A Survey on Intelligent Helmet Systems for Real-Time Accident Detection and Emergency Response in Two-Wheeler Safety

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***Abstract*—Road accidents involving two-wheeler riders often lead to severe injuries or fatalities due to delayed emergency response. Many victims remain unattended because they are unable to call for help after the accident. This paper presents an AI-Powered Smart Helmet designed to automatically detect accident events and send emergency alerts without requiring rider interaction. The system integrates motion sensors, GPS, and communication modules with an intelligent processing unit to analyze real-time motion data and identify crash conditions. When an accident is detected, the system automatically sends the rider's location to predefined emergency contacts. The proposed system aims to reduce response time during accidents and enhance road safety by providing an intelligent and automated accident detection mechanism. In addition to basic accident detection, the proposed helmet focuses on improving the reliability of crash identification using intelligent data interpretation techniques. By continuously monitoring rider motion patterns and analyzing sensor data in real time, the system can identify abnormal movement conditions that are highly associated with accident scenarios. The integration of location tracking and automated communication ensures that emergency alerts are delivered quickly and accurately. The proposed approach aims to enhance rider safety by combining sensing, embedded processing, and intelligent decision-making within a compact wearable device.**

***Index Terms*—Smart Helmet, Artificial Intelligence, Accident Detection, Road Safety, Emergency Alert System, IoT, Embedded Systems.**

I. INTRODUCTION

Two-wheeler vehicles are one of the most widely used modes of transportation, particularly in developing countries. However, motorcycle riders are more vulnerable to road accidents compared to other vehicle users. According to road safety statistics, a significant number of accident victims lose their lives due to delayed medical assistance rather than the accident itself. Traditional helmets provide physical protection but do not offer any intelligent features that can assist in emergency situations. With advancements in embedded systems and artificial intelligence, it is possible to develop smart safety systems capable of detecting accidents and automatically notifying emergency services.

FIGURE: Model Prototype of Smart Helmet

This paper proposes an AI-Powered Smart Helmet capable of detecting crash events using sensor data analysis and automatically transmitting emergency alerts with the rider's location. The system focuses on improving rider safety and reducing emergency response time. With the rapid growth of intelligent transportation systems, the integration of embedded electronics and artificial intelligence in safety equipment has gained significant research attention.

Smart wearable devices such as intelligent helmets have the potential to transform traditional protective gear into active safety systems capable of monitoring rider conditions and responding automatically during emergencies. By incorporating sensing technologies, communication modules, and intelligent data processing, helmets can become proactive safety devices rather than passive protective equipment. This research explores the development of such a system by leveraging AI-assisted analysis to improve accident detection accuracy and emergency response efficiency.

II. SYSTEM MODEL AND ASSUMPTIONS

The proposed smart helmet system consists of several integrated components that work together to detect accident events and trigger emergency alerts. The helmet contains motion sensors such as an accelerometer and gyroscope that continuously monitor the rider's movement and detect abnormal motion patterns. These sensors provide real-time motion data to the processing unit. An embedded computing unit processes the sensor data and applies an AI-based analysis model to distinguish between normal riding conditions and accident events. This intelligent processing helps reduce false alarms caused by sudden braking or road bumps.

