International Journal of
DATA SCIENCE AND IOT MANAGEMENT SYSTEM
ISSN: 3068-272X www.ijdim.com Original Research Paper

SMART HELMET FOR MINE WORKERS

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ABSTRACT: Coal mining involves various risks due to hazardous environmental conditions such as high temperatures, methane, carbon dioxide, and other toxic gases. Frequent accidents in mines highlight the need for advanced safety solutions to protect miners from these dangers. Ensuring the safety and security of workers in underground coal mines requires reliable monitoring and communication systems. The Smart Helmet is designed to address these safety concerns by incorporating sensors to detect temperature, light, and hazardous gases, along with a GPS tracker for location monitoring. It integrates a GSM module to send emergency SMS alerts to predefined contacts during critical situations, ensuring timely responses. A Wi-Fi-based monitoring system, enabled by the WeMos ESP8266 module, collects real-time data from the sensors and facilitates hazard alerts through an app-based interface and a buzzer system. This study provides an advanced safety solution for coal mine workers by enabling real-time monitoring of working conditions, rapid emergency alerts, and location tracking. The Smart Helmet enhances situational awareness, reduces accident risks, and supports swift action in emergencies, offering a practical and reliable approach to improving safety standards in the coal mining industry.

Keywords: Smart helmet; Coal mine safety; IoT-based monitoring; GSM module; ARDUINO NANO + ESP8266; Gas sensor (MQ-2); Temperature sensor (DHT11); GPS tracking; Wireless communication; Emergency alert system; Blynk app; Hazard detection; Environmental sensors.

Received: 16-11-2025 Accepted: 30-12-2025 Published: 07-01-2026

I.INTRODUCTION

Mining is essential for economic growth, supporting various sectors and creating jobs. However, mining operations, especially deep underground, come with significant safety and health challenges due to unstable environments and exposure to dangerous elements like methane, carbon dioxide, and high temperatures. Ensuring the safety of miners is a priority as they face potential hazards, including toxic gas inhalation, collisions, and cave-ins. To improve safety, we propose an IoT-based smart helmet system using microcontroller-based technology. This system incorporates a ESP8266 Wi-Fi module for wireless communication and real-time monitoring of miners' locations. The smart helmet is equipped with a microcontroller circuit that integrates sensors for gas monitoring, and ensuring continuous oversight. Additionally, an emergency button embedded in each helmet allows workers to signal a crisis situation such as gas exposure, bodily harm, or a structural collapse. The microcontroller-based wireless monitoring system reduces the high installation and maintenance costs associated with wired communication systems in mining environments. By using Wi-Fi-enabled microcontroller circuits, this innovative approach ensures real-time data transmission and improves emergency response times, enhancing overall worker safety and minimizing risks in the mining sector.

II.LITERATURE REVIEW

Mardonova, M., & Choi, Y Reviews wearable device technologies (including helmets, eyewear, etc) and how they've been / could be applied in mining operations. Classifies wearable devices by their function, appearance, proximity to the body, etc. Highlights sensor types (gas sensors, physiological sensors, location tracking) and shows that by introducing wearable tech to mines, safety can be improved. Suggests potential wearable safety-management systems for miners, but also points out that at the time (2018) there were relatively few actual mining-deployments. [1]

Lee, P.; Kim, H.; Zitouni, M. S.; Khandoker, A.; Jelinek, H. F.; Hadjileontiadis, L.; Lee, U.; Jeong, Y. Conducts a systematic review from 2010 to 2021 of smart helmet research in

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multiple domains (industry, sports, first responders). Found that 32 % of the 57 included studies were industrial applications; the rest included sports etc. Focuses on four major categories of purpose: activity sensing, physiological monitoring, environmental/hazard sensing, risk-event alerting. Highlights challenges: feasibility testing is weak (avg score 1.6/3 vs sensor calibration ~2.3/3) and many prototypes haven't moved beyond lab/bench level. [2]

Choi, Y.; Kim, Y. Reviews ~103 research articles (2009-2020) on smart helmets, with focus on sensors, microcontrollers, wireless communication technology. Key findings: ~85% of smart helmets use wireless communication tech (RF, Bluetooth, WiFi, Zigbee). Identifies limitations: weight/comfort (sensor + battery makes helmet heavy), durability in harsh environments, privacy/security issues.[3]

Kim, Jinwoo; Lee, Kyeongsuk; Jeon, JungHo. Systematic literature review of wearable devices and data collection for construction safety and health. (Elsevier)Although focused on construction, many lessons apply to mining / industrial safety wearables (environmental sensors, communication constraints).Useful for drawing parallels in work-site wearable adoption, standards, human factors etc.[4]

Ryu, J., Park, J., & Kim, H. This review evaluates modern wearable sensors designed to improve worker safety in industrial environments. The authors examine physiological sensors (heart rate, respiration, temperature), environmental sensors (gas, heat, vibration), and motion sensors (accelerometers and gyroscopes). They highlight that wearable devices support continuous monitoring and early detection of dangerous conditions through real-time alerts. The paper also identifies challenges such as sensor accuracy issues, discomfort during prolonged use, and limited battery life. The authors conclude that integrating IoT connectivity and AI-based analytics will significantly enhance predictive safety for industrial workers.[5]

