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Emergency Response System using Internet of Things and Cloud Computing

Dinish Selvaraj[1], Allan Melvin Andrew[1,2*] and Charis Samuel Solomon Koilpillai[3]

[1]Faculty of Electrical Engineering & Technology, Universiti Malaysia Perlis, 02600 Arau, Perlis, Malaysia
[2]Centre of Excellence for Intelligent Robotics & Autonomous Systems (CIRAS), Universiti Malaysia Perlis, Pauh Putra Campus, 02600 Arau, Perlis, Malaysia
[3]Faculty of Industrial Management, Universiti Malaysia Pahang Al- Sultan Abdullah, 26300 Gambang, Pahang, Malaysia

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ABSTRACT

Industrial workplaces are prone to safety incidents such as hazardous gas exposure, abnormal physiological conditions and falls, where delayed detection and limited real-time visibility can hinder timely response. This paper presents the development of an IoT-based Emergency Response System (ERS) wristband for industrial safety that enables continuous monitoring of environmental and worker physiological parameters, cloud-based data logging and real-time alerting. The system integrates distributed sensors and a wearable platform (Wemos D1 Mini with MAX30102, BMP280, MQ2 and ADXL345), transmitting data to the ThingSpeak cloud and presenting status to supervisors through a Windows Forms dashboard with threshold-based warning indicators. Experimental validation against reference instruments shows an average heart-rate deviation of 1.87 bpm, SpO_2 deviation of 1.27%, temperature deviation of 1.28°C and pressure deviation of 5.13 hPa, demonstrating reliable sensing performance for non-clinical industrial monitoring. Overall, the ERS provides a scalable framework for real-time safety monitoring and hazard notification, supporting improved situational awareness and future integration of predictive analytics.

Keywords: Cloud Based Alert System, Emergency Response System, Industrial Safety, Real-Time Data Monitoring, Wireless Data Transmission

1. INTRODUCTION

Industrial environments such as factories, chemical plants and construction sites are often susceptible to accidents caused by factors including hazardous gas leaks, extreme temperature fluctuations, machinery malfunctions and worker health emergencies [1]. Traditional safety mechanisms in these environments tend to be reactive, relying heavily on human supervision or isolated sensor systems with limited connectivity and data analysis capabilities. As a result, response times are often delayed, and the ability to anticipate and mitigate risks is significantly reduced [2][3].

With the advancement of the Internet of Things (IoT) and embedded systems, there is a growing shift toward proactive safety solutions that leverage real-time data collection, cloud-based analytics and intelligent alert mechanisms [4]. Wearable technology, integrated with robust microcontrollers and multi-parameter sensors, offers a comprehensive solution for real-time industrial safety monitoring [5].

This research presents the development of an IoT-based Emergency Response System (ERS), a wearable safety device designed to continuously monitor both physiological and environmental

*allanmelvin@unimap.edu.my

conditions critical to worker safety. The ERS incorporates a Wemos D1 Mini microcontroller, an OLED display, and a range of sensors such as the MAX30102 for heart rate and SpO_2 monitoring, the BMP280 for atmospheric pressure and temperature, the MQ2 for gas and smoke detection, and the ADXL345 accelerometer for fall detection. Data collected from these sensors is wirelessly transmitted to the ThingSpeak cloud platform, where it is stored, visualized and analysed. To complement the hardware, a desktop application developed using Visual Studio enables real-time monitoring and visualization of key metrics. This interface provides supervisors with immediate insight into worker health status and environmental risks, triggering alerts during emergency events such as hazardous gas detection, abnormal vitals, or sudden falls.

By integrating multiple sensing capabilities into a compact wearable device and enabling remote access to real-time data, the proposed ERS addresses the limitations of traditional safety tools. It enhances situational awareness, improves response times, and contributes to a safer and more responsive industrial work environment. This work underscores the transformative potential of IoT and wearable technologies in modernizing industrial safety practices.

2. RELATED WORKS

The integration of wearable technology, IoT, and intelligent analytics has become a growing area of research in industrial safety monitoring. Traditional safety systems rely mainly on manual supervision and isolated sensors, which are often reactive rather than proactive [6][7]. To address this limitation, modern studies have focused on integrating multiple sensing modalities, cloud-based data processing and machine learning algorithms for real-time anomaly detection and predictive analysis in hazardous environments [8][9].

2.1 Wearable Safety Systems

Wearable technology has evolved from basic fitness trackers to advanced safety systems capable of continuously monitoring workers' physiological and environmental conditions. Studies have demonstrated that combining low-power microcontrollers such as ESP8266 or ESP32 with IoT sensors can significantly improve industrial safety [7][10].

