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Speed Based Adaptive Lighting & Alert Technology for Vehicles

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Abstract: Today in India, we encounter numerous road accidents, resulting in permanent injuries for many individuals and fatalities for some. Major contributors to these accidents include inadequate lighting conditions, difficulty in assessing vehicle speed, and distractions from the high beam lights of approaching vehicles. Hence, it is essential to tackle this problem. This paper examines how vehicle safety is significantly affected by insufficient lighting and a lack of driver awareness regarding speed, frequently resulting in accidents due to traditional, fixed headlight brightness that cannot adapt to varying circumstances. The objective of this paper is to resolve these concerns by creating an innovative adaptive lighting and alert system aimed at improving vehicle safety during both daytime and nighttime. The system operates in two modes: manual and automatic. It employs a light-dependent resistor (LDR) to monitor the illumination from vehicles. The LDR gauges the intensity of oncoming vehicle lights, automatically adjusting the light intensity to an acceptable level. LEDs are utilized for headlamp lighting due to their effective illumination capabilities. By implementing different stages of headlamp illumination, it can minimize illumination waste and conserve battery charge.

Keywords: *Adaptive Lighting; Alert System; Light Intensity; LDR; IR Sensor; Automatic Headlamp.*

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I. INTRODUCTION

Road accidents in India have emerged as a significant and escalating issue, resulting in numerous injuries, disabilities, and deaths every year. Among the various factors that contribute to these incidents, inadequate visibility conditions, particularly at night, are pivotal. Poor street lighting, the difficulty in assessing the speed of approaching vehicles, and the harsh glare from high-beam headlights all create hazardous driving conditions. When high-intensity beams from a nearby vehicle strike a driver's eyes, it can result in temporary blindness, decreasing reaction time and elevating the likelihood of accidents. Furthermore, standard fixed-intensity headlights fail to adjust based on real-time speed and road conditions, worsening the situation. These issues underscore the pressing need for a smart, adaptive solution aimed at enhancing night-time driving safety while reducing the hazards linked to improper vehicle lighting.

To tackle these challenges, this document presents an Adaptive Lighting and Smart Alert System, a technology-focused method intended to optimize vehicle lighting for safer driving conditions. This system dynamically adjusts headlamp brightness according to real-time speed and road conditions, ensuring better visibility without causing discomfort to other road users. At the heart of this system is its capacity to detect the brightness of incoming vehicle lights using a Light Dependent Resistor (LDR), which automatically modulates the brightness of the vehicle's headlights. This mechanism prevents excessive glare while providing adequate illumination for the driver. In contrast to traditional headlight systems that operate at a constant intensity irrespective of road conditions, this adaptive system promotes road safety by modifying light output to match the surrounding environment. The suggested system functions in two modes: manual and automatic, granting drivers the choice of their desired level of control over headlight adjustments. In automatic mode, the system automatically detects approaching headlights and adjusts the illumination intensity in real-time, removing the need for driver involvement. In manual mode, drivers maintain the ability to tweak the brightness settings based on personal preferences and ambient lighting conditions. By adopting LED technology as the primary source of headlamp illumination, the system achieves greater energy efficiency, durability, and enhanced brightness control. LED headlights not only deliver superior illumination compared to conventional halogen lamps but also consume considerably less power, making

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them an excellent choice for modern adaptive lighting solutions.

One of the standout features of this system is its multi-stage illumination approach, which smartly regulates light output according to necessity. This staged illumination method ensures that only the required amount of light is emitted, reducing unnecessary energy usage and extending battery life. This capability is particularly advantageous for electric and hybrid vehicles, where conserving energy is crucial for overall vehicle performance. Additionally, by minimizing excessive headlight usage, the system contributes to the reduction of light pollution, fostering a more sustainable and environmentally friendly driving experience. In addition to adaptive lighting, the system features a smart alert mechanism aimed at enhancing driver awareness. A significant number of accidents occur because drivers do not notice oncoming vehicles quickly enough, especially in low-visibility situations. By integrating an intelligent alert system, the proposed solution delivers real-time notifications to drivers, aiding them in proactively responding to potential dangers. This feature proves especially beneficial on highways and rural roads, where visibility can be considerably diminished due to a lack of street lighting.

In summary, the Adaptive Lighting and Smart Alert System marks a notable advancement in vehicle safety technology. By dynamically adjusting headlamp brightness based on current road conditions and mitigating the negative effects of high-beam glare, this system guarantees a safer and more pleasant driving experience for all road users. The inclusion of LED-based adaptive lighting, multi-stage illumination, and a smart alert mechanism not only boosts visibility but also optimizes energy consumption, making it a feasible and sustainable solution for modern vehicles. With ongoing advancements in sensor technology and artificial intelligence, this system has the capability to be smoothly integrated into future automotive designs, contributing to a smarter and safer transportation ecosystem.