Zhou, C., Liu, J., & Li, X. This paper reviews the development of smart PPE systems that incorporate sensors and communication modules into helmets, vests, and boots. The study highlights features such as collision avoidance, toxic gas detection, fatigue sensing, and posture monitoring. The authors explain how smart PPE is evolving from passive protective gear into active, sensor-based systems capable of real-time safety intervention. The review also notes practical limitations like added weight, low durability in harsh conditions, and data privacy concerns. It concludes that standardization and miniaturization of electronics will be essential for mass adoption.[6]

Zhao, Y., Zhang, P., & Wang, L. This paper reviews the development of smart PPE systems that incorporate sensors and communication modules into helmets, vests, and boots. The study highlights features such as collision avoidance, toxic gas detection, fatigue sensing, and posture monitoring. The authors explain how smart PPE is evolving from passive protective gear into active, sensor-based systems capable of real-time safety intervention. The review also notes practical limitations like added weight, low durability in harsh conditions, and data privacy concerns. It concludes that standardization and miniaturization of electronics will be essential for mass adoption.[7]

Villanueva, J., Bishop, M., & Hargrove, L. This review examines ergonomic and human-factors considerations in designing wearable safety devices. The authors highlight that comfort, ventilation, device weight, and user acceptance play a crucial role in determining whether workers consistently use smart helmets and other wearable's. Poorly designed wearable's can restrict movement, trap heat, or cause

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pressure discomfort. The study stresses the importance of lightweight materials, balanced weight distribution, intuitive interfaces, and low-power electronics. The review concludes that integrating ergonomic design with technical features is essential for long-term adoption of smart helmets.[8]

III. METHODOLOGY

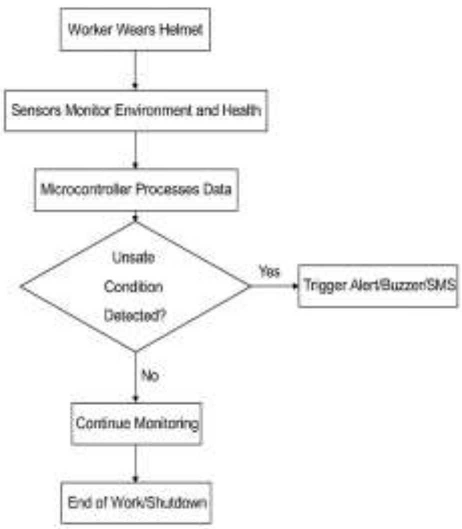

Fig. 1 Flow Chart

IV. WORKING PRINCIPLE

Fig.2 Project Model

The Smart Helmet for Mine Workers is an IoT-based safety device that operates by continuously sensing and transmitting environmental and safety parameters using an ARDUINO NANO + ESP8266 microcontroller. The helmet is equipped with a temperature sensor to monitor the surrounding heat, an MQ-2 gas sensor to detect harmful gases such as methane (CH_4), carbon monoxide (CO), and LPG, and an ultrasonic sensor to detect obstacles or falls in narrow mining tunnels. All sensor readings are processed by the ARDUINO NANO, which acts as the brain of the system. The ESP8266 is connected to the Wi-Fi module for real-time data transmission to a monitoring application or system on the surface. The helmet also includes a GPS module that continuously tracks the miner's location for safety and rescue operations. When the system detects any unsafe condition—like a rise in gas concentration, high temperature, or a fall—the alert system is activated: a buzzer sounds, and LED indicators flash to warn the worker instantly. Simultaneously, the ESP8266 sends an emergency alert message along with the miner's live location to the monitoring app via Wi-Fi. The control room can view these parameters through the monitoring dashboard or a mobile application, allowing quick response in case of emergencies. This system ensures that miners are constantly monitored and protected in real time, reducing the risk of accidents and improving workplace safety in hazardous underground environments.[9]

V. CONCLUSION AND FUTURE SCOPE

The Smart Helmet for Mine Workers is an effective IoT-based safety device designed to protect miners in hazardous underground conditions. It uses components like the ESP32 microcontroller, MQ-2 gas sensor, temperature and ultrasonic sensors, GPS, Wi-Fi, buzzer, and LED indicators to monitor the environment and the worker's safety in real time. The system detects dangerous situations such as gas leakage, high temperature, or falls and instantly alerts both the worker and the control room through an alert system and wireless communication. This ensures quick response and reduces the risk of accidents. In the future, the helmet can be further enhanced by adding health monitoring sensors, AI-based prediction systems, and LoRa or 5G communication for long-range data transmission. A dedicated mobile app with cloud connectivity can also be developed for storing data and analyzing safety patterns. Thus, the smart helmet not only improves current safety standards but also has great potential for future development in intelligent mining and industrial safety systems.[10]

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