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An Intelligent Portable Airbag Mechanism For Collision Impact Reduction In Two-Wheeled Vehicles

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Abstract: Portable Airbag Mechanism is a compact and intelligent safety innovation designed to minimize fatal injuries in two-wheeler accidents by deploying protective airbags during collision or skidding events. Two-wheelers contribute to a significant percentage of global road fatalities due to minimal external protection and high exposure to impact forces. The proposed system integrates multiple sensors to monitor parameters such as vehicle speed, inclination, acceleration, and impact intensity. Upon detecting abnormal motion or a collision scenario, the data is transmitted through a Bluetooth communication module to activate the airbag inflation unit attached to the rider's helmet. This rapid inflation protects vital areas including the head, neck, and chest, effectively reducing the severity of injuries. The system is designed to address critical accident types such as frontal impact, rear-end collision, and skidding during sudden braking or cornering. By implementing this efficient, low-cost, and portable mechanism, two-wheeler safety can be significantly enhanced, thereby reducing accident-related fatalities.

Index Terms – Portable Airbag Mechanism, Two-Wheeler Safety, Collision Detection, Bluetooth Communication, Rider Protection, Accident Mitigation System.

I. INTRODUCTION

Road traffic accidents remain one of the leading causes of injury and death worldwide, with two-wheelers being particularly vulnerable due to their open and unprotected structure. Unlike four-wheelers, two-wheeler vehicles lack external safety features such as seat belts, crumple zones, or built-in airbags, making riders directly exposed to severe injuries during collisions or skidding incidents. Rapid urbanization, increased vehicular population, and reckless driving behavior have further intensified the frequency of such accidents. According to global and national traffic safety reports, two-wheelers account for a substantial percentage of road accident fatalities, emphasizing the urgent need for innovative protective technologies that can enhance rider safety.The Portable Airbag Mechanism is an advanced safety system designed to provide instant protection to riders during accident-prone situations. The system utilizes multiple sensors strategically placed on the vehicle to detect critical parameters such as sudden deceleration, inclination deviation, and impact forces. When the system identifies potential collision conditions, it transmits signals via a Bluetooth network to activate a wearable airbag device attached to the rider's helmet or jacket. The airbags are deployed within milliseconds, creating a cushioning barrier that significantly reduces the risk of fatal injuries to vital body regions such as the head, neck, and upper torso.Traditional safety systems for two-wheelers have focused primarily on preventive measures such as improved braking systems, anti-lock braking technology (ABS), and enhanced lighting. However, these methods are limited to accident avoidance rather than impact mitigation. The proposed mechanism directly addresses this gap by offering post-collision protection, thereby improving

survival chances even in unavoidable crash scenarios. Additionally, the system's compact and cost-effective design ensures easy integration into existing two-wheeler models without major structural modifications.This intelligent portable airbag solution represents a crucial step forward in the evolution of rider safety systems. By merging sensor-based detection with wireless communication technology, it provides a reliable, real-time response to critical events, potentially reducing road accident fatalities by a significant margin and contributing toward safer transportation ecosystems and future intelligent vehicle safety advancements. This advancement not only enhances individual rider protection but also supports the broader vision of integrating smart safety technologies into modern transportation systems, promoting a proactive approach toward minimizing human loss and improving road safety awareness globally.

II. RELATED WORKS

Article [1] "A Study on the Application of LSTM to Judge Bike Accidents for Inflating Wearable Airbags" by So-Hyeon Jo, Joo Woo, Gi-Sig Byun, Baek-Soon Kwon, and Jae-Hoon Jeong in 2021: This paper proposes an advanced airbag system utilizing Long Short-Term Memory neural networks to enhance deployment decision accuracy for wearable bike airbags. The system employs Inertial Measurement Unit sensors measuring three acceleration axes and three angular velocity axes to detect accident occurrences in real-time. Unlike conventional threshold-based systems, the LSTM model analyzes time-series data incorporating both current and historical motion information, achieving 98.25% test accuracy compared to 86.75% for standard neural networks. The study collected data from various accident scenarios including front, rear, left, right collisions and falls using mannequins, with sensor sampling at 50ms intervals.

