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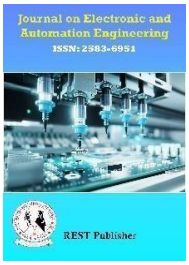

Optimizing Vehicle-to-Vehicle Communication for Enhanced AutomotiveSafety and Collision Reduction

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Abstract: *This manuscript presents a novel hybrid approach aimed at enhancing Vehicle-to-Vehicle (V2V) communication to bolster road safety and diminish collisions. The primary objective is to augment V2V communication to foster safer automobiles and diminish collision occurrences by developing and implementing a system capable of actively detecting, evaluating, and transmitting collision risks in real time. Given the escalating number of vehicles on roads, reliable communication among vehicles is imperative to ensure safety and avert collisions. The proposed system leverages the optimization of Arduino UNO controller parameters, employedto anticipate, and fine-tune the controller settings. Theoutcomes underscore the efficacy of the approach in fortifying V2V communication for safer automobiles and fewer collisions. The experimental findings showcase a notable reduction in errors compared to alternative methodologies.*

Keywords: *Vehicle-to-Vehicle communication (V2V), Road safety, Collision mitigation, Real-time risk detection Automobile safety, Arduino UNO controller optimization, Collision risk assessment, Communication reliability, Collisionprevention*

1. INTRODUCTION

In the year 2022, India revealed that a total of 4,61,312 road accidents were reported, resulting in a staggering 1,68,491fatalities and causing injuries to 4,43,366 individuals. This marks an 11.9% increase in accidents compared to the previousyear, with deaths and injuries rising by 9.4% and 15.3%, respectively. The effects of the COVID-19 pandemic on road accidents during 2020-21 were stark, with a significant decrease attributed to the nationwide lockdown. However, the numbers have surged in 2022, reversing the downward trend observed during the pandemic. An analysis of trends from 2018 to 2022 illustrates this fluctuation in accidents, fatalities, and injuries. Tamil Nadu emerged with the highest number of road accidents(64,105, 13.9%) in 2022, followed closely by Madhya Pradesh(54,432, 11.8%). Uttar Pradesh topped the states in terms of fatalities due to road accidents (22,595, 13.4%), followed by Tamil Nadu (17,884, 10.6%). Detailed state-wise information on road accidents is available in Section 5 of the report. Overall, the report underscores a concerning rise in road accidents, fatalities, and injuries in 2022, highlighting the urgency to address road safety measures and policies to curb this alarming trend. The speed of automobiles is increasing significantly these days due to advancements in intelligentcontrol and active safety technologies. In the meantime, there isa greater chance of getting stuck in traffic jams due to the growing number of vehicles. Road capacity can be increased byspeeding up vehicles and closing the gap between them. However, increased rates of traffic accidents come with the benefit of increased convenience. Reducing vehicle collisions is acknowledged as a global traffic issue, particularly when multiple vehicles are involved in a rear-end collision on a high-speed road. Worldwide, the use of roads is growing in popularity. However, the number of traffic accidents is rising quickly to an unknown level, particularly in cities and towns, which is having a disastrous effect on people's socioeconomic growth.

TABLE 1. Accident Rate (2018-2022) From Nhai

Year	Accidents	% change over previous period	Fatalities	% change over previous period	Persons Injured	% change over previous period
2018	4,70,403	0.2	157593	5.1	4,64,715	-0.6
2019	4,56,959	-2.9	1,58,984	0.9	4,49,360	-3.3
2020	3,72,181	-18.6	1,38,383	-13.0	3,46,747	-22.8
2021	4,12,432	10.8	1,53,972	11.3	3,84,448	10.9
2022	4,61,312	11.9	1,68,491	9.4	4,43,366	15.3

