



(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)



Impact Factor: 8.699

Volume 14, Issue 4, April 2025

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www.ijirset.com |A Monthly, Peer Reviewed & Refereed Journal| e-ISSN: 2319-8753| p-ISSN: 2347-6710|

Volume 14, Issue 4, April 2025

|DOI: 10.15680/IJIRSET.2025.1404671|

Innovative and Affordable Hand Protection for Small Industry Workers

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ABSTRACT: Industrial safety has become a critical concern, especially for small and medium-scale enterprises where advanced safety measures are often lacking. This paper presents a novel, cost-effective solution RF Enabled Smart Gloves designed to enhance worker safety in hazardous environments. The proposed system integrates essential sensors such as temperature, toxic gas, and pulse rate monitors into a wearable glove, which continuously tracks environmental and physiological parameters. In case of abnormal readings, the glove activates a vibration motor to immediately alert the worker, while simultaneously triggering a buzzer and sending a notification to the supervisor's mobile device via cloud connectivity. The communication between the glove and the centralized monitoring unit is established through an efficient RF module, ensuring real-time response with minimal delay. The entire system is lightweight, power-efficient, and highly adaptable to different industrial settings. This project not only improves on-site responsiveness to threats but also introduces an accessible safety tool that supports predictive measures through data logging. The design emphasizes practicality, affordability, and user comfort, making it a scalable option for broader industrial adoption.

KEYWORDS: RF Communication , IOT , Temperature sensor , Gas sensor , Pulse sensor , Vibration motor , Cloud storage , LoRa Module

I. INTRODUCTION

Ensuring the safety and well-being of workers in industrial environments has become increasingly important with the rise in automation and machinery-driven operations. Many workplaces, especially in small and medium-scale industries, expose workers to potentially dangerous conditions such as excessive heat, harmful gases, and physically intensive tasks that can lead to fatigue or health complications. While personal protective equipment (PPE) is commonly used, it often lacks real-time monitoring or alerting features that could help prevent accidents before they occur.

The concept of smart wearables, particularly smart gloves, offers a promising approach to addressing this issue. These gloves can be embedded with sensors that detect various parameters such as temperature, gas concentration, and heart rate. In the proposed project, the RF-enabled smart glove system is developed to provide a dual-layered safety mechanism. The first layer involves alerting the worker immediately through a vibration motor embedded within the glove when abnormal conditions are detected. The second layer ensures that the supervisor is simultaneously alerted via a buzzer and receives a message on their mobile phone through cloud connectivity.

At the heart of this system lies the ESP32 microcontroller, known for its Wi-Fi capabilities, low power consumption, and compact design. The glove integrates multiple sensors for comprehensive monitoring, including a temperature sensor, gas sensor, and pulse sensor. These sensors continuously send data to the ESP32, which processes the readings and determines if a hazardous condition exists. If so, the system activates the alert mechanisms—both local (vibration and buzzer) and remote (mobile message via Wi-Fi).

The glove communicates with a centralized supervisory station through an RF transmitter-receiver pair. This wireless communication ensures that alerts are received without delay, even in areas with limited connectivity. Power to the





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system is supplied by a lightweight lithium polymer battery, ensuring that the glove remains portable and easy to wear without compromising on performance.

This project aims to reduce workplace accidents, provide timely warnings, and ultimately improve the safety standards of industries that cannot afford high-end automation systems. Its low-cost design, adaptability, and efficient functionality make it a viable solution for improving occupational health and safety

1.1 Existing system

In many industrial environments, worker safety is typically managed through conventional methods such as protective clothing, helmets, gloves, and safety shoes. These personal protective equipment (PPE) solutions provide basic protection but lack the ability to actively monitor or respond to hazardous conditions. Most existing systems rely heavily on manual observation and post-incident responses, which may not be effective in preventing real-time accidents. In critical situations such as gas leaks, overheating machinery, or physical strain on workers, the response time is often delayed due to the absence of automated detection and alerting mechanisms.

Some modern industries have started integrating fixed sensor-based systems to monitor environmental parameters like temperature and gas concentration. However, these systems are often stationary and limited to specific areas. They do not offer mobility or personalized safety features, making them ineffective for workers who are constantly on the move or working in isolated zones.

