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A Context-Aware Intelligent Smart Data Recorder for Real-Time Vehicle Tracking and Accident Response

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ABSTARCT

The Intelligent Smart Data Recorder for Vehicle Tracking and Accident Response System aims to enhance road safety by facilitating real-time monitoring, accident detection, and rapid emergency response. The system integrates multiple sensors, including force, vibration, and accelerometer sensors, to accurately detect collision events and continuously record vehicle dynamics. A GPS module provides precise location tracking, while a microcontroller processes sensor data and stores critical information in a secure data recorder for post-accident analysis. Upon detection of a severe collision, the system automatically transmits alert messages containing the vehicle's location and impact details to emergency services and pre-designated contacts using wireless communication technology. This significantly reduces response time and increases the chances of saving lives. Additionally, the recorded data supports accident investigation and insurance claim analysis.

Keywords: Accident Detection, Internet of Things (IoT), Smart Data Recorder, Vehicle Tracking, Emergency Response, Road Safety.

I. INTRODUCTION

The Intelligent Smart Data Recorder is an innovative vehicle safety technology developed to improve accident detection, emergency response, and post-accident analysis. With the rapid increase in vehicle usage, road accidents have become a major public safety concern, often leading to severe consequences due to delayed emergency assistance. To address this challenge, the proposed system functions as a smart black box for vehicles, providing continuous monitoring and intelligent accident detection.

The system integrates Internet of Things (IoT) sensors, a Global Positioning System (GPS), and a microcontroller to track critical vehicle parameters such as speed, impact force, location, and sudden deceleration. An Automatic Accident Notification System (AANS) detects accidents in real time and instantly alerts nearby emergency services, significantly reducing response time and increasing survival rates.

In addition to real-time alerts, the system records sensor data and video footage using an SD card and cloud storage. This information supports detailed post-accident investigations, helps authorities understand accident causes, enhances vehicle security, and enables data-driven strategies for accident

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prevention. By combining real-time monitoring with intelligent data analysis, the proposed system contributes to improved road safety and proactive emergency management.

II. LITURATURE REVIEW

Road safety has been widely studied with a focus on accident prevention, detection, and emergency response. Ukarande Vaibhav et al. highlighted the high risk associated with T-junctions in India, emphasizing government accident reports that indicate a significant number of fatalities occurring at these locations.

Sri Krishna Chaitanya Varma et al. (2024) proposed an automated accident detection and messaging system using onboard sensors integrated with GSM and GPS modules to report vehicle crashes in real time.

Jafari Saeid et al. (2024) investigated adaptive disturbance suppression techniques in control systems, improving the robustness of smart and autonomous vehicle systems.

Additionally, Dayanand Lal N. et al. (2024) presented a vehicle monitoring and tracking system that utilizes real-time location tracking and motion analysis to efficiently detect accidents and enhance emergency response mechanisms.

III. SMARTDATARECORDERANDMODELSOFSYSTEM

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A. Basic Overview

The Intelligent Smart Data Recorder for Vehicle Tracking and Accident Response System is designed to integrate multiple components for real-time accident detection and emergency management. At its core, the system employs a microcontroller that acts as the central processing unit, coordinating inputs from embedded sensors.

These sensors include accelerometers and vibration sensors for crash detection, GPS modules for precise vehicle location monitoring, and additional environmental sensors to track road and driving conditions. The collected data is processed locally and stored on an SD card for immediate access, while simultaneously being transmitted to a cloud server for long-term storage and remote analysis.

This architecture enhances safety and preventive measures by enabling continuous monitoring of vehicle behavior, supporting post-incident investigations, and providing timely accident alerts.

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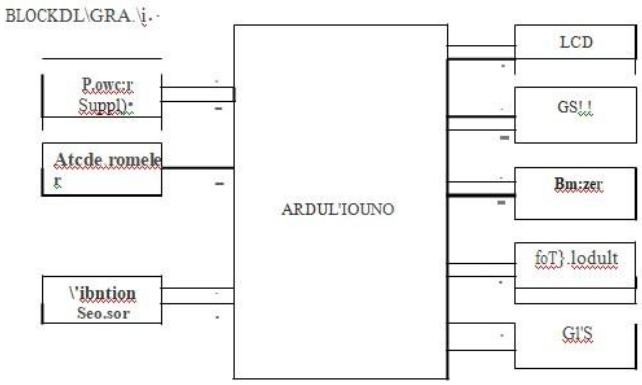


Fig. 1. Intelligent Smart Data Recorder for Vehicle Tracking and Accident Response System (Block Diagram)

B. Intelligent Event Detection Framework

The intelligent event detection framework is responsible for identifying accident conditions and initiating appropriate responses.

