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Enhancing Workers Safety with Smart Helmet

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Abstract*— The "Enhancing Worker Safety with Smart Helmets" initiative leverages IoT and LoRa technology to improve safety in excavation and construction. The helmet monitors vital signs, air quality, hazardous gases, temperature, humidity, vibration, and location using biometric and environmental sensors. It provides real-time alerts to workers and control systems, ensuring timely responses to hazards. By tracking health indicators like heart rate and fatigue, it enhances worker well-being. The collected data helps optimize safety protocols and resource use. Integrated with web apps, the smart helmet enables proactive, data-driven decision-making, making worksites safer and more efficient.

Index Terms*— Smart Helmet, Worker safety, Hazard detection, Long Range (LoRa), Internet of Things (IoT), Productivity Improvement.

I. INTRODUCTION

The construction and mining industries, despite their essential roles, face significant safety challenges due to hazardous environments and dynamic conditions. Traditional safety measures often fall short in addressing these risks effectively. Advancements in wearable technology, particularly IoT-enabled smart helmets, have emerged as transformative solutions to enhance worker safety, communication, and productivity.

This study introduces the **"Enhancing Worker Safety with Smart Helmets"** initiative, leveraging **IoT and LoRaWAN** to create a connected and intelligent protective gear for construction and excavation workers. The helmet integrates environmental and biometric sensors to monitor temperature, humidity, air quality, and hazardous gases while also tracking worker location and detecting potential dangers such as falling objects and uneven terrain.

Real-time alerts and wireless data transmission enable quick emergency responses, improving overall workplace safety. Additionally, GPS tracking, inventory management, and communication tools enhance productivity and coordination on-site. By providing continuous monitoring and data-driven insights, this smart helmet system optimizes safety protocols, boosts efficiency, and ensures a secure working environment in construction and mining sectors.

II. RELATED WORKS

Underground mines contain various gases, both naturally occurring and human-induced, including **carbon dioxide, methane, hydrogen sulfide, and carbon monoxide** (Graham Hill et al., 2023). Each poses significant health and safety risks, requiring miners to take proper precautions.

The construction industry lacks widespread adoption of **Resilience Engineering (RE)-based practices** such as **monitoring, learning, and anticipating**, particularly in smaller projects, which may benefit from tailored approaches (Bhattacharjee et al., 2023). Integrating **pay record management into smart helmets** enhances administrative efficiency by automating record-keeping and real-time monitoring (Vikas Suresh et al., 2022).

Cybersecurity challenges in **IoT-enabled smart helmets for coal miners** have been analyzed, with proposed security measures to mitigate risks, though the study did not explore the impact of breaches on worker safety (Patel et al., 2022). Additionally, **LoRa modulation's resistance to Doppler effects** has been validated in satellite communications, proving effective at frequencies above 31.25 kHz with a spreading factor of 11 (Zadorozhny et al., 2022).

III. PROPOSED SYSTEM DESIGN

A smart helmet aimed at enhancing workers safety in construction and excavation will be developed by the "Enhancing workers safety with smart helmets" initiative. Using IoT and LoRa technologies, this system helps solve important problems and improves safety, productivity, and communication for field workers.

System components include a smart helmet that includes sensors and connectivity modules. A number of sensors are integrated into these devices, including biometric sensors that monitor vital indicators like body temperature and heart rate, as well as environmental sensors that monitor temperature and humidity. An embedded LoRa module in the helmet enables long-range, low-power communication with the central control system. With this smart helmet, workers can be safer in a variety of high-risk environments including construction sites, excavation sites, and other dangerous environments.

To prevent worker entry into dangerous areas, it includes sensors for detecting body temperature and heart rate, gas sensors for identifying hazardous gases, and GPS tracking for preventing deaths due to falls. This also monitors whether the worker is wearing the helmet ensuring the safety. Traditional gear cannot compete with this system's ability to enhance safety, productivity, and communication.