II. PROBLEM STATEMENT AND OBJECTIVES

A. Problem Statement:

Often, vehicle operators encounter the problem of temporary vision impairment caused by high beams at night. This momentary disruption in sight, commonly referred to as "glare" or "seeing spots," can greatly hinder a driver's ability to see clearly, particularly when facing oncoming vehicles. This can lead to serious road accidents. Automatic headlight technology improves safety on the road and enhances driver comfort. Nonetheless, there are several obstacles that still need to be tackled. A primary challenge is the expense associated with the technology, which could restrict its acceptance by certain drivers or car manufacturers.

B. Objectives :

The primary objective of this paper is to create a system that dynamically adjusts vehicle lighting based on speed and ambient light, while also offering alert-based cues for speed awareness on paper research.

III. RELATED STUDY

The headlamps are essential for improving the driver's visibility and ensuring safe driving. However, traditional headlights frequently do not function properly and necessitate manual handling. This paper aims to design and develop a headlight system that operates automatically to enhance safety during nighttime driving. The existing automation highlighted in previous research relies on a conventional approach for measuring vehicle speed, whereas this paper proposes the use of an isolated system equipped with an IR sensor, which provides increased efficiency and accuracy. This element is crucial for the smooth functioning of the vehicle from the standpoint of the control system's effectiveness. Headlamps are important for increasing the driver's visibility and supporting safe driving. Nonetheless, typical headlights often do not work optimally and need to be operated manually. The purpose of this paper is to create and implement a self-regulating headlight system to improve safety when driving at night.

An automatic headlight dimming system that employs a Light Dependent Resistor (LDR) sensor to reduce the brightness of headlights from vehicles approaching from the opposite direction, thus lessening the effect on human eyesight. This system automatically shifts from high beam to low beam by sensing the light intensity of oncoming cars, alleviating glare and eliminating the necessity for drivers to adjust their headlights manually, which can sometimes be forgotten. [1]

This system utilizes image processing technology to detect oncoming vehicles using an ultrasonic sensor, while a camera serves as an image sensor to determine the curvature angle of the road's white line. The adaptive front light systems are intended to automatically adjust a vehicle's headlamp beam to optimize road illumination while reducing glare for other drivers. [2]

The greatest number of deadly traffic accidents occurs on winding roads at night. To enhance nighttime driving safety, this paper aims to develop a prototype for adjustable headlights by modifying a conventional static headlamp while ensuring both cost-effectiveness and dependability. Different components that are easily available in the market and appropriate for constructing a steerable headlight system were assessed. [3]

The glare during nighttime driving poses a significant challenge for drivers. The presence of glare can result in a momentary loss of vision, commonly known as the Troxler effect. This study is centered around the creation and development of a prototype circuit called the automatic headlight dimmer. This system enables motorists to use high beam lights when necessary but automatically switches to low beam when it detects an approaching vehicle. Ultimately, glare is a major factor contributing to accidents that occur after dark. [4]

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A vehicle detection system is designed to identify vehicles by spotting their headlights and taillights in a nighttime road environment. The proposed system comprises two stages for detecting vehicles in front of a car equipped with a camera. First, the system distinguishes bright objects on the roadway; then, these bright objects are subjected to the suggested knowledge-based connected-component analysis technique to pinpoint the vehicle lights and estimate the distance from the camera-equipped vehicle to the identified oncoming cars. [5]

A system that provides benefits compared to conventional front lighting systems by saving battery power and managing beam transitions automatically, which lessens the driver's efforts. The Automatic Headlight Beam Control System (AHBCS) enhances safety and ease of use during driving by automatically activating and deactivating headlights and regulating beam brightness. It consists of two sensors: one facing forward and another placed at a right angle to the road surface. This highlights the progress and innovative features of the AHBCS, along with its advantages for drivers.[6]

That Most accidents predominantly happen at night because of the shortcomings of conventional headlight systems. This suggested solution tackles the problems associated with standard headlight systems by integrating LEDs into the headlamps. Traditional headlight systems usually provide just two lighting settings: low beam and high beam. The proposed innovative design manages the headlight beams through the use of LEDs. In this setup, the beam angles are adjusted according to the steering wheel's position. A relay circuit is used to power the LEDs. LEDs are selected for their effectiveness in energy consumption. Furthermore, this system is easy to implement.[7]

The vehicles are equipped with headlights that light up the path in front of them, but they often do not sufficiently illuminate turns. This shortcoming can lead to poor visibility and challenges in spotting obstacles on curved roads, especially when driving late at night. As a result, the main goal of this system is to offer an affordable solution for lighting blind spots during nighttime travel and in situations with significantly reduced visibility, thereby improving safety in these dark areas and assisting in accident prevention.[8]

When driving on the highway at night, a powerful light beam is crucial for lighting the road ahead. However, this can cause glare for drivers in oncoming vehicles, resulting in temporary blindness and a dazzling effect that makes nighttime driving notably more challenging. To address this problem, dual-filament bulbs are utilized, which contain an additional filament designed to redirect the light beam both downward and sideways, thereby minimizing the chances of blinding drivers in approaching vehicles.[9]

