IJEAST

INTERNATIONAL JOURNAL
OF ENGINEERING APPLIED SCIENCE
AND TECHNOLOGY

VOLUME : 8   ISSUE : 11   Print / Issue Publication Date: 26-Jun-2026

ISSN : 2455-2143

Indexed In

Google Scholar · Open Access · doi · Crossref

WWW.IJEAST.COM

editor@ijeast.com

International Journal of Engineering Applied Sciences and Technology, 2024
Vol. 8, Issue 11, ISSN No. 2455-2143, Pages 232-240
Published Online March 2024 in IJEAST (http://www.ijeast.com)

SMART ROAD SAFETY AND VEHICLE ACCIDENT PREVENTION SYSTEM FOR MOUNTAINOUS ROADS

Ezeja Obinna Michael, Odoh Kenneth Ekene, Amadi Emmanuel Onochiem, Joseph Joseph Chimebuka
Department of Electronic and Computer Engineering
University of Nigeria, Nsukka

Abstract— **People who use mountainous roads are much more likely to be victims of accidents than their counterparts in tablelands. The steepness of such roads which is their unique feature makes it very difficult for drivers to see other vehicles or users especially from the opposite side and more often than not, this has led to accidents that have claimed many lives. The smart vehicle and accident prevention device is a good technological solution that leverages advanced technology to enhance overall road safety and mitigate potential accidents. Traditional safety measures may not effectively address the complexities of modern traffic patterns, diverse road conditions, and the increasing number of vehicles on the road. By incorporating smart systems that can monitor, analyze, and respond to various situations in real-time, the occurrence of accidents and their severity can be greatly reduced. The hardware design began with the circuit, which includes creating a prototype and simulating it using the Proteus simulation tool. This consists of the Arduino controller, sensors, components, modules, and their connections. The hardware aspect also involves implementing the simulated circuit through soldering. The software component of the project involves writing and compiling codes using the Arduino Software IDE. These codes will then be transferred to the Arduino board for execution, allowing it to complete its tasks with ease. The result shows an effective system that effectively mitigates the occurrence of accidents.**

Keywords— **Accident, Microcontroller, Mountainous roads, Safety, Smart systems**

I. INTRODUCTION

Transportation has always been an integral part of human lives. Developments in technology have led to the production of several vehicles used for transportation today by air, road, rail or water. The most common means of transport now is the land, specifically the road transport system. However, with an increasing number of vehicles on the road, the risk of accidents has also risen. This has made road accidents become a much more common cause of death globally and even in Nigeria here with places like Adamawa, Enugu etc. with lots of roads on and across highlands lose people annually as a result. While most existing literatures and statistics discuss road accidents in broad terms, this project narrows focus to road accidents occurring in mountainous roads.

Mountainous roads present a peculiar challenge to road users because of the natural form which they take. They are often characterized by high curvatures and steepness alongside many other blind spots. The challenge posed by hairpin bends lies in the limited visibility for drivers, making it difficult to anticipate oncoming vehicles or obstacles from the opposite side of the curve. When vehicles are traveling at high speeds, maintaining control becomes arduous, increasing the risk of careening off cliffs and, in some unfortunate instances, resulting in untraceable accidents. These locations are not only prone to accidents but also witness incidents where vehicles and drivers disappear into the mountainside terrain, a recurring phenomenon.

Such occurrences result in significant loss of human lives and the degradation of road infrastructure. The narrow nature of mountain roads magnifies the impact of accidents, often leading to prolonged road closures for clearing operations, a scenario we've seen unfold after both minor mishaps and major catastrophes. Effectively extracting vehicles involved in accidents frequently necessitates the deployment of heavy machinery, constituting a colossal undertaking in itself. The resulting toll encompasses financial losses, expended time, lives of accident victims, and the inconvenience faced by stranded travelers enduring hours or even days of immobilization. While convex mirrors and warning horns have traditionally served this purpose, their efficacy remains questionable.

To enhance the safety of travelers on such roads, a smart road safety and vehicle accident prevention system is here by proposed; one which serves as the dual purposes of road surveillance and warning system for road users. Our endeavor involves utilizing micro-controller technology to avert vehicle accidents on hilly and mountainous roads. When a vehicle is moving at excessive speeds, maintaining control becomes challenging, increasing the risk of potential cliffside falls. The proposed solution involves notifying the driver about obstacles or oncoming vehicles from the opposite side of the valley.