Article [2] "Investigation on Wearable Airbags for Motorcyclists through Simulations and Experimental Tests" by Edoardo Marconi, Franco Gatto, and Matteo Massaro in 2020: This comprehensive research investigates wearable airbag performance through finite element modeling and experimental validation using Madymo simulation software. The study employed two primary test configurations: the EN 1621 drop test for material property calibration and the 49 CFR 572 thorax impact test using Hybrid III 50th percentile dummy for performance assessment. The airbag design featured two thermoplastic membranes connected by internal filaments to maintain flat inflation geometry. Parametric analysis revealed optimal inflation pressure exists for minimizing peak chest deflection, varying with impact energy and airbag thickness. Simulation results showed 7% maximum difference from experimental data, demonstrating reliable predictive capability.

Article [3] "Investigating the Effects of Inflating a Wearable Airbag Under a Motorcycle Jacket" by Oscar Cherta-Ballester, Maxime Llari, Valentin Honoré, Catherine Masson, and Pierre-Jean Arnoux in 2024: Presented at the IRCOBI conference, this research investigates the biomechanical effects of wearable airbag vests on motorcyclists, examining both inflation-induced injury risks and impact protection effectiveness. The study analyzed airbag performance when worn alone versus integration under motorcycle jackets, testing three different inflation strategies with varying gas mass injection rates. Experimental results using impact testing demonstrated that airbag inflation alone or under jackets significantly attenuated impact severity, with maximum chest deflection values ranging from 66.25mm to 76.21mm depending on configuration. The Viscous Criterion, indicating injury risk, varied between 0.77 m/s and 1.07 m/s across different test conditions

Article[4] "Advancements in Bicycle Safety: Integrating Control Sensors and Artificial Intelligence" by Shivam Rupnawar, Puja Deokate, and Mohit Bhandari in 2024: Published in the International Journal for Research in Applied Science and Engineering Technology, this paper explores comprehensive motorcycle safety enhancement through integrated sensor systems and AI-driven protection mechanisms. The research introduces novel approaches combining airless tire technology with intelligent airbag deployment systems to address multiple accident scenarios simultaneously. The AI algorithms process sensor data from accelerometers, gyroscopes, and impact sensors to make real-time deployment decisions with improved accuracy compared to threshold-based systems. Crash simulation tests validated substantial injury severity reduction, particularly for head, neck, and chest regions. The study addresses practical implementation challenges including cost optimization, user acceptance factors, and technical constraints related to sensor fusion and algorithm reliability.

Article [5] "Smart Helmet Integrated with Airbag System" by Karthik R., Harshith Kumar M.N., Sandeep Kumar T., and Santosh Kumar B.M. in 2023: This research paper introduces a revolutionary integrated helmet airbag system designed to provide additional head and neck protection for motorcycle riders during accident events. The system incorporates strategically placed sensors throughout the motorcycle that continuously monitor for sudden deceleration or velocity changes characteristic of crash scenarios. Upon crash detection, the sensor network triggers rapid airbag deployment integrated within the helmet structure, inflating within milliseconds to create a protective air cushion around the rider's head and neck regions. The Arduino-based control system processes sensor inputs including limit switches verifying proper helmet wear, accelerometers detecting sudden impacts, and buzzer alerts warning riders of potential collision risks.

