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Embedded Based Smart and Safe Vehicle System

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Abstract: The project "Embedded Based Smart and Safe Vehicle System" presents a cost-effective embedded solution to improve road safety in low- and mid-range vehicles. It tackles problems like poor visibility, high-beam glare, and delayed signaling with smart lighting and sensor technologies. The system includes adaptive headlights that automatically change direction and intensity based on the steering angle, vehicle speed, and ambient light. This feature improves visibility on curves and in bad weather. A smart high-beam controller identifies oncoming vehicles and switches to low beam to prevent glare. Additionally, a color-changing mechanism adjusts headlight color for fog, rain, or darkness, enhancing contrast and reducing eye strain.

Moreover, automatic turn indicators respond to steering movements, which reduces human error and improves communication with other drivers. Ultrasonic sensors spot obstacles and provide audio or visual alerts to lower the risk of low-speed collisions. The system centers around an Arduino R4 microcontroller and includes LDR, DHT11, and ultrasonic modules with servo motors. It has been designed and tested using Arduino IDE and Tinkercad, offering a scalable and retrofit-friendly option for budget vehicles. This project shows how affordable embedded technology can greatly enhance road safety and add useful features to everyday vehicles.

Keywords:Embedded system, smart vehicle, road safety, adaptive headlights, high-beam controller, color-changing mechanism, automatic turn indicators, ultrasonic sensors, Arduino R4 microcontroller, LDR, DHT11, servo motors, Arduino IDE, Tinkercad, cost-effective, scalable, retrofit-friendly, and affordable technology.

I. INTRODUCTION

Roadsafety is still a major problem worldwide, especially in developing countries, where the most common vehicles on the roads are low-cost and mid-range ones. Inadequate visibility, improper use of headlights, and delayed signaling during night driving and bad weather contribute to a very large proportion of road accidents. The use of intelligent headlight control systems has shown that they can make the road safer by increasing visibility and thus lowering the risk of accidents. This is achieved through their ability to adjust the light intensity and direction automatically depending on the road and weather conditions [1]. But such expensive and complicated systems are, in most cases, confined only to luxury cars.

Oneof the major issues with standard vehicle lighting is that environmental factors like fog, rain, and high humidity scatter the white light which is then observed as glare thus worsening the visibility below the level that can be reached under the dark conditions. Various studies concerning the automation of fog lights using the detection of humidity have suggested that the use of adaptive lighting considerably raises the contrast and the driver's perception under bad weather conditions [2]. The first experiments on the use of automated light intensity control circuits have demonstrated the possibility of the implementation of microcontroller-based lighting automation with the use of simple sensors [3]. Further innovations have paved the way for the introduction of smart lighting systems that are more energy-efficient and have better safety performance[4].Color-adaptivelighting has been proven to improve visibility as well as decrease eye fatigue by changing thecolor temperature automatically based on the surroundings [5].

One of the foremost safety concerns is that of a vehicle turning when fixed headlights do not illuminate the curved road properly. The use of steering-linked adaptive headlight systems has resulted in a significant improvement in road lighting and a reduction in accidents caused by cornering [6].While vehicle-to-vehicle communication systems are designed to improve cooperative road safety, the fact that they are

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scarcely available in low-cost vehicles raises the question of whether safety solutions that are simply embedded in the vehicle are more effective. Therefore, the demand for a low-priced, seamlessly integrated, smart vehicle safety system capable of functioning independently and, at the same time, substantially enhancing driver awareness and road safety is very high [7].

II. METHODOLOGY

Thesuggested Embedded Based Smart and Safe Vehicle System is a sensor-driven, real-time control, system that is aimed at improving visibility, correct signaling, and recognizing obstacles. To understand the situation around the vehicle, the system is always getting the data from many cheap sensors and then it uses an embedded controller to do the required control operations. The Light Dependent Resistor (LDR) is used to detect the ambient light intensity as well as the glare from an oncoming vehicle and thus enable the system to select automatically between a high and a low beam. This is well illustrated in cheap Arduino-based headlight control systems [8].

Relay-based lighting control and PWM methods are employed to adjust the beam intensity as well as to ensure that the switching behavior is carried out in a stable manner [9]. The ultrasonic sensor is used to locate obstacles and thus it can give accurate distance measurements which can be used in collision warning systems for low-speed and low-visibility situations [10].SmartLED-based lighting methods are used to enhance visibility at night and also to decrease the driver's fatigue [11].

