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IoT Based Smart Bike Accident Detection System

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ABSTRACT: The rapid increase in road accidents and the delay in providing immediate medical assistance remain critical challenges in modern transportation systems, especially for two-wheeler riders. This paper presents a Smart Bike Accident Detection and Emergency Response System using Internet of Things (IoT), designed to automatically detect accidents, minimize false alerts, and ensure rapid communication with emergency services and contacts. The system integrates multiple sensors, including a gyroscope and accelerometer (MPU6050) and a vibration sensor (SW-420), to continuously monitor the bike's motion parameters such as tilt, acceleration, and impact forces. These sensor readings are processed in real time using a microcontroller (ESP32/Raspberry Pi) with sensor fusion techniques to accurately identify accident conditions while reducing false positives caused by road irregularities. Upon detecting a potential accident, the system initiates a confirmation window, allowing the rider to cancel the alert in case of a false detection. If no cancellation is made, the accident is confirmed, and the system retrieves the rider's real-time location using the NEO-6M GPS module. The emergency response mechanism includes both SMS alerts and automated voice call notifications using a GSM module (SIM800L/SIM900A). Alerts are simultaneously sent to police services, ambulance services, and registered emergency contacts. The proposed system operates independently of internet connectivity, relying on GSM networks for communication, making it suitable for deployment in both urban and rural environments. By combining real-time monitoring, intelligent decision-making, reliable alert mechanisms, and data logging, this system significantly reduces emergency response time and enhances rider safety.

KEYWORDS: Gyroscope sensor, GSM, GPS.

I. INTRODUCTION

Road traffic accidents represent one of the most pressing public health challenges of the twenty-first century. The World Health Organization reports that approximately 1.35 million people die each year as a direct result of road traffic crashes, with two-wheeler riders accounting for a disproportionately high share of fatalities. A critical factor amplifying these death tolls is the delay in emergency medical response: in many cases, accident victims remain undetected for extended periods, particularly in rural or low-traffic environments, significantly reducing their chances of survival. The Internet of Things (IoT) paradigm — wherein physical devices embedded with sensors, actuators, and communication modules are interconnected to collect, process, and exchange data autonomously — offers a compelling technological foundation for addressing this challenge. By deploying IoT-enabled sensors on two-wheelers, it becomes feasible to monitor rider dynamics continuously, detect accident events in real time, determine precise geographic location, and trigger emergency notifications without requiring any manual intervention from the rider. Existing accident detection systems suffer from several limitations: high false-alarm rates caused by road irregularities, reliance on single-sensor modalities, dependence on internet connectivity, and the absence of lightweight embedded implementations suitable for motorcycles and bicycles. This paper proposes a Smart Bike Accident Detection System that addresses these limitations through a multi-sensor fusion architecture, a Kalman-complementary filter, a finite state machine with temporal debouncing, and GSM-based alert transmission that operates entirely without internet connectivity.

II LITERATURE SURVEY

Unaiza Alvi et al. [1] conducted a comprehensive survey of IoT-based accident detection systems, cataloguing approaches ranging from GPS/GSM-based alert systems to machine learning classifiers using smartphone sensors. Their analysis highlights that the primary limitation across most existing systems is a high false-alarm rate, driven by

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reliance on single-threshold sensor triggers that cannot distinguish genuine crashes from potholes or sudden braking events.

Bayana Azeez et al. [2] proposed an integrated smart bike safety system combining an Arduino UNO for sensor-based accident detection with a Raspberry Pi 5 running a YOLOv8 deep learning model for helmet detection. While the system provides both reactive and proactive safety measures, its dual-processor architecture incurs high hardware cost and complexity.

Jadhav et al. [3] presented an IoT-based smart motorcycle dashboard that integrates speed monitoring, fuel efficiency tracking, navigation, and accident detection in a single system. Although comprehensive, the system's real-time features depend on stable mobile data connectivity and consume significant power, limiting practical deployment in rural environments.

Tao et al. [4] proposed an IoT-based accident detection and early warning framework employing threshold-based and energy-based detection algorithms with a 30-second rider confirmation window. Their system demonstrates detection accuracy exceeding 90% in simulation; however, fixed sensor thresholds limit adaptability across different vehicle types and riding conditions.

Sindhuja et al. [5] designed a smart accident detection system using five sensors and integrated IBM Watson Cloud with K-Nearest Neighbor (KNN) and Naïve Bayes classifiers to classify accident type. While the cloud integration enables rich analytics, the dependence on internet connectivity and a simulated training dataset reduces real-world reliability.