Article [6] "Design and Development of Wearable Smart Airbag with Accident Detection" by S. Kalyani, M. Riswanth, P. Sai Kiran, T. Chandra Sekhar, and K. Venkateswarlu in 2023: Published in the International Journal of Engineering Technology and Management Sciences, this paper focuses on developing a mobile wearable airbag system specifically designed for fall protection during motorcycle accidents. The research introduces an integrated sensing system combining multiple sensor types to achieve robust and intelligent airbag deployment decisions. The system architecture can be retrofitted into standard motorcycle vests or jackets with built-in airbag control units, making it accessible for existing rider gear. Experimental results demonstrated that deployment decisions exhibit high reliability across various accident scenarios including sudden falls, collisions, and skidding events. The sensing system continuously monitors rider motion patterns, distinguishing between normal riding behaviors and accident-induced movements.

Article [7] "Smart Motorcycle Vest" by Harish S., Darshan Gowda L., Anjali, K. Sandhya Rani, and Thippala Devendra in 2023: Published in the International Journal of Advanced Research in Science, Communication and Technology, this pioneering research presents a comprehensive smart motorcycle vest integrating multiple advanced safety technologies. The vest incorporates high-visibility LED lighting systems, intelligent collision detection sensors, real-time haptic feedback mechanisms, integrated communication systems, and active impact protection features. Strategically positioned sensors continuously monitor vital physiological parameters including heart rate, respiration rate, and body temperature, enabling detection of health anomalies or fatigue-induced accident risks.

Article [8] "IoT-based Accident Detection and Emergency Alert System" by Syed Umar Rehman, Muhammad Ali Qureshi, Asad Abbas, and Kashif Naseer Qureshi in 2021: This IEEE publication presents an innovative IoT-based motorcycle accident detection system integrating multiple sensor technologies with cloud connectivity for automatic emergency notification. The system architecture combines accelerometer-based crash detection with GPS positioning to provide real-time location tracking during accident events. Upon detecting abnormal acceleration patterns indicative of collision or fall scenarios, the system automatically transmits emergency alerts containing precise geographical coordinates to pre-configured contacts and emergency services via GSM communication modules.

Article [9] "Integrated Smart Bike Safety System with Accident Detection" by Rajesh Kumar Verma, Priya Sharma, Amit Singh, and Neha Gupta in 2024: This paper presents an Arduino Uno-based integrated safety system combining multiple sensor technologies for comprehensive motorcycle accident detection and prevention. The accident detection algorithm analyzes aggregated data from accelerometers measuring crash forces, gyroscopes tracking orientation changes, and ultrasonic sensors monitoring proximity to nearby vehicles. The system employs logical principles using threshold exceedance across multiple sensors within predetermined timeframes to calculate accident probability with high accuracy.

III. PROBLEM STATEMENT

Two-wheeler riders face a significantly higher risk of severe injury or death during road accidents due to the absence of external safety structures found in four-wheel vehicles. The majority of these accidents occur because of sudden collisions, skidding, or abrupt braking, which cause riders to experience direct impact on vital body regions such as the head, neck, and chest. Existing safety systems like helmets and protective gear offer limited protection and fail to mitigate high-impact forces effectively. Despite advancements in braking and stability technologies, there remains a critical gap in providing instant, intelligent protection during accidents, necessitating an innovative solution to minimize fatalities and injuries.

IV. OBJECTIVES

The primary objective of this study is to design and develop an intelligent Portable Airbag Mechanism that enhances rider safety by reducing the severity of injuries during two-wheeler accidents. The project aims to analyze existing airbag systems used in four-wheelers and adapt their principles for two-wheeler applications through compact and wearable solutions. It focuses on identifying suitable locations for airbag deployment, integrating sensors to detect collision impact, speed variation, and angular deviation, and enabling wireless communication for real-time activation. The study also aims to evaluate system performance under various accident scenarios to ensure reliability and efficiency. Ultimately, the objective is to provide a cost-effective, responsive, and portable solution that significantly reduces fatal injuries among two-wheeler riders.