The system detects weather conditions like fog and rain with a temperature and humidity sensor and changes the headlight color for better penetration and less glare automatically [12].Hybrid sensor integration strategies have been found to have a higher performance level than single-function systems in terms of reliability and decision accuracy [13].Automatic beam switching depending on ambient light levels is one of the measures taken to ensure that no ill effects from the beam fall on the eyes of the oncoming traffic [14][15].

The comprehensive system layout is in line with the prevailing patterns of intelligent vehicle lighting, which focus on the light adapting its behavior, the computational complexity being low, and the system being able to respond in real-time [16].

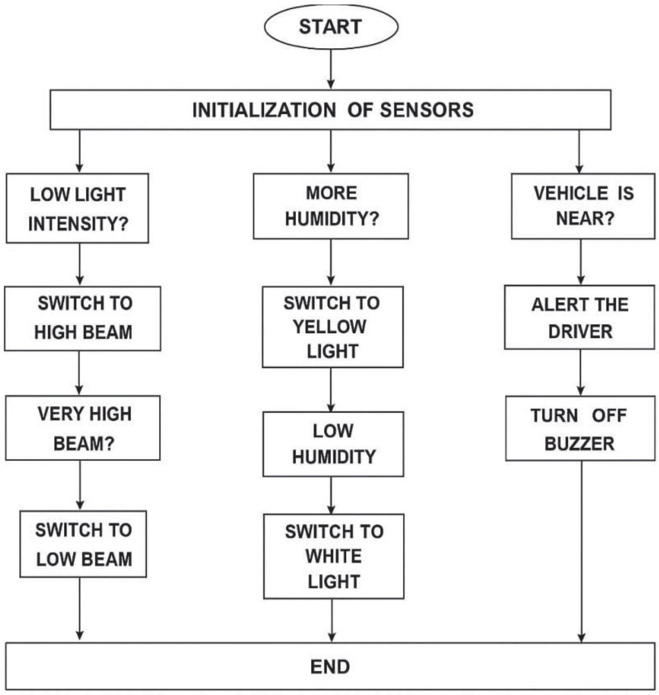

Figure 1: flow chart [8-9]

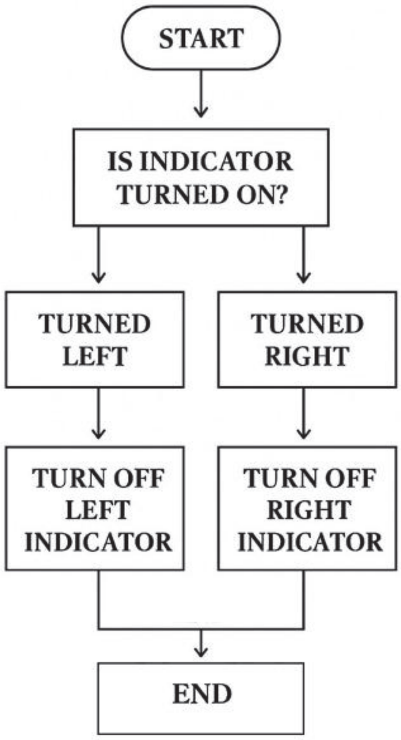

Figure 2 : flow chart of Indicator control system [31]

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III. IMPLEMENTATION

The implemented system is a functional hardware prototype that aims to simulate typical vehicle conditions in the real world. At its heart is an Arduino R4 microcontroller, which was chosen for its capability to perform real-time processing and its general suitability for embedded automotive applications [17][25]. The controller connects several sensors and actuators to carry out the functions of adaptive lighting, signaling, and obstacle detection.

Adaptive headlight control is done with the help of servo motors powered by PWM signals thus allowing the headlights to turn proportionally to the steering movement in line with the adaptive front lighting system (AFS) principles [18][19]. The hardware and software integration being guided by sensor-based safety architectures that are modular and scalable in nature [20]. The necessity of inexpensive safety features is once again confirmed by worldwide road safety studies that put a strong emphasis on the requirement of cost-efficient solutions for vehicles that are produced in large volumes [21].

