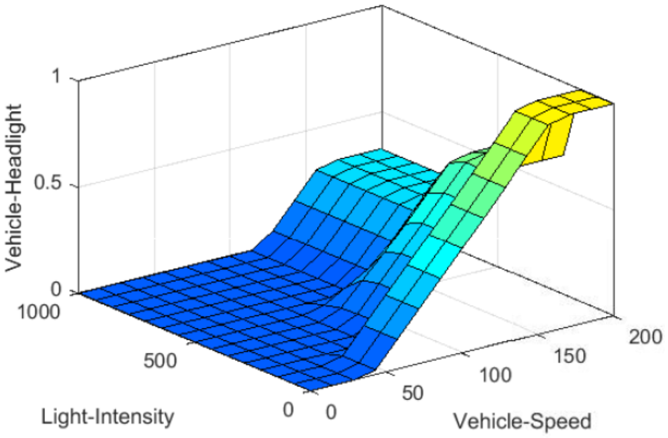


Fig. 5. Rules surface viewer.

5. Experimental Results and Discussions

A simple prototype is implemented to the proposed system using the mentioned parts previously. A vehicle speed measuring is represented using a simple DCmotor with fixed punched disk on its shaft. Speed is measured using a speed sensor fixed with the punched disk as shown in Fig. 6. All parts are controlled using Arduino UNO microcontroller that acted as Fuzzy controller system.

The implemented representation above is tested in many cases, and readings from the sensors are explained as follows affecting the output as shown in Fig. 7.

In Figs. 7(a), (b) and (c), the vehicle speed values in (km/h) are representing the gradual increase in speed from (SLOW, NORMAL, FAST to VERY FAST).

In Fig. 7(a), light intensity values in (LX) are representing the range of (VERY LOW) case and it can be seen that the high beam operates according to the rules from (OFF, DIM, GLOW to BRIGHT GLOW). In Fig. 7(b), light intensity values in (LX) are representing the range of (LOW) case and it can be seen that the high beam operates according to the rules from (OFF, DIM to GLOW). In Fig. 7(c), light intensity values in (LX) are representing the range of (OVERCAST) case and it can be seen that the high beam operates according to the rules between (DIM and GLOW).

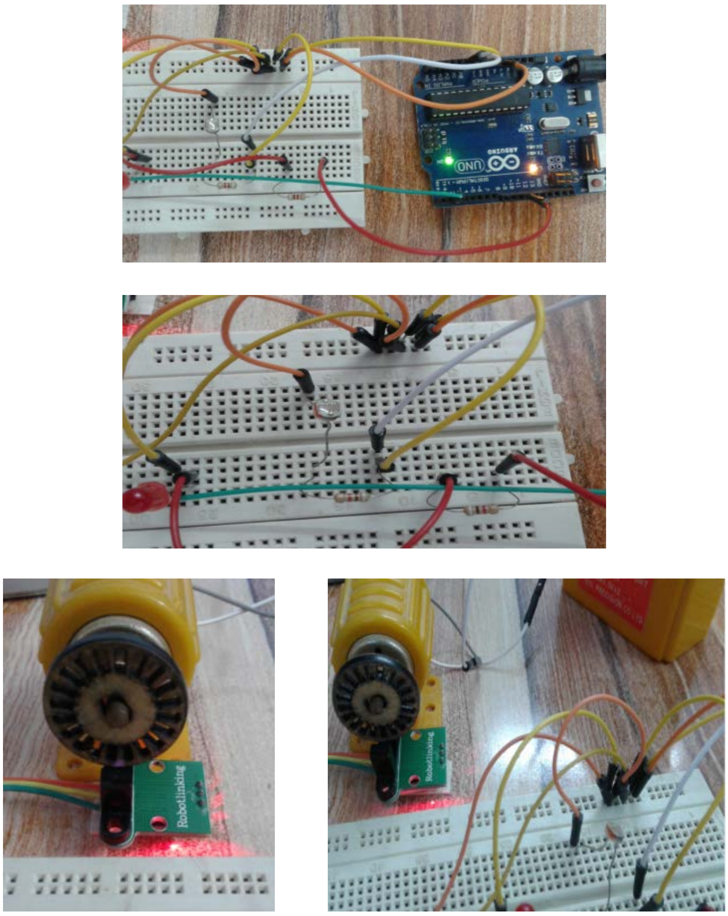


Fig. 6. Implementation of the representative system.

