Chain Accident Prevention by Applying Automatic Braking via Vehicle to Vehicle Communication

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Keywords: Vehicular Ad-Hoc Networks (VANETs), Collision Detection, Zigbee Communication, Arduino UNO, ESP32, UV Sensors, ADXL345 Accelerometer, Light Dependent Resistor (LDR), Telegram-Based Notifications, Internet of Things (IoT), Smart Transportation, Emergency Response Systems, Road Safety Systems, Real- Time Data Exchange, Centralized Communication Hub, Low-Latency Communication, Automated Braking.

Abstract: Chain collisions are significant causes of traffic-related accidents and casualties as well as property damage, resulting largely from delayed driver reaction time and inadequate communication between various vehicles. This research shall design an IoT-based system equipped with V2V communication capability and automatic braking to preclude such accidents. Implementing the system by taking advantage of cost-effective materials such as Arduino UNO microcontrollers, Zigbee communication modules, and UV sensors ensures real-time danger detection and response. A centralized hub powered byESP32 facilitates emergency notifications via the Telegram platform, hence enhancing coordination with stakeholders. Other features include glare reduction using LDR sensors and real-time environmental monitoring to enhance night-time visibility and driving safety. Combining these technologies, the system reduces chain collisions, shortens response times in emergencies, and improves overall traffic safety. This research points out the enormous potential of integrating IoT and V2V technologies to shape smarter, safer transportation networks.

1 INTRODUCTION

Chain collisions on roads and highways are a significant cause of site visitors' accidents internationally, often resulting in excessive injuries, fatalities, and full-size property harm. These injuries typically occur due to behind schedule driver reactions, bad visibility, and the absence of effective communication be- tween vehicles. As the need for safer and smarter transportation systems grows, modern answers that leverage emerging technologies are vital to addressing those challenges. This study introduces an IoT-based machine that makes use of Vehicle-to-Vehicle (V2V) conversation and automatic braking mechanisms to save.

Additionally, it contains a centralized communication hub that transmits critical indicators, consisting of accident notifications warnings, to nearby automobiles and emergency responders through Telegram. By combining hardware and software components, the system ensures seamless communication and reliable responses to emergencies.

At the core of the system are UV sensors for obstacle detection and ADXL345 accelerometers for impact sensing, which monitor the vehicle's environment continuously. Zigbee communication modules enable low-latency data exchange be- tween vehicles, facilitating rapid hazard detection and response. Arduino UNO microcontrollers process

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sensor data to make decisions in real time, while LDR sensors dynamically adjust headlight intensity to reduce glare during nighttime driving. The centralized hub, equipped with WiFi connectivity, relays alerts to a Telegram based notification system, ensuring timely communication with drivers and authorities. The system aims to reduce the likelihood of rear-end and chain collisions by enabling real-time hazard detection and intervention. It additionally enhances driving safety with the aid of enhancing midnight visibility and providing reliable emergency communication. By addressing those important gaps in current road protection measures, the proposed system gives a complete technique to mitigate accidents, enhance response times. Early checks of the system dis- play its potential to noticeably improve road protection, marking a leap forward in the development of intelligent transportation networks.

This research paper details the design, implementation, and testing of the proposed system, high- lighting its contribution to advancing IoT-based road safety solutions. Through this integration of sensors, communication modules, and centralized control, the project lays the foundation for smarter, safer roads in the future.

2 BACKGROUND AND RELATED WORK

2.1 Background

Chain collisions are among the most hazardous types of traffic accidents, often resulting in multiple fatalities and extensive property damage. These accidents typically occur due to a cascade of delayed reactions among drivers, particularly in high-speed or congested traffic scenarios. Factors such as poor visibility, insufficient warning systems, and the lack of Real Time communication be- tween vehicles exacerbate these events. As mod- ern transportation systems evolve, there may be a pressing need for technological advancements that no longer only beautify motive force protection but also cope with those systemic challenges comprehensively. Vehicle-to-Vehicle (V2V) verbal exchange has emerged as a promising solution for enhancing avenue protection. By permitting cars to percent- age real-time records about their environment and riding situations, V2V communication structures can offer timely signals to drivers or even trigger computerized responses, consisting of braking or lane adjustments. The integration of Internet of Things (IoT) technologies in addition enhances the ability of such systems, bearing in mind seam- less communication, advanced threat detection, and centralized manipulation of safety mechanisms.

Despite significant advancements, current implementations face limitations. Most existing solutions rely heavily on expensive hardware, such as LIDAR or radar systems, which are not eco- nomically feasible for widespread adoption. Additionally, issues such as connectivity disruptions, latency in data transmission, and environmental sensitivity of sensors remain significant hurdles. Addressing these challenges requires a cost effective, robust, and scalable solution that integrates affordable hardware with reliable communication protocols.