Sasireka et al. proposed an IoT-enabled safety system for sewage workers that monitors environmental parameters and worker health using a wearable device connected to cloud services [11]. Similarly, Ikeda et al. developed a wristband-type wearable capable of detecting ammonia emissions from the human body surface, demonstrating how compact wearables can provide early hazard warnings [12].

Chung et al. introduced an IoT-based safety monitoring system for construction sites, showing how wireless sensor networks can enhance real-time situational awareness [10]. However, these systems often face challenges such as power limitations, sensor drift, and dependence on wireless connectivity.

2.2 Physiological and Environmental Sensors

Integrating both physiological and environmental sensors has been proven to enhance accuracy and responsiveness in industrial monitoring. The MAX30102 has been widely adopted for heart rate and SpO_2 tracking due to its high precision and low power consumption [9][12]. The BMP280 sensor provides accurate temperature and pressure data, essential for fire or explosion detection [13][14]. The MQ2 gas sensor has been utilized in IoT-based systems to identify hazardous gases such as LPG, methane and carbon monoxide, while the ADXL345 accelerometer has been used for fall detection and movement monitoring in wearable safety devices [1][11][15][2][7].

These studies collectively demonstrate the feasibility of multi-sensor integration for enhanced workplace safety. However, they also highlight challenges including signal interference, sensor calibration drift and limited energy efficiency during prolonged operation [8][9].

2.3 Cloud-Based Data Transmission and Analytics

Cloud computing platforms such as ThingSpeak, AWS IoT and Azure IoT Hub play a vital role in enabling remote visualization and analytics for industrial IoT systems. Awolusi et al. and Häikiö et al. demonstrated that cloud-based monitoring improves data accessibility and allows supervisors to track worker safety trends in real time [10][11].

IoT architectures utilizing ThingSpeak have also been implemented in environmental monitoring systems, such as Ahamed et al., who designed a real-time temperature monitoring system using Wi-Fi-enabled microcontrollers [4]. Pikri et al. applied a similar approach for beekeeping monitoring, showcasing ThingSpeak's efficiency in handling real-time sensor data [13].

While these studies validate the reliability and scalability of cloud systems, issues such as latency, bandwidth dependency and data privacy remain critical challenges for large-scale industrial deployment [16].

2.4 Current Limitations

Despite technological progress, current wearable IoT safety systems still encounter power consumption, connectivity instability and computational inefficiencies during real-time processing [8][15][16]. Many lack unified frameworks combining physiological, environmental, and predictive analytics for a holistic safety solution [17].

Addressing these challenges requires the development of hybrid IoT architectures capable of real-time anomaly classification, local decision-making, and seamless cloud synchronization [18]. Future research should focus on incorporating low-power AI accelerators, edge computing and secure wireless protocols to build scalable, predictive and proactive safety systems for industrial applications [19][20].

3. METHODOLOGY

This study outlines the design, development and validation of the Emergency Response System (ERS), a wearable IoT device designed to improve safety in industrial environments. The ERS functions as a smart monitoring platform capable of collecting physiological and environmental data in real time, transmitting it to the cloud and generating alerts during hazardous conditions. The methodology involved systematic stages, including architecture design, component selection, hardware and software integration, data transmission and testing under both laboratory and field conditions. The overall goal was to create a compact, reliable and adaptive system that enhances workplace safety through intelligent sensing and rapid response.

3.1 System Architecture

The architecture of the ERS consists of three primary layers: the sensing layer, the processing layer and the cloud layer. The sensing layer integrates multiple sensors to collect both physiological and environmental parameters. These include the MAX30102 for heart rate and SpO_2 measurement, the BMP280 for temperature and atmospheric pressure, the MQ2 for gas and smoke detection, and the ADXL345 accelerometer for fall detection. A push button allows users to manually trigger emergency alerts, while a buzzer provides immediate audible feedback. All sensor readings are processed by the Wemos D1 Mini microcontroller, which handles data acquisition, local processing, and Wi-Fi-based transmission to the ThingSpeak cloud platform.

The cloud layer is responsible for storing, visualizing, and analysing incoming sensor data. A custom Windows Forms monitoring interface was developed to provide supervisors with a real-time display of vital parameters and environmental readings. This interface ensures rapid visibility of potential hazards and allows decision-makers to act immediately during emergency situations.

Figure 1 illustrates the detailed system architecture. The sensing layer comprises the environmental and physiological sensors (MAX30102, BMP280, MQ2, ADXL345) powered by a Li-Po battery management system. Data is transmitted to the processing layer, where the Wemos D1 Mini microcontroller aggregates readings and triggers local feedback via the OLED display and Buzzer. Finally, the cloud layer utilizes Wi-Fi to transmit data to the ThingSpeak platform, which synchronizes with the Windows Forms application for real-time supervisor monitoring.