This project presents a viable model for the design and implementation of such smart devices.

According to the World Health Organization (WHO) [1] showed that about 1.3 million people die each year due to road traffic collisions, that is, over 3,000 deaths per day, which is simply astonishing and sad. It's not just the fatalities that are concerning; even more people sustain non-fatal injuries from collisions, causing disabilities and long-lasting effects. Further statistics from the WHO showed that about 80% of road traffic deaths occurred in low and middle-income countries, despite having only about one-third of the world's registered vehicle fleet [2]. It is especially alarming to know that road traffic injuries are among the top three causes of death for people aged 5 to 44, which could be attributed to the rapid increase in motorization without sufficient improvement in road safety strategies and land use planning.

Accidents are a critical concern in Nigeria, with most incidents happening on the road. In comparison to other modes of transportation such as air, rail, and water, road transportation is the most widely used means of travel in Nigeria. Despite the benefits that technology has brought to transportation, road accidents have become an alarming phenomenon in Nigeria, and it is believed that the occurrence rate has risen exponentially. According to the road transport data from the Nigerian bureau of statistics, about 2,080 road crashes occurred in Nigeria during the second quarter of 2020 alone. Further breakdown revealed that 5,535 of these accidents resulted in injuries and 855 deaths recorded [3]. Also, in the first quarter of 2022, about 12,128 people were involved in road accidents, with 10,294 injured and 1,834 killed [4]. In essence, Nigerian roads have become hazardous and lethal for travelers, with no effective safety measures in place to protect them. For those who travel on these roads, simply arriving at their destination can be a huge relief. As stated by Afolabi [5], the causes of road accidents in Nigeria can be categorized into three major factors:

1. Human factors
2. Mechanical factors and
3. Environmental factors

Fig. 1: A pictorial representation of a Nigerian mountainous road (Milken Hill, Enugu) [31]

According to Piyoosh Rautela et al [6], the sinuosity of a mountainous road increases with the terrain becoming more rugged and this is responsible for:

a) Limiting visibility across the curves and thus increasing probability of the driver being surprised by a speeding vehicle approaching him or an obstruction on the road.
b) The speeding vehicle not being able to negotiate curves and thereby losing control.
c) The fatigue of drivers while negotiating recurrent curves during long hill driving and the ensuing loss of control of the vehicle. The sinuosity of the roads is a major factor responsible for road accidents in the hills and it can be hypothesized that accident proneness of the mountain roads increases with increasing sinuosity of the roads.

In the plains, roads generally follow a consistent topography, but mountain roads face several obstacles that prevent them from being contour aligned. These obstacles include accommodating buildings at varying elevations, avoiding costly bridges, adhering to geo-technical limitations, and dealing with physiographic constraints. Therefore, mountain roads cannot always follow the contour and must navigate different elevations, resulting in some sections of the road being quite steep. This steepness, along with the road's sinuosity, makes driving in the hills risky. Hence, it can be hypothesized that as the gradient of the mountain roads increases, so does the likelihood of accidents.

The implementation of standard road safety measures is hindered by geographical constraints, such as the rugged terrain. It poses a challenge to ensure efficient safety measures. Moreover, emergency response time can be further delayed in rescuing accident victims in remote mountainous areas due to difficult access and communication difficulties.

Dwaipayan Saha et al [7] proposed a system that includes proximity sensors, RGB LEDs, buzzers, and counters for accident prevention on mountainous roads. The proximity sensor detects the presence of a vehicle on one side of the road, and the counter keeps track of the number of vehicles coming from that particular direction. The data sensed is transmitted to the microcontroller, which then triggers the LEDs. For instance, if five vehicles are coming down the hill (Side A), and two vehicles are moving up the curvy road (Side B), the proximity sensor at Side B senses that two cars are approaching it, and the counter on Side A shows a count of 2. Similarly, on the Side A of the curve, the proximity sensor senses that five cars are coming towards it, and the counter situated on Side B displays 5. The LEDs' colours on both sides of the road turn to red, signaling danger. As the vehicles go away from the sensor, the count goes down to zero, and the colour of the LED turns to green. When there is only one car on either side, the signal is green, and the driver knows there is no vehicle on the other side.

This design's benefits include increased effectiveness, given that it uses more than one signaling system (Visual and Audio). However, the use of audio signaling systems (buzzers, horns, etc.) can add costs without yielding the intended benefits, particularly during rainy seasons.

