International Journal of Electrical, Electronics and Computer Systems
ISSN: 2347-2820
Volume 15 Issue 1s (2026) | Pages: 256-260

Cranium Guard Pro an IoT - Based Smart Helmet for Coal Miner's Safety

Sujata Girawale[1], Pranav Pisal[2], Harshada Patil[3], Poonam Yewale[4]
[1,2,3,4,5] Department of Patil Computer Engineering, Genba Sopanrao Moze College of Engineering Balewadi, Pune, India

Peer Review Information

***Type**: Article*
***Received**: 3 February 2026*
***Revised**: 4 March 2026*
***Accepted**: 1 April 2026*
***Published**: 22 May 2026*

Abstract

Coal mining environments pose serious safety risks due to hazardous gases, extreme conditions, and potential underground accidents. The purpose of this study is to enhance miner safety by developing Cranium Guard Pro, an IoT-based intelligent helmet for real-time monitoring. The methodology involves integrating an ESP32 microcontroller with gas sensors, a temperature–humidity sensor, and an accelerometer to continuously collect environmental and motion data. The system processes this data to detect unsafe conditions such as gas leaks, abnormal temperature levels, or sudden movements indicating accidents, and alerts miners through a buzzer while transmitting data wirelessly to a remote monitoring station. The findings show that the system can effectively detect hazardous conditions and provide timely alerts, improving situational awareness. In conclusion, Cranium Guard Pro offers a reliable and efficient solution for enhancing safety in coal mining environments through continuous monitoring and rapid response capabilities.

Keywords: Smart Helmet; IoT; Coal Mining Safety; Gas Detection; Real-Time Monitoring; Wireless Sensor Networks.

How to Cite This Article

Girawale, S., Pisal, P., Patil, H., & Yewale, P. (2026). Cranium Guard Pro an Iot - Based Smart Helmet for Coal Miner's Safety. *International Journal of Electrical, Electronics and Computer Systems*, 15(1s), 256-260.

2347-2820/ © 2026 The Authors. This is an open access article under the CC BY-NC-ND license (https://creativecommons.org/licenses/by-nc-nd/4.0).

Introduction

Coal plays a significant role in global energy production, yet underground mining environments remain highly hazardous for workers. Exposure to toxic gases such as methane and carbon monoxide, along with extreme temperature and humidity conditions, poses serious health risks. In addition, sudden accidents like cave-ins and impacts can lead to severe injuries or fatalities. Traditional safety equipment does not provide continuous monitoring or instant alerts. To address this issue, Cranium Guard Pro is proposed as an IoT-based smart helmet that tracks environmental and motion parameters, delivers real-time warnings, and supports remote monitoring to improve miner safety.

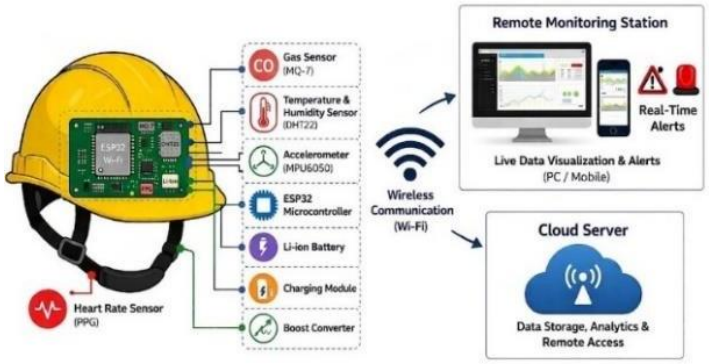


Fig 1. *Cranium Guard Pro-Smart Helmet*

Literature Review

Several researchers have contributed significantly to improving safety in coal mining using advanced technologies. Their work is summarized as follows:

In [1], "Smart Helmet for Coal Miners using IoT" by Madhuri et al. (2023), the authors presented an IoT-based helmet capable of detecting hazardous gases such as methane and carbon monoxide. The system focused on real-time monitoring and wireless data transmission; however, it required periodic sensor calibration to maintain accuracy.

