AUTONEX – An IOT Enabled Smart Autonomous Electric Vehicle Safety System with Emergency Communication

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Abstract: Car accidents involving heavy traffic are a significant international issue, with about 1.19 million fatalities each year. In third world countries such as India, it is more serious because of the low visibility of the night, the slow emergency response, the inability of cars to move, and the inability to have the modern safety systems. Such challenges show that it is necessary to have a smart and connected solution which will be capable of preventing accidents as well as acting swiftly when they happen.

The paper suggests AUTONEX, a free electric vehicle safety system created with the help of the Internet of Things (IoT) technology to make the road safer and operate more efficiently. The system will combine numerous synchronized units: (1) an obstacle detection device based on an ESP32-CAM to observe and avoid collisions in real time, (2) a smart headlight dimming to minimize glare on the road at night, and (3) an alcohol-detection system to ensure safety in the use of a vehicle. This system also incorporates (4) the accident detection and emergency communication unit based on GSM and GPS to exchange data in real-time and share locations to achieve quicker responses to rescue. Also, it features (5) a solar-powered charging module, which is activated under low battery conditions to enhance the efficiency of energy. (6) A battery control system can be used to provide stability of power and reliability. The suggested system offers an efficient method of addressing the emerging transportation systems of the next generation by offering a comprehensive approach in accident prevention, pinpointed energy regulation, and instant emergency response.

Keywords: IoT, Autonomous Vehicle Safety, Smart Headlight, BMS, Accident Detection, GSM-GPS, Smart Solar Charging Assistant.

1. Introduction

The areas of rapid development of electric vehicles and intelligent transportation systems have contributed to raising the concerns about vehicle safety at a global scale greatly. Despite technological advancements, road accidents continue to be a major cause of fatalities and serious injuries. On the road, in India alone, an annual report of 4.8 lakh road accidents [7] were registered in 2023, and this ratio touched 1.72 lakh in 2024, an average of about 485 per day. Such statistics point out that the current safety mechanisms remain inadequate to cope with the current traffic problems.

Some of the causes of a significant number of accidents include low night visibility, driver tiredness and drunkenness, unanticipated obstacles, battery faults in electric cars and slow response to emergencies. The traditional safety devices, such as seat belts, airbags, ABS can offer passive protection only [5]; the current GPS-based systems do not offer real-time intelligence and automatic decision-making. This makes these systems fail to be integrated to give a coordinated response in cases of emergencies, increasing the damages and delayed medical attention. Nonetheless, recent innovations in the sphere of IoT, embedded systems, and sensor technologies allow creating intelligent safety solutions that can ensure substantial monitoring and handle the latter proactively [7].

The proposed system AUTONEX should eliminate these challenges and unite several safety features into one intelligent platform. It integrates headlight dimming (automatic), visualizing obstacles, alcohol linking, solar energy regulation, battery surveillance, and communication in case of an emergency to improve the general protection of vehicle safety and performance. The rest of this paper will proceed in the following way: Section 2 will provide a review of the existing systems, Section 3 will provide the proposed AUTONEX system, Section 4 will explain the prototype and implementation of the newly developed system, Section 5 talks about results and discussion , and the final section will focus on conclusion and reference.

2. Existing work

Being applied in recent years, the major research has been carried out to enhance vehicle safety with embedded systems, sensor-net networks, and IoT-based technologies. The available solutions, to which most solutions mostly focus on accident detection and communicating with an accident victim, are mainly based on vibration sensors or impact sensors with GSM and GPS modules to send information about the location to the emergency services [8]. Although they save on time used in rescuing, such systems are mostly responsive and only work once an accident is within the fray. Other solutions are automatic controlling of the intensity of the beam in order to see better in the night (LDRs) [1], Battery Management Systems (BMS) to monitor the parameters of an electric vehicle [2]-[3], MQ3-based alcohol detection in order to avoid drunk driving [4], and obstacle detection with ultrasonic sensors to help the driver [5]- [6]. Moreover, it has considered the integration of solar energy in a bid to enhance the efficiency of electric vehicles in terms of consumption. Nevertheless, the systems are usually independent modules with no coordination and smart decision-making. This discussion demonstrates that the current solutions are mostly safety issues away from each other and not combined in one, real-time, proactive manner. In order to address these shortcomings, the proposed AUTONEX system will incorporate various safety capability functionalities with one smart platform.

