

Accident Prevention and Landslide Update in Ghat Section

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Abstract— The system combines cutting-edge technology to address challenges such as limited visibility, poor communication between vehicles, and adverse weather conditions. A novel feature of this system is the application of a machine learning model to classify vehicles as heavy or light, enabling dynamic traffic signal adjustments that prioritize heavier vehicles, particularly in the challenging context of hilly terrains. This adaptive traffic management reduces congestion and enhances safety by preventing dangerous situations where smaller vehicles might struggle to yield appropriately. To ensure seamless communication, the system employs ZigBee technology to transmit real-time alerts from a central hub to vehicle models. Drivers are promptly notified of approaching vehicles, adverse weather, or potential hazards, giving them enough time to react and navigate safely. The hardware backbone includes an Arduino Uno microcontroller integrated with IR sensors to detect vehicles approaching from either side of the curve. This detection triggers motor-operated gates that regulate vehicle flow, ensuring that only one side has access at a time to prevent simultaneous entry. Additionally, accelerometer and rain sensors play a crucial role in monitoring critical environmental conditions such as landslides and heavy rainfall, significantly enhancing safety by providing real-time data to pre-empt and mitigate potential hazards. In hazardous situations, automatic warnings are displayed, and gates are closed to prevent accidents. The system's functionality is further enhanced by an LCD display that provides clear visual warnings to drivers. This comprehensive approach not only minimizes collision risks but also improves overall traffic flow in challenging terrains. Future enhancements like GPS integration, V2I communication, and solar-powered components aim to improve scalability and sustainability. Designed for accident-prone hilly roads and Ghat sections, this innovative solution is a step toward safer and smarter transportation.

Index Terms— Vehicular Ad-hoc Networks (VANETs), Landslide Updates, ZigBee Communication, Arduino UNO, ESP32, IR Sensors, ADXL345 Accelerometer, Telegram-based Notifications, Internet of Things (IoT), Emergency Response Systems, Road Safety Systems, Real- Time Updates, Vehicle Priority, Machine Learning.

I. INTRODUCTION

Traffic management in hilly regions, especially in areas with sharp curves and challenging terrain, poses significant difficulties. These include poor visibility, limited communication between vehicles, and hazardous weather conditions such as heavy rainfall and landslides.

In such environments, the risk of accidents increases, and the need for adaptive, dynamic solutions becomes critical. Current traffic systems are often unable to adapt to changing conditions, which leads to congestion and increased chances of collisions.

Moreover, traditional traffic signal systems do not account for vehicle weight, which is particularly important in hilly terrains where larger vehicles require more space and time to navigate. This paper proposes an advanced, technology-driven system to address these challenges and enhance safety. This paper presents a comprehensive solution that integrates real-time detection, vehicle classification, and environmental monitoring to mitigate risks and enhance transportation systems in challenging terrains. Its robust design and scalability make it a significant contribution to road safety and traffic management research.

II. BACKGROUND AND RELATED WORK

Several studies have focused on improving road safety and traffic flow through the use of advanced technologies. These efforts include the implementation of sensors, machine learning, and real-time communication systems. Machine learning models, like the YOLO (You Only Look Once) algorithm, have been successfully applied to object detection tasks, including vehicle classification. Such models can distinguish between different types of vehicles, enabling optimized traffic management systems that prioritize larger vehicles in complex road conditions.

Real-time communication systems, such as Zigbee, have also been explored for transmitting alerts between vehicles and traffic control units, reducing response times and improving safety. Furthermore, sensor technologies, such as IR sensors for vehicle detection and accelerometers for monitoring environmental risks, have been integrated into traffic management systems.

A. Related Work

Previous studies have demonstrated the potential of machine learning techniques for vehicle classification and adaptive traffic signal control. The YOLO (You Only Look Once) algorithm, widely used in object detection, has proven effective in distinguishing between light and heavy vehicles, enabling more efficient traffic prioritization. Research findings indicate that adaptive traffic signal systems, which factor in vehicle types and real-time traffic conditions, can significantly enhance road safety and reduce congestion [1], [2].