2.2 Related Work

Several research efforts have focused on improving road safety through V2V communication and automated systems. Studies on Adaptive Cruise Control (ACC) and Lane Departure Warning Systems (LDWS) have demonstrated the benefits of automated systems in reducing accidents. ACC systems help maintain safe distances between vehicles, while LDWS systems alert drivers to un- intended lane departures. However, these systems are often standalone and lack the ability to communicate with other vehicles in real-time, limiting their effectiveness in preventing chain collisions.

Recent research has explored the use of Zig- bee communication modules for V2V interaction. Zigbee offers low-latency and energy- efficient data exchange, making it suitable for real-time communication in vehicular networks. Researchers have also investigated the use of UV sensors for obstacle detection and accelerometers for impact sensing, which provide critical data for hazard identification. However, these systems often lack integration with centralized hubs for emergency communication, reducing their scope of applicability. IoT-enabled systems have further expanded the possibilities for road safety. Projects utilizing WiFi and mobile networks to transmit accident notifications to authorities have shown promise in improving emergency response times. The use of messaging platforms, such as Telegram, for real- time alerts adds another layer of efficiency and convenience. Despite these advancements, the challenge of creating a cohesive system that combines hazard detection, automated response and emergency communication remains largely unaddressed.

The system proposed in this research builds upon these advancements by integrating affordable and reliable hardware, such as Arduino UNO microcontrollers, UV sensors, and Zigbee modules, with a centralized communication hub. Un- like standalone systems, this approach ensures seamless coordination between vehicles, enabling rapid response to hazards and reducing the likelihood of chain collisions. By addressing the limitations of existing solutions, this project con- tributes to the development of safer and smarter transportation networks.

3 SYSTEM DESIGN

The proposed system integrates Arduino UNO as the primary microcontroller for vehicles and ESP32 for the centralized communication hub. This design ensures cost-effective and efficient vehicle-level operations while leveraging the ESP32's advanced connectivity capabilities for emergency communication. The architecture is divided into three primary components: vehicle hardware, vehicle-to-vehicle (V2V) communication, and the centralized communication hub.

Vehicle Hardware: Each vehicle is equipped with Arduino UNO to control essential sensors, actuators, and communication modules. The hardware components include:

UV Sensors: Positioned at the front and rear of the vehicle to measure distances from nearby obstacles or vehicles. These sensors enable real-time hazard

ADXL345 Accelerometers: Detect sudden acceleration changes along three axes (X, Y, Z) to identify potential collisions or abrupt movements.

LDR Sensors: Monitor ambient light levels to dynamically adjust the vehicle's headlight in- tensity, reducing glare during nighttime driving.

Arduino UNO: Functions as the vehicle's primary processing unit, handling sensor data acquisition, processing, and triggering actions like braking or V2V communication.

Motor Drivers and Relays: Enable control over the vehicle's movement and safety mechanisms, such as braking and headlight adjustments.

Vehicle-to-Vehicle Communication: Zigbee modules connected to the Arduino UNO facilitate real-time communication between vehicles. This V2V communication ensures prompt data sharing for critical scenarios, such as Obstacle detection alerts to nearby vehicles. Notifications of sudden deceleration or impact. Warnings about low fuel levels to prevent breakdowns. The Arduino UNO collects and processes sensor data and transmits these alerts via Zigbee modules to nearby vehicles, ensuring a rapid and coordinated response.

Centralized Communication Hub: The central communication hub, using ESP32, plays an important role in managing the emergency notification and more widespread communication. Equipped with WiFi connectivity, the ESP32 connects to the internet for sending messages to the cloud-based services or the stakeholders. It integrates with a Telegram bot for forwarding the critical alerts such as accident reports and low-fuel warnings to the preconfigured contacts including the authorities and owners of the vehicles. It processes incoming Zigbee messages that it translates into actionable alerts for efficient dissemination.

The hybrid system workflow starts with hazard detection by Arduino UNO-based vehicles using UV sensors and accelerometers, which sends safety signals such as auto-braking and alerting other vehicles in the neighborhood through Zigbee. These alerts are received by ESP32 hub and broadcast to concerned parties in real-time, which makes this hybrid design an economical option of Arduino UNO-based design with ESP32-based connectivity for hazard detection, which can be scaled in the future. It addresses gaps in transportation safety, paving the way for smarter, safer roads.

4 METHODOLOGY

Sensor Integration: UV sensors are used for front object detection and blind spot monitoring. ADXL accelerometer sensor detects sudden changes in vehicle movement, identifying accidents. The LDR sensor detects high beams from on- coming vehicles for automatic headlight adjustment message transmission.