It uses ESP32-CAM based obstacles detecting to provide proactive collision avoidance, alcohol detecting to stop unsafe driving and auto-headlight dimming to help with better visibility at night. Moreover, it integrates solar-assisted charging and battery monitoring to ensure efficient energy consumption and IoT-based emergency communication system to plunge real-time notification with full location accuracy. Through a combination of these capabilities, AUTONEX offers a progressive intelligent vehicle safety system, which exceeds the conventional single format.

.3. Proposed Method

Proposed system AUTONEX is an autonomous intelligent electric vehicle safety system based on the IoT and planned to provide road safety, energy efficiency, and responsiveness in case of emergency. In contrast to the conventional solutions where distinct safety modules are used, AUTONEX combines sensing, monitoring, and communication into a unified embedded platform that handles an ESP32 microcontroller. The system constantly gathers real-time data provided by various sensors LDRs to detect ambient light, battery sensors to detect voltage, MQ3 alcohol sensor, ultrasonic sensors to detect obstacles and vibration sensors to detect accidents.

The system uses these inputs as inputs to make wise decisions, and to initiate automatic actions eliminating human involvement. The most important safety functions are automatic headlight dimming to minimize glare during evening driving, alcohol sensing to eliminate the risk of operating vehicles irresponsibly, and the obstacle detection to warn the driver and prevent the collisions. Moreover, AUTONEX integrates effective energy management by monitoring battery levels in real time and solar-assisted charging system is featured so that when the battery is low compared to a predefined threshold, a solar-assisted charge should be provided. During accidents, or other emergencies, the vibration sensor captures any sudden impact and sends real-time alerts through GSM, whereas GPS ensures it can give the exact location data that will be located more quickly by the rescuers. AUTONEX provides a scalable and full-service next-generation electric vehicle safety system by incorporating safety monitoring, intelligent control, emergency communication, and renewable energy support into one platform to provide a comprehensive solution

.3.1 System Architecture

The AUTONEX system is built on a modular layer architecture combining sensing, processing, decision making, execution and cloud communication in a single platform. The system is structured with five major layers as shown in Fig. 1 which are well interconnected in a seamlessmanner.

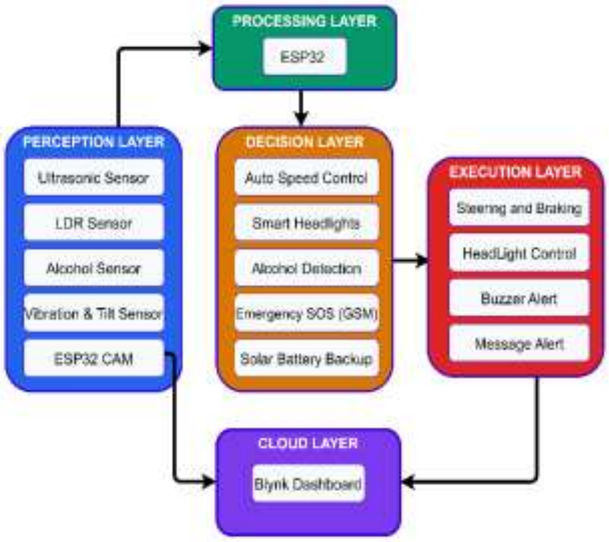

Fig.1 Block Diagram

The Perception Layer: This is a segment of sensors including ultrasonic sensors to detect obstacles, an LDR to measure the intensity of light, MQ3 to detect alcohol, vibration sensors to detect accidents, ESP32-CAM to monitor the vision. These elements constantly receive real-time information of the environment of the vehicle. The data gathered is then sent to the Processing Layer, which the ESP32 microcontroller processes and makes ready to be intelligently analyzed. The Decision Layer analyzes the information that has been processed and decides the right measure to be undertaken, such as controlling speed, turning on the headlights automatically, alcohol detection response, emergency SOS, and managing the battery upon the power of the sun. Such decision making is implemented into the Execution Layer, which undertakes operations like braking control, lighting like switching, buzzer warnings, and emergency messaging to provide an instant reaction. Last but not the least, the Cloud Layer allows viewing real-time and remote access with the help of platforms such as Blynk, where users are able to monitor the state of the system and get notifications.

All in all this multi-layered architecture has provided a means of efficient real-time monitoring, smart response decision-making and coordinated emergent response within the AUTONEX system.

3.2 System Flow

The operating process of the AUTONEX system is depicted in Fig. 2 which presents the schematic process of how the built-in safety mechanisms function.