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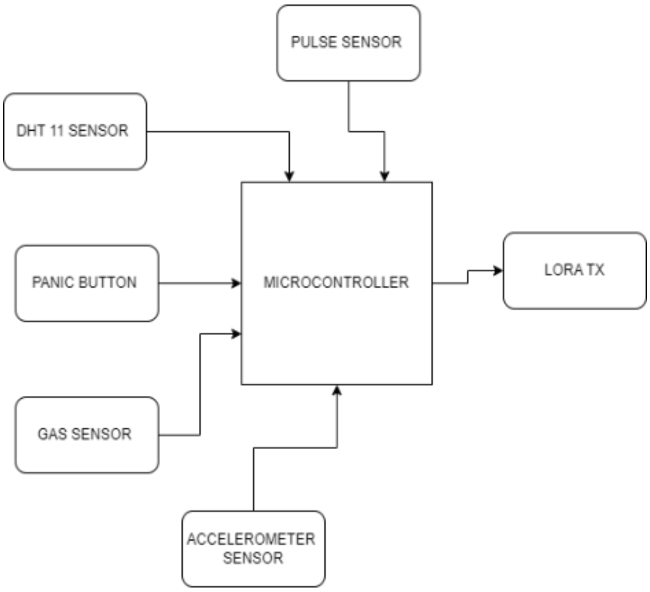

Fig. 1: Block diagram of transmission side

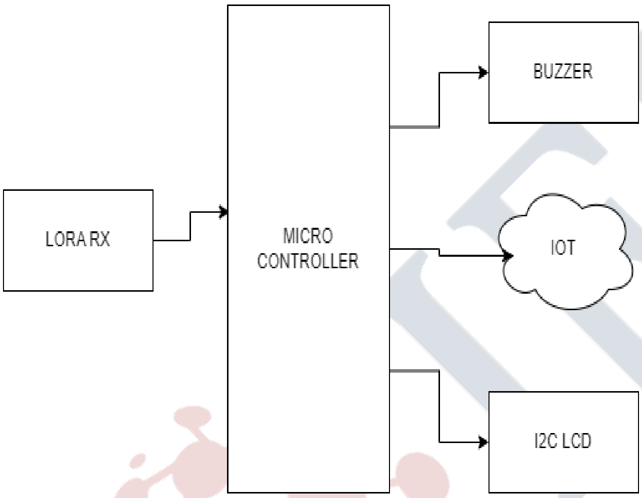

Fig. 2: Block diagram of receiver side

IV. METHODOLOGY

The suggested smart helmet system incorporates various sensors and communication modules to improve worker safety in dangerous settings such as mining and construction. The transmission sensors module features a DHT11 sensor for measuring temperature and humidity, a gas sensor for detecting harmful gases, an accelerometer to identify impacts, a pulse sensor for monitoring heart rate, and a panic button for emergency notifications. The communication module is equipped with a buzzer for audible alerts, an I2C LCD display that shows real-time environmental data, IoT connectivity for remote monitoring, and a LoRa RA02 receiver for long-distance wireless data transmission. The software module allows real-time monitoring of sensor information via a LoRa Data Receiver Module, transmitting data to a web server interface for analysis and visualization. A data processing middleware guarantees smooth integration between the LoRa system and the database, facilitating real-time decision-making. The materials utilized consist of a microcontroller for processing sensor information, a DHT humidity sensor for climate tracking, a vibration sensor for evaluating structural stability, and a gas sensor for detecting hazardous gas levels. The LoRa transmitter and receiver module supports low-power, long-range communication within industrial, scientific, and medical frequency bands. The LoRaWAN network enables effortless data interchange, allowing centralized monitoring through IoT dashboards and mobile applications. The system architecture, depicted in the block diagrams, ensures constant monitoring of environmental conditions and worker health. The microcontroller serves as the main processing unit, gathering data from all sensors and transmitting it via LoRa technology to the receiver side for further examination, thereby enhancing safety and efficiency in excavation and construction projects.

V. EXPERIMENTAL RESULTS AND DISCUSSION

Facilitate real-time environmental monitoring, a set of sensors was deployed to measure temperature, humidity, gas concentrations, motion levels, and geographical location. The DHT11 sensor, which utilizes a single-wire serial communication protocol, recorded a temperature of 36.3°C and a humidity level of 63%. Given that an alert is triggered when humidity exceeds 86% or when the temperature rises above 35°C, the recorded temperature indicates a potentially hazardous condition, necessitating ventilation or cooling measures in enclosed environments.