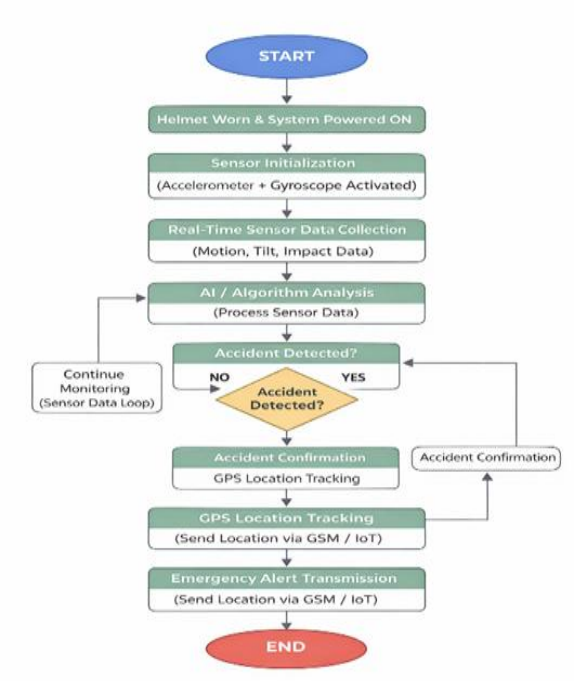

FIGURE: Methodology Flow Chart

When the system detects an accident condition, the GPS module retrieves the rider's current location coordinates. The communication module then sends an emergency alert message containing the location information to predefined contacts such as family members or emergency services.The system operates autonomously and does not require manual intervention from the rider. This ensures that emergency alerts can be transmitted even if the rider is unconscious or unable to use a mobile device. The proposed system follows a real-time monitoring approach where sensor data is continuously collected and processed to detect abnormal motion patterns. The motion sensors measure parameters such as acceleration, angular velocity, and sudden changes in orientation. These signals are analyzed using an intelligent detection algorithm that evaluates multiple conditions before confirming an accident event. This multi-parameter analysis helps reduce false alarms and improves system reliability. Once an accident is verified, the emergency alert mechanism is triggered automatically to ensure that help can reach the rider as quickly as possible.

III. SYSTEM ARCHITECTURE

The proposed AI-Powered Smart Helmet system is designed as an integrated embedded safety device capable of monitoring rider motion and automatically triggering emergency alerts in the event of an accident. The system architecture consists of several interconnected modules that work together to perform real-time sensing, intelligent data analysis, location tracking, and communication. The primary components of the system include motion sensors, an embedded processing unit, a GPS module, a communication module, and a power management unit. Motion sensors such as accelerometers and gyroscopes are responsible for continuously monitoring the rider's movement and orientation. These sensors generate real-time data that reflects acceleration, angular velocity, and sudden changes in motion that may indicate a crash event. The collected sensor data is transmitted to the processing unit where intelligent analysis is performed. The processing unit evaluates the incoming data and applies an AI-based detection approach to determine whether the motion pattern corresponds to normal riding behaviour or a potential accident scenario.

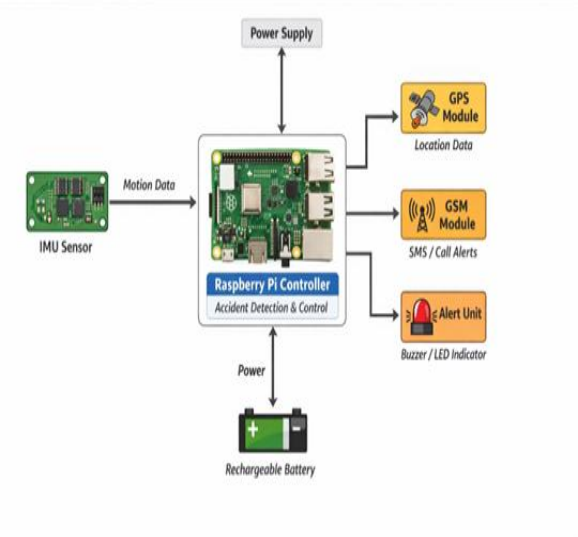

FIGURE: Project Architecture

The decision-making process is based on analysing sudden impact values, abnormal tilt conditions, and rapid changes in motion signals. Once the system confirms the occurrence of an accident, the GPS module retrieves the geographical coordinates of the rider's location. This information is then transmitted through the communication module to predefined emergency contacts. The alert message typically contains the rider's location details and a notification indicating that an accident has occurred. The entire system operates autonomously and does not require any manual input from the rider. This ensures that emergency alerts can still be transmitted even if the rider is unconscious or unable to access a mobile phone. The system architecture therefore integrates sensing, intelligent processing, and wireless communication to create a reliable safety mechanism capable of improving emergency response time in road accident situations.