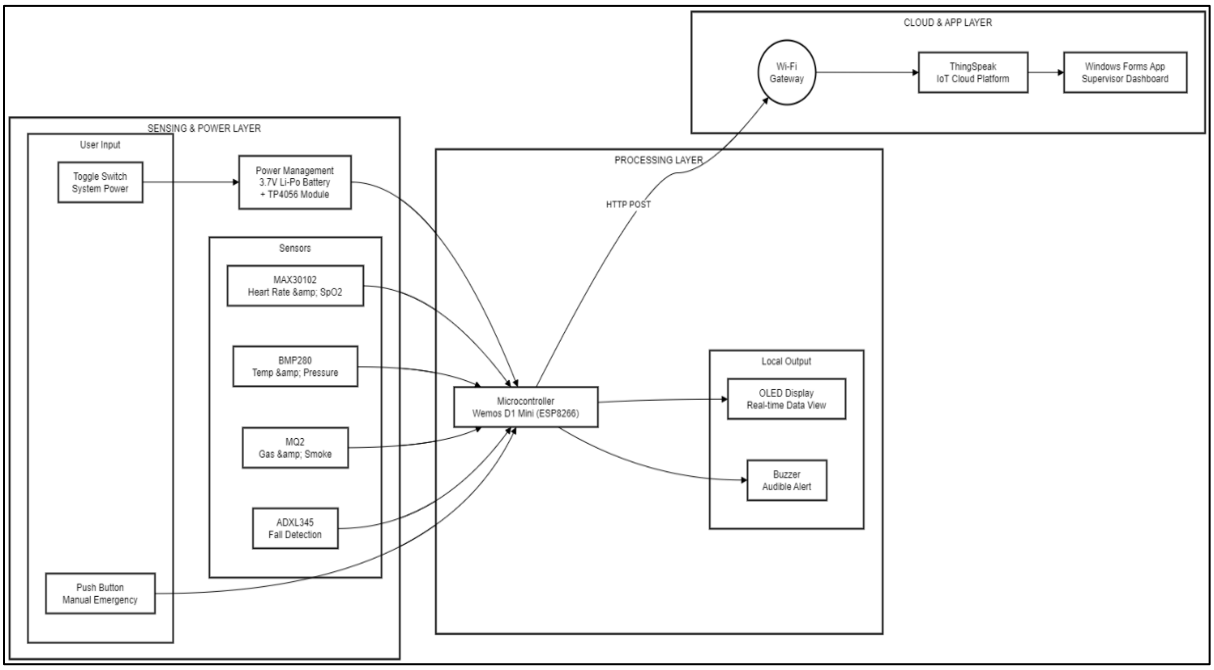


Figure 1. Detailed system architecture

3.2 Component Selection

Each component of the ERS was carefully selected based on criteria such as accuracy, low power consumption and compactness. The Wemos D1 Mini microcontroller was chosen for its built-in Wi-Fi capabilities and suitability for IoT-based wearable systems. The MAX30102 sensor was used for monitoring heart rate and oxygen saturation, utilizing infrared and red LEDs to detect blood flow changes. The BMP280 sensor was integrated to measure environmental temperature and barometric pressure, which helps identify early signs of fire or sudden atmospheric changes.

The MQ2 sensor provides gas and smoke detection, capable of identifying carbon monoxide, methane, LPG, and other hazardous gases. The ADXL345 accelerometer is used for fall detection, calibrated to differentiate between normal movements and serious falls. The system also includes an emergency button for manual alerts and a buzzer for local alarms. A 0.96" OLED display provides real-time readings directly on the wearable device, while the TP4056 charging module and a Li-Po battery ensure stable power supply for continuous operation. Figure 2 shows the overall circuit design of the ERS prototype.

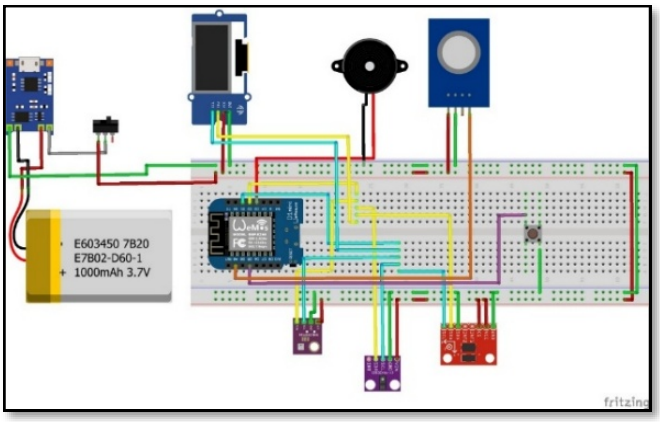


Figure 2. Overall circuit layout

3.3 Software and Data Processing

Software development was carried out using the Arduino IDE. Each sensor was interfaced using its respective libraries: SparkFun's MAX3010x for the heart rate and SpO_2 module, Adafruit BMP280 for environmental readings and Adafruit SSD1306 for the OLED display. Analog and digital inputs were used for MQ2 and ADXL345 sensors, with threshold-based algorithms to detect anomalies.