Systemplanning for safe execution takes into account the functional safety concepts, which were specifically derived from automotive embedded systems [22]. It is planned to utilize sensor fusion methods by including steering, light, weather, and distance data to get the agreeable result system precision and resiliency [23]. Affordable embedded architectures are used to confirm the integration of various safety features in a single controller platform [24].

The metal parts concept follows the official microcontroller documentation and the best practices of real-time control and power management [25]. Standards for vehicle lighting and visibility set up ideal safe conditions for performing tasks and complying with the rules [26]. The struggle for control and the response of the actuator have been helped by control engineering principles of classical nature [27]. The literature on driver assistance systems is additionally a source of evidence that automation can lessen the driver's workload and the occurrence of human errors [28].

Embodied safety modules based on ultrasonic methods contribute to the reliable detection of obstacles and the giving of timely alerts [29]. The entire implementation thus serves as a proof of an intelligent, inexpensive embedded system, which is capable of upgrading vehicle safety and driver awareness effectively without the necessity of costly ADAS technologies [30].

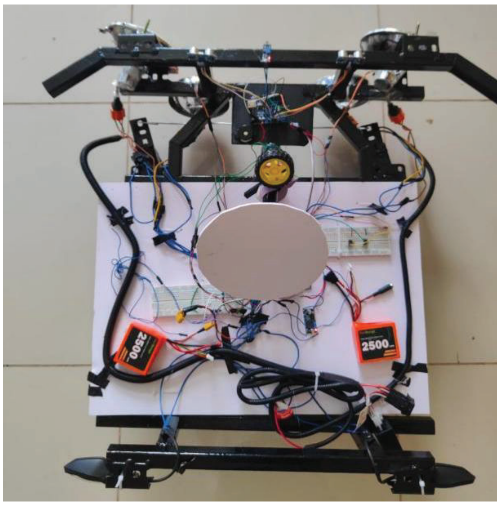

Figure 3: Implementation

IV.RESULTS AND DISCUSSION

The embedded smart vehicle system instigated safety features effectively through automation and sensor integration. Ultrasonic sensor was main device that can shows the obstruction in the region. While the adaptive headlights adjusted the direction and the brightness of the light according to the steering angle and the ambient light. Overhead beam light prevented the brightening of the other vehicles; drivers. The DHT11 sensor contributed to the headlight color change in fog or rain. Automatic indicators turned on and off correctly during vehicle turning. The vehicle system significantly made the human eye brighter, at the same time lessening human error and met the criteria of being affordable and suitable for low-cost and mid-range vehicles.

1. Adaptive Headlights

The adaptive headlight system featured the ability to adjust the light beam direction based on the vehicle& steering angle. Arduino R4 Minima in real-time ingested analog data from the potentiometer that represented steering rotation. It then sent out equivalent PWM signals to the servo motor for the control. Consequently, the headlight which is attached to the servo was able to turn left or right alongside the steering motion. In this way, the lighted way was always the road, thus making it safer during night driving or in the cornering of the road.

The system was dependable during the test. It exhibited minimal response time and motion without any jitter. Even in the dark and foggy cases, the adaptive method kept the same level of performance, thus, it was very helpful in safety. The findings supported that the adaptive headlight works as a more intelligent and safer lighting system than the standard one, hence, it is a good choice for future intelligent vehicle systems.

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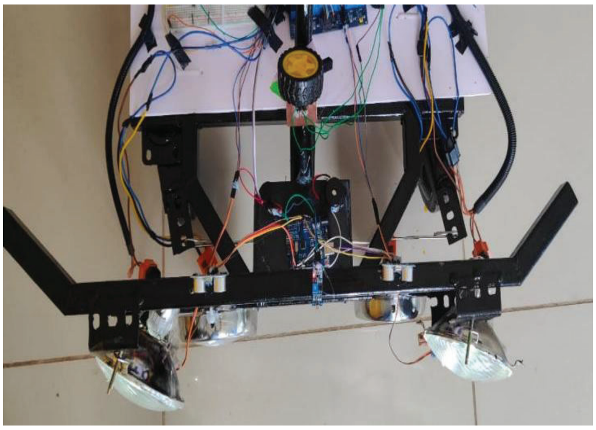

Figure 4: Adaptive headlights

2. Automatic High/Low Beam Control

The automatic high/low beam control system was developed to make night driving safer by changing the beam strength when new cars appeared. LDR sensor gave the Arduino information about the light of the next headlights so it melded the car beam from high to low. By doing so, both road users were safe from the dazzling effect of the lights. If there were no lights from the other side, the system switched back to the high beam by itself to give more light to the road in front. The whole changing from one step to the other was very quiet and it was done within milliseconds signifying that it was very fast and efficient.