Real-Time Detection and Communication: Advancements in real-time vehicle detection, particularly using infrared (IR) sensors, have contributed to the development of more responsive traffic management systems [1]. These systems can accurately detect vehicle presence and issue alerts to prevent potential collisions. Moreover, the use of ZigBee technology for vehicle-to-infrastructure (V2I) communication has been explored to transmit real-time alerts and warnings, thereby supporting safer navigation in high-risk zones [4], [9], [10]. **Environmental Hazard Monitoring:** Recent research emphasizes the integration of environmental sensors to monitor and mitigate natural hazards affecting traffic. Sensors such as accelerometers for landslide detection and rain sensors for weather monitoring enable early detection of potential dangers [5]–[7]. These systems can automatically trigger preventive actions—such as closing barriers or issuing driver warnings—thereby enhancing safety in adverse or mountainous environments [8], [10].

Integrated Hardware Systems: The combination of sensors and microcontrollers into unified hardware architectures has become a major focus area. Arduino-based systems have gained prominence for prototyping and real-time applications in traffic management due to their cost-effectiveness, reliability, and ease of integration [2], [3], [9], [11]. Such setups are particularly beneficial for real-time vehicle detection and environmental monitoring, especially in regions with limited infrastructure.

Scalability and Future Developments: Recent studies highlight the importance of scalability and sustainability in intelligent traffic systems. Integration of V2X (Vehicle-to-Everything) communication enhances coordination between vehicles and infrastructure, leading to more adaptive and responsive systems [4], [9]. Additionally, the adoption of solar-powered components promotes energy efficiency and supports operation in remote areas, thus reducing long-term operational costs and supporting sustainable smart city initiatives [8], [11].

III. SYSTEM DESIGN

The design incorporates vehicle classification, real-time vehicle detection, environmental hazard monitoring, and communication systems to ensure safety and efficient traffic flow. The system is built on a modular architecture that combines hardware and software components, each contributing to the overall functionality as shown in Fig.1.

A. Overview of System Components

The system consists of the following key components: Vehicle Classification and Signal Optimization, Real-Time Vehicle Detection and Communication, Environmental Hazard Monitoring, Integrated Hardware Architecture, User Interface and Alerts.

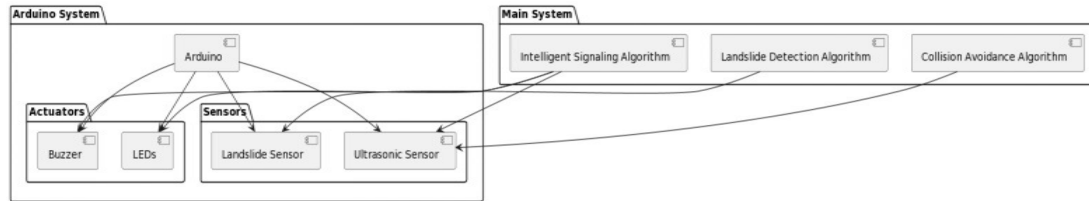


Fig. 1: Block diagram

B. System Architecture

The system's architecture is divided into two primary components: the Central Control Unit- for processing data, making decisions, and managing traffic signals and gates, and the Vehicle/Infrastructure Communication Unit for vehicle detection and environmental hazard monitoring, communication modules for real-time alerts, and motorized gates for regulating traffic flow. The system operates through a feedback loop, where data from the sensors is processed in real time, triggering actions (such as signal changes or gate activation) based on vehicle classification, environmental conditions, and vehicle proximity.

C. Vehicle Classification and Traffic Signal Optimization

Using machine learning (YOLO) algorithm, vehicles are detected and classified as heavy or light. Based on the classification of vehicles, traffic signal phases are adjusted dynamically.

D. Real-Time Vehicle Detection and Communication System

Infrared sensors alerts about approaching vehicles, adverse weather conditions, or potential hazards are transmitted to nearby vehicles, allowing drivers to react in time. When two vehicles are detected approaching from opposite directions, the system controls motorized gates to prevent simultaneous access. Only one direction is allowed to pass at a time, ensuring traffic flow is regulated and reducing the likelihood of accidents.