A regulated power supply provides stable DC power to all system components, ensuring consistent and reliable operation. An accelerometer continuously monitors abrupt changes in acceleration along multiple axes to detect crashes and severe braking events. Vibration sensors complement this by detecting abnormal vibrations or impacts on the vehicle body, improving accident detection accuracy.
The Arduino Uno acts as the central processing unit, collecting sensor data, analyzing accident conditions, and coordinating communication and output actions. An LCD displays real-time system status, sensor readings, and alert messages for user awareness.

1) Sensor Layer

The Sensor Layer ensures the accuracy and reliability of the accident detection system.
Microelectromechanical System (MEMS)-based accelerometers and gyroscopes monitor sudden acceleration, deceleration, and directional changes, which are key indicators of collisions or abnormal driving behavior.

Force sensors integrated into vehicle bumpers or structural frames measure the magnitude of impact during a collision, helping confirm accident occurrence and assess severity. Additionally, a GPS module continuously tracks the vehicle's location, allowing accurate position data to be included in emergency alerts.
Together, these sensors enable timely, reliable, and intelligent accident detection.

2) Microcontroller Layer

The Microcontroller Layer acts as the central processing unit of the system. It collects, processes, and analyzes data from multiple sensors in real time. Inputs from MEMS accelerometers, gyroscopes, force sensors, and the GPS module are integrated to continuously monitor vehicle conditions.

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A collision detection algorithm evaluates sensor readings against predefined thresholds to identify sudden changes in acceleration, velocity, or impact force. To improve detection accuracy and reduce false alarms, a multi-layered sensor fusion approach is implemented, combining force, acceleration, and gyroscopic data.

System reliability is further enhanced through anomaly detection techniques and machine learning models trained on real-world accident datasets. Upon verification of an accident, the microcontroller triggers automated alerts to emergency responders while securely storing processed data on an SD card for post-incident analysis.

3) Cloud Storage and Communication Layer

The Cloud Storage and Communication Layer ensures secure data preservation and efficient coordination with emergency responders. Critical sensor data, including GPS coordinates and force sensor readings, are continuously transmitted to a cloud server for centralized storage.

This approach provides data redundancy and enables continuous monitoring and analysis, ensuring essential information remains accessible even in the event of onboard microcontroller failure. The cloud platform supports real-time data processing to evaluate accident severity and overall system performance.

Additionally, the system generates immediate alerts containing precise accident location, impact intensity, and available occupant safety information. By integrating cloud communication with local emergency infrastructure, this layer significantly reduces response time and enhances overall accident management and road safety.

4) Emergency Response System Layer

After an accident, the Emergency Response System Layer reduces reaction time and improves outcomes. Using real-time GPS data, it instantly informs emergency responders of the exact accident location, helping them determine the quickest routes for police, ambulance, and rescue teams.
The system calculates an accident severity score by evaluating sensor inputs such as impact force, vehicle dynamics, and seatbelt engagement. This assessment supports response prioritization, ensuring critical cases receive immediate attention.

Automated notifications containing essential information—including location, possible injuries, and required resources—are sent to hospitals and law enforcement agencies. This coordinated, timely intervention enhances occupant safety and overall accident management.

5) User Interface Layer

The User Interface (UI) Layer serves as the primary communication channel between administrators, vehicle owners, and the monitoring system. It provides a comprehensive, user-friendly interface displaying real-time vehicle information such as speed, GPS location, and sensor status.

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The UI supports post-incident analysis by allowing users to review recorded camera footage and sensor data, offering insights into accident causes and severity. It also monitors system health and provides diagnostics for sensors, microcontrollers, and communication modules.

By integrating monitoring, analysis, and maintenance capabilities into a unified interface, the UI enhances user control, supports informed decision-making, and ensures overall system reliability and safety.