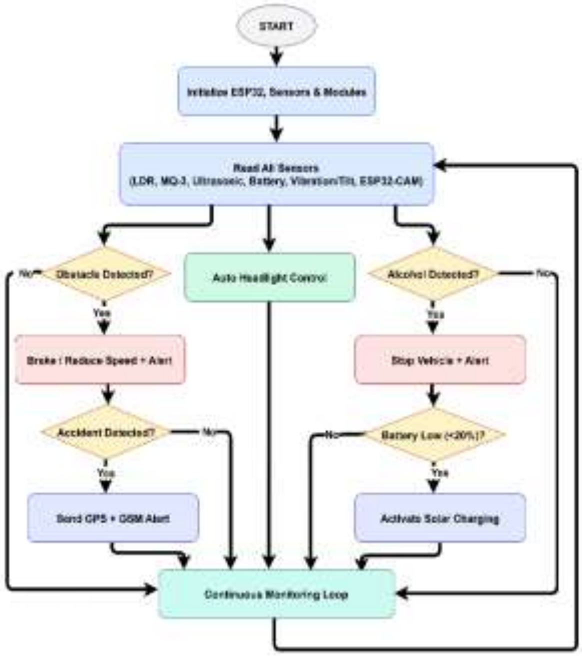

Fig.2 Flow Chart

Upon starting initiation of the system, the ESP32 controller will turn on all sensors and communication modules. The system subsequently keeps gathering real-time data of various inputs such as the LDR, MQ3 alcohol sensor, ultrasonic sensor, battery monitoring unit, vibration sensor, and ESP32-CAM. Through this information, the system in a sequence considers various conditions in order to guarantee safe vehicular operation. First, the ultrasonic sensor scans and obstacles in a particular range within a critical range, will cause braking, slowing down, and alerting the driver. When there is no hindrance, the LDR sensor is used to regulate automatic headlight where it depends on the ambient light conditions.

The system then measures the presence of alcohol; in case alcohol is detected it limits the operation of the vehicle and sends out a warning and normal operation resumes. The battery levels are constantly checked, and in case they drop below a specified limit (the usual being 10-20 percentage.), the solar charging system is turned on to keep the power levels stable. At the same time, the vibration sensor will be functional to monitor accidents; when the vehicle hits an object, it will retrieve the location, using GPS and transmit emergency alerts to pre-established contacts, with the help of GSM. Once these checks are done, the system will run on a continuous checks loop and will also provide immediate action and allow the smooth combination of both preventive and reactive safety mechanisms into one decision system.

4. Prototype model

The Hardware architectural solution of proposed AUTONEX system demonstrates a working prototype of integrating all safety and monitoring modules in small vehicle platform as illustrated in Fig. 3. The elements are organized in a logical way so that they can operate effectively and with a minimal complexity. The system comprises six major modules: an ultrasonic sensor, used to detect obstacles and avoid collisions, an LDR-based intelligent headlight system, which allows to maintain the brightness in accordance with the technical needs, an MQ3-based alcohol detector, to prevent unbearable driving, and a vibration sensor, along with GSM-GPS modules, to identify the accidents and effectively communicate in case of an emergency.

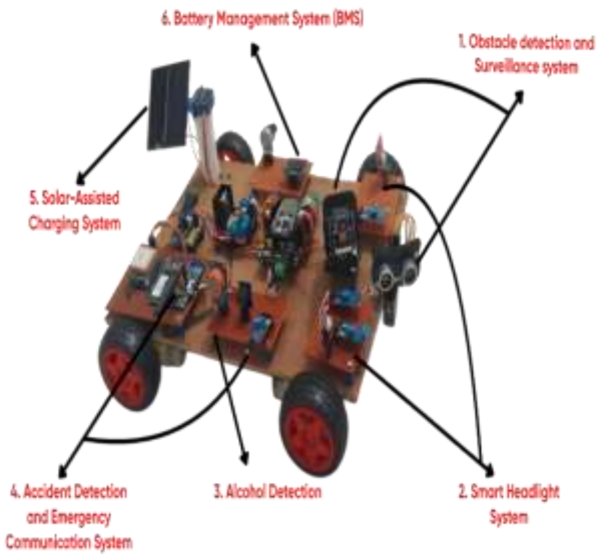

Fig.3 Prototype of the model

Also, a battery management system and a solar-assisted charging system will enhance energy efficiency, but a solar-assisted charging system will also provide a stable voltage and reliable performance. The ESP32 microcontroller is the central processing unit that connected all the modules. The prototype shows that it is possible to efficiently integrate several safety features into a single embedded platform and use it as a means of detecting obstacles in real-time, monitoring the driver, controlling the energy flow, and responding to an emergency.The developed model as demonstrated in Fig. 3 validates the viability and efficiency of the AUTONEX system, which explains its applicability in the real world with respect to intelligent transportation systems..