Data Processing: The Arduino UNO microcontroller collects and procedures information from all of the sensors in actual- time.

Collision Detection: When a potential collision or accident is detected, the system immediately identifies the hazard using UV and accelerometer data.

Vehicle-to-Vehicle Communication: Zigbee communication is utilized to send alerts to nearby vehicles, warning them of potential danger.

Automatic Braking: Upon receiving the collision alert, nearby vehicles automatically apply their brakes to prevent a chain accident.

Headlight Adjustment: If an LDR sensor detects a high beam from oncoming traffic, the vehicle will receive a message to switch to a low beam to improve visibility.

Emergency Communication: A central hub collects accident data and sends emergency alerts to pre-configured contacts via Telegram for quick assistance.

Real-Time Monitoring: The "Chain Accident Prevention by Applying Automatic Brake via Vehicle-to-Vehicle Communication" project utilizes IoT-based technology to improve road safety and prevent chain collisions. Here, the system uses UV sensors for real-time object detection along with blind spot monitoring wherein the system triggers immediate responses if obstacles are detected to be within critical range. An ADXL accelerometer finds sudden deceleration or im- pacts, prompting accident alerts. Zigbee modules enable low- latency vehicle-to-vehicle communication, allowing surrounding vehicles to activate automatic braking mechanisms, reducing re- action times and mitigating collisions. To address night-time driving hazards, LDR sensors detect and with the help of Zigbee send messages to adjust headlights from high to low beams, reducing glare and enhancing visibility. The system also includes a centralized hub that relays emergency notifications with location details via Telegram, ensuring swift response from emergency services. Each car carries an LCD which will be displaying real-time sensor data, alerts, and system statuses. This means there will be a greater improvement in safety, with reduced accidents and a more efficient driving environment.

Below are the core components and functionalities of the proposed system:

Front Object Detection and Blind Spot Monitoring: The system utilizes UV sensors to monitor the distance between the vehicle and obstacles in front or within blind spots. This ensures continuous tracking of close by items, alerting the machine if an impediment is within a predefined safe range.

Accident Detection System: ADXL accelerometer is used to come across unexpected changes in acceleration, including those as a result of a collision or difficult braking. If the gadget detects values exceeding the protection threshold, it acknowledges the occasion as a potential accident and triggers alerts.

Vehicle-to-Vehicle Communication (V2V): Zig- bee modules facilitate verbal exchange between vehicles within a defined range. When a car detects a coming near collision or a coincidence, it sends an alert to close by motors. These cars routinely have interaction with their braking structures upon receiving the alert, preventing a chain reaction.

Automatic Braking Mechanism: Upon receiving a collision alert, the machine automatically activates the vehicle's braking gadget. This function removes human response delays, imparting a faster reaction to keep away from or mitigate collisions.

High Beam Detection: The system incorporates an LDR sensor to detect high beam headlights from oncoming vehicles. When detected, the system automatically informs the other vehicle to switch to a low beam, enhancing visibility and reducing glare for all drivers on the road.

Centralized Hub and Emergency Communication: The proposed system includes a centralized hub connected to all vehicles via the Zigbee network. In the event of an accident, the hub receives alerts and sends emergency notifications to pre- configured contacts through the Telegram plat- form. This ensures timely assistance and quick response from emergency services.

Real Time Monitoring and Display: LCD is in- stalled in the vehicle to provide real-time feed- back to the driver. The display shows critical information, including the distance to obstacles, system alerts, and the status of vehicle-to-vehicle communication. This helps drivers stay aware of their surroundings and the system's actions.

System Workflow is discussed below

Continuous Monitoring: UV sensors and the ADXL accelerometer continuously monitor the vehicle's environment and movement.

Hazard Detection: If an obstacle or sudden decel- eration is detected, the system evaluates the risk of a collision.

Alert Transmission: The vehicle sends alerts to nearby vehicles via Zigbee.

Automatic Braking: On receiving an alert, the nearby vehicles automatically apply brakes to pre- vent a chain collision.

High Beam Adjustment: LDR sensors detect on- coming high beams and communicate to switch headlights to low beam to the other vehicle.

Emergency Alerts: In case of an accident, the system communicates with the hub, which sends notifications through Telegram for emergency response.