E. Environmental Hazard Monitoring

Accelerometer Sensors detect the slightest ground movements or vibrations that could indicate a landslide. Data Fusion system integrates data from all sensors (IR, accelerometer, rain) to make real-time decisions. If a hazardous condition (e.g., landslide or heavy rain) is detected, the system will close the gates and display warnings to drivers via an LCD screen.

F. Hardware Architecture

The hardware backbone of the system includes several key components: Arduino Uno Microcontroller which interfaces with the sensors (IR, accelerometer, rain) and ZigBee modules, processing sensor data and controlling actuators (motorised gates, signals).IR Sensors which are placed at the curve entrances to detect vehicles approaching from both directions.

IV. METHODOLOGY

The methodology for the proposed system is divided into several stages: System Design, Data Collection, Model Development, Hardware Implementation, System Integration, and Testing & Evaluation. Each stage is essential to the successful development, deployment, and evaluation of the system for traffic management and safety in hilly, accident-prone areas. Fig.2 shows the flowchart of the proposed system.

A. System Design and Requirements Analysis

The first step involves identifying the system's key requirements based on the unique challenges of hilly terrains. These challenges include limited visibility, hazardous weather, and the need for real-time decision-making. The system must: Classify vehicles based on their weight (heavy or light), Optimize traffic signal control in real time to prioritize heavy vehicles, particularly in areas with sharp curves and steep gradients, Detect environmental hazards such as landslides and heavy rainfall, Communicate real-time alerts to drivers through a Vehicle-to-

Infrastructure (V2I) communication system, Regulate traffic flow using motorized gates and an automated control system. The design incorporates machine learning for vehicle classification, real-time sensors for vehicle and environmental monitoring, and ZigBee communication for system coordination.

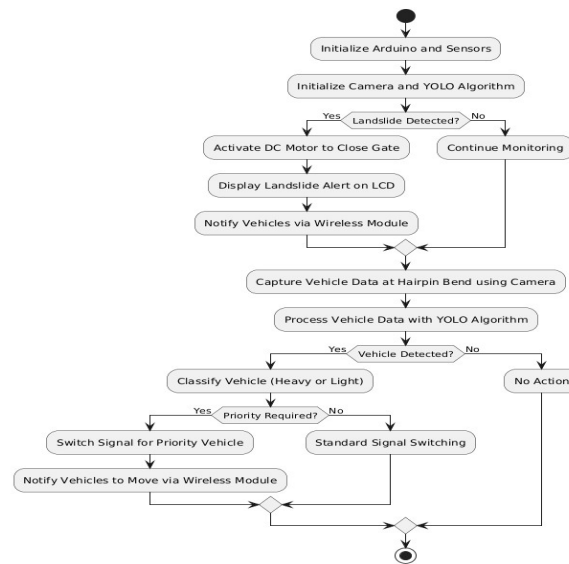


Fig. 2: Flowchart

B. Data Collection is Carried Out in Two Main Phases

Vehicle data and environmental data. The system collects real-time data from video feeds captured by cameras mounted at strategic points along the road. These video feeds are processed using the YOLO (You Only Look Once) algorithm for object detection and classification. This process enables the system to identify whether the vehicle is heavy (e.g., trucks, buses) or light (e.g., cars, motorcycles). Environmental data is collected from a variety of sensors, including Infrared (IR) sensors, Accelerometer sensors, Rain sensors.

C. Vehicle Classification Model Development

A key component of the system is the vehicle classification model, which utilizes the YOLO algorithm for vehicle detection and classification. The methodology for model development is as follows: i) Training Data Preparation: A large dataset of vehicle images (captured in various environments, including hilly roads) is used to train the YOLO model. This dataset includes labeled images indicating the type of vehicle (heavy or light) based on size, shape, and other distinguishing features. ii) Model Training: The YOLO algorithm is trained to recognize and classify vehicles in real-time from video feeds. Transfer learning is applied, using pre-trained weights to speed up the training process. The model is fine-tuned to achieve high accuracy in detecting and classifying vehicles in challenging environments such as hilly terrains with poor visibility. iii) Model Evaluation: The trained YOLO model is evaluated on a separate validation dataset to assess its accuracy, precision, recall, and F1-score. The evaluation metrics ensure that the model can reliably classify vehicles in real-time.