4.1 Obstacle Detection and Surveillance System

In the ultrasonic sensing process, the conduct trace module is assumed to have the capability of sensing the objects in its proximity and avoid a collision. The physical implementation of the same is provided in Fig. 4 in which HC-SR04 ultrasonic sensor is interconnected with ESP32 microcontroller.

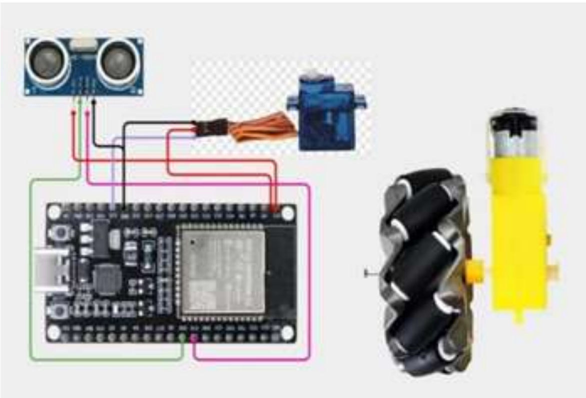

Fig.4 Obstacle Detection and Surveillance System

HC-SR04 sensor is connected to four pin connections one of which is the VCC, Trig, Echo and GND thus the circuit in Fig. 4. This pulse which is sent by ESP32 triggers Trig pin making the sensor send ultrasonic waves somewhere around 40 kHz. They are sound waves which found their way to air, reflected on an object and redirected them to the receiver. Time of pulse of As echo pin A was a measure of longer time pulse compared to the time of passing through an object and being reflected by it.

Time of flight principle The distance is calculated based on the following meaning:

$$d = \frac{v \times t}{2} \quad \text{....(1)}$$

$$d = \frac{343 \times t}{2} \quad \text{....(2)}$$

Where:

- d= Distance (meters)
- v= Speed of sound (343 m/s)
- t= Time for echo (seconds)
- Division by 2 → accounts for to-and-fro travel

It comes with an alarm (buzzer/warning) and a motor driver is free to do anything in case the distance traversed may not reach a pre-set safety margin threshold (Foster). The barriers should be refreshed continuously in real-time and as such make the system a reality in the case of the traffic situation, parking shortage, and poor visibility.

4.2 Smart Headlight System

Light Dependent Resistor (LDR) assists the smart system of headlight to either brighten or dim the state of headlights of the vehicle forcefully depending on condition of the ambient light. Fig. 5 shows that the circuit was possible to be implemented in the following manner: LDR has to be connected to the ESP32 ADC and a voltage divider circuit.

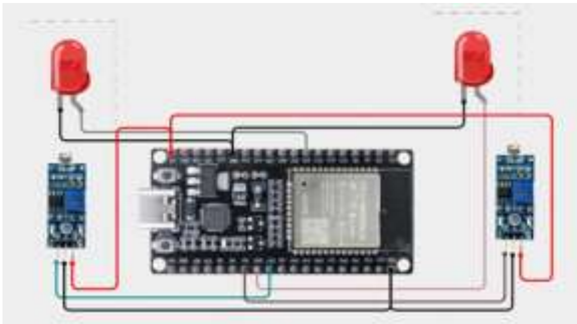

Fig.5 Smart Headlight System

This operates in the same system only that an incessant analog signal is received by an LDR instead of the modules being based on LM393 that do not provide a digital signal (HIGH/LOW). This enables the strength of the light to be addressed and the Headlights to be regulated also, through the assistance of the PWM.

The output voltage of the LDR voltage divider is given by:

$$V_{out}=V_{in}\times\frac{R_{LDR}}{R_{fixed}+R_{LDR}} \quad ....(3)$$

where R_{LDR} varies with light intensity.

The relationship between LDR resistance and light intensity (lux) is approximately:

$$R_{LDR} \propto \frac{1}{L^{\alpha}} \quad ....(4)$$

where Lis light intensity and α (typically 0.7–1.0) depends on the LDR material.