The firmware also included data preprocessing steps such as moving average filtering to smooth noisy signals. This ensures that the data transmitted to the cloud is accurate and stable. Whenever the system detects abnormal physiological readings, sudden movement, or hazardous gas levels, it triggers both local and cloud-based emergency alerts for immediate response.

3.4 Wireless Communication and Cloud Integration

Wireless communication is a critical component of the ERS system. The Wemos D1 Mini transmits sensor data to the ThingSpeak IoT platform using HTTP POST requests at fixed intervals of 15 seconds. The platform stores and visualizes the data in real time. A retry mechanism was implemented to handle potential network interruptions, allowing unsent data to be stored temporarily in memory for retransmission.

Through this setup, continuous monitoring is maintained even in areas with unstable Wi-Fi connectivity, such as large manufacturing floors or underground facilities. The ThingSpeak dashboard visualizes real-time readings, while the Windows Forms application simultaneously mirrors this data for supervisors. Together, these tools enable prompt decision-making and efficient safety management in industrial operations

3.5 Emergency Response Mechanism

The Emergency Response System incorporates both automatic and manual alert mechanisms to ensure comprehensive safety coverage. In automatic mode, alerts are triggered when the system detects abnormal readings such as low oxygen saturation, elevated body temperature, excessive gas levels, or a sudden fall. These events activate multiple warning outputs, including an "Emergency" message on the OLED display, a loud buzzer alarm, and red indicators within the monitoring dashboard.

For manual activation, workers can press and hold the emergency button for more than three seconds to trigger the same set of alerts. This dual-mode alerting mechanism enhances system reliability, ensuring that emergencies are detected and reported regardless of whether they are sensed automatically or manually. The emergency flag is also updated in the ThingSpeak database to enable remote tracking and event logging.

3.6 Data Acquisition and Filtering

The ERS collects data continuously from all connected sensors. The Wemos D1 Mini converts raw analog data into digital signals and transmits them to both the ThingSpeak cloud and the Windows Forms interface. This dual-platform setup enables synchronized monitoring, ensuring that critical physiological and environmental data are available in real time.

To enhance data reliability, filtering techniques were applied during preprocessing. The moving average filter was primarily used to remove high-frequency noise while retaining important signal characteristics. To identify the most suitable filtering approach, six filters (moving average, Butterworth, Savitzky-Golay, Kalman, median and exponential moving average) were compared in terms of smoothness, computational cost, and preservation of important signal features. Table 1 summarizes the performance of these filters, which leads into the selection of moving average filter to be used.

Table 1. Filter analysis

Filter	Pros	Cons
Moving Average Filter	- Simple to implement - Low computational cost - Effective for high-frequency noise removal	- Can distort sharp features in the signal - Introduces lag, especially with large window sizes
Butterworth Filter	- Smooth response, preserves signal shape - Customizable order for sharpness - No phase distortion	- Computationally more complex than simpler filters - Roll-off may be too gradual, allowing some unwanted frequencies to pass
Savitzky-Golay Filter	- Preserves sharp features and transitions - Flexible (adjustable window size and order)	- Computationally intensive - Can over-smooth at higher polynomial orders, removing important signal variations
Kalman Filter	- Real-time performance, adaptive to changes - Minimizes estimation error - Good for noisy, dynamic signals	- Complex implementation, requires mathematical modelling - Computationally expensive, especially for high data rates
Median Filter	- Excellent for removing spikes and outliers - Preserves edges and sharp transitions better than moving averages	- Less effective at filtering smooth, high-frequency noise - Sensitive to window size choice
Exponential Moving Average (EMA)	- More responsive to recent data - Smoother results than simple moving average	- Still introduces lag, although less than simple moving averages - May not perform well with sudden large variations in the signal

4. RESULTS AND DISCUSSION

This section presents the results obtained from the design, implementation and validation of the ERS wristband. The outcomes cover hardware functionality, data acquisition and processing, wireless data transmission, dashboard performance, and physical assembly evaluation. Experimental testing was carried out under both controlled laboratory conditions and real-world industrial simulations to verify the system's performance, accuracy and reliability.

4.1 Hardware Functionality

The finalized ERS prototype successfully integrates the Wemos D1 Mini microcontroller, OLED display and multiple sensors including MAX30102 for heart rate and SpO_2 detection, BMP280 for temperature and pressure monitoring, MQ2 for gas and smoke detection, and ADXL345 for fall detection. Additional components such as the push button and buzzer ensure both automatic and manual emergency alerts.