D. Hardware Implementation

The hardware for the system consists of sensors, a microcontroller, and communication modules. The following hardware components are used:

Arduino Uno Microcontroller: Serves as the central processing unit for the system. It interfaces with all sensors (IR, accelerometer, rain) and communication modules (Zigbee). **Infrared (IR) Sensors:** These sensors are placed along the road curves to detect the presence of vehicles approaching from either side. The sensors send data to the microcontroller to initiate vehicle flow management actions. **Zigbee Communication Modules:** Zigbee modules enable real-time communication between the central system and vehicles, as well as between different infrastructure elements. Each vehicle is equipped with a Zigbee receiver, which receives alerts from the central unit regarding approaching vehicles or hazardous conditions. **Motorized Gates:** Controlled by the Arduino microcontroller, motorized gates regulate traffic flow, ensuring that only one side of the road is accessible at a time. **LCD Display:** Provides visual alerts and messages to drivers about approaching hazards or conditions.

requiring caution. Power Supply: Solar panels are used to power the system, ensuring sustainability and reducing reliance on external electricity sources.

E. System Integration

The integration phase involves combining the vehicle classification, real-time detection, environmental hazard monitoring, and communication components into a cohesive system. The integration process includes: i) Sensor Integration: The IR, accelerometer, and rain sensors are connected to the Arduino Uno microcontroller. The sensor data is continuously monitored and processed to detect vehicles. ii) Environmental hazards in real time. Communication System: The Zigbee communication system is set up to send and receive data between vehicles and the central unit. The central unit continuously processes incoming vehicle data and environmental conditions, sending alerts and triggering actions as necessary. Control System: The Arduino Uno microcontroller processes all data and makes decisions regarding traffic signal optimization, gate operation, and hazard management based on the input from the sensors. It communicates these decisions to the motorized gates and the LCD display.

F. Testing and Evaluation

The testing phase includes both simulation-based testing and real-world field testing to evaluate the system's effectiveness under varying conditions. i) Simulation-Based Testing: Initial tests are conducted in a simulated environment where different scenarios (e.g., heavy traffic, adverse weather conditions, landslides) are modeled. The system's ability to respond to these scenarios is evaluated for accuracy and speed. ii) Field Testing: Field tests are conducted on a set of roads with hilly terrains to evaluate the system's real-world performance. The system is tested for: Accuracy of vehicle classification: Ensuring that the YOLO algorithm classifies vehicles accurately. Real-time hazard detection: Evaluating the performance of accelerometer and rain sensors in detecting hazardous conditions. System Response Time: Testing how quickly the system processes data and triggers appropriate actions (e.g., gate operation, alert transmission). Communication Efficiency: Assessing the effectiveness of Zigbee communication in transmitting real-time data to vehicles and infrastructure. iii) Safety and Traffic Flow Improvement: The final evaluation is focused on assessing the system's impact on road safety and traffic flow. Metrics such as reduced congestion, fewer accidents, and improved driver awareness are collected through direct observation and data logging.

V. RESULTS

Main Model is designed to be installed near hairpin curves or sharp turns where visibility is limited. Hub Model is placed inside vehicles to receive alerts, ensuring drivers are informed in real-time. Fig.3 shows the main model and fig.4 shows the hub model respectively.