The brightness of the headlight is controlled using PWM:

$$\text{Duty Cycle} = \frac{ADC_{value}}{ADC_{max}} \times 100 \quad ....(5)$$

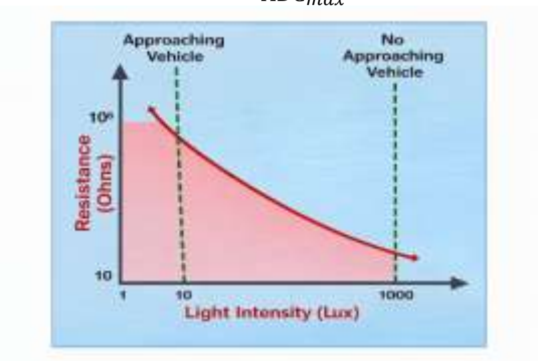

Fig.6 Graphical Representation

cripple of dim headlights reduced through discouragement of PWM duty cycle. The dependence of the intensity of light and resistance in the LDR is inverses as in Fig. 6. This will assist the headlights to adapt continuously in order to maximize the visibility, reduce the on traffic glare as well as reduce the amount of power used.

4.3 Alcohol Detection

The alcohol detection mechanism will make drivers safe as it will detect the content of alcohol in the breaths of the driver. The ESP32 microcontroller is connected to MQ3 gas sensor as illustrated in Fig. 7 and it constantly detects the air around the device. The system will sound an alarm when the alcohol concentration in the air is above a set limit to avoid unsafe transportation the engine will be shut down.

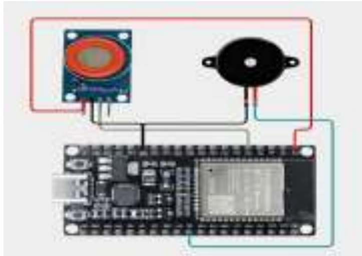

Fig.7 Alcohol Detection

MQ3 sensor is based on a principle where the sensor will vary its resistance to the presence of alcohol vapours based on the material they are coated with to accomplish the task. It also provides out analog output (AO) that is deemed to be continuously measurable and digital output (DO) that is deemed to be senseable with a threshold. Through this system the outcome of the analog is used to monitor.

Sensitivity of sensor will be determined as:

$$\text{Rs} = R_L\left(\frac{Vout}{\text{Vc}}-1\right) \quad ....(6)$$

where

- R_s is the sensor resistance,
- R_L is the load resistance,
- V_c is the supply voltage, and
- V_{out} is the output voltage from the sensor.

The relationship between gas concentration and sensor resistance is given by:

$$\frac{R_s}{R_0} = A \cdot (C)^{-B} \quad ....(7)$$

The more the concentration of alcohol the lesser the sensor resistance consequently leading to greater output voltage. This is compared with some preset value by the microcontroller. Exceeding such limit will result into warnings (buzzer/notification) and termination of vehicle, operation. The real-time alcohol monitoring depicted in Fig. 7 would make sure that drunk driving is avoided accordingly resulting in a safer road in general.

4.4 Accident Detection And Emergency Communication System

The system of sensing an accident will be provided to identify unexpected hits and open an emergency channel automatically.The design of the whole implementation will be provided in Fig. 8 which will interface the ESP32 with vibration sensors, tilt sensors to recognize the abnormal motion.

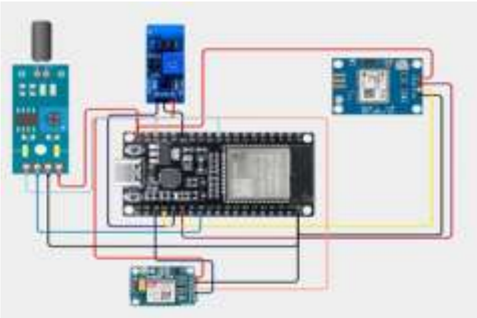

Fig.8 Accident Detection And Emergency Communication System

The SW-420 vibration sensor and tilt sensor always monitor the movement of cars. Returning to usual conditions the output is on the LOW. When an object collides with it or when the sensor is struck by something the sensor reading is likely to be high, in order to indicate an abnormal vibration or orientation change. This signal is interpreted by ESP32 and the emergency mode activated.

The vibration signal can be approximated as:

$$V(t) = A\sin(\omega t) \ldots (8)$$

where

- A represents vibration amplitude and
- ω is angular frequency.