Significant advancements have been achieved in LED lighting systems for vehicles. Improvements in LED technology have made them a more energy-efficient option compared to incandescent and halogen bulbs, leading to lower energy consumption while delivering high brightness levels. Researchers have incorporated control systems like Pulse Width Modulation and DC-DC converters to manage brightness levels effectively. Furthermore, studies on Buck and Boost converters have aimed at enhancing LED power efficiency under different battery voltage scenarios. [10]

When navigating urban settings, the large number of lights can affect the performance of the device; as a result, it can be set to manual mode to avoid flickering headlights. When both cars are fitted with the "Automatic Dipper," they successfully adjust their headlight beams downward towards one another.[11]

IV. METHODOLOGY

The design concept of the system in controlling brightness of LED is shown in Figure. 1 the system consists of four main parts which are microcontroller, Sensing Unit, Switching Unit, LED. These components are used to assemble the system for any automobile.

A. Block Diagram Design

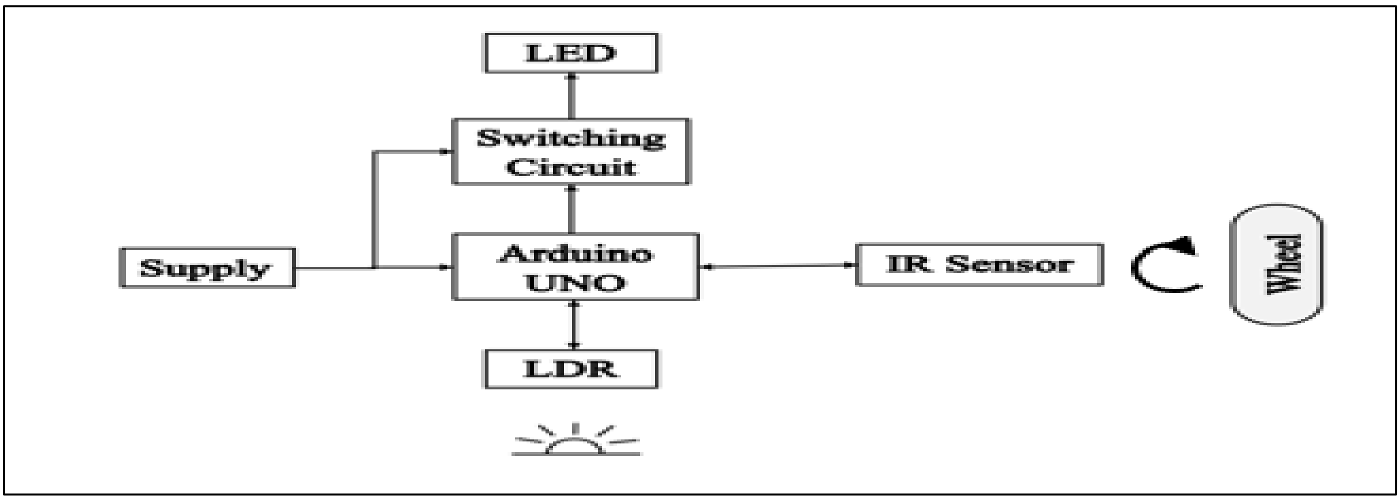

Fig 1: Basic Block Diagram of Working System

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In this projects about on Speed Based Adaptive Lighting And Alert Technology for vehicle, the system design is done by two requirements,

- *Hardware Requirements*
- *Software Requirements*

- *Hardware Requirements*

Hardware requirements of SBALAT for Vehicles are developed by using the following components:

- *Arduino Uno*

The Arduino Uno R3 CH340G with an ATMega328P is the main controller that manages the operations of the entire circuit. It processes inputs, executes programmed logic, and controls connected components. The Arduino plays a crucial role in this system, as it manages the entire process by interpreting and adjusting the input from the sensor.

- *IR Sensor*

An infrared (IR) obstacle sensor is a straightforward and cost-effective device commonly used for measuring rotations per minute (RPM) and detecting speed, such as in Arduino-based speed detection applications. It typically consists of an IR emitter, usually an IR LED, and an IR receiver, like a photodiode or phototransistor, which are positioned side by side.

- *LDR Sensor*

A Light Dependent Resistor (LDR) is a type of semiconductor whose conductivity changes in proportion to the intensity of light it is exposed to. An LDR is a resistor that decreases its resistance as the intensity of incident light increases, exhibiting a property known as photoconductivity. LDRs are particularly useful in light and dark sensor circuits. Typically, the resistance of an LDR is very high, sometimes reaching up to 1,000,000 ohms, but when illuminated, its resistance drops dramatically. In this system LDR is acts to sense the headlight beam of oncoming vehicles.