Each module was interconnected and calibrated to function seamlessly. The system transmits real-time data every 15 seconds to the ThingSpeak cloud platform via Wi-Fi. The OLED display provides immediate user feedback with alert messages such as *"Gas Leak Detected"* or *"Fall Detected"*. These notifications allow workers to take quick action during emergencies, while supervisors can monitor the same data remotely.

4.2 Data Acquisition and Processing

Sensor data were continuously collected from the wristband and processed by the Wemos D1 Mini before cloud transmission. The microcontroller used internal flags to detect specific events such as gas leakage, falls, or abnormal physiological readings. These events were stored temporarily in memory, ensuring they were transmitted even if they occurred between upload intervals.

Before analysis, the raw data underwent preprocessing and cleaning using a moving average filter, which effectively reduced high-frequency noise and smoothed sudden fluctuations in the readings. This step was particularly useful in filtering noise from the MAX30102 and BMP280 sensors caused by motion or environmental variations. As a result, the processed data exhibited improved stability and accuracy.

4.3 Result Analysis

The performance of the ERS sensors was validated against calibrated reference instruments. The MAX30102 sensor's heart rate readings were compared with those from a medical-grade oximeter, showing an average deviation of 1.87 bpm, demonstrating strong correlation and reliability for non-clinical applications.

Similarly, the SpO_2 readings recorded an average deviation of 1.27% from the reference oximeter, indicating excellent real-time accuracy in measuring blood oxygen levels. The BMP280 sensor's temperature readings were compared with those from an Apple Watch and exhibited a mean deviation of 1.28°C, confirming precise and consistent tracking of thermal changes. Pressure measurements differed by only 5.13hPa from a laboratory barometer, ensuring the system's dependability for detecting air pressure variations in industrial conditions. Figure 3 to Figure 6 shows the comparison of the sample data with the comparison data.