IV. AI-BASED ACCIDENT DETECTION ALGORITHM

The core functionality of the proposed smart helmet system lies in its ability to accurately detect accident events using intelligent data analysis techniques. Unlike traditional threshold-based systems that rely on simple sensor triggers, the proposed system utilizes AI-assisted pattern recognition to analyze motion data in real time. The accident detection algorithm operates by continuously monitoring sensor signals and identifying abnormal motion patterns. The algorithm evaluates parameters such as sudden acceleration spikes, abrupt changes in angular orientation, and prolonged inactivity after a high-impact event. These parameters are analyzed collectively to determine whether the detected motion corresponds to an accident. The intelligent detection process consists of several stages. First, raw sensor data is collected from the accelerometer and gyroscope modules. This data is then pre-processed to remove noise and normalize the signal values. After preprocessing, the processed data is analyzed using decision rules or lightweight AI models designed to identify crash patterns. If the algorithm determines that the detected motion pattern matches an accident condition, the system triggers the emergency alert mechanism. To minimize false alerts, the algorithm may also incorporate verification checks such as monitoring rider movement for a short period after the impact event. The implementation of AI-assisted accident detection improves the accuracy of the system by allowing it to differentiate between genuine crash events and normal riding activities such as sudden braking or riding over uneven road surfaces.

V. RESULT AND DISCUSSION

The proposed AI-powered smart helmet system is designed to improve accident detection reliability and emergency response efficiency. The system continuously monitors rider motion and evaluates sensor signals in real time. By using intelligent analysis of motion patterns, the system can detect accident conditions more accurately than conventional threshold-based systems.

One of the key advantages of the proposed system is its ability to minimize false alerts. Traditional accident detection systems may trigger alerts due to road bumps or sudden braking. However, the use of AI-assisted data interpretation allows the system to analyze multiple sensor parameters simultaneously before confirming a crash event. Another important aspect of the system is its ability to provide immediate emergency notifications.

Sl. No.	TITLE	METHODOLOGY	ADVANTAGES	DRAWBACKS
1.	Smart Helmet with Message Alert System 2018	Sensors detect crash → GSM sends alert message.	Quick emergency alert.	Low detection accuracy.
2.	IoT Smart Helmet for Accident Detection 2021	Accelerometer + GPS + IoT sends accident data.	Real-time monitoring.	Needs internet connection.
3.	Vision and Sensor Based Smart Helmet 2019	Sensors + image processing detect crashes.	Better detection accuracy.	Higher system cost.
4.	Smart Helmet for Accident Prevention 2020	Alcohol sensor + helmet detection + microcontroller.	Prevents drunk driving.	Limited crash detection.
5.	Smart Helmet System 2020	Analysis of IoT helmet technologies.	Identifies research gaps.	No implementation.
6.	MEMS Sensor Based Smart Helmet 2022	MEMS accelerometer detects abnormal motion.	Lightweight system.	Sensor sensitivity issues.
7.	Smart Helmet Accident Reporting System 2021	Accelerometer detects crash → GPS sends location.	Fast emergency notification.	False alerts possible.
8.	Real-Time Accident Detection Smart Helmet 2023	NodeMCU + vibration + alcohol sensors + IoT alert.	Multi-safety features.	Network dependent.
9.	IoT Helmet for Accident Prevention **2024**	Sensors detect crash → GPS sends alert message.	Automatic accident alert.	Limited intelligence.
10.	Smart Helmet Notification System 2024	Sensor network monitors rider safety.	Improves rider protection.	Power consumption issues.

FIGURE: Literature Survey

Once an accident is detected, the system automatically retrieves the rider's location using GPS and transmits this information to emergency contacts. This significantly reduces the delay in emergency response, which is often a critical factor in accident survival. The system also demonstrates the feasibility of integrating intelligent safety features into wearable protective equipment such as helmets. By combining sensing technologies, embedded computing, and communication modules, the proposed design provides a practical solution for improving rider safety.

VI. CONCLUSION

This paper presented the design and development of an AI-Powered Smart Helmet capable of detecting accident events and automatically transmitting emergency alerts. The system integrates motion sensors, intelligent data analysis, and wireless communication to create an autonomous safety mechanism for motorcycle riders.The proposed system continuously monitors rider motion and applies AI-assisted analysis to identify abnormal crash conditions. Once an accident is detected, the system retrieves the rider's location and sends an emergency notification to predefined contacts. This automated response mechanism helps reduce the delay in emergency assistance and enhances overall road safety.

The proposed smart helmet demonstrates the potential of combining artificial intelligence and embedded systems to develop advanced safety solutions for transportation applications. Future work may focus on improving the AI detection models, integrating additional health monitoring sensors, and enabling cloud-based accident monitoring systems for enhanced safety and emergency management.

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