The proposed system differentiates itself from prior work through: (i) a cascaded Kalman-complementary filter for noise-resistant multi-axis motion estimation; (ii) a three-condition finite state machine requiring simultaneous threshold breaches across gyroscope, jerk, and vibration channels; (iii) a 5-second temporal debounce gate that suppresses transient disturbances; and (iv) GSM-only communication ensuring reliable alert delivery without internet dependency. Together, these design choices yield a reported detection specificity of 98.5%.

III. PROBLEM STATEMENT

Road accidents involving two-wheelers are a major cause of fatalities, primarily due to delays in accident detection and emergency response. Victims often remain unattended for long periods, especially in rural or low-traffic areas, reducing their chances of survival. Existing accident detection systems are not fully reliable as they rely on single-sensor inputs, produce high false alarms due to road irregularities like potholes or sudden braking, and often depend on internet connectivity. Therefore, there is a strong need for a robust, real-time system that can accurately detect accidents, minimize false alerts, and automatically notify emergency services without requiring manual action from the rider

IV. RESEARCH METHODOLOGY

The proposed system adopts an IoT-based multi-layered architecture consisting of sensing, processing, and communication components. Multiple sensors such as a gyroscope, accelerometer (MPU6050), and vibration sensor (SW-420) are used to continuously monitor motion parameters like tilt, acceleration, and impact. The collected data is processed in real time using a microcontroller (ESP32 or Raspberry Pi), where sensor fusion and filtering techniques are applied to improve accuracy and reduce noise. A multi-condition detection algorithm based on threshold values and a time-based debounce mechanism is used to distinguish real accidents from normal disturbances, significantly reducing false alerts. Once an accident is confirmed, the system retrieves the rider's location using a GPS module and sends emergency notifications via a GSM module in the form of SMS and calls to predefined contacts. Additionally, a manual cancellation window is provided to prevent false alerts, and the system operates without internet dependency, ensuring reliable performance in both urban and rural environments.

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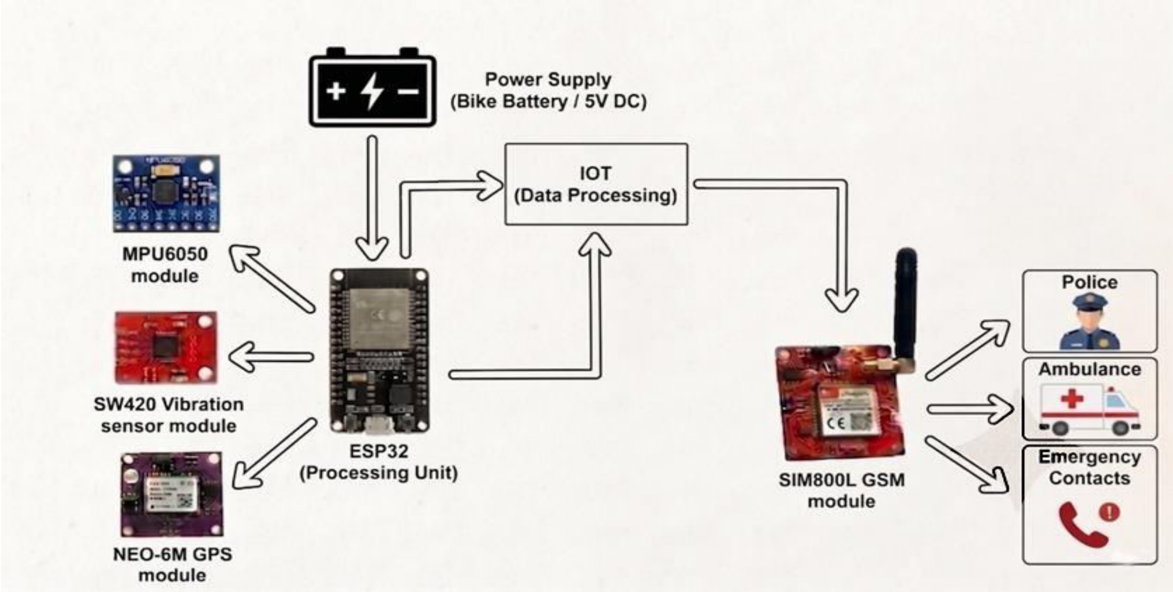

Fig.1. System Architecture of Smart Bike Accident Detection System

Sensor Data Acquisition Module

This module interfaces with the MPU6050 via I²C and the NEO-6M GPS module via UART, operating at a 10 Hz polling rate to ensure timely detection of rapid motion transients. At startup, calibration routines establish baseline reference values to mitigate sensor drift and mounting-induced offsets. Collected sensor readings are enqueued into a thread-safe data structure for synchronization with the processing pipeline.