Experimental results pointed out that the system was very prompt and reliable when it came to bearing the changing light intensities. System was able to eliminate complete glare for the oncoming traffic while maintaining sufficient visibility for the driver. Such an intelligent control of beam intensity helped to make the road safer and gave the driver more comfort during the night trips. Demonstrated in the system can be taken as a proof of the LDR-based automatic beam control as a low-cost and efficient lighting solution for vehicle lighting systems.

Figure 5: Automatic High Beam Control

Figure 6: Automatic Low Beam Control

3. Weather-Based Light Color Control

The weather-based light color control system comprised a DHT11 temperature and humidity sensor and a yellow incandescent light. The sensor was in charge of monitoring the surrounding temperature and humidity levels to recognize adverse weather conditions like fog, rain, or high humidity. After detection of such conditions, the system would change the headlight color from white to yellow by the use of the relay module automatically. Yellow light can go through fog and mist better than white thus the visibility in the road was improved and the glare from the moisture particles in the air was reduced.

The system was also able to perform such a function during the tests when it changed the color of the light every time the humidity was above the predetermined threshold, or the temperature was within the fog range. This adaptive response assured lighting at an optimal level for the road to be safe for driving in all-weather scenarios. By linking environmental sensing with lighting control, the system reliability and functionality were enhanced, thus providing an intelligent and affordable method of adapting vehicle headlights to the weather in low-cost cars.

Figure 7 : Weather-Based Light Color Control

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4. Automatic Turn Indicators

The automatic turn indicator system was masterminded to minimize faults of the human brain and to keep the user signal at the right time during vehicle turns. A potentiometer recognized the steering angle. The Arduino using direction and degree of rotation data activated the left or right indicator corresponding to the relays module. When the steering wheel came back to the center, the indicators turned off automatically. Signaling method accuracy was ensured by this mechanism without the need for human operation which thus guaranteed that every turn or lane change was correctly signaled.

The system underwent the testing process through several types of steering movements. The results showed the indicators' prompt and accurate reaction to the movements. The lights blinked at a uniform rate thus, the visibility of the vehicle users such as drivers and pedestrians was increased. The self-canceling feature got to its point effectively as there was no delay in turning off the indicators at the right time. In brief, besides the automatic turn indicators system, driver safety and a sense of ease were enhanced and driver workload as well as signaling mistake cases were reduced in real-world driving situations.

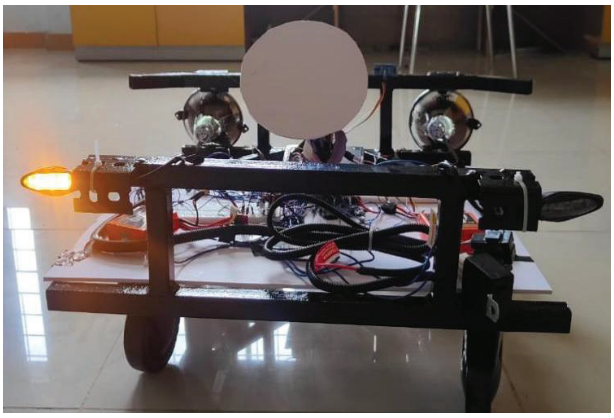

Figure 8 : Automatic Turn Indicators

5. Ultrasonic Obstacle Detection

Integration of the ultrasonic obstacle detection system was done with an aim to enhance safety by informing the driver about the nearby objects or cars. The system using the HC-SR04 ultrasonic sensor continuously checked for the distance between the vehicle and the obstacles. Once an object came closer to a predetermined safe distance, the Arduino sent out the signal to the device that makes the noise and thus, it is the driver who gets the alert. This feature is quite significant in parking, reversing, and low-visibility situations where it is challenging to find an obstacle manually.

During the test, the sensor pinpointed the location of objects in the range of 5 cm to 300 cm with great accuracy and consistency. The time between the event and the reaction was practically zero thus, the driver would be in the position to make the right move in good time. System execution was stable not only in good lighting and open-air conditions but also in the closed room and under the tent. Thus, this feature has brought about a considerable enhancement to the driver awareness of the situation and has lessened the risk of minor accidents, thereby making it a precious addition to the total embedded vehicle safety system.