6) Accident Detection Using Mathematical Models

The system's accident detection capability is based on mathematical models that analyze sensor data and determine the probability of an accident. The model can be represented as:

$$e = f\left(\sum_{i=1}^{n} m_i v_i + t\right)$$

Where:

- e = Network output
- f = Activation function
- m_i = Synaptic weights
- v_i = Input features
- t = Bias term

This model processes multi-sensor inputs and produces a decision output indicating accident likelihood.

7) System Testing and Evaluation

Comprehensive system testing and evaluation were conducted to ensure reliability in both simulated and real-world scenarios. The system's robustness was assessed through controlled crash simulations and on-road driving trials.

Accuracy was validated using ground truth verification. Key performance metrics—including precision, recall, and F1-score—were calculated using labeled datasets. Sensor accuracy was thoroughly examined to guarantee precise detection of acceleration changes, impact force, and seatbelt engagement.

The effectiveness of the collision detection system was evaluated to ensure prompt alert generation and rapid accident identification. Emergency response time was measured to verify timely information delivery to first responders.

Additionally, data handling mechanisms were assessed to ensure proper storage and secure transmission, guaranteeing that all essential information is available for post-incident analysis and decision-making.

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IV. TRAININGMETHODS

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Vehicle Black Box Training Technique

The Vehicle Black Box Training Technique is designed to ensure that every component of the system functions seamlessly, from accident detection to real-time emergency response. The training methodology focuses on developing accurate accident detection models, maximizing sensor data collection, and refining the machine learning algorithms that analyze vehicle parameters.

The approach is divided into multiple stages, each concentrating on a specific aspect of system functionality. By systematically training each component, the Vehicle Black Box technique ensures reliable performance, efficient data analysis, and rapid, accurate detection and response in realworld scenarios.

A. Data Collection and Sensor Calibration

The initial phase of the training methodology focuses on data collection and sensor calibration, both of which are critical for precise accident detection. The system gathers data from various sensors, including MEMS accelerometers, force sensors, and GPS modules. Each sensor provides specific measurements related to vehicle motion, impact forces, occupant safety, and location tracking.

To ensure accuracy and reliability, sensor readings must be properly calibrated. Calibration involves testing each sensor in a controlled environment and comparing its output with predefined reference values. Special attention is given to MEMS accelerometers and force sensors, which detect subtle changes in acceleration and impact force. Proper calibration enables the system to accurately distinguish between normal driving behavior and actual accident events.

B. Sensor Data Acquisition and Calibration

The training process begins with systematic data acquisition from all onboard sensors.

1) Collecting Sensor Data

The system incorporates GPS modules, force sensors, and MEMS-based motion sensors. Each sensor provides specific information related to vehicle movement, impact intensity, and geographic location. Data is collected under both simulated crash scenarios and real-world driving conditions to ensure the system can handle diverse operational environments.

2) Sensor Reading Calibration

Calibration is essential to ensure that each sensor delivers accurate and consistent data. Sensors are tested in controlled environments, and their outputs are compared against established reference standards. Proper calibration enables the detection algorithm to differentiate between normal driving conditions and actual collision events.

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When MEMS accelerometers and force sensors are correctly calibrated, the system can identify subtle variations in acceleration and impact forces, thereby improving detection reliability and minimizing false alarms.

C. Data Preprocessing

After data collection, preprocessing is performed to ensure high-quality inputs for machine learning models. Raw sensor data may contain noise, outliers, or irregular fluctuations caused by minor vibrations or sudden but non-critical vehicle movements.

To address this, filtering techniques are applied to remove noise and retain only relevant data for training. Signal processing methods such as low-pass filtering and smoothing algorithms help eliminate discrepancies while preserving meaningful patterns.

Normalization and feature scaling are also performed to bring all input features into a comparable range. This improves learning efficiency and prevents the algorithm from favoring features with larger magnitudes. Common preprocessing methods include:

- Z-score normalization, which standardizes features based on mean and standard deviation
- Min–Max scaling, which scales values within a predefined range (typically 0 to 1)

Effective preprocessing enhances model accuracy, improves generalization, and ensures that the system makes reliable and trustworthy accident detection decisions.

V. PROPOSEDALGORITHM

Context-Aware Intelligent Smart Data Recorder for Real-Time Vehicle Tracking and Accident Response.