- *LCD (Liquid Crystal Display)*

An LCD (Liquid Crystal Display) is a commonly used visual output component in various electronic applications, including Arduino projects like "Speed Based Adaptive Lighting and Alert Technology for Vehicle". LCD displays have become popular due to their versatility, as they effectively communicate information, status, and data to users in a clear and readable format. It provides real-time feedback and engages users by showcasing information such as the current status of the headlamp system, sensor measurements, and system diagnostics. This feature enhances the user experience and allows for troubleshooting and system optimization.

- *Switching Circuit*

A switching circuit controlled by an Arduino can adjust a light between dim and bright modes. It uses PWM signals to regulate brightness, providing efficient and precise control to the headlights.

- *LED*

LED headlights in vehicles provide brighter, more energy-efficient illumination compared to traditional halogen bulbs. They have a longer lifespan, enhance visibility, and contribute to modern vehicle aesthetics.

- *Supply*

A 7V battery supply powers the Arduino Uno R3 CH340G ATMega328P, delivering a stable voltage to the entire circuit. This ensures reliable operation for all interconnected components.

- *Wheel*

The wheel creates rotational movement, enabling the IR sensor to speed detect and read interruptions or reflection changes.

- *Software Component*

- *Aurdino IDE*

The Arduino IDE is a free software platform designed for writing and uploading code to Arduino boards. It works on multiple operating systems, such as Windows, Mac OS X, and Linux. The IDE allows programming in both C and C++. The term "IDE" stands for Integrated Development Environment. Programs created in the Arduino IDE are commonly called "sketches." To upload a sketch, you must connect your Arduino board to the IDE. Sketches are stored with the file extension ".ino".