The consequences include enormous expenses associated with losing one's livelihood, leaving families penniless, and losses and damages to infrastructure. One of theprimary concerns to be covered in this study is how to prevent human casualties in the event of an accident. The governments of the majority of these developing nations, including South Africa, are pursuing a goal to work on the best methods for reducing the frequency of these traffic incidents by awareness-raising and providing practical road safety courses. Since accidents typically happen suddenly or by mistake, getting to the accident victims quickly and getting them to the hospital fortreatment has been the biggest obstacle. This problem is typically brought about by late reports or even incomplete information being sent to the emergency services or rescue authorities regarding the accident, including the scene'slocation. Therefore, there is a greater need to introduce and setup an automated system related to the IoT that can detect an accident, alert the closest emergency services so that they can provide the victims with immediate medical attention, andpromptly alert the immediate family member to an efficient rescue system so that lives can be saved. One of the most notable advantages of the upgraded smart traffic signal is that itprioritizes decongesting lanes with higher traffic density over others. The most significant aspect of this idea is that traffic signals are made to use Radio Frequency (RF) communicationto make room for emergency vehicles. At all times during an accident or disaster, emergency vehicles are expected to provide prompt assistance. In emergencies involving potential death, these cars are permitted to disregard all traffic laws to create a path that will enable them to get at their destination ontime. Traffic congestion, particularly in cities and towns at peakhours, poses a significant challenge for emergency vehicles since it causes delays in reaching their intended destinations. There is a higher risk of fatalities and property damage whenever these emergency vehicles take longer than expected to arrive at any location in a real life-threatening emergency, such as a fire or car collision. When an emergency vehicle is inemergency mode, it is permissible for it to speed excessively and run red lights, hence in other cases, emergency cars are alsoinvolved in traffic accidents.

2. EVOLUTION OF CARS

The evaluation of cars within the roadway system encompassesvarious critical factors, each contributing to overall safety,automation, assistance, and crashworthiness. Safety is a paramount concern in the automotive industry, with modern cars equipped with advanced safety features aimed at minimizing the impact of collisions. This includes robust airbagsystems, collision avoidance systems, and structural designs that meet stringent safety standards. Automation plays a pivotal role in the evaluation of contemporary vehicles. The rise of autonomous drivingfeatures, such as adaptive cruise control, lane-keeping assist, and automatic emergency braking, reflects the industry's commitment to enhancing road safety. These technologies reduce the risk of accidents by providing additional layers of assistance and intervention. Assistance systems go beyond automation, incorporating features designed to assist drivers in various scenarios. This may include parking assistance, blind- spot monitoring, and cross-traffic alerts, which enhance

overalldriver awareness and reduce the likelihood of collisions. Evaluating cars based on the effectiveness of these assistance systems is crucial for determining their practical impact on roadsafety. Crash testing is a cornerstone of car evaluation, withorganizations like the National Highway Traffic SafetyAdministration (NHTSA) and the Insurance Institute for Highway Safety (IIHS) conducting rigorous tests to assess a vehicle's crashworthiness. Ratings derived from frontal, side, and rollover crash tests provide consumers with valuable insights into a car's ability to protect occupants in different collision scenarios. Moreover, the integration of advanced materials in vehicle construction, such as high-strength steel and composite materials, contributes to improved crashperformance. Evaluating cars based on these material choices isvital for understanding their structural integrity and crash resilience. In an increasingly interconnected world, the evaluation of cars extends to their communication capabilities.Vehicle-to- Vehicle (V2v) communication systems enable carsto share data and with the infrastructure, contributing to safer roadways through real-time information exchange. The comprehensive evaluation of cars within the roadway system involves a meticulous examination of safety features, automation technologies, assistance systems, crashworthiness, and communication capabilities. As the automotive industry continues to innovate, these evaluations play a crucial role in shaping a safer and more technologically advanced driving experience for individuals and communities.