Dattaraj Vidyasagar et al [8] proposed a similar system. Two red lamp posts are fixed at the starting points of the U-turn. Each red post is controlled by a sensor. Whenever a sensor detects a vehicle passing on one side of the road, the red post on the other side of the curve turns on. This way, a signal is given to vehicles coming from the other side of the mountain/curve. This system also has similar flaws as the one discussed before it.

Asha M. et al [9]in their paper also came up with a mechanism to prevent accidents by producing a system made up of Arduino, IR sensors, RFID sensors and IOT module. The IR sensors were put on either side of the bend to notify the opposite side of incoming vehicles. The speeds of each vehicle, both coming and going were also recorded and sent to the relevant authorities for necessary disciplinary actions. The paper however failed to mention the source of power for this system to function as a constant power supply of 9V would be needed constantly to power the micro-controller.

Tanmay Krishna et al [10] also studied on road accidents and came up with an accident prevention system as seen in their paper. The system was to help prevent accidents on mountainous roads in India. The system comprised of an Arduino board, infra-red sensors, LED lights and a buzzer. The LED lights were installed on the bends of the roads on the sides of the mountains, especially on blind spots. The infra-red sensors were also placed on both sides of the roads to detect oncoming vehicles from both directions. These sensors sent signals to the Arduino controller which triggered the lights. The lights changed colours according to the vehicles coming and the distance between two vehicles. A red light meant that there was a vehicle coming from the opposite direction at a very close distance and the buzzer would be triggered to give a danger signal. If the light was green, it meant that it was safe to pass. This model was also good but failed to capture some aspects like what would happen when a vehicle was broken down close to the sensor and this model did not offer solutions to a busy road because it means each vehicle would wait for the one in front to move ahead of them by a distance before they can move.

Ranga et al [11]proposed a system to decrease the number of accidents in curve roads. It involved the use of ultrasonic sensors, Arduino UNO and LED lights. This was done by alerting the driver by means of LED light which glowed when vehicles came from the other side of the curve. The system worked efficiently. However, the power supply unit was not discussed in the paper as the system would need to be powered by at least 5V to function. Also, there was no use of audio signals in the design which means that the drivers would be subject to only visual road safety aid.

Anvit Srivastava et al [12] proposed a mountainous road accident safety system based on a load gauge and Wheatstone circuit. The system utilizes force sensing modules (load cells) mounted at precise locations on the road. Resistance and voltage produced by the load cell vary almost linearly with an increase in weight of the object placed on them. These changes can be used to signal the presence of a vehicle on one part of the road. The short-coming of this approach is that the system would cost much more to design and maintain but would be less accurate.

In Road Safety Assistance using Piezoelectric Sensor [13], Anand Balaji et al proposed the use of piezoelectric sensors for vehicle detection on curved and mountainous roads. The system is similar in design to [12], except that a piezoelectric sensor is used for vehicle detection. The principle of operation is quite simple. However, some potential limitations include the long-term cost of managing wear and tear typical of mechanical systems. Additionally, the system is relatively large and requires breaking open the road for installation and maintenance purposes, resulting in additional costs and degradation of the roads.

Vaibhav Yadav et al [14] also proposed a system which used ultrasonic sensors to sense the presence of an oncoming vehicle and transmitted the information to the controller (Arduino) which then triggered a red LED to warn the driver on the other side to slow down. The paper also presented an inexpensive but intelligent framework that could identify and report an accident to the family member using GSM and GPS modules. If in case accident occurred, a button would get pressed and it would send message to the family members using GSM module and send location of the accidental place using GPS module. This system was very accurate but also very elaborate and expensive.

This system, designed by Stephen Eduku et al [15] was simulated using Proteus software and not implemented practically. It involved a system that prevented accidents by checking the drowsiness of the driver. The vehicle accident prevention system used wireless technology, eye blink sensor and automatic braking system to ensure that the vehicle slowed down and halted when drowsiness was detected. The wireless technology which was the backbone of this project work was achieved through radio frequency wave and was then used to send information (slow down there is halt car ahead) to other vehicles at a transmission distance of wavelength 0.69m with a frequency of 433MHz. the limitation of this project was that it was simulated and not done practically, as effects of nature tend to play a part in practical implementation of projects.