Gas concentration levels were measured using the MQ135 sensor to assess air quality and detect potential leaks. The collected data showed CO: 101 ppm, CO_2: 10,473.18 ppm, and CH_4: 9,850 ppm. The elevated CO_2 levels suggest inadequate ventilation, which could pose a risk in confined spaces. High concentrations of NH_4 (ammonia) indicate the possibility of chemical exposure, which is crucial in industrial or mining environments where hazardous gases can accumulate.

The system also incorporated a GPS module, logging latitude: 11.54 and longitude: 70.47 for precise location tracking. This feature is particularly beneficial for monitoring workers in remote or high-risk areas, ensuring rapid response in case of emergencies.

To assess structural stability and detect excessive motion, a MEMS accelerometer sensor was employed, recording acceleration values along three axes: x-axis: 0.25 m/s^2, y-axis: 1.48 m/s^2, and z-axis: 10.01 m/s^2. The significantly high z-axis acceleration suggests substantial vertical movement, which could indicate vibrations, impacts, or unstable working conditions. Alongside the accelerometer, additional sensors like a gyroscope and magnetometer were used for rotational and angular velocity monitoring.

The collected sensor data was processed by the STM32L4R5 microcontroller, ensuring efficient real-time analysis. Furthermore, a smartphone application facilitated heart rate monitoring via Bluetooth, enhancing worker health surveillance. The integrated system provided comprehensive insights into environmental safety, enabling proactive decision-making.

Overall, the results highlight the effectiveness of the proposed monitoring system in detecting temperature fluctuations, humidity variations, gas leaks, and abnormal motion patterns. The integration of multiple sensors ensures a holistic approach to workplace safety, particularly in industrial and mining environments. Future improvements may include addition of cameras to improve safety where a before indication is given when there is a fall and the incorporation of predictive analytics for enhanced risk assessment.

VI. SOFTWARE OUTPUT DATA ANALYSIS

The collected sensor data is processed and analyzed using dedicated software, which converts raw digital values into meaningful insights for monitoring and control. In the event of worker movement, both the acceleration magnitude and directional changes are captured, providing real-time feedback on motion patterns. Additionally, a gyroscope measures angular velocity and rotational motion along three axes. In this study, since the recorded output for each axis was zero, no rotational motion was detected.

A comparative analysis of digital values obtained from different sensors against predefined safety thresholds is summarized in the following table. The DHT11 sensor was utilized to measure temperature, humidity, CH_4 (methane), CO_2 (carbon dioxide), CO (carbon monoxide) and pulse rate, while the MQ135 sensor focused on detecting CH_4, CO and CO_2 concentrations. Based on the "Remark", all recorded values were within safe operational limits, confirming the system's reliability in environmental monitoring.

By integrating multiple sensors and leveraging real-time data processing, the smart helmet ensures accurate hazard detection and enhances worker safety in high-risk environments such as mining and construction sites. This analytical approach strengthens workplace safety protocols, enabling proactive risk mitigation and efficient decision-making.