Advancement in automobile accessories: Recent advancements in automobile accessories represent a change in basic assumptions, marked by a surge in smart and connected technologies. Among these innovations, Advanced Driver Assistance Systems (ADAS) stand out, introducing features such as lane departure warnings and adaptive cruise control. These technologies not only contribute to heightened safety but also redefine the driving experience, providing drivers with enhanced control and situational awareness. Moreover, the contemporary automotive landscape greatly emphasizes connectivity and infotainment. Voice-activated controls have become integral, allowing drivers to interact withtheir vehicles without diverting attention from the road. Integrated smartphone compatibility further enhances convenience, seamlessly integrating personal devices with in- car systems. The integration of in-car Wi-Fi has transitioned from being a luxury to a standard feature, underscoring the industry's commitment to keeping vehicles connected and passengers entertained during journeys. The advent of electric vehicles (EVs) has spurred significant innovation in accessories, particularly in battery technology and charging infrastructure. Advancements in battery efficiency anddurability have led to increased driving ranges, addressing oneof the primary concerns associated with EV adoption. Simultaneously, the expansion of charging infrastructure, including fast-charging networks, has alleviated range anxiety,fostering greater confidence in the use of electric vehicles. These multifaceted developments collectively represent a dynamic evolution in modern automotive accessories, encapsulating a comprehensive approach toward enhancingsafety, convenience, and sustainability. The integration of smarttechnologies not only elevates the driving experience but also aligns with broader industry trends toward connected and electric mobility. As these innovations continue to shape the automotive landscape, the future holds promise for even more sophisticated and integrated accessory solutions, further solidifying the role of technology in the evolution of the drivingexperience. Various automobile accessories are susceptible to malfunctions, presenting potential hazards to both safety and performance. Among these, airbag system malfunctions,arising from issues with sensors or deployment systems, pose asignificant safety concern, as compromised airbags during collisions can escalate the severity of accidents. Sensor malfunctions, including those for anti-lock braking systems (ABS) or traction control, can adversely affect overall vehicle safety and performance. Brake system failures, such as malfunctions in the ABS or electronic stability control, may result in diminished braking efficiency, increasing the risk of accidents. Engine Control Module (ECM) issues, causing poorfuel efficiency and reduced engine performance, contribute to potential breakdowns and accidents. Faulty ignition systems, power window and door lock failures, and issues with lighting systems can compromise overall vehicle functionality, impacting safety, especially during adverse conditions. Moreover, a malfunctioning fuel pump affecting fuel supply and climate control system failures can further compromise safety and lead to performance issues. Infotainment system glitches, encompassing touch screen problems or connectivity issues, may distract drivers, increasing the likelihood of accidents. Recognizing and addressing these accessory malfunctions are imperative to mitigate the risk of accidents anduphold the safety and reliability of automobiles. Regular maintenance, prompt repairs, and adherence to safety recalls play crucial roles in preventing these malfunctions from escalating into potential safety hazards on the road.

Proposed method: This system is designed as a comprehensive accident detectionand alert system for vehicles. At its core is a microcontroller, serving as the system's main processing unit. It operates on lowpower, ensuring efficiency without draining the vehicle's battery. Multiple sensors are integrated into the system. An accelerometer detects sudden changes in the vehicle's acceleration or orientation, signaling potential accidents. The ultrasonic sensor measures distances between nearby vehicles using reflected sound waves. GPS and GSM modules are incorporated

to pinpoint the vehicle's location and send alerts toemergency services, respectively. For communication between vehicles, ZigBee technology is employed, enabling wireless transmission of accident alerts to nearby vehicles. Additionally,the ESP32 interfaces with cameras for capturing visual data, enhancing security, and providing accident-related information.The Node MCU collects data from the microcontroller, integrating it into the IoT system. A warning system is activated upon detection of an accident. This system can provide accurate accident location information in SMS or phone call alerts to emergency services or the owner of the car. Moreover, the system can be set up to automatically notify the owner of the vehicle or emergency personnel, offering more details about thecollision. This setup ensures a prompt response to accidents, with emergency services such as ambulances or the police receiving immediate notifications, allowing them to swiftly reach the accident site and provide necessary aid. Overall, this system aims to enhance vehicle safety by detecting accidents inreal time and promptly alerting concerned parties for quick andeffective intervention.