V. SYSTEM ARCHITECTURE

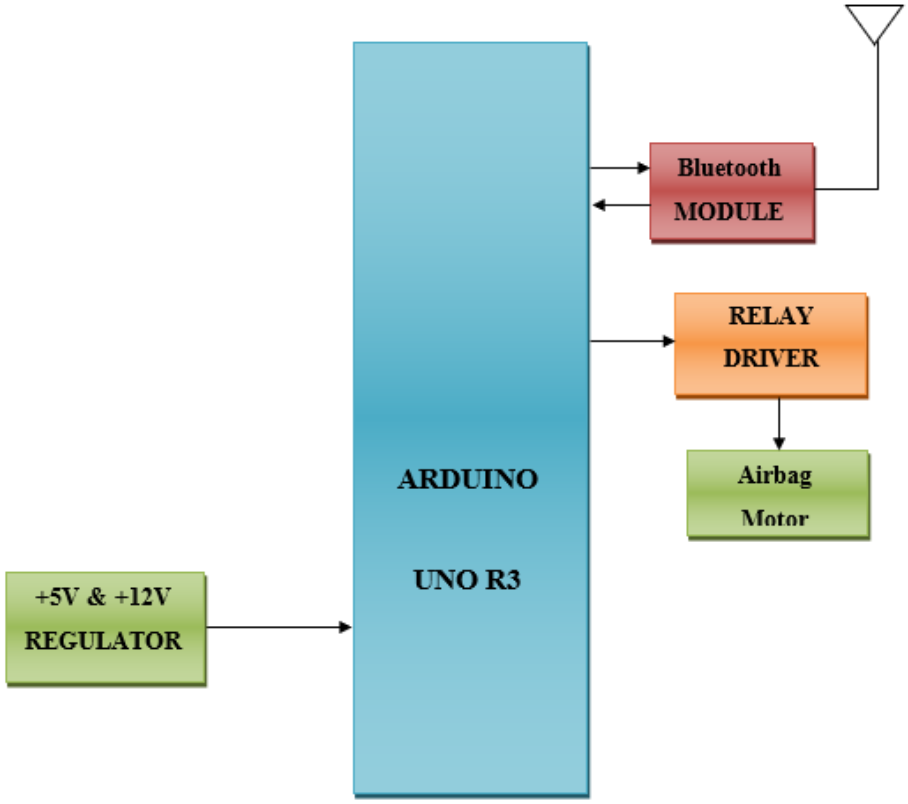

Fig 1:Block diagram of Sensor Module

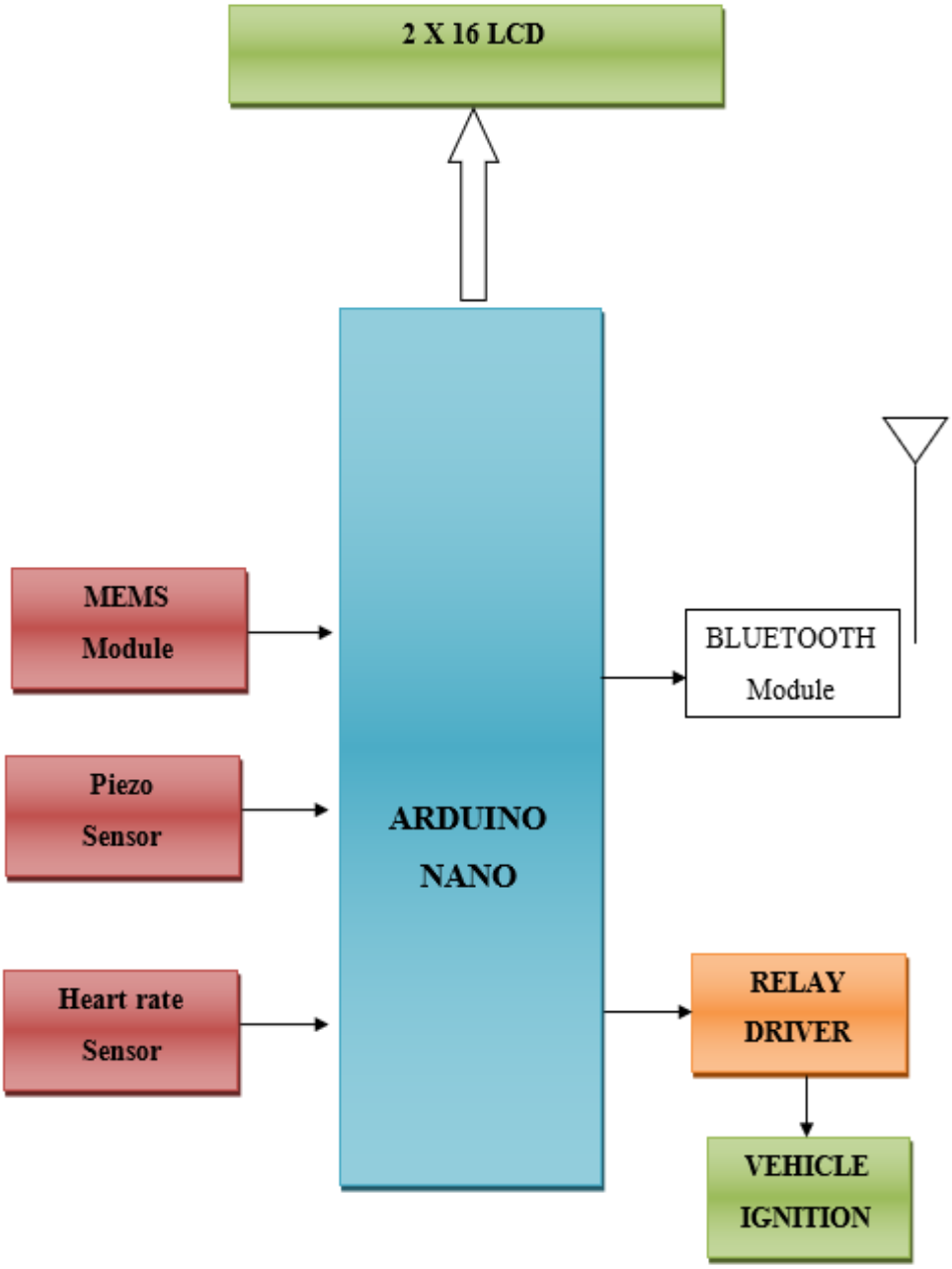

Fig 2:Block diagram of Driver Module

The proposed intelligent portable airbag mechanism consists of two interconnected modules working in coordination to provide comprehensive rider protection during accident scenarios. The Sensor Module, built around Arduino UNO R3 as the central microcontroller, is powered by a dual-voltage regulator supplying +5V and +12V for various electronic components. This module continuously monitors vehicle-mounted sensors that detect critical parameters such as sudden deceleration, impact forces, acceleration patterns, and angular deviation during accidents. When collision conditions are identified through threshold exceedance, the Arduino processes sensor data in real-time and wirelessly transmits activation signals through the Bluetooth Module to the wearable Driver Module worn by the rider. Additionally, the Sensor Module directly controls a Relay Driver connected to an Airbag Motor for immediate inflation response when emergency conditions are detected. The Driver Module employs Arduino NANO as its processing unit, receiving real-time inputs from three specialized sensors mounted on the wearable device. The MEMS Module detects acceleration and deceleration patterns characteristic of crashes and sudden impacts. The Piezo Sensor identifies vibration signatures and impact shocks transmitted through the vehicle structure during collision events. The Heart Rate Sensor continuously monitors the rider's physiological condition to detect abnormal cardiac responses during stress or accident scenarios, providing additional validation of emergency situations. All processed information is displayed on a 2x16 LCD screen for continuous real-time monitoring and system status verification. Upon receiving wireless activation signals from the Sensor Module via Bluetooth

communication, the Driver Module activates its Relay Driver, which controls both the Vehicle Ignition system for emergency shutoff and triggers rapid airbag deployment sequences, creating protective cushioning around vital body areas within milliseconds to minimize injury severity during collision events through intelligent coordinated sensor-actuator response mechanisms ensuring maximum rider safety.