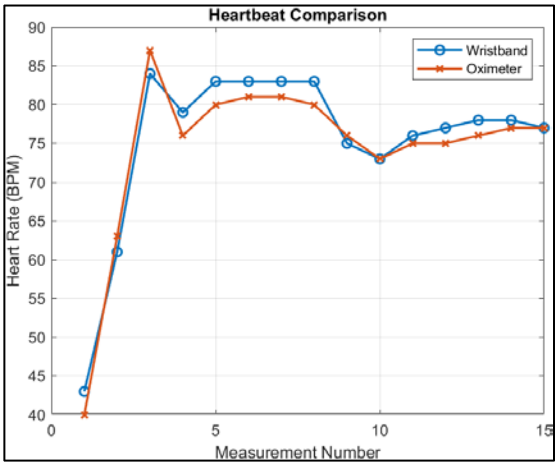


Figure 3. Comparison of heart rate readings between ERS and reference oximeter

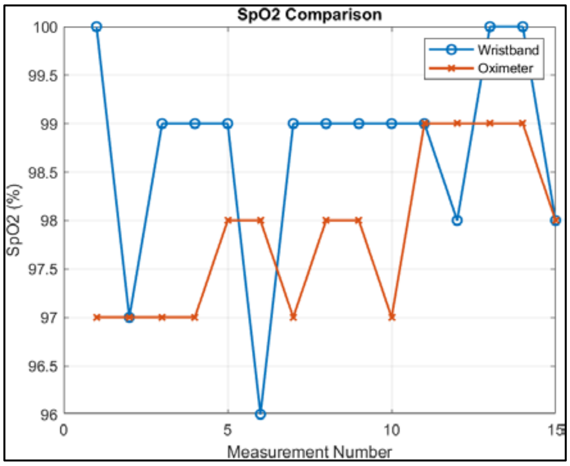


Figure 4. Comparison of SpO_2 readings between ERS and reference oximeter

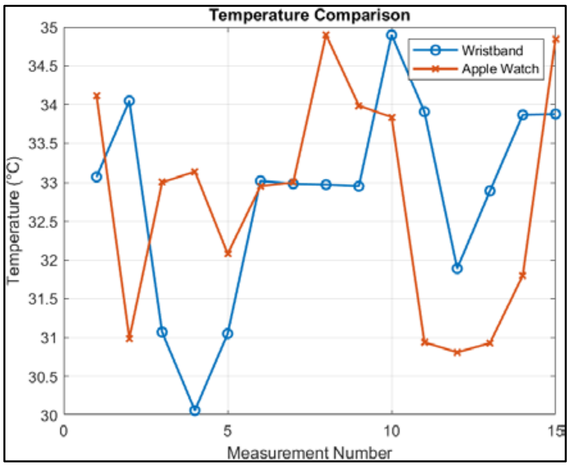


Figure 5. Comparison of temperature readings between ERS and Apple Watch

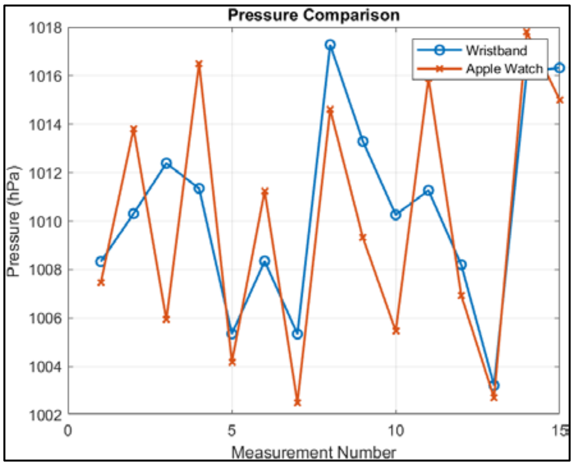


Figure 6. Comparison of pressure readings between ERS and barometer

4.4 Data Transmission to Cloud Platform

The ERS uses the ESP8266 Wi-Fi module within the Wemos D1 Mini to send sensor data to ThingSpeak every 15 seconds using HTTP POST requests. During testing, network interference occasionally caused data loss; however, the system's buffer-and-retry mechanism allowed the temporary storage and retransmission of missed data once the connection was restored. This ensured data continuity and reliability even in environments with unstable Wi-Fi connectivity.

All data communications were encrypted using HTTPS protocols to maintain data privacy and prevent interception. In practice, this secure cloud transmission architecture supports scalability, allowing integration with future predictive analytics or machine learning modules.

4.5 Windows Forms Dashboard

A custom desktop dashboard was developed using Visual Studio to retrieve, visualize and monitor the data from ThingSpeak. The dashboard refreshes automatically every 15 seconds, displaying key physiological and environmental parameters. The interface features solid gauges for temperature and pressure, color-coded according to safety thresholds. For instance, temperatures exceeding 50°C switch to yellow, while those above 75°C appear in red. Pressure readings outside the range of 950–1050 hPa also trigger alerts. Heart rate and SpO_2 values are displayed as numerical readings.

Four indicator panels represent emergency conditions: Fire, Fall, Gas, and Emergency Button. These panels change colour from green to red when an abnormality is detected and revert once conditions normalize. A timestamp label provides confirmation of the last data update. This dashboard design ensures supervisors receive clear, real-time insight into workers' safety. Figure 7 shows the Visual studio interface.

The colour-coding scheme used in the ERS Wristband Dashboard follows the requirements of the IEC 60073 standard (based and safety principles for man-machine interface, marking and identification – coding principles for indicators and actuators). In accordance with this standard, Green is used for the status indicators. For example, Fall, Fire and Gas Detection to indicate a 'Normal' or 'Safe' condition where no hazards are currently detected. Red is solely for the Emergency Button. This is consistent with the standard's need for 'Emergency' and 'Danger' actuation. This unique colour separation provides for immediate visual recognition of critical functions and a consistency with ISO 3864 safety colour conventions.

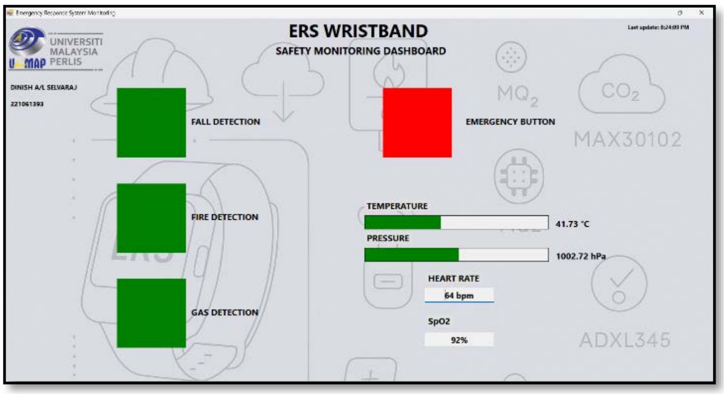
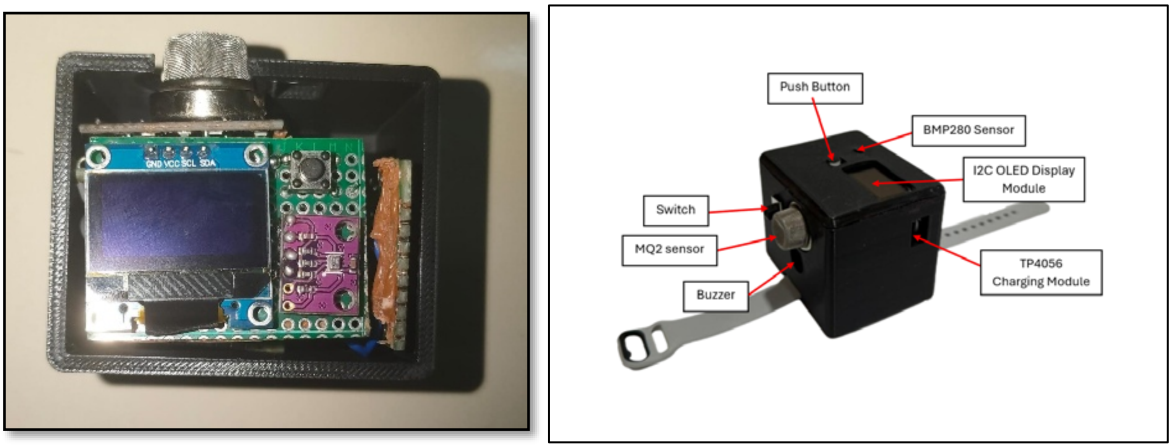