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B. Working Principle

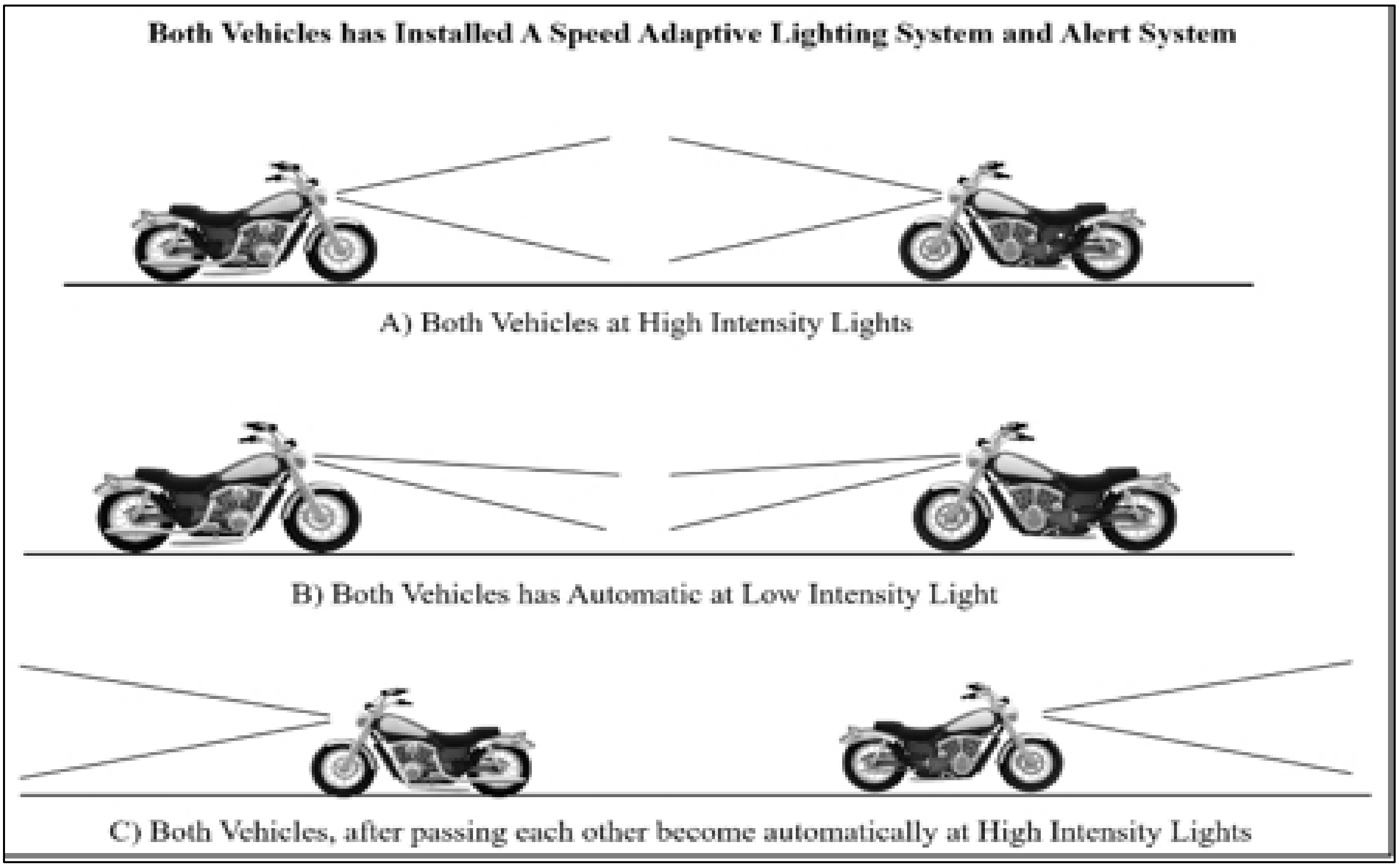

Fig 2: Detection of a Approaching Vehicle Headlight

Basically, there are two modes of working viz. manual and automatic mode, for selecting and automatic mode switch is provided. In manual mode for the by default user requirement adjustment for switch(S_1) controlling upper and dipper condition of the headlight. In Automatic mode (S_2) is consisting of Speed Based Adaptive Lighting & Alert Technology for vehicles. In above figure show the brief idea about working in real scenario. In Fig A) Both the vehicle is bypass each other and the system is instant capture the upcoming light and LDR sends the signal to Arduino Uno R3 Microcontroller has clock speed is 16 MHz, which means it can execute one instruction set within 62.5 nanoseconds. Whereas the operation cycle of switching circuit is of 20 ms or less. The PWM(pulse with Modulation) technique is used for switching and dimming operation. In fig. B) Both Vehicles has automatic shift at low intensity by using switching circuit. And fig. C) Both Vehicles, after passing each other, become automatically in normal running condition. The complete operation perform in mini second and reliable.

C. Technical Data

In this project, the system based on the working Model system is divided into three ranges such that:

Table 1: Model System

Ranges	Speed Limit	Boosters
Range 1	Below 40 Km (Normal)	0
Range 2	40 to 60 Km (Medium)	1
Range 3	60 to 80 Km (High)	2

The system is work on particular speed range is shown in above table. The Range 1 is a normal running condition and normal headlight intensity. And Range 2 is to enhance the light intensity by boster 1 is on that is medium level headlight intensity extender. And range 3 after crossing the speed limit the high level headlight intensity is blow and all the boster is on in that stage.