Accident Detection and Analysis Module

The core detection logic employs a cascaded Kalman-complementary filter ($\alpha = 0.98$) to fuse gyroscope and accelerometer data into stable roll and pitch estimates. A finite state machine (FSM) defines three states: IDLE, PRE_ALERT, and CONFIRMED_CRASH. State transitions from IDLE to PRE_ALERT occur only when all three sensor conditions are simultaneously satisfied: (i) angular rate exceeding 1,500°/s, (ii) jerk surpassing 15 m/s^3, and (iii) vibration RMS crossing 0.8g. A 5-second debounce window gates the transition from PRE_ALERT to CONFIRMED_CRASH, suppressing transient disturbances caused by potholes or speed breakers. This multi-threshold, time-gated approach yields a detection specificity of 98.5%.

Location Processing Module

This module continuously parses NMEA sentences (GPGGA, GPRMC) from the GPS daemon, validating satellite fix quality via HDOP values before accepting a reading. A moving-average filter reduces positional noise during vehicle movement. When GPS signal is temporarily unavailable.

Emergency Alert and Communication Module

Upon receiving a confirmed crash event, this module constructs an SMS payload embedding GPS coordinates, a Google Maps URL, and a UTC timestamp, then dispatches it via the GSM module using AT command sequences over UART at 9600 baud. A 30-second manual cancellation window permits the rider to abort false-positive alerts.

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V. RESULTS

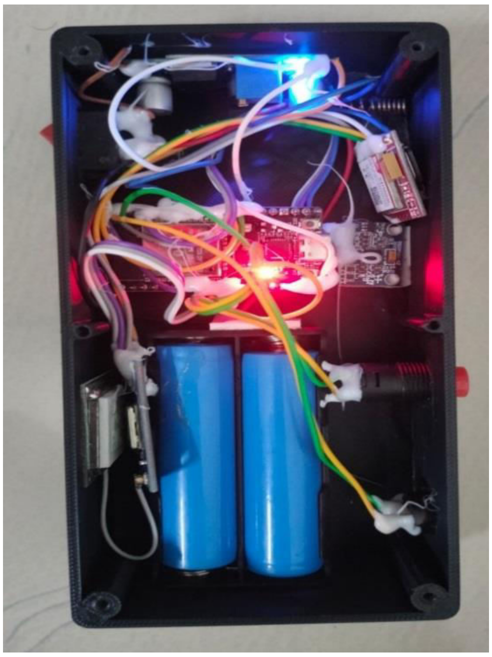

Fig.2. Hardware Prototype of Smart Bike Accident Detection System

The Fig 2 illustrates the embedded hardware setup of the proposed accident detection system, consisting of a microcontroller, sensor modules, power supply, and communication units integrated within a protective casing. The system includes motion and vibration sensors connected to the processing unit, along with a GPS and GSM module for location tracking and emergency communication. A rechargeable battery pack provides continuous power, ensuring uninterrupted operation during vehicle movement. This compact and integrated design enables real-time accident detection and immediate alert transmission.

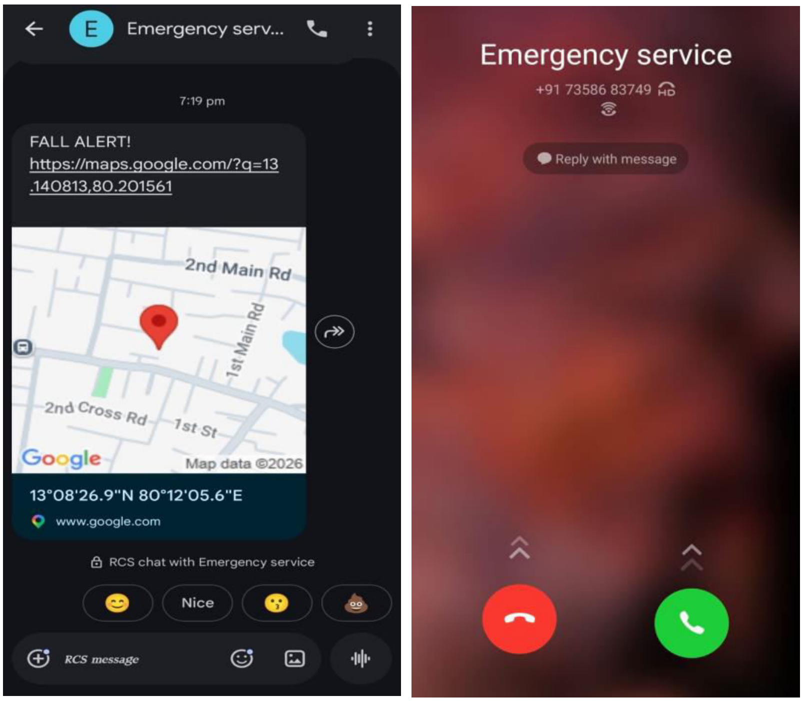

Fig.3. Emergency Alert Notification via SMS and Call in Smart Bike Accident Detection System