A sudden increase in amplitude indicates a possible accident.Once an accident is detected, the GPS module determines the vehicle's location using satellite-based positioning. The distance between satellite and receiver is calculated as:

$$d = c \times t \ \ldots .(9)$$

where

- c is the speed of light and
- t is the signal travel time.

For accurate positioning, GPS uses trilateration:

$$(x - x_i)^2 + (y - y_i)^2 + (z - z_i)^2 = di^{\,2} \ \ldots .(10)$$

where

- $(x, y, z)$is the receiver position and
- $(x_i, y_i, z_i)$are satellite coordinates.

The obtained latitude and longitude are transmitted using the GSM module. The signal propagation is affected by path loss, given by:

$$PL = 20log_{10}(d) + 20log_{10}(f) + 32.44 \ldots .(11)$$

where

- d is distance (km) and
- f is frequency (MHz).

The frequency relation for GSM communication is:

$$f = \frac{c}{\lambda} \ldots .(12)$$

Where

- c is the speed of light, and
- λ is wavelength.

After receiving the location information, GSM module (SIM800/SIM900) sends an SMS alert and sends the same to pre-programmed contacts. This is an entirely automated process and enhances quick communication as well as minimizing response time in case of an emergency. Fig. 8 depicts a system which has been established to be reliable in the accident identification alongside real-time positioning of the site coupled with wireless transmission, hence a required component in the AUTONEX safety system.

4.5 Solar-Assisted Charging System

The solar-assisted system is designed to increase the efficiency of the energy using the renewable solar energy. This is implemented as shown in Fig. 9 with a combination of solar panel, charge controller, LDR sensor, and tracking mechanism are added to ESP32. The sun tracking also comes with this system compared to the fixed panels that provide the panel with a chance to take the direction of the good sunlight so as to produce more energy.

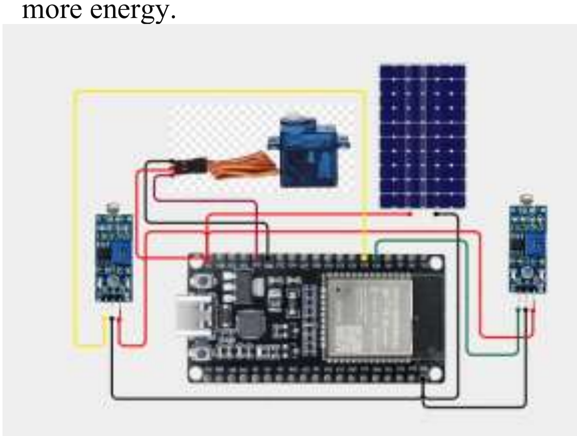

Fig.9 Solar-Assisted Charging System

The photovoltaic reaction assists the solar panel to convert the sunlight to electricity with the aid of photovoltaic effect. The generated current is given by:

$$I = I_{ph} - I_0 \left(e^{\frac{qv}{nkT}} - 1 \right) \quad \ldots(13)$$

where I_{ph} is the photocurrent, I_0 is the saturation current, q is electron charge, V is output voltage, n is ideality factor, k is Boltzmann constant, and T is temperature.
The output power of the panel is:

$$P = V \times I \quad \ldots(14)$$

To maximize power generation, the system adjusts the panel orientation using light intensity feedback from LDR sensors. The resistance of the LDR varies inversely with light intensity:

$$R_{LDR} \propto \frac{1}{L} \quad \ldots(15)$$

The controller uses a servo motor to tilt the solar panel depending on the difference between voltages in order to optimize energy collection. A charge controller can control the amount of power generated to provide safe charge by preventing undercharging and overcharging of the battery. It is charged when there is ample sunlight and is switched off when sunlight is low to prevent loss of energy. Such an intelligent solar monitoring system as shown in Fig. 9 enhances the efficiency of energy usage, expands the range of the battery life, and lessens the reliance on external power, as well as fosters the idea of environmentally-friendly vehicle usage.

4.6 Battery Management System

The position of the battery is monitored continuously and friendly and efficient operation of the vehicle is a task of the Battery Management System (BMS). It can listen to a significant number of parameters such as battery voltage and quantitate the State of Charge (SoC) in real time. Fig.10 reveals that the system is connected to the solar charging one. An ADC measures the battery voltage through a voltage divider circuit, and then measures it to approximate the SoC.