D. Simulation Diagram for Design

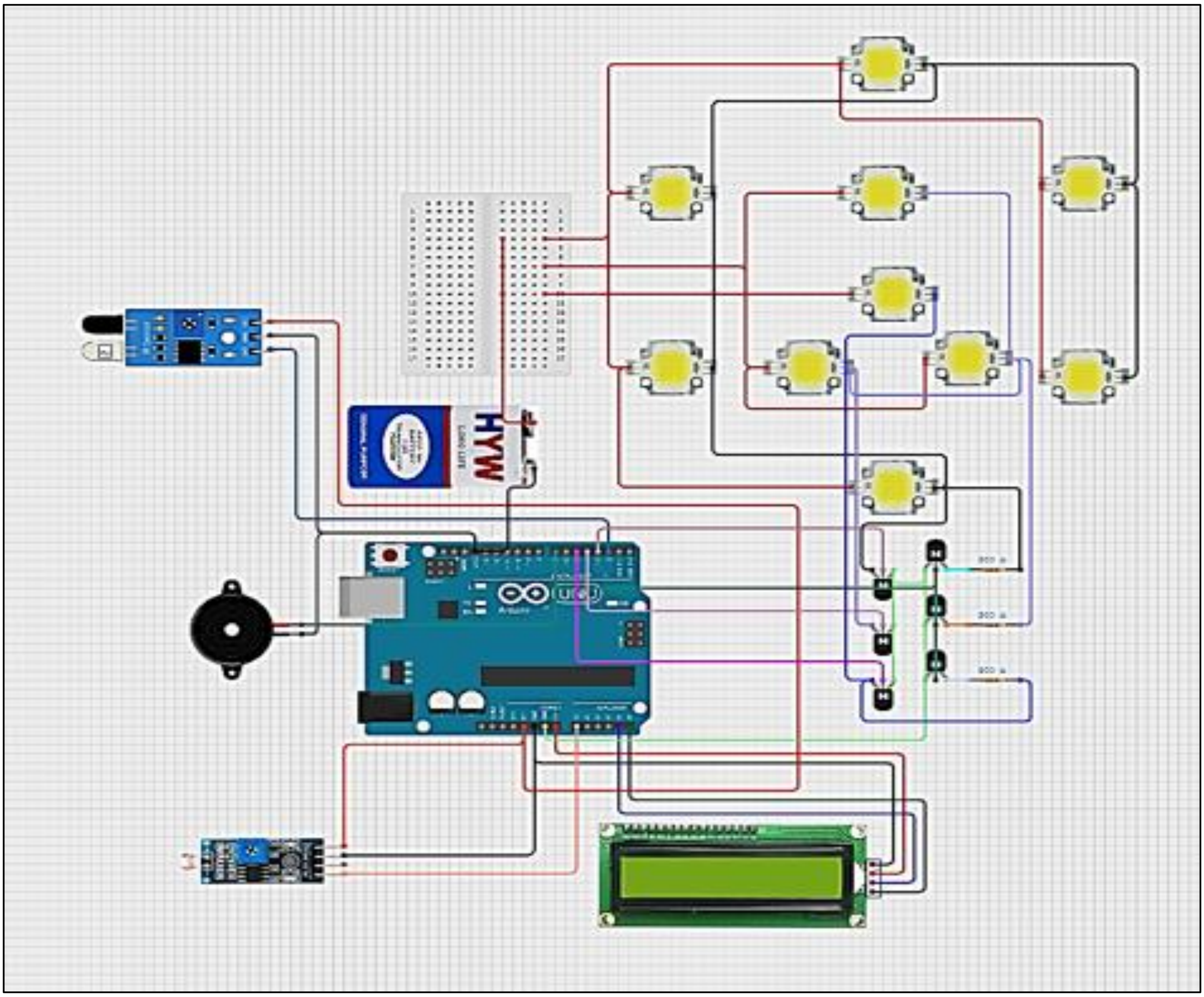

Fig 3: Simulation Diagram for System Design.

E. Algorithm and Flow Chart of the System

➢ *Algorithm of operation*

- ***Step 1:*** *Circuit Connections*

✓ Connect the IR sensor, LDR, and proximity sensor to the Arduino board. Make sure to connect power (VCC and GND) and signal (Trig, Echo for IR sensor; Analog pin for LDR).
✓ Connect DC motor to with the external regulator module. Power the DC motor with an external power source.
✓ Connect the LED switching module to the Arduino for control. The grounds of the Arduino and LED power supply are common.

- ***Step 2:*** *Write the Arduino Code to Control the Entire System. This Code Should Include the Following Functionality:*

✓ IR Sensor: Measure the Speed of the wheel rotation.
✓ LDR Sensor: Monitor ambient light levels. When it gets bright (Low LDR reading), turn on the deem the LED headlamp automatically. When it gets Dark (High LDR reading), turn on the bright the LED headlamp automatically.
✓ Switching Circuit : Control the LED (headlamp) based on inputs from the IR sensor and LDR.
✓ DC motor (Transmission system): We create the rotation motion of wheel by connecting the pulley mechanism to wheels shaft, and the DC motor is controlled by regulator.

- ***Step 3:*** *Assemble and Test*

- Assemble the components and circuits in a suitable enclosure.
- Upload your Arduino code to the Arduino board.
- Test the system to ensure that it functions as expected. Verify that the headlamp turns on/off based on light levels, the anti-collision system activates when an obstacle is detected.

- ***Step 4:*** *Fine-Tuning and Calibration*

Calibrate the system to ensure that it responds appropriately to various lighting and road scenarios. Adjust sensor thresholds and timing as needed.

- ***Step 5:*** *Safety and Compliance*

Ensure that your project adheres to safety regulations and compliances. Make sure it does not pose a hazard while in use in a vehicle.

- ***Step 6:*** *Deployment*

Mount the system in your vehicle and periodically test it to make sure it functions correctly.