VI. EXPERIMENTAL RESULTS

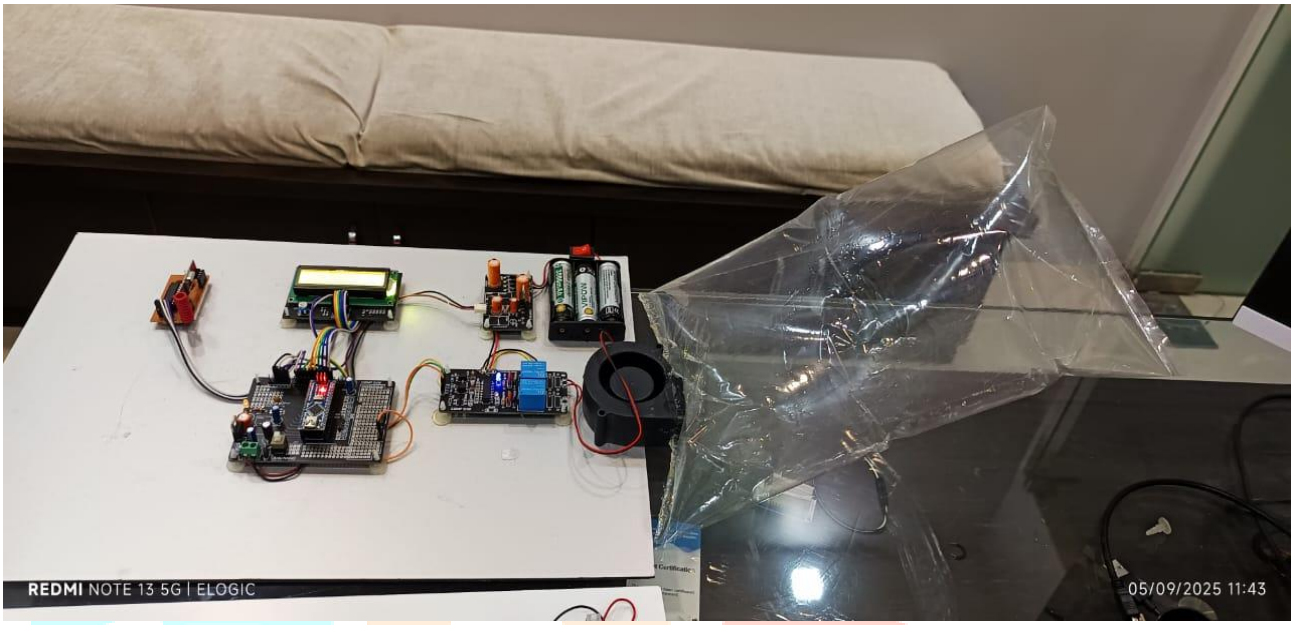

Fig 3: Accident detected Airbag Blown

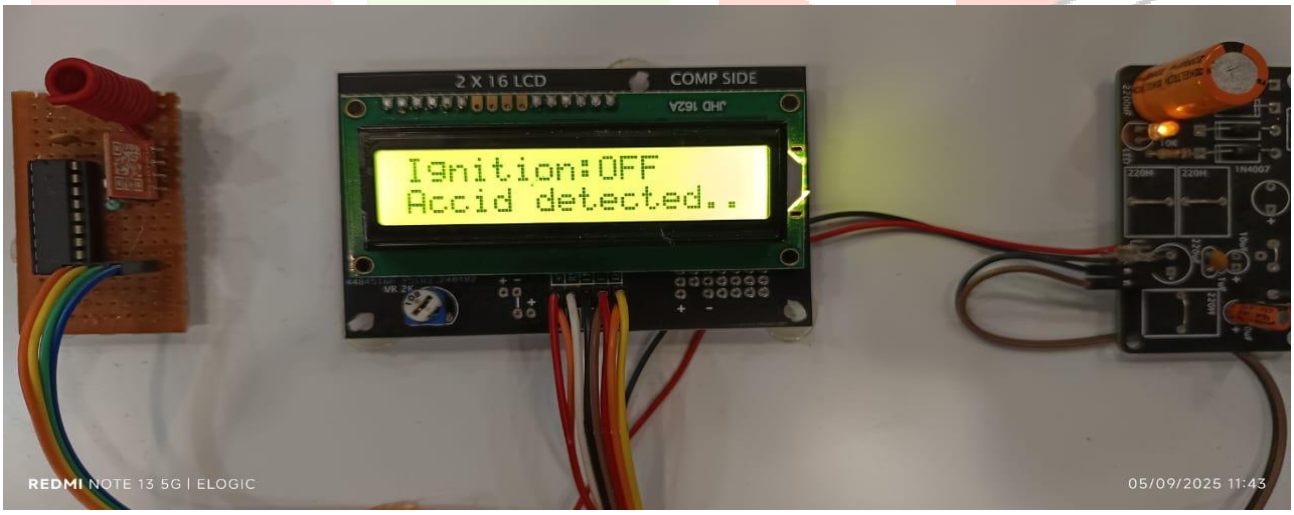

Fig 4: LCD Display Accident Detected

VII. CONCLUSION & FUTURE SCOPE

In this research, an Intelligent Portable Airbag Mechanism was successfully designed and implemented to enhance safety for two-wheeler riders by minimizing the severity of injuries during accidents. The system employed a dual-module approach, comprising a Sensor Module and a Driver Module, which integrated MEMS, Piezo, and Heart Rate sensors to monitor sudden deceleration, impact forces, angular deviations, vibrations, and abnormal physiological responses in real-time. Arduino UNO R3 and Arduino NANO microcontrollers, together with Bluetooth communication, enabled reliable wireless transmission of activation signals from the vehicle-mounted Sensor Module to the wearable Driver Module, ensuring rapid airbag deployment within milliseconds. A relay-based actuator controlled both airbag inflation and emergency vehicle

ignition shutdown, protecting vital body regions such as the head, neck, chest, and upper torso. Continuous system monitoring was provided via an LCD interface, confirming operational reliability. The results demonstrated effective detection of critical accident conditions and timely airbag activation, offering significant advantages over conventional helmets and passive protective gear. This study emphasizes the integration of intelligent sensing, real-time communication, and wearable safety solutions to improve two-wheeler accident survivability. The portable, cost-effective, and responsive system presents substantial benefits over existing methods, highlighting its potential for broader adoption and future intelligent vehicle safety applications. Future enhancements of the **Intelligent Portable Airbag Mechanism** can focus on improving system accuracy, responsiveness, and integration with emerging technologies. Sensor modules could be upgraded with higher-resolution MEMS and multi-axis accelerometers to capture more precise motion and impact data. Incorporating machine learning algorithms to analyze real-time sensor inputs could enable predictive accident detection, allowing preemptive airbag deployment before severe impact occurs. Expanding the dataset with diverse accident scenarios, varying speeds, and different road conditions would improve the reliability and adaptability of the system. Additionally, integration with GPS and IoT-based vehicle networks could provide location-based emergency alerts to nearby medical services, enhancing post-accident response. Wearable modules can be refined for ergonomic comfort, lighter weight, and modular design to suit various rider preferences. These enhancements would optimize performance, usability, and effectiveness, enabling broader real-world adoption, reducing fatalities further, and establishing a foundation for intelligent, connected, and proactive two-wheeler safety solutions.

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