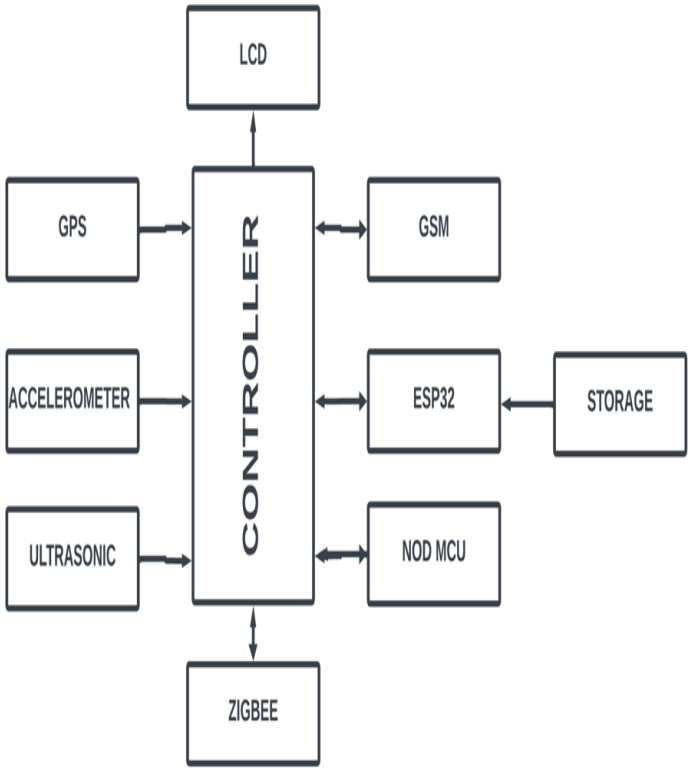

FIGURE 1. block diagram of v2v safety communication system

Flow diagram: The proposed advanced vehicle safety system is meticulously designed to offer a comprehensive suite of collision detection and communication features in a compact and efficient package. The enhanced vehicle-to-vehicle communication system for automobiles, aimed at reducing collisions, operates in a systematic flow. Beginning with the detection of objects inclose range, the system proceeds to measure the intensity of a crash if an object collides with the vehicle. When the crash intensity is below the predetermined threshold value, the systemdisplays the crash's intensity and distance, providing valuable information about the incident. If the crash intensity exceeds the set threshold value, the systeminitiates a series of actions. It promptly sends the live location,including latitude and altitude data, and triggers an SOS emergency call. This critical data is seamlessly transferredthrough the ZigBee module, ensuring rapid communication. Simultaneously, the system captures a photo of the incident, documenting the details. These images are then stored in a dedicated Telegram Chabot, creating a comprehensive record of the event. This systematic flow ensures that the system not only detects collisions but also responds intelligently, utilizingvarious sensors, communication modules, and data-sharing mechanisms for real-time incident detection, response coordination, and documentation.