➢ *Flow Chart*

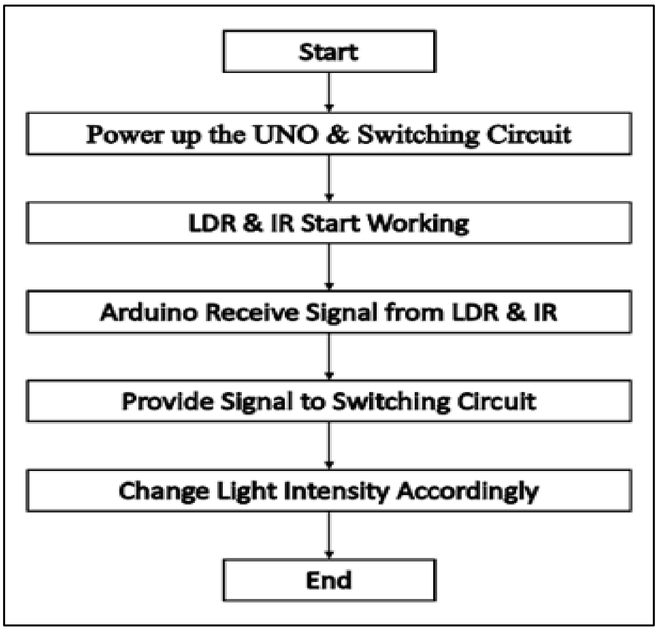

Fig 4: Flow Chart of the System

F. Hardware Implementation

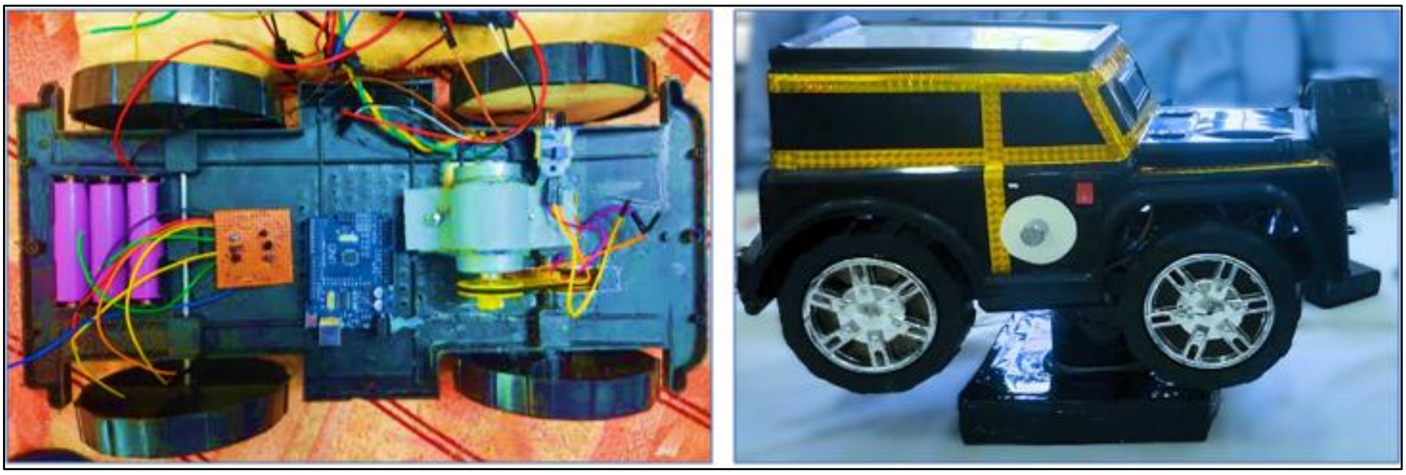

Fig 5: Developed System Model for Implementation

The practical implementation is an important and extensive stage that will give a clear and precise idea about the hardware installation process of the project. It is a productive stage of the project through which can be earned various skills and obtained practical experience by practically interacting with several components of different features and specifications.

Firstly, fixation the several hardware components inside the body of the vehicle. Proving the 12V battery, 12V Motor with Regulator, Arduino Uno, LCD Display, Switching Circuit, IR Sensor into the inside surface by using glue gun. Then, solder the required wires and place switch button for on & off purpose.

G. Design of System Device

The design of this device was done and placed on phototype model toy car of dimensions 35 mm x 15 mm x 15 mm. We use phototype model of toy car because all the components placed properly and protected from disconnection problem & dust and others. Vero board is called strip board. The purpose of the strip board is the switching circuit make. It is a widely-used type of electronics prototyping board characterized by a 0.1 inch (2.54 mm) regular (rectangular) grid of holes, with wide parallel strips of copper cladding running in one direction all the way across one side of the board. In using the board, breaks are made in the tracks, usually around holes, to divide the strips into multiple electrical nodes. With care, it is possible to break between holes to allow for components that have three pin rows only one position apart such as thrice row headers for

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Thyristor 2n222. Components were placed on the plain side of the board, with their leads protruding through the holes. The leads are then soldered to the copper tracks on the other side of the board to make the desired connections, and any excess wire is cut off. The continuous tracks were easily and neatly cut as desired to form breaks between conductors using a 5mm twist drill, a hand cutter made for the purpose, or a knife. Tracks were linked up on either side of the board using wire. The soldering process was carried out using a lead and soldering iron. This was done by joining the supposed terminals together before soldering. And after soldering each unit, test was carried out using a meter to ensure good contact.

Table 2: System Device

Test Parameter (Testing)	Light Dependent Resistor (LDR)	Infrared Sensor (IR)
No. of Tests applied	10	10
No. of Tests Pass	9	8
No. of Tests Fail	1	4
% of Tests Pass	90 %	80 %
% of Tests Fail	10%	20%

The Arduino Uno R3 CH340G with an ATMega328P Measures 68.6 mm x 53.4 mm, fitting standard Arduino cases and shields was interfaced with a 12 V power supply, LDR sensor module, IR module, and serial cable. The individual circuit were interconnected with Male Jumper and Female Jumpers or M to F connector and power cables to form one circuit.

V. EXPERIMENTATION AND CALCULATION

A. Experimentation

The circuit is built according to circuit diagram and place on the mini car model for testing and 12V Power Supply is applied to the circuit.

Speed Based Adaptive Lighting Technology for Vehicles is tested 10 times respectively and the results of the infrared sensor and light dependent resistor are shown in table below.