5 BLOCK DIAGRAM

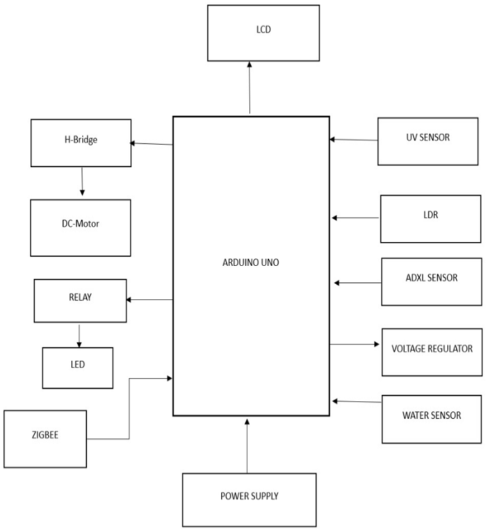

Figure 5.1: Block diagram of the proposed System.

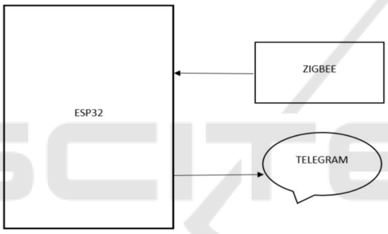

Figure 5.2: ESP32 interface.

6 RESULTS OF THE RESEARCH

Reliable Hazard Detection: The system was found to be working well in detecting obstacles and hazards through UV sensors while monitoring the surroundings of a vehicle in Real Time. Accelerometers (ADXL345) successfully detected jerks or collisions, thus enabling alerts and safety mechanisms accordingly.

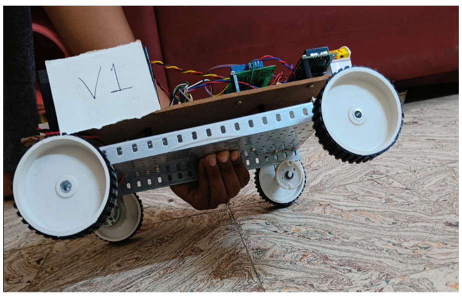

Figure 6.1: Prototype of the system.

Figure 6.2: Result 1.

Improved Communication: Communication modules based on Zigbee ensured low-latency trans- mission of data between vehicles efficiently, thus allowing for swift transmission of alerts about potential hazards, accidents, or sudden braking.

Figure 6.3: Result 2.

Automatic Braking Implementation: Vehicles with the system deployed automatically applied brakes in case of collision alerts, preventing chain reaction accidents.
Centralized Emergency Response: The ESP32-based centralized hub relayed emergency notifications to preconfigured contacts via Telegram, thus ensuring timely responses from authorities and other stakeholders.

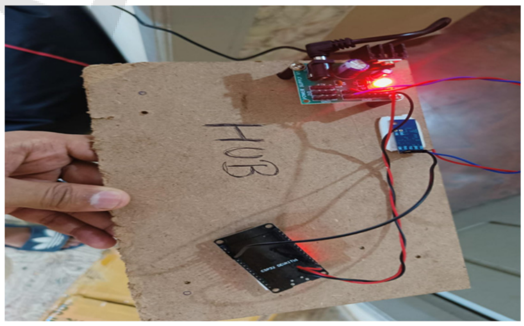

Figure 6.4: HUB.

Scalability and Cost Efficiency of the System: The use of low-cost hardware, such as Arduino UNO and Zigbee modules, made the system cost- effective enough for mass adoption without affecting reliability. The system would allow easy integration of additional sensors or technologies in the future

because of its modular structure.
Real-time monitoring and feedback: The inclusion of an LCD in the vehicle allowed the drivers to continuously monitor distance to obstacles, status of the system, and alerts, thereby enhancing situational awareness and decision-making.

Figure 6.5: Result 3.

Overall Safety Enhancement: In the initial tests, a significant reduction in the likelihood of rear end and chain collisions was observed, whereas response in emergency situations was faster thus indicating the scope of saving lives on the roads is vast.

7 CONCLUSION

In conclusion, it's the project "Vehicle-to-Vehicle Communication" an ambitious development aimed toward improving road safety through reducing a common danger found in present-day traffic, namely the chain collision. Advanced technologies of IoT in the system allow real-time communication from one vehicle to another which enables immediate automated response. UV sensors perceive obstacles or blind spots; the accelerometer ADXL picks up rapid deceleration and impacts hence, prompt detection of accidents is ensured. Zigbee communication ensures smooth data transfer, automated braking to minimize human factors, and prevention of multi-car collisions. The LDR sensor enhances night safety from glare by informing the driver about adjusting headlights. It is a centralized hub that ensures proper emergency response through alerts on Telegram, making sure timely help reaches the affected area. An LCD keeps the driver updated about the status of the system and the environment, ensuring an informed decision. This will be an all-inclusive approach by combining automation, communication, and safety technologies for safer roads. Scalable and adaptable, it can be used in smart city infrastructures and future development like machine learning.

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