Wearable technology has emerged as a potential solution in recent years, but most available products are either too costly, too complex, or focused primarily on fitness and health monitoring rather than occupational safety. Furthermore, very few existing solutions provide real-time alerts to both the worker and the supervisor simultaneously, especially in cases of emergency.

In summary, the current safety systems in industrial settings either lack real-time response capabilities or fail to offer personalized, portable protection for workers. There is a clear need for an affordable, intelligent, and responsive system that can monitor vital safety parameters and provide instant alerts. The proposed RF-enabled smart glove aims to bridge this gap by combining wearable sensors, wireless communication, and cloud-based alerts into a single, compact solution.

1.2 Proposed Solution

The proposed system introduces an innovative and practical solution to enhance worker safety in industrial environments through a smart, sensor-integrated glove. This RF-enabled smart glove is designed to continuously monitor the surrounding environment and the worker's vital signs, providing real-time alerts to prevent accidents and ensure timely responses during emergencies.

At the core of the system is a microcontroller ESP32 embedded within the glove, connected to multiple sensors. These include a temperature sensor to detect excessive heat in the surroundings, a gas sensor to identify the presence of harmful gases, and a pulse sensor to monitor the worker's heart rate. In case any parameter crosses a predefined safety threshold, the system immediately processes the data and triggers an alert.

An RF transmitter module is integrated into the glove, which wirelessly sends signals to a centralized receiver located at the supervisor's station. The supervisor module includes an Arduino board, RF receiver, and buzzer. When an abnormal condition is detected such as a rapid increase in temperature, gas leakage, or irregular heartbeat the RF signal activates the buzzer, notifying the supervisor instantly.

In addition to local alerts, the glove also uses Wi-Fi connectivity via ESP32 to send a notification to the supervisor's mobile phone through cloud-based messaging, ensuring the alert reaches even if the supervisor is away from the workstation. This dual-alert system significantly improves response time during emergencies and helps prevent accidents more effectively.





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To provide feedback directly to the worker, a small coin vibration motor is embedded in the glove. It vibrates to alert the wearer in real time, allowing them to move away from danger or take preventive measures. The entire system is powered by a lightweight lithium polymer battery, making the glove portable and user-friendly without adding bulk.

II. LITERATURE SURVEY

The advancement of wearable technology has opened new avenues for enhancing worker safety, especially in industrial environments prone to accidents. Researchers have explored various smart glove designs and sensor-based systems, each contributing unique insights but also exhibiting certain limitations. This section outlines key related works and the necessity for an improved RF-enabled smart glove system.

1. Smart Gloves for Industrial Applications

Initial designs of smart gloves were primarily intended for supporting industrial tasks such as equipment maintenance and force monitoring. These systems utilized tactile or pressure sensors to assist workers in precise operations. However, they did not focus on real-time hazard detection or environmental monitoring, limiting their application in critical safety scenarios.

2. Wireless Sensor-Based Safety Systems

Several studies explored the integration of wireless technologies in wearable devices to improve safety. These systems often included basic sensors for monitoring temperature, movement, or presence, but lacked a centralized alert mechanism to immediately inform supervisors in case of danger. Moreover, they were not equipped to handle multiple hazards simultaneously.

3. IoT-Driven Wearables

Recent research has emphasized the use of Internet of Things (IoT) to connect smart devices with cloud services for real-time data access. Though beneficial, many IoT-based gloves struggled with latency issues and network dependency, which can be problematic in environments with poor connectivity. Additionally, most lacked local alert features such as vibration or sound.

4. RF Communication for Emergency Alerts

Radio Frequency (RF) modules have been studied for their potential in short-range, quick-alert systems. Unlike cloudbased communication, RF modules enable real-time messaging without relying on external networks. This makes them suitable for critical industrial environments where fast alerts are essential. However, RF systems alone have limited use unless combined with multi-sensor data and intelligent processing.

5. Multisensory Glove Systems

A few advanced models incorporated multiple sensors such as gas detectors, temperature sensors, and pulse monitors. These gloves aimed to detect environmental hazards and worker health conditions. Despite being effective in data collection, many lacked a proper feedback mechanism to alert both the user and the supervisor instantly.