In [2], "Wireless Sensor Network for Coal Mine Safety Monitoring" by Yadav and Jaiswal (2023), the authors developed a monitoring system using wireless sensor networks (WSN). Their approach utilized multi-hop communication to ensure reliable data transmission in deep underground environments.

In [3], "Review on Smart Helmet Systems for Industrial Safety" by Singh and Kumar (2021), the authors analyzed various smart helmet designs and highlighted the importance of integrating multiple sensors to improve detection efficiency and system reliability.

In [4], "IoT-Based Industrial Safety Helmet" by Kartik and Manimaran (2023), the study introduced a helmet system incorporating environmental sensors and accelerometers to detect falls and hazardous conditions in industrial settings.

Methodology

The research follows a hardware-based design and implementation approach to develop the Cranium Guard Pro smart safety helmet. The system is designed by integrating an ESP32 microcontroller with multiple sensors, including the MQ-2 gas sensor for detecting harmful gases, the DHT11 sensor for temperature and humidity monitoring, and the MAX30100 sensor for measuring heart rate and oxygen levels. These components are assembled on a wearable helmet and programmed to continuously monitor environmental and physiological conditions. Data collection is carried out through real-time sensor readings during system testing under different simulated conditions. The collected data is transmitted wirelessly to the Blynk IoT platform using Wi-Fi, where it is visualized and monitored remotely. Tools used in this project include Arduino IDE for programming, ESP32 module, sensor modules, and the Blynk mobile application. The sample size consists of multiple experimental trials conducted to test system performance, accuracy, and reliability under varying environmental conditions.

Block diagram

The block diagram illustrates the architecture of the Cranium Guard Pro smart helmet system. Multiple sensors, including gas, temperature, accelerometer, and heart rate sensors, are interfaced with the ESP32 microcontroller for continuous monitoring. The collected data is transmitted to a cloud platform and monitoring dashboard via IoT communication, while alerts are generated using a buzzer. The system is powered by a Li-ion battery integrated with a charging module and boost converter to ensure stable operation.

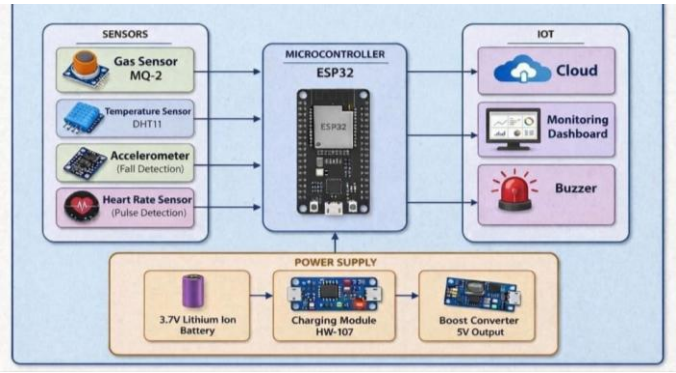


Fig 2. *Block Diagram*

Circuit diagram

The circuit diagram represents the hardware implementation of the Cranium Guard Pro smart helmet system using an ESP32 microcontroller. Various sensors, including MQ-2 gas sensor, DHT11 temperature sensor, accelerometer, and MAX30100 heart rate sensor, are interfaced to monitor environmental and physiological parameters. The system generates alerts through a buzzer and transmits data wirelessly for real-time monitoring. Power is supplied using a Li-ion battery connected to a charging module and boost converter to ensure stable voltage output.