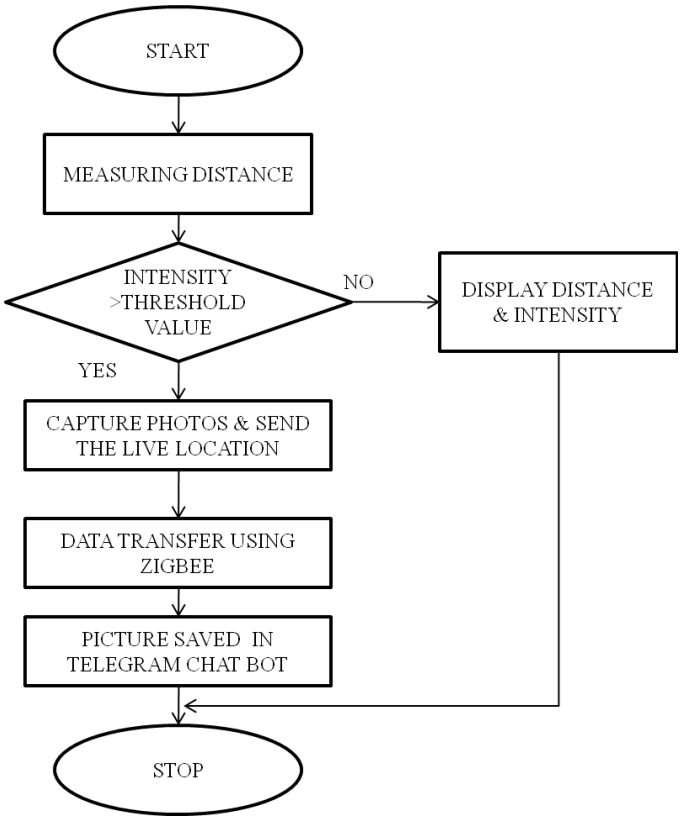

FIGURE 2. Flow diagram v2v safety communication system

3. EXPERIMENTAL RESULTS & DISCUSSIONS

The prototype model was successfully implemented and tested.The microcontroller was programmed to read sensor data and detect an accident. The system was also able to send an alert inthe form of a call to emergency services which are beingactivated during the initial stages (such as hospital, and fire force) with the location of the accident using GSM and GPS modules. The system's sensors are triggered when an accident is detected, and GPS coordinates are sent to the emergency services. The system was able to operate autonomously and didnot require any intervention from the vehicle's occupants. The system's response time was evaluated, and it was found to be significantly faster than traditional methods of reporting accidents. This is due to the system's ability to automatically detect accidents and send alerts to emergency servicesimmediately. Automatic Vehicle Accident Detection and Rescue System has several advantages over traditional methodsof reporting accidents. Firstly, the system can operate autonomously, which means that it can detect and report accidents without requiring any intervention from the vehicle'soccupants. This is especially useful in situations where the occupants are unable to call for help themselves. Secondly, the system's response time is significantly faster than traditional methods of reporting accidents. This is because the system candetect accidents immediately and send alerts to emergencyservices with the location of the accident. Also, the system is integrated with a monitoring system which provides surveillance over the incident sending recorded data for securityand other safety purposes. The system configuration is as follows.

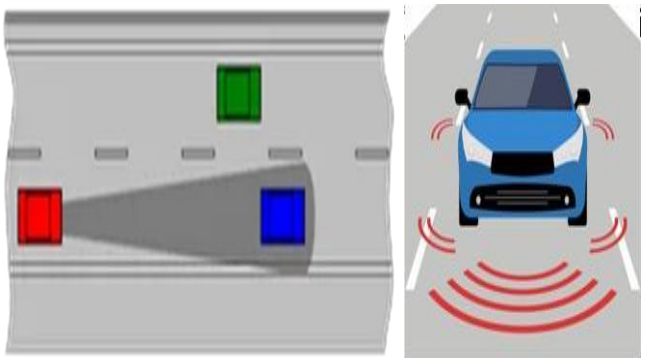

FIGURE 3. Ultrasonic range measurement

The ultrasonic sensor functions by emitting ultrasonic waves (sound waves at a frequency beyond the range of human hearing) and then measuring the time it takes for these waves tobounce back after hitting an obstacle. This sensor is typically placed on the vehicle's body, usually on its front or rear, to detect objects or vehicles in proximity. When the vehicle approaches an obstacle or another vehicle, this ultrasonic sensor begins its operation. It emits ultrasonic waves, which thenbounce off the obstacle or the vehicle in front. By measuring the time taken for these waves to return, the sensor calculates the distance between the vehicle and the obstacle or vehicle ahead. This distance measurement allows the vehicle's monitoring system to assess how close the potential collision is. Simultaneously, a monitoring system, often integrated into thevehicle's control system, starts recording the incident. This recording may include various data points, such as the time of the incident, the distance between the vehicle and the obstacle,the vehicle's speed, and potentially other relevant parameters. This recorded information can be utilized for various purposes,such as real-time warnings for the driver, data logging for analysis, or triggering automated safety systems, such as collision avoidance or braking mechanisms, to prevent accidents.

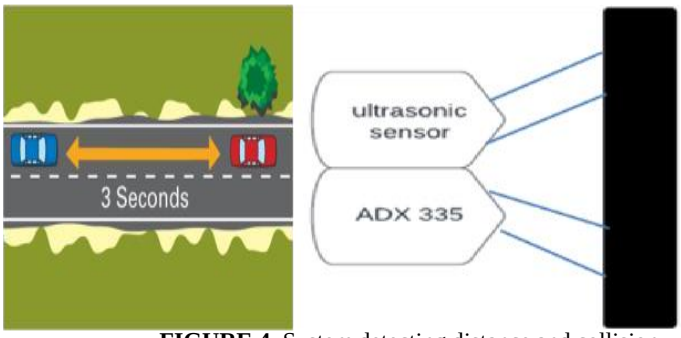

FIGURE 4. System detecting distance and collision.