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Car Speed = 64 km/h,    Light intensity = 103 LUX,    High Beam = OFF
Car Speed = 69 km/h,    Light intensity = 99 LUX,    High Beam = OFF
Car Speed = 73 km/h,    Light intensity = 104 LUX,    High Beam = OFF
Car Speed = 81 km/h,    Light intensity = 110 LUX,    High Beam = OFF
Car Speed = 86 km/h,    Light intensity = 101 LUX,    High Beam = DIM
Car Speed = 92 km/h,    Light intensity = 106 LUX,    High Beam = DIM
Car Speed = 97 km/h,    Light intensity = 111 LUX,    High Beam = DIM
Car Speed = 102 km/h,    Light intensity = 117 LUX,    High Beam = DIM
Car Speed = 108 km/h,    Light intensity = 106 LUX,    High Beam = DIM
Car Speed = 114 km/h,    Light intensity = 106 LUX,    High Beam = GLOW
Car Speed = 120 km/h,    Light intensity = 106 LUX,    High Beam = GLOW
Car Speed = 125 km/h,    Light intensity = 106 LUX,    High Beam = GLOW
Car Speed = 132 km/h,    Light intensity = 109 LUX,    High Beam = GLOW
Car Speed = 137 km/h,    Light intensity = 109 LUX,    High Beam = GLOW
Car Speed = 142 km/h,    Light intensity = 109 LUX,    High Beam = Bight GLOW
Car Speed = 149 km/h,    Light intensity = 109 LUX,    High Beam = Bight GLOW
Car Speed = 153 km/h,    Light intensity = 110 LUX,    High Beam = Bight GLOW
Car Speed = 159 km/h,    Light intensity = 112 LUX,    High Beam = Bight GLOW
Car Speed = 163 km/h,    Light intensity = 108 LUX,    High Beam = Bight GLOW
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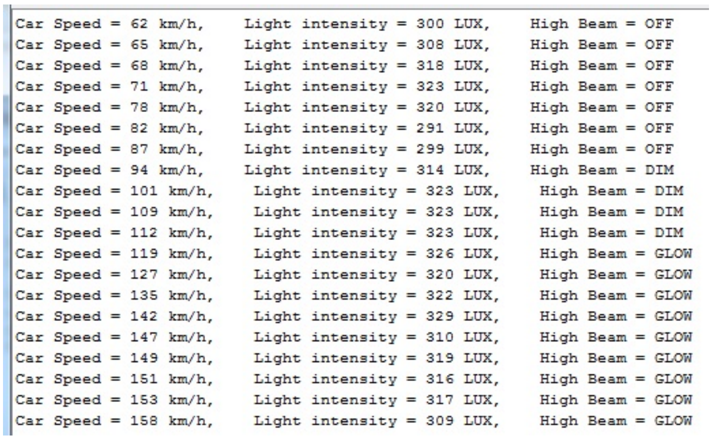
(a)