Algorithm: Context-Aware Accident Detection

Algorithm: Real-Time Accident Detection and Response

1. Initialize the microcontroller, accelerometer, gyroscope, GPS module, communication unit, and storage device.
2. While vehicle ignition is ON do
3. Acquire real-time sensor data (acceleration, angular velocity, speed, and GPS position).
4. Apply noise filtering and normalization to the sensor data.
5. Analyze driving context using threshold-based or machine learning-based decision logic.
6. If an abnormal event is detected then
7. Perform multi-sensor data fusion for validation.
8. If an accident is confirmed then
9. Store pre-event, event, and post-event data in the smart data recorder.
10. Transmit an emergency alert containing GPS location and accident severity.
11. Enable continuous vehicle tracking for emergency response.
12. End If
13. End If

3. End While

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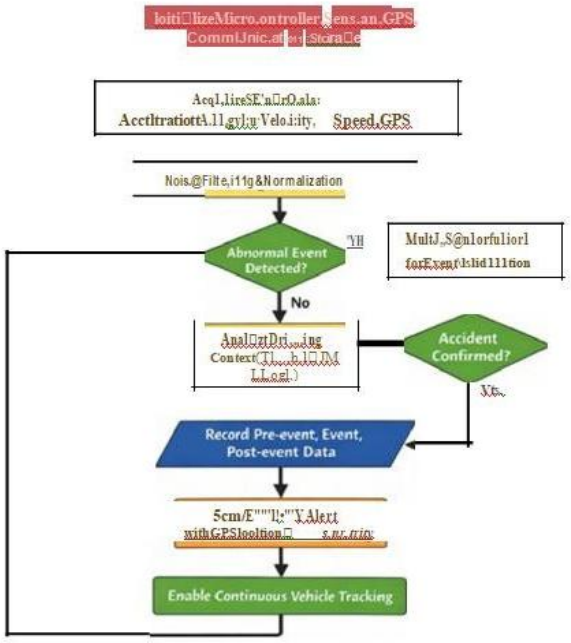


Fig. 2. Flowchart of Context-Aware Intelligent Smart Data Recorder System

A. Machine Learning Model Training

The core of the vehicle black box system is the machine learning model, which processes sensor data to detect accidents in real time. Training this model involves a multi-step process comprising the following key stages:

1) Model Evaluation

After training, the model is evaluated using performance metrics such as:

- Accuracy
- Precision
- Recall
- F1-score

Minimizing false positives (incorrectly detecting an accident when none has occurred) and false negatives (failing to detect an actual accident) is critical due to the serious consequences of misclassification.

Cross-validation techniques are employed to ensure that the model generalizes well across different datasets and driving conditions.

2) Hyperparameter Adjustment

Hyperparameter tuning enhances the performance of machine learning models by systematically optimizing model parameters. Techniques such as grid search and random search are commonly used to identify the optimal parameter configuration.

Important hyperparameters include:

- Depth of decision trees
- Number of trees in ensemble models (e.g., Random Forest)
- Learning rate in neural networks

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Proper tuning reduces overfitting, improves generalization capability, and increases detection accuracy, resulting in more reliable accident detection performance.

Metrics	P1	P2	P3	Fina
Acclënn etect:Jon ccuracy	75	82	89	95
EmergencyResponseTimeReduction(%)	20	35	50	70
FalsePositiveRate (%)	10	8	5	3
FalseNegativeRate (%}	12	9	6	2
System Latency(111s)	500	400	300	200

TABLE
PERFORMANCEMETRICS

3) Real-Time Accident Detection Implementation

Once trained and validated, the machine learning model is deployed on a microcontroller for realtime accident detection.

The microcontroller continuously processes incoming sensor data and feeds it into the trained model to generate an accident detection score. This enables prompt identification of accident events and supports immediate emergency response actions.

4) Optimizing Real-Time Performance

To operate effectively under strict time constraints, real-time performance optimization is essential. Since sensor data must be analyzed continuously, the model is optimized to reduce latency and computational load.

Optimization techniques include:

- Model quantization, which reduces numerical precision to lower memory usage and execution time
- Model pruning, which removes unnecessary parameters while maintaining accuracy
- Hardware acceleration, using specialized chips or co-processors to improve processing speed and energy efficiency

These techniques ensure seamless real-time operation, prevent microcontroller overload, and enable prompt and accurate accident detection without compromising system stability.

B. Validation and Testing

After implementation, the system undergoes rigorous validation and testing to ensure dependable performance under real-world conditions.