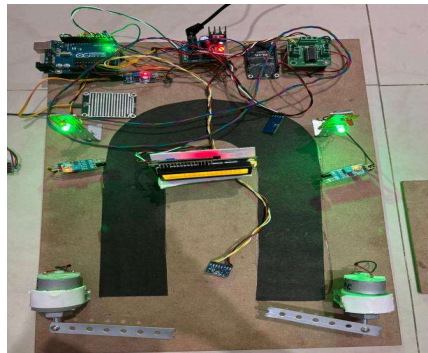


Fig.3: Main model

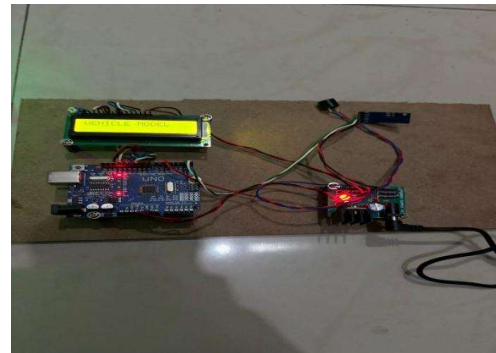


Fig. 4: hub model

Case 1: Heavy Vehicle Priority

- When a truck approaches from the left side of the hairpin bend, it is prioritized for safe passage. The traffic lights are set to green for the left side road, allowing the truck to proceed, while the right side road is held with a red light for safety.
- When a truck approaches from the right side of the hairpin bend, it is prioritized to move first. The traffic lights switch to green for the right side and red for the left side, ensuring a safe and smooth passage, as illustrated in figures 6,7,8 and 9 respectively.

Case 2: Heavy Vehicle v/s Light Vehicle

- In this scenario, heavier vehicles like trucks are given priority over lighter ones to reduce accident risks and avoid traffic congestion. The system also warns drivers about oncoming vehicles from the opposite direction, enhancing overall safety.
- For example, if a truck is coming from the right side and a car from the left, the truck is prioritized. The signals turn green for the truck's side and turns red for the car, ensuring an organized and safe flow of traffic, as illustrated in figures 10 and 11 respectively.



Fig.6: detection of vehicle on left road

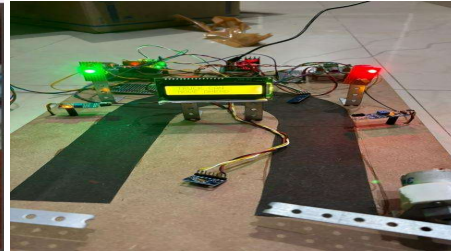


Fig. 7: red signal on the right road to indicate vehicle on left side



Fig.8: detection of truck on right road

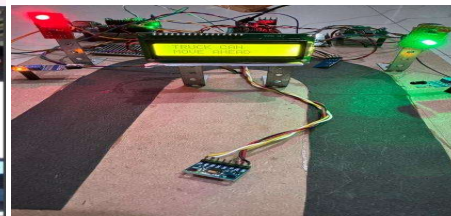


Fig. 9: red signal on left side since truck on right

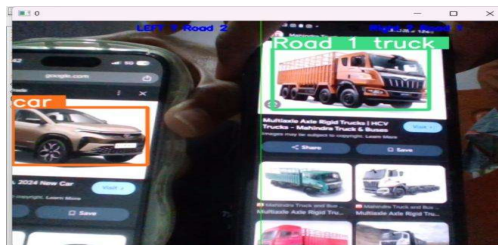


Fig.10: heavy vehicle vs light

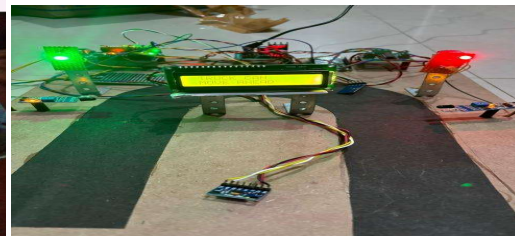


Fig.11: priority for heavy vehicle

Case 3: Light v/s Light

- In cases involving two lighter vehicles, the one that reaches the IR sensor first is given priority. This helps prevent confusion and accidents at the bend.

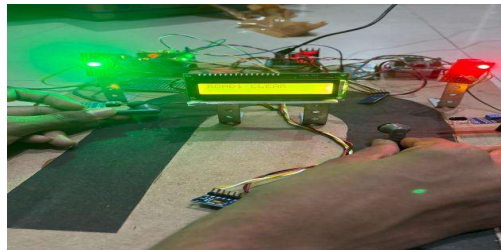


Fig.12: light vs light. Priority for vehicle which reaches IR sensor first

Case 4: Landslide Detection and Update

- If the ADXL sensor detects any movement, indicating a possible landslide, an alert is sent to the in-car hub model and the drivers' mobile phones. Simultaneously, the gates close automatically to block entry into the affected area, ensuring no additional vehicles enter the danger zone as shown in ig.12.