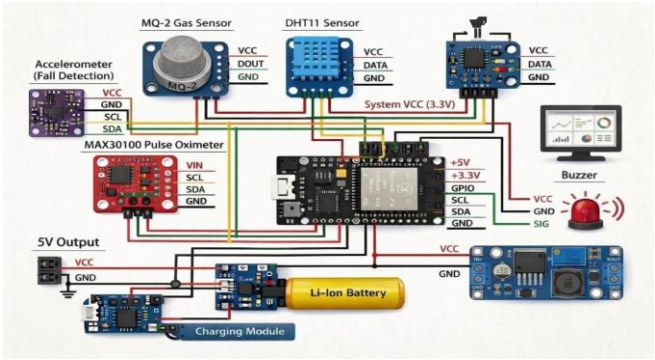


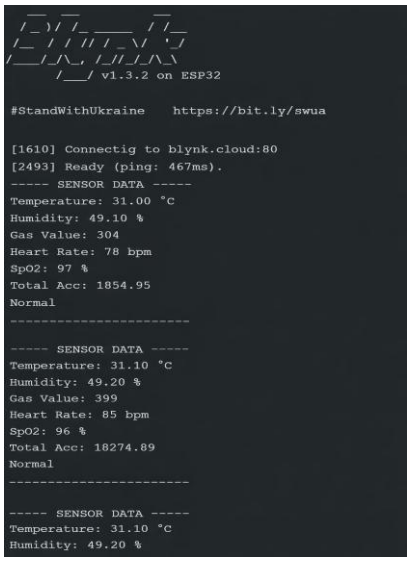
Fig 3*. Circuit Diagram*

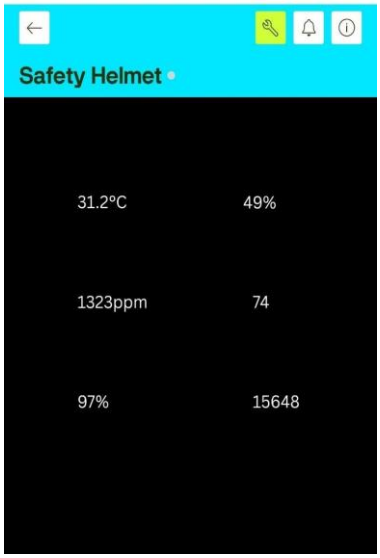
Results/findings

The developed Cranium Guard Pro system was tested under various simulated environmental conditions to evaluate its performance. The MQ-2 gas sensor successully detected the presence of harmful gases such as smoke and LPG, showing increased output values when exposed to gas sources. The DHT11 sensor accurately measured temperature and humidity within its specified range, while the MAX30100 sensor provided stable readings for heart rate and oxygen saturation. All sensor data was transmitted in real time to the Blynk application via the ESP32 module. The system effectively generated alerts when predefined threshold values were exceeded, ensuring timely warnings. The following observations were recorded:

- Gas levels increased significantly in the presence of smoke, triggering alerts.
- Temperature and humidity readings remained consistent with environmental changes.
- Heart rate and SpO_2 values were displayed accurately on the Blynk dashboard.
- Wireless communication showed minimal delay in data transmission.

Overall, the system demonstrated reliable performance, real-time monitoring capability, and effective hazard detection.





Discussion

The results indicate that the Cranium Guard Pro system effectively achieves its objective of enhancing worker safety through real-time monitoring. The system successfully detected hazardous gas levels, environmental changes, and physiological parameters, thereby addressing the research question of whether an IoT-based wearable device can improve safety in mining environments. The immediate alert mechanism and continuous data transmission to the Blynk platform demonstrate the system's ability to provide early warnings and reduce response time during critical situations. The performance of the system was stable, with minimal delay in wireless communication, ensuring timely delivery of data. The integration of multiple sensors enabled comprehensive monitoring of both environmental and health conditions, which is essential in hazardous workplaces. This multi-parameter monitoring increases the reliability of the system in detecting potential risks. These findings are consistent with existing literature, which emphasizes the importance of IoT-based wearable devices for improving safety and reducing accidents. Previous studies have shown that real-time monitoring and remote supervision significantly enhance workplace safety. Overall, the project validates that smart helmets integrated with IoT technology can provide an efficient, reliable, and scalable solution for safety management in mining and industrial environments.