Figure 7. Visual Studio-based ERS monitoring dashboard interface

4.6 Final Assembly and Design

The final hardware assembly was enclosed within a 3D-printed PLA wristband housing, measuring 62 mm × 51 mm. The compact design supports durability and comfort, making it suitable for extended industrial use. The sensors, microcontroller and power module were optimally positioned to balance heat dissipation, accessibility and usability.

User feedback gathered during field testing emphasized comfort, readability and ergonomic design. Minor design improvements, such as increasing OLED font size, enhancing screen brightness and repositioning switches, were implemented to improve practicality and user experience. Figure 8 (a) shows the Final Assembly of the ERS, and (b) shows the labelled model of the ERS wristband prototype.



(a) (b)

Figure 8. (a) Final physical assembly of the ERS wristband prototype, and (b) labelled model of the ERS wristband prototype

The experimental results confirm that the ERS fulfils its intended objectives for accurate real-time monitoring and rapid emergency response. The minimal deviations observed in sensor readings validate its capability to provide reliable physiological and environmental data. The dual-alert framework combining local alerts (buzzer and OLED) with cloud-based alerts (ThingSpeak and dashboard) significantly supports timely notification and reduces the risk of undetected emergencies. The inclusion of filtering algorithms improved signal clarity, and the retry mechanism ensured uninterrupted data transmission.

User testing demonstrated that the device was both comfortable and intuitive to use. Workers reported clear notifications and easy operation, even in noisy environments. With average sensor deviations below two units and high transmission reliability, the ERS wristband proves to be an effective, scalable and practical solution for industrial safety monitoring.

5. CONCLUSION

In conclusion, this research successfully developed an ERS wristband that enhances industrial safety through real-time physiological and environmental monitoring. By integrating multiple sensors like MAX30102, BMP280, MQ2 and ADXL345 within a compact and wearable design, the system effectively detects hazards such as gas leaks, fire risks, abnormal vitals and worker falls. The Wemos D1 Mini microcontroller and ThingSpeak cloud platform enabled continuous wireless data transmission and real-time visualization, providing both workers and supervisors with instant safety awareness.

The experimental results demonstrated the reliability, accuracy, and responsiveness of the system. Sensor readings showed minimal deviation compared to reference-grade instruments, validating its suitability for non-clinical industrial applications. The combination of on-device alerts via OLED and buzzer, along with remote monitoring through the Windows Forms dashboard, ensured rapid and coordinated responses to potential emergencies. Challenges such as Wi-Fi interruptions and sensor drift were mitigated through buffering, recalibration and error-handling mechanisms, improving the robustness of the device.

Overall, the ERS wristband and dashboard form a scalable, user-friendly and proactive safety framework for high-risk environments like manufacturing plants and chemical facilities. With its accurate sensing, reliable connectivity and intuitive interface, this system lays a strong foundation for future advancements in AI-driven predictive safety systems, ensuring a safer and smarter industrial workspace.

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REFERENCES

[1] K. M. Mehata et al., 2019. IoT Based Safety and Health Monitoring for Construction Workers, Int. Conf., vol. 4, no. 1.
[2] S. D. Rajendran, S. N. Wahab, S. P. Yeap, 2020. Design of a smart safety vest incorporated with metal detector kits for enhanced personal protection, Saf. Health Work, vol. 11, no. 4, pp. 537–542, doi: 10.1016/j.shaw.2020.06.007.
[3] Q. Wong, N. M. Sapuan, M. W. Ali Khan, 2023. The impact of safety and health towards construction workforce productivity, J. Governance Integrity, vol. 6, no. 1, pp. 504–514.
[4] J. Häikiö, J. Kallio, S.-M. Mäkelä, J. S. Keränen, 2020. IoT-based safety monitoring from the perspective of construction site workers, Int. J. Occup. Environ. Saf., vol. 4, no. 1, pp. 1–14, doi: 10.24840/2184-0954_004.001_0001.
[5] C. Legner, U. Kalwa, V. Patel, A. Chesmore, S. Pandey, 2019. Sweat sensing in the smart wearables era: Towards integrative, multifunctional and body-compliant perspiration analysis, Sens. Actuators A Phys., vol. 296, pp. 200–221, doi: 10.1016/j.sna.2019.07.020.
[6] J. M. Gómez-de-Gabriel, J. A. Fernández-Madrigal, M. C. Rey-Merchán, A. López-Arquillos,