Pramod Mali et al [16] explained that in their system, ultrasonic sensors were used to detect whether a vehicle was coming from one side of the road or the other by calculating distance. If the vehicle was coming from a particular side, the system would send a RED signal to the opposite side of the road. If the vehicle side was safe, the system would display a yellow LED on the opposite side of the road. Green LED was also used for safety indication, indicating that no vehicles were passing or that vehicles had passed securely. Solar panels were used as the power source to ensure consistent running of the system. This system was very efficient even though it would cost very much to install. The system would also be good for areas without power from the grid or where it is not feasible to conduct routine maintenance and battery replacement. This kind of system could be recommended for real life implementation on roads as it would be very durable.

Shubham et al [17] in their paper proposed a system in which accidents were prevented using ultrasonic sensor. The design was similar to the one described above but the difference was that in this case, lamps and buzzers were used. Lamps will glow and the buzzer will ring loudly. ultrasonic sensors were used to detect the vehicles and the lamp glowed to signal presence of oncoming vehicles in order to avoid accidents at a turning point. They also implemented a drowsy system using eye blink sensor which served as the detection unit to ascertain whether the driver was drowsy or not during driving period. In case of an accident, the system also sent information about the accident including the location, the time and angle of the accident to a rescue team like a first aid center and the police station using a GSM module is used to send the alert message and a GPS module was used to detect the location of the accident. This system was all encompassing but also very expensive and rigorous to implement.

Sanjay Kashyap et al [18] in their accident prevention system used sensors which were powered by the Arduino board. The design consisted of IR sensors, LED lights, LCD display and buzzer. Oncoming cars when at either side of the mountain curve were symbolized with a red LED display and the buzzer would trigger giving signal of danger and then one LED would change from red to green to allow one car to pass and then the other LED also turned green. It also used an LCD to display distance as well. The disadvantage of this system was that it could cause vehicle traffic during busy road hours.

Mrs. K. Aravinda Shilpa et al [19] also developed a system that consisted of a controller, IR sensors, LEDs and buzzers. The system was also quite effective. If vehicles were coming from either side of the road at different times, the lane with the vehicle would have a green LED display while the opposite side would have a red display and a buzz from the buzzer to prevent motion. When vehicles were detected from both sides at the same time, both sides would have a red display and buzzes to tell them both to slow down and then one side would turn green before the other in order to reduce accidents. The limitation of this system is similar to the one discussed above.

Yashwantkumar S.S et al [20] also proposed an accident prevention road safety model that used infrared sensors and light control to improve road safety on mountain roads. The proposed model was aimed at detecting potential hazards on the road and controlling traffic lights accordingly to prevent accidents. Infrared sensors were used to detect the presence of vehicles and pedestrians and traffic lights were controlled based on the data collected by the sensor. A warning mechanism was also included to warn the driver of potential dangers on the road. The effectiveness of this proposed model was evaluated by simulation and the results showed that the number of accidents significantly reduced. The limitation of this system was that for it to be implemented, it would need a more lasting power source. This system however was not implemented but simulated.

Similar to most works discussed, Priyanshu et al [21] followed a slightly different approach. The architecture of their accident prevention system was still similar, but it functions differently from others. When a car comes from any of the sides of the mountain curve, the ultra-sonic sensor detects the cars, and the LED glows, raising the buzzer to signal danger. If there is no presence or motion detected, the LED does not glow in order to allow to signal the vehicle on that side of the road to pass safely without interruption. This system was very effective but there was no stated source of power supply for the system because the system would need at least 9V to power it. This means that the system was just simulated and not actually implemented in real life.

These reviewed works all have very similar configuration patterns with our design because they all require the use of sensors, controllers and final control elements (LEDs). However, our design also goes further to give a solution to reduce traffic congestion on these roads. The accident prevention system then begins to function as a traffic control system.

The rest of the paper is organised as follows: The Design Methodology is explained in Section II. Experimental results are presented in Section III, while concluding remarks are given in section IV.

II. METHODOLOGY

The design methodology encompasses the system's conceptualization, hardware and software integration, circuit design, and testing processes.

A. Hardware Subsystem

The block diagram in Figure 2 shows a high level of abstraction of the system being discussed. There are four units in the diagram that make up the system which can be further sub-divided. The sensory unit contains the ultra-sonic sensor which senses the presence of movement. It is powered by the micro-controller. The micro-controller unit is a system of two micro-controllers that communicate by wireless means and serve as an interface between the sensory unit and the switching unit. It sends signals to the switching unit to control and trigger devices depending on the signals received from the sensory unit. The switching unit is responsible for the triggering of other devices in response to a directive from the micro-controller. The power supply unit is in charge of supplying input power to the micro-controller and to the relay module.