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Car Speed = 62 km/h,    Light intensity = 300 LUX,    High Beam = OFF
Car Speed = 65 km/h,    Light intensity = 308 LUX,    High Beam = OFF
Car Speed = 68 km/h,    Light intensity = 318 LUX,    High Beam = OFF
Car Speed = 71 km/h,    Light intensity = 323 LUX,    High Beam = OFF
Car Speed = 78 km/h,    Light intensity = 320 LUX,    High Beam = OFF
Car Speed = 82 km/h,    Light intensity = 291 LUX,    High Beam = OFF
Car Speed = 87 km/h,    Light intensity = 299 LUX,    High Beam = OFF
Car Speed = 94 km/h,    Light intensity = 314 LUX,    High Beam = DIM
Car Speed = 101 km/h,    Light intensity = 323 LUX,    High Beam = DIM
Car Speed = 109 km/h,    Light intensity = 323 LUX,    High Beam = DIM
Car Speed = 112 km/h,    Light intensity = 323 LUX,    High Beam = DIM
Car Speed = 119 km/h,    Light intensity = 326 LUX,    High Beam = GLOW
Car Speed = 127 km/h,    Light intensity = 320 LUX,    High Beam = GLOW
Car Speed = 135 km/h,    Light intensity = 322 LUX,    High Beam = GLOW
Car Speed = 142 km/h,    Light intensity = 329 LUX,    High Beam = GLOW
Car Speed = 147 km/h,    Light intensity = 310 LUX,    High Beam = GLOW
Car Speed = 149 km/h,    Light intensity = 319 LUX,    High Beam = GLOW
Car Speed = 151 km/h,    Light intensity = 316 LUX,    High Beam = GLOW
Car Speed = 153 km/h,    Light intensity = 317 LUX,    High Beam = GLOW
Car Speed = 158 km/h,    Light intensity = 309 LUX,    High Beam = GLOW
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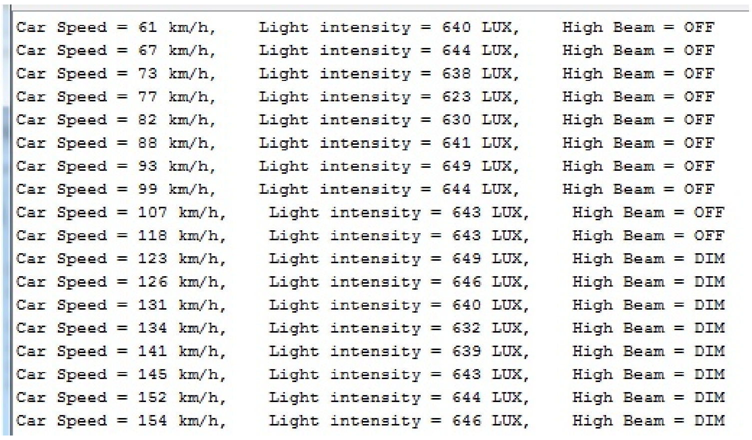
(b)



```
Car Speed = 61 km/h,    Light intensity = 640 LUX,    High Beam = OFF
Car Speed = 67 km/h,    Light intensity = 644 LUX,    High Beam = OFF
Car Speed = 73 km/h,    Light intensity = 638 LUX,    High Beam = OFF
Car Speed = 77 km/h,    Light intensity = 623 LUX,    High Beam = OFF
Car Speed = 82 km/h,    Light intensity = 630 LUX,    High Beam = OFF
Car Speed = 88 km/h,    Light intensity = 641 LUX,    High Beam = OFF
Car Speed = 93 km/h,    Light intensity = 649 LUX,    High Beam = OFF
Car Speed = 99 km/h,    Light intensity = 644 LUX,    High Beam = OFF
Car Speed = 107 km/h,    Light intensity = 643 LUX,    High Beam = OFF
Car Speed = 118 km/h,    Light intensity = 643 LUX,    High Beam = OFF
Car Speed = 123 km/h,    Light intensity = 649 LUX,    High Beam = DIM
Car Speed = 126 km/h,    Light intensity = 646 LUX,    High Beam = DIM
Car Speed = 131 km/h,    Light intensity = 640 LUX,    High Beam = DIM
Car Speed = 134 km/h,    Light intensity = 632 LUX,    High Beam = DIM
Car Speed = 141 km/h,    Light intensity = 639 LUX,    High Beam = DIM
Car Speed = 145 km/h,    Light intensity = 643 LUX,    High Beam = DIM
Car Speed = 152 km/h,    Light intensity = 644 LUX,    High Beam = DIM
Car Speed = 154 km/h,    Light intensity = 646 LUX,    High Beam = DIM
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(c)

Fig. 7. System results and outputs from sensors.

Table 4 lists the action of headlight high beam status according to (Vehicle Speed and Light Intensity). In Table 4, case (1) tests three ranges of (Vehicle Speed and Light Intensity), the first two ranges (64 - 81) km/h and (62 - 87) Km/h forces the high beam to stay OFF (as we get in both simulated and experimental tests) even if Light Intensity has lower ranges in LX since at these speeds it is not necessary to operate high beam. The third range (61 - 118) Km/h must force high beam to operate to DIM status (as we get in experimental test) but Light Intensity has higher ranges in LX that indicates of daytime so that forced high beam to stay OFF (as shown in the simulated results).