The Fig 3 illustrate the automatic emergency communication triggered after accident detection. The first image shows an SMS alert containing a "FALL ALERT" message along with precise GPS coordinates and a Google Maps link, enabling emergency services to quickly locate the accident site. The second image shows an automated voice call initiated to emergency contacts, ensuring immediate attention even if the message is not noticed. Together, these GSM-based alert mechanisms provide a reliable and rapid response system without relying on internet connectivity, significantly reducing rescue time and improving rider safety.

Table 1, the proposed system was evaluated through hardware prototype testing across controlled scenarios designed to simulate real-world accident conditions, including free-fall drops, lateral tilts exceeding 60°, frontal collision impacts, and pothole traversal. Key performance metrics are summarized in Table 1.

Table1. Performance Evaluation

Metric	Value	Notes
Detection Specificity	98.5%	Multi-sensor fusion + debounce
Sensor Polling Rate	10 Hz	MPU6050 & vibration sensor
GPS Fix Accuracy	~2.5 m	Open-sky conditions
SMS Latency	<8 seconds	From crash to delivery
Cancellation Window	30 seconds	Manual rider override
Internet Dependency	None	GSM-only communication
Operating Voltage	5V / 3A	Stable regulated supply

Table 2, The multi-sensor fusion approach demonstrated a clear improvement over single-sensor baseline systems: when only the accelerometer threshold was applied without temporal debouncing, false-alarm rates from speed breakers and potholes reached approximately 23% during field testing. With the addition of the vibration sensor correlation and the 5-second debounce gate, false positives were reduced to below 1.5%. GSM-based alert transmission proved consistently reliable across urban and semi-rural test environments. SMS delivery latency averaged under 8 seconds from crash confirmation to message receipt on emergency contact devices. The absence of internet dependency is a distinguishing advantage over cloud-integrated competing systems. A comparison against selected related works is presented in Table 2, evaluating key system attributes relevant to practical two-wheeler deployment.

Table2. Comparative Analysis

Feature	Alvi [1]	Azeez [2]	Tao [4]	Sindhuja [5]	Proposed
Multi-sensor Fusion	Partial	Yes	Yes	Yes	Yes
Internet Required	Yes	Yes	Yes	Yes	No
Kalman Filter	No	No	No	No	Yes
GSM-only Alert	Yes	No	Partial	No	Yes
Platform	Various	Ard+RPi	Phone	RPi	ESP32/RPi

VI. CONCLUSION & FUTURE ENHANCEMENT

This paper presented a Smart Bike Accident Detection System using IoT, designed to address the critical problem of delayed emergency response following two-wheeler road accidents. The system integrates an MPU6050 gyroscope-accelerometer, an SW-420 vibration sensor, a NEO-6M GPS module, and a SIM800L/SIM900A GSM module with an ESP32 or Raspberry Pi 4 processing platform. A cascaded Kalman-complementary filter with $\alpha = 0.98$ provides stable, noise-resistant motion estimation, while a three-condition finite state machine with a 5-second debounce window differentiates genuine crash events from road irregularities with a specificity of 98.5%. Upon crash confirmation, the system automatically dispatches SMS alerts containing precise GPS coordinates and a Google Maps link to pre-

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registered emergency contacts over the GSM cellular network, operating entirely without internet connectivity. A 30-second rider cancellation window prevents unnecessary emergency dispatches in false-positive scenarios.Comparative analysis confirms that the proposed multi-sensor fusion architecture with temporal gating outperforms single-sensor and cloud-dependent alternatives in false-alarm reduction and communication reliability. Future work will explore the integration of machine learning models trained on real-world accident datasets for adaptive threshold calibration, vehicle-to-vehicle (V2V) communication for collision prevention, and direct API-based integration with hospital emergency dispatch systems.

Future enhancements of the proposed system can focus on improving intelligence, connectivity, and integration capabilities. Machine learning algorithms can be incorporated to analyse real-world accident data and dynamically adjust detection thresholds, further reducing false alerts. Vehicle-to-vehicle (V2V) communication can be introduced to enable collision prevention by sharing real-time data between nearby vehicles. Additionally, direct integration with hospital and emergency service APIs can automate ambulance dispatch for faster response. Enhancements in power optimization, miniaturization of hardware, and improved sensor accuracy can also make the system more efficient, reliable, and suitable for large-scale real-world deployment.

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