During this phase, sensors and the microcontroller are exposed to various accident-like scenarios, including:

- Sudden impacts
- Rapid deceleration
- Abnormal vibrations

Controlled simulations are conducted to evaluate detection accuracy and system robustness.

The system's ability to distinguish between real accidents and false triggers caused by normal driving conditions (e.g., potholes, speed breakers, harsh braking) is thoroughly assessed to minimize false alarms and ensure operational reliability.

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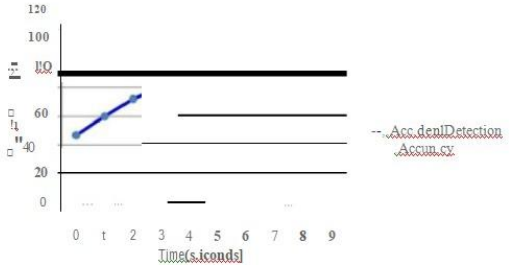


Figure1: Graphical representation

VI. RESULTS AND DISCUSSIONS

The performance of the proposed Context-Aware Intelligent Smart Data Recorder for Real-Time Vehicle Tracking and Accident Response was evaluated across four implementation phases: Phase 1 (P1), Phase 2 (P2), Phase 3 (P3), and the Final Phase.

The evaluation focused on the following key performance metrics:

- Accident detection accuracy
- Emergency response time reduction
- False positive rate
- False negative rate
- System latency

As presented in Table I, accident detection accuracy improved significantly from 75% in Phase 1 (P1) to 95% in the Final Phase. This improvement is primarily attributed to the integration of context-aware analysis and multi-sensor data fusion, which enhanced the system's ability to accurately identify real accident scenarios.

The false positive rate decreased from 10% to 3%, while the false negative rate was reduced from 12% to 2%. These reductions indicate substantial improvement in decision reliability and a significant decrease in the misclassification of normal driving conditions as accident events.

Additionally, emergency response time reduction improved from 20% in P1 to 70% in the Final Phase, demonstrating faster alert transmission and more efficient real-time vehicle tracking capabilities.

System latency was also significantly reduced from 500 ms in P1 to 200 ms in the Final Phase, reflecting effective optimization of data processing and communication mechanisms.

Overall, the experimental results confirm that the proposed system delivers:

- High detection accuracy
- Low latency
- Reduced error rates
- Reliable real-time performance

These characteristics make the system highly suitable for real-time vehicle monitoring, intelligent accident detection, and rapid emergency response applications.

VII. Final Thoughts and Prospective Discussions

This project presents an IoT-based intelligent vehicle safety system that integrates real-time accident detection, automated emergency alert generation, and post-incident data analysis to significantly enhance road safety.

Continuous monitoring of critical vehicle parameters is achieved through the integration of MEMS sensors, force sensors, and GPS tracking modules. This multi-sensor architecture ensures accurate detection of collision events and abnormal driving behavior.

The microcontroller-based design enables efficient real-time data processing, while cloud connectivity supports instant transmission of accident alerts along with precise location information to emergency services. This rapid communication significantly reduces response time and improves the likelihood of saving lives.

Furthermore, the collected data supports detailed post-accident investigations, assists authorities in identifying accident patterns, and enables the development of data-driven preventive safety strategies.

Future Prospects

Future enhancements may include:

- Integration of AI-based predictive accident prevention models
- Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communication
- Advanced occupant health monitoring systems
- Edge AI deployment for ultra-low-latency processing
- Integration with smart city emergency management platforms

By combining intelligent sensing, machine learning, and real-time communication technologies, the proposed system represents a significant step toward safer, smarter, and more responsive transportation ecosystems.

REFERENCES:

[1] M. Geetha, D. Janakan, E. Narthakumar, S. Sanjaykumar, and B. C. Kaviyarasan, "Vehicular Accident IoT-Based Detection and Alert Generation," in *Proceedings of the 5th International Conference on Intelligent Communication Technologies and Virtual Mobile Networks (ICICV)*, IEEE, 2024, pp. 333–336.

[2] H. Lingling, L. Jian, X. Xu, and L. Haifeng, "An intelligent vehicle monitoring system based on Internet of Things," in *Proceedings of the Seventh International Conference on Computational Intelligence and Security*, IEEE, 2011, pp. 231–233.