Conclusion and Future Scope

The proposed Cranium Guard Pro system presents a robust, efficient, and scalable solution for real-time safety monitoring in underground mining and other hazardous environments. By integrating gas sensors, temperature–humidity sensors, motion detection, and heart rate monitoring with the ESP32 microcontroller, the system enables continuous multi-parameter monitoring and rapid detection of unsafe conditions. The implementation of real-time alerts through a buzzer and wireless data transmission to the Blynk platform ensures quick response and improved situational awareness for both miners and supervisors. Additionally, the PCB-based compact design and optimized power management using a Li-ion battery, charging module, and boost converter enhance portability, energy efficiency, and suitability for wearable applications. A key strength of the system is its dual monitoring capability, which not only detects environmental hazards but also tracks the physiological health of miners. This combined approach significantly improves reliability and helps in early identification of both external dangers and health-related risks, making it more effective than traditional safety systems. In the future, the system can be enhanced by integrating LoRa communication for long-range connectivity in deep underground mines, GPS modules for real-time location tracking, and machine learning algorithms for predictive hazard detection. Further improvements in sensor calibration, data accuracy, and the development of a centralized monitoring dashboard can enhance system performance, reliability, and scalability for large-scale industrial deployment. The integration of gas, temperature–humidity, motion, and heart rate sensors with the ESP32 microcontroller enables continuous multi-parameter monitoring and rapid hazard detection. The system ensures low-latency alert generation and reliable wireless data transmission, while the PCB based design and optimized power management using a Li-ion battery, charging module, and boost converter enhance portability and energy efficiency. The system not only detects hazards but also monitors phyiological conditions of miners, enabling early identification of health-related risks. This dual monitoring approach (environmental and health) makes the system more reliable than existing solutions. Future enhancements may include the implementation of LoRa communication for extended range in deep underground conditions, integration of GPS for location tracking, and the application of machine learning algorithms for predictive

hazard analysis. Additionally, improving sensor calibration techniques and developing a centralized monitoring platform can further increase system reliability and scalability for large-scale deployment.

References

1. Bhattacharjee, S., Roy, P., & Ghosh, S. (2021). IoT-based smart helmet for coal miners safety monitoring and alert system. International Journal of Advanced Computer Science and Applications, 12(4), 512–519. https://doi.org/10.14569/IJACSA.2021.0120464
2. Dange, S. P., & Chatterji, S. (2018). IoT based smart helmet for unsafe event detection for mining industry. Proceedings of the International Conference on Intelligent Computing and Control Systems, 117–122. https://doi.org/10.1109/ICCONS.2018.8663011
3. Karthick, T., & Kumar, P. R. (2020). Smart helmet using IoT for coal mine workers safety. Materials Today: Proceedings, 33, 4578–4582. https://doi.org/10.1016/j.matpr.2020.07.630
4. Chavan, P., Patil, S., & Deshmukh, A. (2019). Coal mine safety monitoring system using IoT and wireless sensor networks. International Journal of Innovative Technology and Exploring Engineering, 8(9), 2278–3075. https://doi.org/10.35940/ijitee.I8374.078919
5. Saha, H. N., Auddy, S., & Pal, S. (2017). Wearable smart helmet system for mining industry applications. 2017 Devices for Integrated Circuit (DevIC), 472–476. https://doi.org/10.1109/DEVIC.2017.8073985
6. Prasad, K. V. N., Rao, G. N., & Rao, M. S. (2021). Real-time coal mine worker safety monitoring using IoT-enabled smart helmet. Journal of Physics: Conference Series, 1916(1), 012145. https://doi.org/10.1088/1742-6596/1916/1/012145
7. Singh, R., & Sharma, V. (2022). IoT and embedded systems-based smart helmet for hazardous environment monitoring in mines. Microprocessors and Microsystems, 90, 104486. https://doi.org/10.1016/j.micpro.2022.104486
8. Kumar, A., Verma, S., & Mishra, D. (2020). Wireless sensor network and IoT-based miner health and safety monitoring system. International Journal of Communication Systems, 33(14), e4518. https://doi.org/10.1002/dac.4518
9. Li, X., Wang, Y., & Zhang, H. (2019). Intelligent safety monitoring system for underground coal mines using IoT technologies. Sensors, 19(18), 3958. https://doi.org/10.3390/s19183958
10. Mahmud, M. S., Rahman, M. M., & Hossain, M. A. (2021). An IoT-enabled wearable smart helmet to detect environmental hazards for mine workers. IEEE Access, 9, 123957–123969. https://doi.org/10.1109/ACCESS.2021.3110456