Case 5: Rainfall detection is illustrated in fig.13.

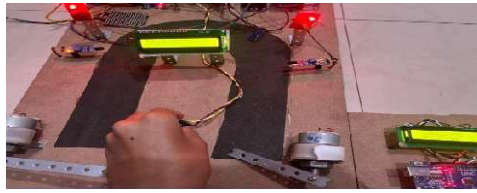


Fig.12: Landslide detected (gates close)



Fig.13: Rainfall detected and displayed

VII. CONCLUSION

Managing roads in difficult terrains requires addressing landslides and ensuring safety on sharp bends, where poor visibility, high speeds, and weather challenges often lead to accidents. Modern technologies like IoT sensors, AI-based monitoring, adaptive lighting, and V2I systems offer real-time alerts and navigation support, improving safety and reducing risks. Techniques such as slope stabilization and AI-powered geotechnics also play a crucial role in mitigating landslides. However, high costs, limited infrastructure, and the need for expertise pose challenges, especially in developing countries, emphasizing the need for affordable and adaptable solutions. 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.

REFERENCES

- [1] Lorate Shiny,Rajakumaran, S.Vijay (2019) are proposed “Vehicle Control System with Accident Prevention by Using IR Transceiver” Vol. 4, Issue 6.
- [2] R.S. Rakul, S. Ravia and K.N. Thirukkuralakani(2016) proposed a paper on “Implementation of Vehicle Mishap Averting System Using Arduino Microcontroller”Vol. 5 Issue 04. April.
- [3] K.P. Sreevishakh, Prof.S.P. Dhanure,(2015) “Automotive Crash Insight using AMR Sensor System,” International Journal of Advanced Research in Computer and Communication Engineering, Vol. 4, Issue 5.May.
- [4] S. Uvaraja and V. Raghav Prashanth, (2012) “Advanced Pre-Warning System (Railways),” IACSIT International Journal of Engineering and Technology, Vol. 4, no. 2.
- [5] S. Kundu, D. Sharma, and A. Saha, “GisBased Statistical Landslide Susceptibility Zonation: a Case Study in Ganeshganga Watershed, the Himalayas,” Esriindia.Com, pp. 1–9, 2011.
- [6] S. Hidayat, H. Pachri, and I. Alimuddin, “Analysis of Landslide Susceptibility Zone using Frequency Ratio and Logistic Regression Method in Hambalang, Citeureup District, Bogor Regency, West Java Province,” IOP Conf. Ser. Earth Environ. Sci., vol. 280, no. 1, 2019, doi: 10.1088/1755-1315/280/1/012005.
- [7] Mousumi Gupta, M. Ghose, and L. Sharma, “Application of Remote sensing & GIS for landslides hazard and assessment of their probabilistic occurrence - A case study of NH31A between Rangpo and Singtam,” J. Geomatics, vol. 3, no. 1, pp. 59–63, 2009.
- [8] Harshada Targe, Anushka Mahajan, Mohit Patil, Yogesh Lilake and Vijay Sonawane, “Advance Road Safety For Ghat Road’s At Hairpin Bend”, International Research Journal of Engineering and Technology, Volume: 05, Issue: 01, January 2018.
- [9] Aravinda B, Chaithralakshmi C and Deeksha, “Sensor Based Accident Prevention System”, International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering, Volume: 04, Issue: 06, June 2016.
- [10] R. Anusha, K. Sonia, V.M.K. Vamsi Prasad and J.Raj Kumar, “Collision Avoidance At Hairpin Curves Using Sensors”, Journal of Emerging Technologies and Innovative Research, Volume: 06, Issue: 04, April 2019.
- [11] Anand M G, A Dhanyakumar, Bhaskar N and Mahaling S B, “Sensor Based Accident Prevention System in Curving”, International Journal of Advance Research and Innovative Ideas in Education, Volume: 05, Issue: 02, December 2019.