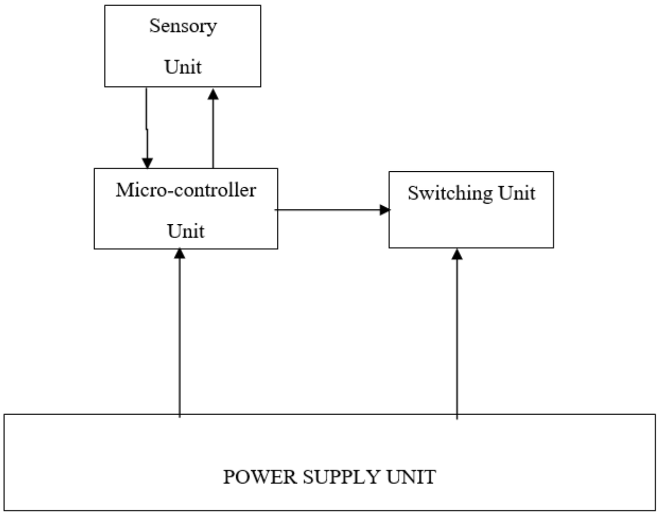

Fig. 2. Block Diagram of the Hardware System

B. The Schematic Diagram of the System
The schematic diagram in Figure 3 illustrates how the project was implemented and the various parts and components involved. It gives a low-level abstraction of how all the units and their various sub-units are interconnected. It is basically a circuit diagram of all the components connected together. It was simulated using the Proteus software.

1. The Power Supply Unit
The power supply unit mainly supplies the power needed to run the whole system. As stated earlier, it supplies power to the switching unit and the micro-controller which in turn supplies power to the sensory unit.

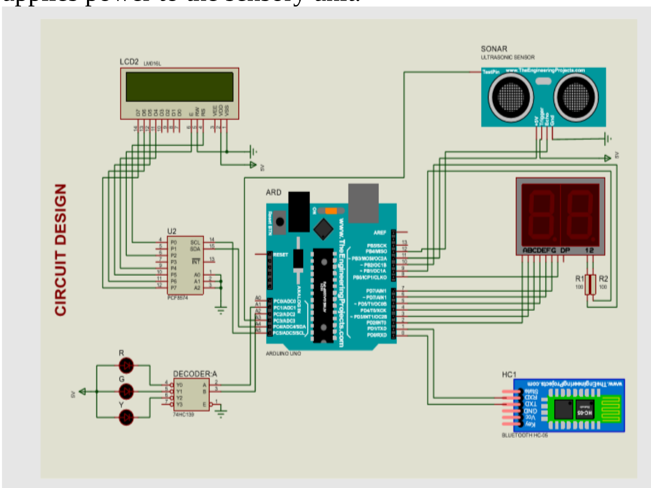

Fig. 3: A circuit diagram showing the inter-connected components

The process involves the use of transformers to step down the AC voltage, then voltage rectification takes place with the use of diodes. The rectified DC voltage is then passed through a capacitor to smoothen it and finally sent to a voltage regulator like LM-7805 to allow a certain amount of DC voltage to power the components. This method however effective was not chosen due to cost complications and also to reduce connection complexities. The latter is a much more simplified method. It involves using a DC battery alongside a voltage regulator to power the components. This was the method chosen and used for power supply to the system. The power system unit was soldered on the same board as the switching unit for ease of connections. The power supply unit consists of the 12V battery, LM-7805 voltage regulator, capacitors, heat sink, switch and a DC port.

2. The Micro-Controller Unit
Arduino UNO is a micro-controller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. You can tinker with your UNO without worrying too much about doing something wrong, worst case scenario you can replace the chip for a few dollars and start over again [22]. The micro-controller chip i.e. the ATmega328P chip can easily be replaced, as it is not soldered to the board. The ATmega328P also features 1kb of EEPROM, a memory which is not erased when powered off. The Arduino UNO features a barrel plug connector, that works great with a standard 9V battery[19]. The Arduino UNO board can be powered from the USB port (which provides 5V DC) or from the Vin pin which takes a voltage of 7-12V DC and regulates it to the Arduino 5V standard usable voltage. In this project, the Arduino was powered using the Vin pin.