The purpose of applying ten tests into the system is to check and ensure that the Infrared sensor and light dependent resistor are working properly within the comprehensive vehicle headlights system.

In case of testing LDR sensor to sense the availability of a vehicle is coming from an opposite direction, the system is responding nine times out of ten times however, it failed for one times only out of total attempts. These numbers mean LDR sensor achieves good performance with 90 percentage of passing score.

In case IR sensor the test ten times at different speed level of a wheel, the system is responding Eight times out of ten times however, it failed for two times only out of total attempts. These numbers mean IR sensor achieves good performance with 80 percentage of passing score. Due to this property Infrared sensor inappropriate for accurate speed measurements.

B. Calculations

To create a formula for an Arduino-based speed meter using an IR sensor, we need to understand the basic principle of operation. The IR sensor detects the rotation of an object (like a motor shaft) by counting the interruptions or reflections of the IR beam caused by a marker on the rotating surface.

Formula:

➢ *Revolutions Per Minute (RPM) Calculation:*

$$RPM = \left(\frac{count * 60}{Time\ Interval\ (seconds)}\right) \quad \ldots(1)$$

- **Count:** Number of pulses detected (interrupts or reflections) in the given time interval.
- **Time Interval:** The time period in seconds over which the pulses are counted.

Multiply by 60 to convert seconds to minutes.

➢ *If there are Multiple Pulses Per Revolution:*

$$RPM = \left(\frac{count*60}{Time\ Interval * Pulses\ per\ Revolution}\right) \quad \ldots(2)$$

- **Pulses per Revolution:** The number of pulses generated per complete rotation of the object.

Example:
If the IR sensor detects 20 pulses in 5 seconds and there is 1 pulse per revolution:

$$RPM = \left(\frac{20 * 60}{5 * 1}\right) = \mathbf{240}$$

This formula can be applied in the Arduino code to measure and display the RPM.

To convert the RPM calculated using the IR sensor to the real-time speed of a vehicle (in km/hr), we need to know the following:

✓ **Wheel Diameter (D)** in meters: Measuring the diameter to find the circumference, it is vary depending upon the size of wheel.
✓ **Circumference of the Wheel (C)**: Given by the formula

$$C = \pi * D \quad \ldots(3)$$

Where $\pi \approx 3.1416$

➢ *Step-by-Step Conversion:*

- Distance per Revolution (meters):

$$Distance = C = \pi * D \quad \ldots(4)$$

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- Speed in meters per minute (m/min):

$$Speed_{m/min} = RPM * C \quad \ldots(5)$$

- Convert m/min to km/hr:

$$Speed_{Km/Hr} = \frac{Speed_{m/min}*60}{1000} \quad \ldots(6)$$

✓ **Final Formula:** From Above Eq. (4), (5) and (6)

$$Speed_{Km/Hr} = \frac{RPM*\pi*D*60}{1000} \quad \ldots(7)$$

Where:

- **RPM** = Revolutions per minute (measured using the IR sensor)
- **D** = Wheel diameter in meters
- π ≈ 3.1416

➢ *Example:*

Consider a moving vehicle with it's wheel rotation speed of 300 rpm **and let the w**heel diameter D = 0.5 meters

$$Speed_{Km/Hr} = \frac{300 * 3.1416 * 0.5 * 60}{1000} = \frac{282.74}{1000}$$
$$= \mathbf{28.27 Km/hr.}$$

This formula will give you the real-time speed of the vehicle based on the RPM measured with the IR sensor.

➢ *Adjustments:*

- Change wheel Diameter for your vehicle's wheel size.
- Update pulses Per Revolution based on your setup (if the IR sensor detects multiple pulses per revolution).

VI. RESULTS

- Enhance exiting functionality of the vehicle headlight system. And save the battery power consumption.
- Enhanced visibility for drivers during both daytime and nighttime conditions, thereby reducing the probability of accidents.
- Improved driver awareness of vehicle speed through the implementation of auditory alerts.
- Elevated overall safety and comfort levels during driving, contributing to a more secure driving experience.
- It's an cost effective solution for the problem of night time accidents occurring due to insufficient headlight intensity.
- It can be easily mounted on the existing or running vehicles and adapt that system cost effectively.

VII. CONCLUSION

This paper shows the aims to significantly enhance vehicle safety by implementing advanced adaptive lighting systems that adjust according to the vehicle's speed, measured in kilometres per hour (km/h). In addition to improved visibility, the system will also incorporate speed-indicating tones that vary based on the time of day, ensuring that drivers receive appropriate auditory cues during both daytime and nighttime driving conditions. By optimizing lighting conditions to match speed and surrounding environments, this technology helps drivers maintain high levels of awareness and visibility, thereby decreasing the likelihood of accidents. Furthermore, this paper underscores the critical importance of safety features in the automotive sector, where the effective application of these technologies can play a pivotal role in enhancing overall vehicle safety.

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