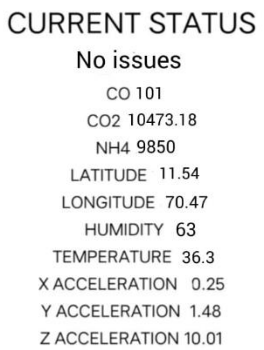

Fig.3: Digital values

VII. CONCLUSION

The Smart Helmet for Dig Crafters presented in this study is a technologically advanced solution designed to enhance worker safety, efficiency, and real-time environmental awareness. By integrating IoT and LoRa technology, this system enables seamless communication, continuous monitoring of hazardous conditions, and precise tracking of both worker health and location. With its user-friendly design, it ensures worker comfort while maintaining extended battery life, making it a practical and effective tool for industrial and mining environments. The experimental results validate the system's capability to detect temperature fluctuations, humidity changes, harmful gas concentrations, and excessive motion, all of which contribute to a safer working environment. Furthermore, the helmet's GPS-based tracking and motion analysis features reinforce workplace safety by allowing real-time supervision and early hazard detection. This innovation not only minimizes risks but also enhances operational efficiency by enabling data-driven decision-making and proactive safety measures. As the construction and excavation industries continue to evolve, adopting smart technologies like this helmet becomes crucial for compliance with industry standards and fostering a culture of safety. The Smart Helmet for DigCrafters represents a significant leap forward in worker protection, transforming the way safety is approached in high-risk environments. By ensuring an interconnected, secure, and efficient work ecosystem, this system lays a strong foundation for future advancements in industrial safety and smart wearable technology.

REFERENCE

[1] Buniya, M. K., Othman, I., Sunindijo, R. Y., Kineber, A. F., Mussi, E., & Ahmad, H. (2021). Barriers to safety program implementation in the construction industry. Ain Shams Engineering Journal, 12(1).

[2] Demirkesen, S., Sadikoglu, E., & Jayamanne, E. (2021). Assessing psychological safety in lean construction projects in the United States. Construction Economics and Building, 21(3).

[3] Dobrucali, E., Demirkesen, S., Sadikoglu, E., Zhang, C., & Damci, A. (2022). Investigating the impact of emerging technologies on construction safety performance. Engineering, Construction and Architectural Management.

[4] Graham hill, Liam, et. Al., (2023) Numerous types of flammable and toxic gases present within standard mining activities in journal of chemistry.

[5] Han, B., Son, S., & Kim, S. (2021). Measuring safety climate in the construction industry: A systematic literature review. In Sustainability (Switzerland) (Vol. 13, Issue 19).

[6] Iqbal, M., Ahmad, N., Waqas, M., & Abrar, M. (2021). COVID-19 pandemic and construction industry: Impacts, emerging construction safety practices, and proposed crisis management framework. Brazilian Journal of Operations and Production Management, 18(2).

[7] Kaushik Bhattacharjee et. Al., (2023) An analysis of safety practices for construction projects: A resilience engineering

perspective in safety science volume 169.

[8] Ninni singh, Vinit Kumar Gunjan, Gopal Chaudhary, Rajesh Kaluri, Nancy victor “IoT Enabled Helmet to Safeguard the Health of Mine Worker, Computer Communication, Vol-193, 1 September 2022.

[9] Nnaji, C., Jin, Z., & Karakhan, A. (2022). Safety and health management response to COVID-19 in the construction industry: A perspective of fieldworkers. Process Safety and Environmental Protection, 159.

[10] Patel, R. et al. (2022) "Cybersecurity Challenges in IoT-enabled Smart Helmets for Coal Miners" in IEEE on computer communications.

[11] Polmear, M., & Simmons, D. R. (2022). Industry Perspective on the Role of Visualization Technology in Construction Safety Training. International Journal of Construction Education and Research, 18(4).

[12] Rafindadi, A. D., Shafiq, N., Othman, I., & Mikić, M. (2023). Mechanism Models of the Conventional and Advanced Methods of Construction Safety Training. Is the Traditional Method of Safety Training Sufficient? International Journal of Environmental Research and Public Health, 20(2).

[13] T. Sowmya, G. SrinivasaRao, Ch. Sruthi, I. Tanuja, I. Bhavya, M. Sindhu Priya, Smart Helmet for Mining Workers, Journal of Engineering Sciences, ISSN:0377-9254, Vol14, Issue 04, 2023.

[14] Vikas Suresh, et. al., (2022) A Construction Safety Tool Embedded with Health Monitoring and Salary Deduction Function in International Conference on Smart Structures and Systems.

[15] Wang, L., & Cheng, Y. (2022). Exploring a comprehensive knowledge map for promoting safety management research in the construction industry. Engineering, Construction and Architectural Management, 29(4).

[16] Zadorozhny, A. M., Doroshkin, A. A., Gorev, V. N., Melkov, A. V., Mitrokhin, A. A., Prokopyev, V. Y., & Prokopyev, Y. M. (2022). First flight-testing of LoRa modulation in satellite radio communications in low-earth orbit. IEEE Access, 10, 100006-100023.