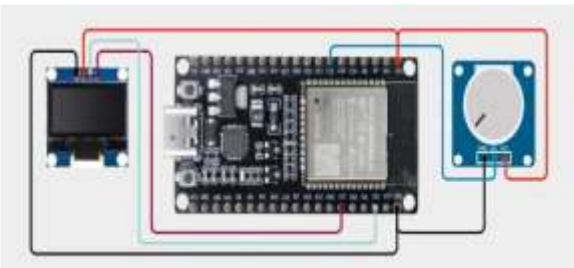

Fig.10 Battery Management System

It may be considered that the State of Charge is:

$$\text{SoC}(\%) = \frac{V_{battery} - V_{min}}{V_{max} - V_{min}} \times 100 \quad \ldots(16)$$

where

- $V_{battery}$ is the measured battery voltage,
- V_{min} is the minimum safe voltage, and
- V_{max} is the fully charged voltage.

Once the charge controller is switched on it then controls the solar power which is received and then it makes sure that the battery is charged and nothing goes wrong and there is no excess charge which is other way round. The battery system will slow down the charging rate or even stop charging once the battery capacity has surpassed the threshold to conserve energy and well-being of the battery. The advantages of such smart control approach are in that it offers continuous operation, lengthens battery life, removes the tendency to use external charging systems, and boosts the energy efficiency of the AUTONEX system.

5. Results and Discussion

The proposed IoT-enabled system AUTONEX was experimented under a variety of conditions in real-time to analyze the system concerning its performance, reliability, and reaction time. The findings of the experiment are verified to say that the system was an established and successful vehicle safety platform, reacting faster and coordinating the activities of the traditional stand-alone systems.

Fig.11 Blynk – Obstacle detection

The monitoring interface created in Blynk (Fig. 11) can effectively show real-time data on the obstacle distance, vehicle speed, camera streaming, and pan-tilt control. ESP32-CAM offers real-time visual feedback, allowing to perform efficient surveillance and remote monitoring of the vehicle environment. The system was stable in its connectivity through Wi-Fi and the latency in responding was found to be minimal and therefore real-time control was smooth.

Fig.12 ESP32-CAM

The ESP32-CAM visualization (Fig. 12) and the obstacle detection system based on ultrasonic sensors can give precise real-time distance measurement. The system can easily identify the obstacles around and help avoid collisions. The visual feedback also helps in the improvement of situational awareness to the user.

Fig.13 Blynk - Headlight Control

The automatic headlight control (Fig. 13) was found to be in good working state since the output of the system altered the intensity of the headlights dynamically because of the quantity of ambient light detected with LDR sensor. During testing, it was found that the system would turn dark in instances of high-intensity (lux) and light in low light because of high light on oncoming cars. This is an adaptive mechanism which increases the night time visibility, minimizes glare on approaching vehicles.

Fig.14 Blynk – Alcohol Detection

An alcohol detecting mechanism (Fig. 14) was also immediate to response. The engine ignition would automatically be switched off and warnings issued in case the alcohol contents of the alcohol reached higher levels than the pre-programmed level. The Blynk notification system was able to pass real-time notifications with success, which proves the stability of the safety mechanism.

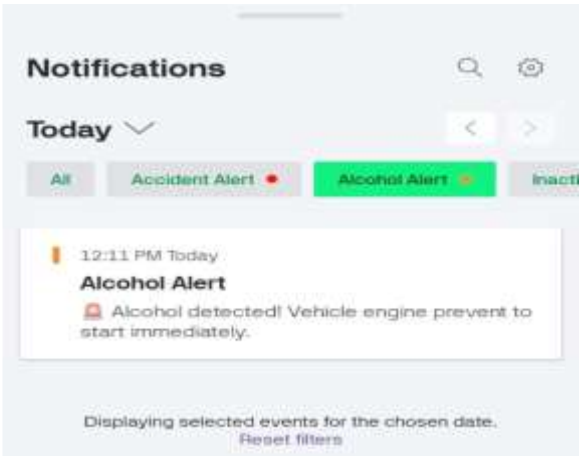

Fig.15 Blynk – Alcohol Alert

The alert mechanism of Alcohol Detection & Accident detection and emergency communication (Fig. 15 and Fig. 16) worked well in the process of identifying the abnormal conditions as a result of use of defects of vibration and tilt sensor.