There's a mechanism triggered by an increase in frequency sensed by an ultrasonic sensor, indicating a reduction in distance between two vehicles. This situation prompts activating a monitoring system designed to capture the sequence of events. As the ultrasonic sensor detects an increasein frequency, the vehicles are drawing closer, indicating apotential risk of reduced separation between them. This changein frequency serves as a trigger for the monitoring system, prompting it to initiate a recording process. Once activated, themonitoring system systematically captures the unfoldingincident. It gathers relevant data related to the proximity, potentially including distance measurements, the relative speedof the vehicles, and timestamps. Moreover, this system not only records these details but also generates visual data, likely in the form of an image, encapsulating the event's critical moments. This image, coupledwith the collated incident data, serves as a comprehensiverecord of the situation. Additionally, this

captured data is intended for transmission, to another system or entity for furtheranalysis or action. The image and associated incident data could be transmitted for analysis, decision-making, or archival purposes, providing valuable insights into the detected scenario.

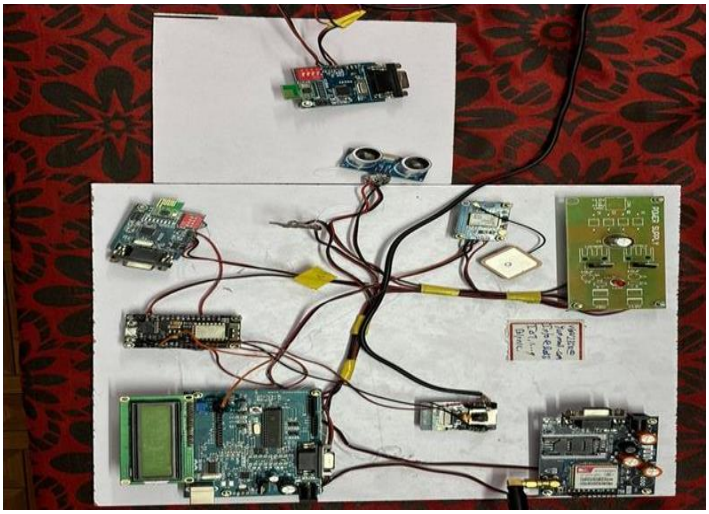

FIGURE 5. Prototype

The detailed prototype model of the suggested vehicle-to- vehicle communication system for improving safety, which includes each of the operations, is shown in Figure 5.

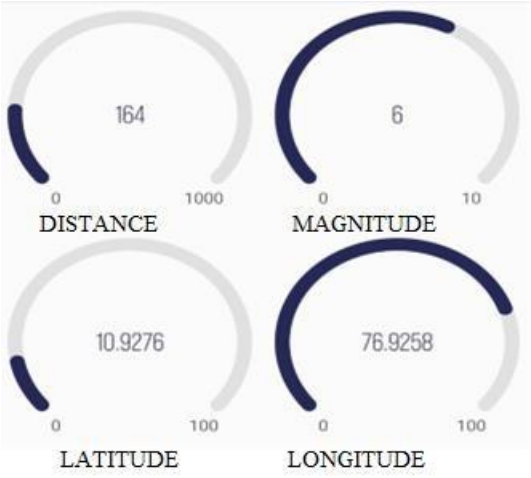

FIGURE 6. Measurement unit in Blynk App

The Blynk App's ultrasonic, accelerometer, latitude, and longitude measurements for the car's position, speed, and distance are shown in figure 6.