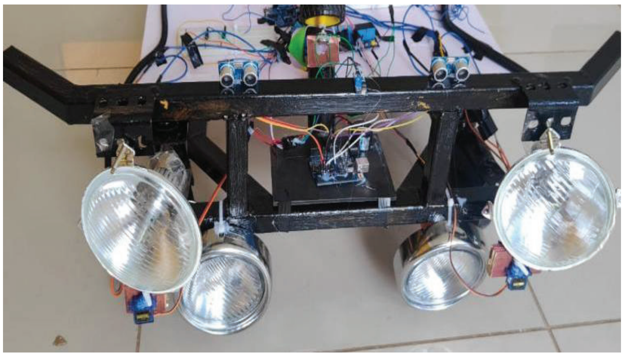

Figure 9: Ultrasonic Obstacle Detection

V.CONCLUSION

The Embedded-Based Smart and Safe Vehicle System is a case powerfully showing the application of embedded technology to vehicle safety, automation, and driver comfort. Through the use of sensors such as the LDR, DHT11, and ultrasonic module, and actuators like servo motors and relays, the system is able to adjust lighting and signaling in real-time based on road, traffic, and environmental conditions. The features of cornering headlights, automatic beam switching, weather-dependent light color, self-canceling indicators, and obstacle alerts, therefore, help to enhance the driver's field of vision and lower the chances of human errors.
In essence, the team has demonstrated a small-scale and inexpensive embedded solution that can smartly respond to changing driving conditions. It serves as an inspiration in the largely unexplored field of multi-sensor integration and control logic for the development of advanced smart automotive safety systems, thus, presenting a feasible and scalable way of implementing the next-generation intelligent vehicles.

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Ethical Approval and Consent to Participate	No, the article does not require ethical approval or consent to participate, as it presents evidence that is already publicly available.
Availability of Data and Materials	Not relevant.
Authors Contributions	All authors have equal participation in this article.

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AUTHOR PROFILE

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Kavitha N M is an ECE (Electronics and Communication Engineering) student. She is deeply interested in topics like Embedded Systems, Autonomous Systems, and Intelligent Technology Solutions. Besides academic projects, she has practically done the following: autonomous drones, sensor-based systems, image processing applications, smart vehicle safety solutions. Her technical area of interest also includes VLSI, Embedded Systems, UI/UX Design, and Full-stack Development with the latest technologies. She is an active member in creative and start-up-related activities and is driven to use her engineering skills to solve real-world problems in a way
that is both efficient and scalable.

VijayCJ is an Electronics and Communication Engineering graduate (ECE) with a keen interest in the areas of embedded systems, IoT-based solutions, robotics, and intelligent automation technologies. He has been part of both academic and practical projects, such as an embedded-based smart and safe vehicle system, smart irrigation systems, sensor-integrated robotics, and safety-focused automation solutions. His are deep technical interests in the junction of the ECE field cutting-edge technologies like embedded systems; VLSI; PCB design; microcontroller programming; and intelligent control systems. In addition to this, he is a skillful and active performer in technical challenges, and activities related to innovation and entrepreneurship, and he is driven by the desire to use engineering knowledge to solve real-life problems with efficient, reliable, and scalable technology solutions.

Jayanth A is a final-year student of the Electronics and Communication Engineering department at MIT Thandavapura. He is deeply interested in Embedded Systems, IoT, Automotive Electronics, and Coding. Jayanth has a strong technical background and he is good in Arduino IDE, C programming, sensor interfacing, and circuit design. He is an enthusiastic Core Electronics dream of getting a job and he wants to invest his energy in inventing hardware solutions. As a part of a show, he came up with the concept of "Smart Adaptive Headlight & Safety System" which is a real-world example of automation and safety comprised of mechanics. He is looking forward to a career in the Core Electronics industry that will challenge him and enable him to indulge in the passion of innovative hardware developments. He wants to earn a living by doing hands-on work in the field of Embedded Systems and Product Development.

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I am also very creative and love to solve problems. As a result, I have been involved in several hackathons, such as a home automation project in my first semester and robot war competitions in my second year. These challenges have helped me to develop my skills, become a better team player, and improve my ability to perform under pressure and in limited time situations.