[3] S. Peddakrishna, Z. Basha Shaik, J. Dontabhaktuni, S. Bhavani, C. Dharani, S. Kollem, and P. Kumar, "Autonomous Vehicle Accident Detection with Event Data Recording for Accident Analysis," in *Proceedings of the 4th International Conference on Artificial Intelligence and Signal Processing (AISP)*, IEEE, 2024, pp. 1–5.

[4] D. Lohani, D. Acharya, Nikhil, and Kumar, "An IoT-based vehicle accident detection and classification system using sensor fusion," *IEEE Internet of Things Journal*, vol. 8, no. 2, pp. 869–880, 2020.

[5] G. S. Rathod, K. Jajulwar, and R. C. Tipale, "Intelligent accident detection and alerting system based on machine learning over the Internet of Things network," in *Proceedings of the International Conference on Futuristic Technologies (INCOFT)*, IEEE, 2022, pp. 1–6.

[6] H. C. Gabler, R. Sherony, and K. D. Kusano, "Methodology for using advanced event data recorders to reconstruct vehicle trajectories for use in safety impact methodologies (SIM)," *Traffic Injury Prevention*, vol. 14, no. sup1, pp. S77–S86, 2013.

[7] C. A. Vinifred and A. S. Abishek Anand, "Event data transmitter and recorder for vehicle analysis," in *Proceedings of IC3IoT: Computing and Internet of Things*, IEEE, 2022, pp. 1–4.

[8] S. Murugaanandam Shiva and P. Kumar, "Event data recorder and transmitter for vehicular mishap analysis based on sensor," in *Proceedings of the International Conference on Computer Communication and Informatics (ICCCI)*, IEEE, 2023, pp. 1–6.

[9] W. Rahman et al., "Vehicle speed control and accident-avoidance system based on ARM M4 microprocessor," in *Proceedings of the Industry 4.0 Technology International Conference (I4Tech)*, IEEE, 2023.

[10] J. Grande et al., "Design of FINFET based DRAM cell for low power applications," in *ComputerAided Developments: Electronics and Communication*, 2019, pp. 35–43.

[11] G. N. Jyothi et al., "Energy Efficient Compact Approximate Multiplier for Error-Resilient Applications," in *2025 International Conference on Intelligent Communication Networks and Computational Techniques (ICICNCT)*, IEEE, 2025.

[12] G. N. Jyothi, K. Debanjan, and G. Anusha, "ASIC implementation of fixed-point iterative, parallel, and pipeline CORDIC algorithm," in *Soft Computing for Problem Solving (SocProS 2018)*, Springer, 2019, pp. 341–351.

[13] P. Sandhya and G. N. Jyothi, "Energy Efficient CAM Design Using FinFET for IoT Applications," in *2025 IEEE International Conference on Advanced Computing Technologies (ICACT)*, IEEE, 2025.

[14] G. N. Jyothi, R. Kiran Kumar, and B. Subbarayudu, "Automatic Analysis and Detection of MultiChannel ECG Signals Using Neural Network," in *International Conference on Innovations in BioInspired Computing and Applications*, Springer, 2023.

[15] R. Sakthivel, G. N. Jyothi, and N. Dilip Kumar, "A low power 10-bit 50 MS/s sample and hold OTA amplifier," in *Proceedings of the International Conference on Communication Engineering and Technology*, 2018.

[16] S. Sonika et al., "Intelligent accident identification system using GPS and GSM modem," *International Journal of Computer and Communication Engineering Advanced Research*, 2021.

[17] Y. Zhang et al., "Stability analysis and variable speed limit control of traffic flow models," *IEEE Transactions on Intelligent Transportation Systems*, 2024.

[18] H. D. Pham et al., "Development of vehicle tracking system using GPS and GSM modem," in *Proceedings of an IEEE Conference*, IEEE, 2024.

[19] S. K. C. Varma et al., "Automatic vehicle accident detection and messaging system using GPS and GSM modems," *Scientific and Engineering Research International Journal*, 2024.

[20] S. Jafari et al., "Robustness and performance of adaptive suppression of unknown periodic disturbances," *IEEE Transactions on Automatic Control*, 2024.

[21] A. Potu Talar, B. Chandra, S. Aarthi, G. Bhavana, A. A. Jose, and S. Gomathi, "IoT-based automotive drive recorder as black box," in *Proceedings of the International Conference on Computer, Power, and Communications (ICCPC)*, IEEE, 2022, pp. 557–561.