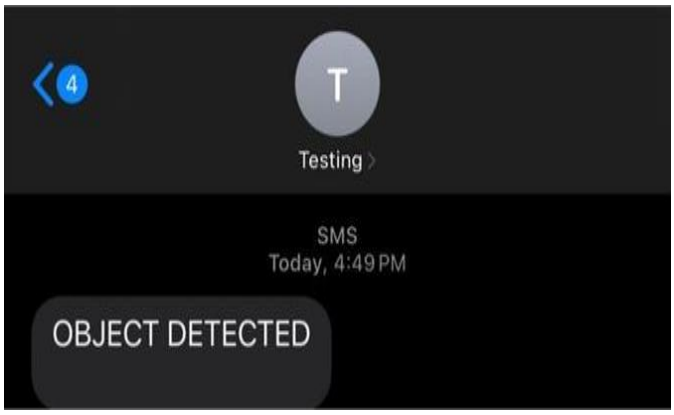

FIGURE 7. Object detected notification

The ultrasonic sensor will identify a potential collision when the object is close by and report "Object detected." exploiting an accelerometer sensor to detect the collision is shown in Figure 7.

FIGURE 8. Crash detection

The ultrasonic distance and strength of the collision are shownin Figure 8. The crash will be classified as a typical hit-and- run incidence if its intensity is below the set point. The Blank app displays this collision and accident detection.

FIGURE 9. Accident Detection Output

Figure 9 The system will notify the user with the message "Accident detected!" when the intensity exceeds the predetermined threshold (>5). utilizing the GSM module to share the live location and the ZigBee module. To

expedite therescue effort and preserve the lives of the individuals in jeopardy, this data will also be transmitted to the next vehicle, which has a 500-meter range ZigBee module. By upgrading thissystem to a more recent version, a call to the service provider like a service station can be placed.

FIGURE 10. Crash detection images

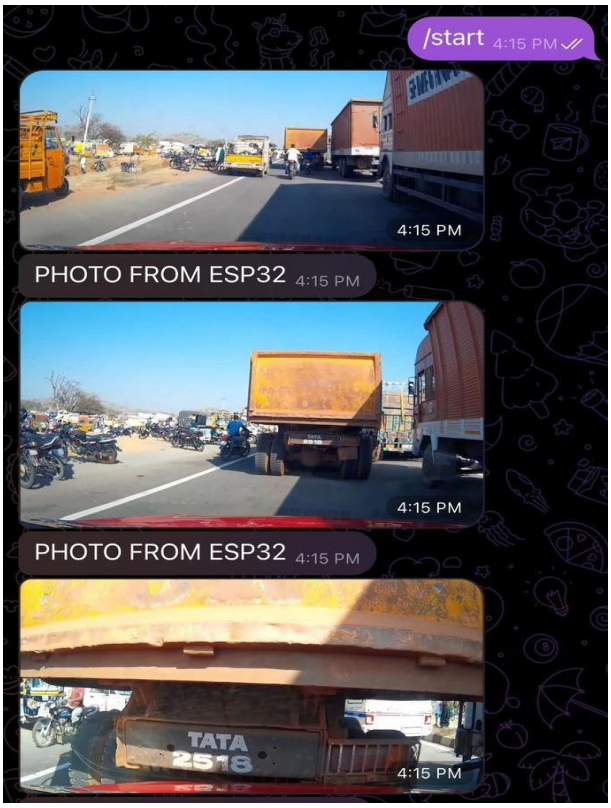

FIGURE 11. Telegram chat bot

To provide information on the accident cause, which is depicted in figures 2.8 and 2.9, the camera will simultaneously record apicture of the crash detection at a rate of four frames per secondand transmit it to the Telegram account. The telegram chat botis programmed to act like a storage system that can be accessedby the car owner and the car company similarly in the form of a server that collects the data from the camera capturing the collision.

4. CONCLUSION

The proposed system is developed to provide information aboutthe accident and the location of the accident. It helps to easily provide assistance and help the victim of the accident. If an accident occurs the GPS and GSM modules installed in the system send the information to the related person or emergencyservices. Also, it has a monitoring and surveillance system thatprovides the victim with sufficient data regarding the accident which can be used in the later part as proof. The systems we developed here are a kind of both hardware and software-basedtechnology. Rescue measures in time with sufficient preparation at the correct place can save many lives. Thus, the proposed system can serve humanity a great deal as human lifeis valuable.

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