3. The Sensory Unit
The sensory unit of this project comprised of a system with the ability to detect the presence of vehicles and send this information to the micro-controller to take the necessary actions on either side of the road. It consisted of the ultra-sonic sensor and the Bluetooth module which was mainly used for communication between the micro-controllers. The Ultra-Sonic Sensor (HC-SR04) Module is responsible for the detection of motion in this project. It senses the motion of an oncoming vehicle, calculates its distance and sends this information to the micro-controller. The transmitter emits 8 bursts of a directional 40KHz ultrasonic wave when triggered and starts a timer. Ultrasonic pulses travel outward until they encounter an object, the object causes the wave to be reflected back towards the unit The ultrasonic receiver would detect the reflected wave and stop the stop timer. The velocity of the ultrasonic burst is 340m/s in air. Based on the number of counts by the timer, the distance can be calculated between the object and transmitter. This distance is given by

$$Distance\ =\ Speed * Time.$$

The speed of sound waves is 343 m/s. So,

International Journal of Engineering Applied Sciences and Technology, 2024
Vol. 8, Issue 11, ISSN No. 2455-2143, Pages 232-240
Published Online March 2024 in IJEAST (http://www.ijeast.com)

$$Total\ Distance = \frac{343 * Time\ of\ height\ (Echo)\ or\ pulse}{2}$$

The total distance is divided by 2 because signal travels from HC-SR04 to object and returns to the module HC-SR04.

4. The Bluetooth (HC-05) Module

HC-05 module is an easy-to-use Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup. Serial port Bluetooth module is fully qualified Bluetooth V2.0 + EDR (Enhanced Data Rate) 3Mbps Modulation with complete 2.4GHz radio transceiver and baseband. It uses CSR bluecore 04-External single chip Bluetooth system with CMOS technology and with AFH (Adaptive Frequency Hopping Feature). It has the footprint as small as 12.7mm x 27mm. The Bluetooth module hc-05 could serve both as a master or a slave depending on configuration. This mode of communication between devices was chosen because it was an efficient and wireless means of communication. The Bluetooth module uses the UART mode of communication.

5. The Switching Unit, the Relay module, the Buzzer, and the Seven-segment display

The switching unit displays the action sent from the micro-controller. They consist of LEDs (red and green), two-digit 7 segment display, 16 x 2 LCD and buzzer. The switching action itself takes place with the aid of relays which was implemented using a relay module. The relay module was used in this project to switch between the LEDs being triggered. When motion was detected, it would switch on the red LED and when the reverse was the case, the green lights would be triggered on. Our project required the display of timing, especially when working in the traffic control mode so the 2-digits seven-segment display was used to give the impression of a traffic light countdown during traffic periods. The display was also configured using common cathode for no particular reason because both modes would have worked just fine.

C. The System flow chart

The flowchart of the system is shown in Figure 4. The flowchart shows the organized, diagrammatic procedure taken to show the functionality of the system. The flowchart shows the working of the system both as an accident prevention system and a traffic control system. The flowchart explains that the system works on the principle of time and distance. That is, the mode the system works in is determined by how long the ultra-sonic sensor detects motion or obstruction in its path. If the sensor detects constant obstruction for a particular amount of time known as the epoch time, it would switch into the traffic control mode but if the epoch time has not elapsed, it would work in the accident prevention mode.

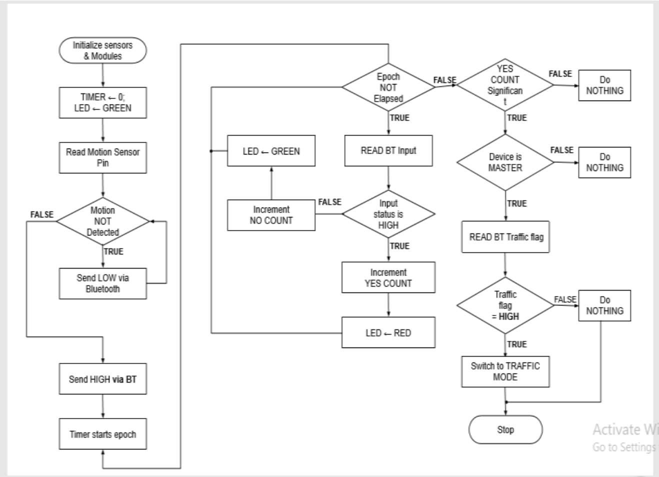

Fig. 4: Flowchart of the system

D. The System Implementation

The Power Supply Unit

As earlier stated, the power supply unit was mainly a system of three (3) 4V DC batteries which were connected in series to get 12V DC. This power is passed through a voltage regulator and connected to the Vin pin of the Arduino micro-controller and also to the relays of the switching unit for easier connections. The power unit supplies both systems at both sides of the road with electrical power to function. The power unit was attached to a Vero board which also housed the relays of the switching unit for easier connections. The relays were soldered to the Vero board while the power supply unit was taped to the board as shown in Figure 5:

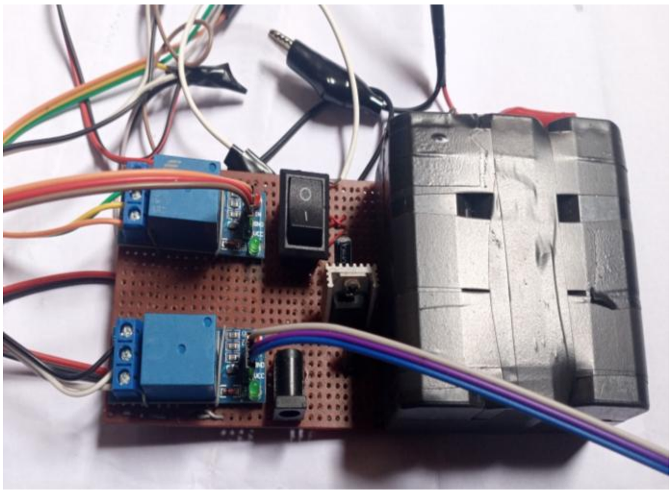

Fig. 5: Implementation of the power supply unit

The Sensory Unit

The sensory unit consisting of the ultra-sonic sensor and the Bluetooth module were connected together to the Arduino micro-controller for ease of communication between sensor and controller. The ultra-sonic sensor detects the presence of motion at a particular distance and sends this information to the controller which in turn communicates with the second micro-controller to either trigger the red LED or the green LED on its side of the road depending on the information gathered from the previous micro-controller. The Bluetooth module is used as a wireless means of communication between the micro-controllers. The ultra-sonic sensor, Bluetooth module and micro- controller were both connected to the Vero board using soldering technique (Figure 6).

The Switching Unit

The switching action was carried out by relays which were connected to the power supply unit. The remaining components that constitute the switching unit were both soldered together. The LEDs (red and green) were soldered together alongside the buzzer and the seven-segment display. The switching unit basically houses the output devices which give a response based on the transmission from the micro-controller. The switching unit asides the relays are placed on either sides of the road and give a reaction to tell oncoming users of the opposite road to either slow down or move on depending on directives from the micro-controller. The relays switch the LED system to either red or green or to traffic mode (Figure 7).

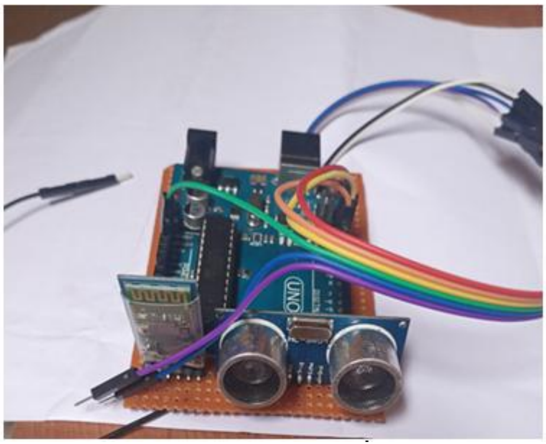

Fig. 6: Implementation of the Sensory Unit

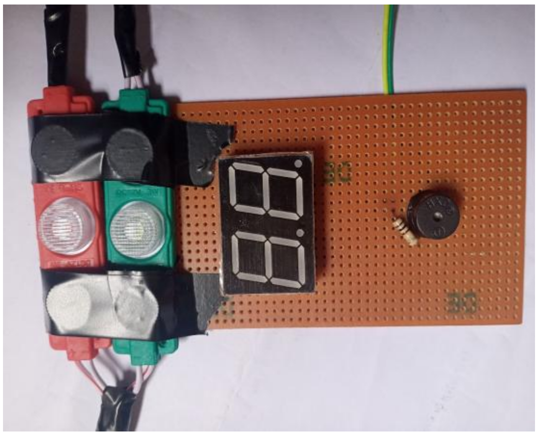

Fig. 7: Implementation of the Switching Unit

Software Implementation

The microcontroller is the heart of the system, it controls the input and gives the required output. It does this through the program which new developed using Arduino IDE. Initially, it did not give the required output so we made the corrections where necessary till we got the output we wanted. The code for the project design is written with the Arduino IDE and uploaded to the Arduino board before it is coupled. In writing the code, some factors considered are:

- Initialize and set up the sensors/modules
- Receive the sent message to the module and perform action based on the messages.
- If the epoch is elapsed, switch modes of operation.