2023. A safety system based on Bluetooth Low Energy (BLE) to prevent the misuse of personal protection equipment (PPE) in construction, Saf. Sci., vol. 158, Art. no. 105995, doi: 10.1016/j.ssci.2022.105995.
[7] I. Awolusi, E. Marks, M. Hallowell, 2018. Wearable technology for personalized construction safety monitoring and trending: Review of applicable devices, Autom. Constr., vol. 85, pp. 96–106, doi: 10.1016/j.autcon.2017.10.010.
[8] H. Chen, Y. Mao, Y. Xu, R. Wang, 2023. The impact of wearable devices on the construction safety of building workers: A systematic review, Sustainability, vol. 15, no. 14, Art. no. 11165, doi: 10.3390/su151411165.
[9] E. Svertoka, S. Saafi, A. Rusu-Casandra, R. Burget, I. Marghescu, J. Hosek, A. Ometov, 2021. Wearables for industrial work safety: A survey, Sensors, vol. 21, no. 11, Art. no. 3844, doi: 10.3390/s21113844.
[10] W. W. Chung, S. Tariq, S. R. Mohandes, T. Zayed, 2023. IoT-based application for construction site safety monitoring, Int. J. Constr. Manag., vol. 23, no. 1, pp. 58–74, doi: 10.1080/15623599.2020.1847405.
[11] P. Sasireka, A. A. Ajay M., P. N, 2021. Smart safety monitoring system for sewage workers using IoT, in Proc. Int. Conf. Emerging Technol. Innov. Bus. Manage., pp. 1–6.
[12] S. Ikeda, M. Fujioka, Y. Kitade, K. Nakashima, M. Ito, M. Goto, 2022. Development of a wristband-type wearable device for the colorimetric detection of ammonia emanating from the human skin surface, Results Chem., vol. 4, Art. no. 100343, doi: 10.1016/j.rechem.2022.100343.
[13] M. I. M. Pikri, S. A. Ibrahim, N. M. S. M. Faisal, M. Z. Mustafa, S. Mansor, 2023. IoT-based temperature and humidity real-time monitoring system for beekeeping using LoRa technology, in Proc. Multimedia Univ. Eng. Conf. (MECON), Atlantis Press, pp. 303–313, doi: 10.2991/978-94-6463-082-4_28.
[14] M. I. Ahamed, N. Islam, M. H. Rahman, S. M. T. Reza, M. S. Hossen, 2019. Design a real time temperature monitoring system to protect DC motor, in Proc. 22nd Int. Conf. Comput. Inf. Technol. (ICCIT), Dhaka, Bangladesh, pp. 1–5, doi: 10.1109/ICCIT48885.2019.9038312.
[15] M. A. Torad, M. A. Salam, 2021. Smart helmet using internet of things, Int. J. Reconfigurable Embedded Syst., vol. 10, no. 2, pp. 90–98, doi: 10.11591/ijres.v10.i2.pp90-98.
[16] A. Lodhi, V. Köppen, G. Saake, K. Turowski, 2018. Streamlining processes for digitalization, in Proc. 11th IADIS Int. Conf. Information Systems (ICIS), Lisbon, Portugal, pp. 138–145.
[17] S. Schnier, C. Glaser, J. Li, A. Marco, 2016. Power management reference design for a wearable device with wireless charging using the bq51003 and bq25120, Texas Instruments, Dallas, TX, USA, Application Rep. SLUA748A.
[18] J. Somavia, 2005. Facts on safety at work, International Labour Organization, Geneva, Switzerland.
[19] B. Arbaoui, Y. O-manee, P. Yuso, Y. Hareebin, 2022. An agent-based model for situational awareness at workplace, Int. J. Adv. Sci. Syst., vol. 15, no. 5, pp. 1–8.
[20] J. Zhang, J. Zeng, Y. Su, Y. Wu, J. Yuan, Q. Tong, L. Gan, 2023. The application of Bluetooth technology in the internet of things, in Proc. SPIE, vol. 12793, Int. Conf. Mechatronics Intell. Control (ICMIC 2023), Art. no. 1279340, doi: 10.1117/12.2691551.