Case (2) tests three ranges of (Vehicle Speed and Light Intensity), the first two ranges (86 - 108) km/h and (94 - 112) km/h change high beam status to DIM (as tested in both simulated and experimental tests) since Light Intensity ranges lay approximately at dark region of the LDR characteristics. The third range (123 - 154) km/h must put the high beam at OFF status since Light Intensity has higher ranges in LX that indicates of daytime but at these higher speeds DIM status operated (as we get in simulated test) and GLOW status operated (as we get in experimental test).

Case (3) tests two ranges of (Vehicle Speed and Light Intensity), (114 - 137) km/h and (119 - 158) km/h, which forced the high beam to operate at GLOW status (as we get in both simulated and experimental tests) since Light Intensity ranges lay at dark region of the LDR characteristics.

Case (4), at Vehicle Speeds over (160) km/h and Light Intensity ranges that lay at dark region of the LDR characteristics, high beam is forced to be operate at Bright GLOW status (as we get in both simulated and experimental tests).

From Table 4, as a comparison between simulated and experimental results it can be seen that there is a simple difference between high beam statuses at the pointed (*) marks, and this difference is due to the readings of the real time sensors at experimental test and the reason of electronic circuitry behaviours.

Table 4. High beam status according to tested values of (Vehicle Speed and Light Intensity).

Case No.	Vehicle Speed ranges (km/h)	Light Intensity ranges (LX)	High Beam Status (Simulation)	High Beam Status (Experimental)
1	64 - 81	99 - 110	OFF	OFF
	62 - 87	291 - 323	OFF	OFF
	61 - 118	623 - 649	OFF*	DIM*
2	86 - 108	101 - 117	DIM	DIM
	94 - 112	314 - 323	DIM	DIM
	123 - 154	632 - 649	DIM*	GLOW*
3	114 - 137	106 - 109	GLOW	GLOW
	119 - 158	309 - 329	GLOW	GLOW
4	142 - 163	109 - 112	Bright GLOW	Bright GLOW

6. System Drawbacks

The system may be operating un-accurately if another vehicle comes a head from the opposite side of the road with its high beam switched ON, affecting the photocell resistor in the designed system and leads to increase light intensity and switch OFF the high beam headlight where the surrounding environment has low light intensity. This system is limited with two inputs as explained before (Vehicle Speed and Light Intensity).

7. Conclusion

In this work, a simple, low cost design of a smart automatic switch is proposed and implemented to switch automatically the high beam of vehicle's headlight bulb with four modes (OFF, DIM, GLOW, BRIGHT GLOW) depending on; vehicle's speed (SLOW, NORMAL, FAST, VERY FAST) utilizing optical speed sensor; and surrounding environment light intensity with the cases (VERY LOW, LOW, OVERCAST). The system is designed utilizing Arduino UNO based (ATmega328 microcontroller), optical speed sensor and LDR photocell resistor. Fuzzy logic control utilized for generating system rules and according to these rules we found that the high beam operates about (10% to 60%) of its brightness at (DIM) case, (30% to 90%) of its brightness at (GLOW) case, and operates fully at (BRIGHT GLOW) case, and this is accomplished according to the vehicle speed and the light intensity status.

As a future work this system can be developed by using more than two inputs to the designed system, like the headlight status of the opposite incoming vehicle, fog status and rain status. We can use the recent optimization algorithms to tune the membership function of fuzzy system to improve the performance of the system.

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Abbreviations

ABS	Anti-lock Braking System
ACC	Adaptive Cruise Control
AHC	Adaptive Headlight Controller
CAN	Controller Area Network
CU	Control Unit
DSA	Driver's Situational Awareness
FDMS	Fuzzy-based Driver Monitoring System
FLC	Fuzzy Logic Control
IVTM	Integrated Vehicle Tire Pressure Monitoring
LDR	Light Independent Resistor
LED	Light Emitted Diode
LX	LUX (illuminance SI unit)
PWM	Pulse Width Modulation
RPM	Revolution Per Minute

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