An LCD was also used in the implementation of this circuit but as a back-end device just to display the different modes of operation of the system. The LCD was not added to display anything to the driver

III. SYSTEM RESULTS AND DISCUSSION

After the components and units were successfully mounted on the Vero board, soldered and tested, the system was placed on the platform designed for the project. The testing was done after the writing of codes using the Arduino IDE. After connections were permanently made on the Vero board, we used digital multimeter to check for discontinuity. For the testing phase the steps below were followed:

- Initialization of sensors and modules
- Detection of motion from the ultra-sonic sensor. This information is sent to the first micro-controller
- The first micro-controller receives the message from the sensor and communicates to the other micro-controller using a Bluetooth module.
- The other micro-controller receives the message and activates its switching unit to either trigger the red or green LED. When the red LED is triggered on, the buzzer also sounds to inform an oncoming motorist of danger and to reduce his speed.
- The traffic mode was triggered due to continuous sensing of motion after a certain amount of time (epoch) had passed. This switched the system into a traffic control system with the seven-segment display triggered on and acting as a timer to switch between both lanes of the road.

A System default state (Accident Prevention Mode)

1. The accident prevention system was tested first when no cars were present or on the road and the following information was obtained:

Table 1: Default state of the system.

Route / Lane	Sensor	RED	BUZZER	GREEN
Left	OFF	OFF	OFF	ON
Right	OFF	OFF	OFF	ON

The results displayed in the table 1 show that the default colour of the LEDs on either side of the road is green to signal that the road is free on the other side or that there is no obstruction or hindrance at the other side of the road.

2. The system was also tested when either lane has a car or few cars on its lane. Here, the sensor sends a signal to the opposite side informing the other lane that it has some cars coming and the opposite side would have a red LED while that lane would have a green LED as seen in the table 2:

Table 2: Results observed when the Left lane of the system was active

Route / Lane	**Sensor**	**RED**	**BUZZER**	**GREEN**
Left	ON	OFF	OFF	ON
Right	OFF	ON	ON	OFF

Table 2 shows what happened when the left lane had cars coming and the right lane had none coming.
Similarly, when the right lane was active, we had the following:

Table 3: Right lane of the system active

Route / Lane	**Sensor**	**RED**	**BUZZER**	**GREEN**
Left	OFF	ON	ON	OFF
Right	ON	OFF	OFF	ON

3. The system was also tested when both lanes when both lanes were active and these were gotten:

Table 4: Both lanes of the system active

Route / Lane	**Sensor**	**RED**	**BUZZER**	**GREEN**
Left	ON	ON	ON	OFF
Right	ON	ON	ON	OFF

B. System Unique State (Traffic Control Mode)

When the sensor keeps detecting motion for a particular amount of time called an epoch (15secs), it switches to the traffic control mode because the sensor assumes that a lot of cars are present around that period and this is necessary to control more amounts of vehicles at certain times e.g. in order to avoid a traffic jam on such an area, we could use this mode to reduce and organize the traffic system at such times like during the festive periods when more vehicles tend to use these roads.

For a traffic control mode, both sides turn red at first, then a certain lane (for example, left) would have its LED display green while the other lane still displays a red LED for a while and then the seven-segment display starts a countdown. Once the countdown gets to zero, the system would then switch to the other lane (right) i.e., the other lane would then have its LED display green and that of the former lane would display a red.

IV. CONCLUSION

This project report has discussed the design and implementation of a smart road safety and vehicle accident prevention system for mountainous roads. The objectives of this project were achieved. From the components selected and design simulations produced, the project was designed bearing in mind the purpose of efficiency and quality. In this report, the outcomes generated were all that we hoped it would turn out to be. It can therefore be concluded that the project design is highly efficient and reliable and can be improved on based on data collected from this report.

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AUTHORS

- Ezeja Obinna Michael
- Odoh Kenneth Ekene
- Amadi Emmanuel Onochiem
- Joseph Joseph Chimebuka

2455-2143