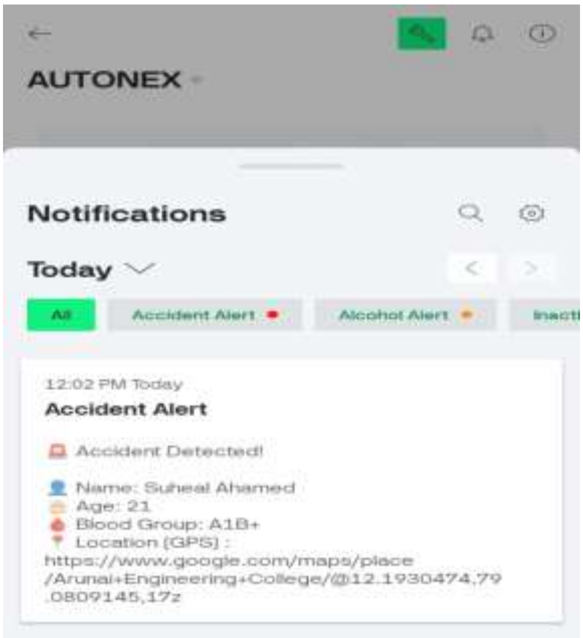

Fig.16 Blynk – Accident Alert

In the case of the collision being identified, the system was capable of automatically sending alert messages and their GPS location with the help of GSM. The alert carrier contained such significant user information as name, age, blood group and exact location that would require an eternity before emergency services were attracted to the place.

Fig.17 Blynk – Solar Charging & BMS

A test under various conditions was also loaded with Battery Management System (BMS) and solar charging module (Fig. 17). The battery percentage and battery voltage were recorded in the system. The solar charging mechanism was switched on automatically due to the low battery level of 10. This ensured the uninterrupted operation and increased consumption of the energy.

In general, there was high performance in the AUTONEX system in all modules. Its ability to incorporate IoT, real-time tracking, autonomous safety response, and effective power consumption has made it a modern and scalable system that could be utilized in an advanced car protection.

5.1 Compression table

Feature	Previous Methods	AUTONEX System
System Design	Separate standalone systems	Integrated single IoT platform
Headlight Control	Manual / fixed intensity	Automatic (LDR-based smart adjustment)
Battery Monitoring	Basic or no real-time tracking	Advanced BMS with real-time IoT monitoring
Driver Safety	Limited (no alcohol detection)	Alcohol detection with alerts
Obstacle Detection	Basic sensors / not real-time	Ultrasonic-based real-time detection
Accident Response	Manual reporting	Automatic detection + instant GSM-GPS alert
Emergency Communication	Delayed / not automated	Instant location sharing via GSM
Energy Source	Only battery dependent	Solar + battery hybrid system
System Efficiency	Low coordination	High coordination & smart automation
Safety Level	Moderate	High (multi-layer protection)

5.2 Discussion

The results are effective to prove that there is a significant improvement regarding the system of vehicle safety to use as a substitute of the AUTONEX. The system is an integrated platform that incorporates the different safety and monitoring functions on one platform as opposed to the traditional systems that laid focus on the singular feature. The synchronized working of all modules is aimed at system reliability, decreasing the response, and real-time intelligent decision-making. In addition, solar power can be used together to create more energy efficiency and sustainability. The relevance of this multidimensional measure to the recent tendencies related to the intelligent transportation systems and demonstrates that the implementation of smart safety features to the modern electric cars represents a reasonable opportunity.

6. Conclusion

The paper shows the design and execution of AUTONEX an IoT-based smart autonomous electric vehicle safety system that unites various safety, monitoring, emergency response, and energy managing functionalities into one intelligent platform.

The system grants the obstacle detection, intelligent headlight control, alcohol detection, crash detection with emergency communication, battery management, and solar assisted charging all into a single architecture to alleviate the shortcomings of individually installed safety systems. The system exhibits a stable operation in different working conditions. The smart headlight system makes the night time more visible and lessens glare, and obstacle detection is effective in preventing collisions. The alcohol detection system enhances the safety of drivers by limiting unsafe driving. Moreover, the unit of accident detection and emergency communication will allow carrying out quick aids in the form of sending up-to-date location data through GPS and GSM.

The solar-assisted charging and battery management also play a bigger role in guaranteeing the efficiency of energy and reliability of the system. On balance, AUTONEX demonstrates that a combination of various intelligent modules into one Internet-of-Things facilitates platform will result in a substantial improvement of car safety, efficiency, and ability to respond to emergencies. The system is sensible and can be expanded and deployed real-life application in the next-generation smart transport systems.

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