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III. BLOCK DIAGRAM



3.1 Block Diagram Explanation

The block diagram of the RF-enabled smart glove system illustrates a comprehensive safety mechanism designed to protect industrial workers in hazardous environments. At the core of the system lies the gloves unit, which integrates various sensors, a microcontroller (ESP32), a vibration motor, a power supply, and communication modules. This glove acts as a wearable safety device, continuously monitoring the worker's health and surroundings. The system is powered by a compact battery, ensuring portability and ease of use without being tethered to an external power source. The sensors embedded in the gloves include a temperature sensor, a gas sensor, and a pulse sensor. These components are responsible for detecting any abnormal rise in temperature, the presence of harmful gases, and irregularities in the worker's pulse rate, respectively. The data gathered from these sensors is fed into the ESP32 microcontroller, which processes the inputs in real-time.

Upon identifying a dangerous condition such as an elevated temperature, toxic gas leakage, or abnormal heart rate the ESP32 promptly triggers a local vibration motor within the glove. This vibration serves as an immediate warning signal to the worker, enabling them to respond or move away from the hazardous area swiftly. Simultaneously, the microcontroller activates a LoRa (Long Range) transmitter module that sends a signal to the remote safety alert unit. The LoRa communication protocol is selected for its ability to transmit data over long distances with low power, which is crucial in large industrial settings. The signal transmitted reaches the LoRa receiver installed in the safety alert unit, which is typically located in the supervisor's area. This receiver is connected to an Arduino Uno, which interprets the incoming data. If a hazard is confirmed, the Arduino triggers a buzzer, producing an audible alert to notify the supervisor about the emergency.

In addition to the LoRa-based communication, the system also incorporates Wi-Fi-enabled cloud connectivity, taking advantage of the ESP32's built-in features. The microcontroller connects to a cloud service to log critical safety data and sends notifications to a user interface accessible via the supervisor's mobile phone or computer. This provides a dual-alert system that not only ensures the worker is aware of the danger but also allows the supervisor to receive timely updates, even if they are not physically close to the workstation. The cloud platform adds a layer of reliability and enhances the overall safety response, making it possible to store and analyze data over time for predictive safety measures. Overall, the block diagram represents a compact yet powerful solution that blends real-time sensing, efficient communication, and rapid alert systems into a wearable format, significantly improving workplace safety and response efficiency.





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IV. FLOWCHART



4.1 Flowchart explanation

The flowchart outlines the step-by-step operational logic of the RF-enabled smart glove system designed for monitoring and ensuring worker safety in industrial environments. It begins with the initialization of the system, where all the essential sensors such as temperature, gas, and pulse sensors are activated. These sensors are embedded within the glove and are responsible for collecting real-time environmental and health-related data.

Once the sensors are initialized, the system enters the monitoring phase. During this stage, the glove continuously gathers data from the surroundings and the worker's physiological parameters. The microcontroller (ESP32) plays a key role in processing this data and evaluating whether any values exceed predefined safe limits. These limits are set based on industrial safety standards for temperature, toxic gas concentration, and normal human pulse rates.

The next step in the flowchart involves a decision-making process. The system checks whether any of the monitored values are abnormal. Specifically, it looks for three conditions: high temperature, dangerous gas levels, or abnormal pulse rates. If all the parameters are within safe limits, the system continues to monitor the data in real-time without triggering any alerts.

However, if any of the sensor readings fall outside the safe range, the system proceeds to the alert-triggering phase. At this point, the glove vibrates using a built-in vibration motor, which instantly alerts the worker about the potential danger. This immediate feedback allows the worker to become aware of the situation without depending on external systems.

In parallel, the system activates the communication module. It uses LoRa (Long Range Radio) technology to send a signal to the supervisor's unit, where an Arduino UNO board and buzzer are present. The buzzer gives an audible





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warning to the supervisor, helping them to take necessary action quickly. In addition to this, the ESP32 module sends the alert data to the cloud through a Wi-Fi-based cloud connectivity module.

The cloud connection serves two main purposes. First, it forwards the alert to a user interface, which can be a mobile app or dashboard accessible by the supervisor. Second, it logs the incident for future reference, analysis, or safety reporting.

After the alert has been sent, the system re-enters the monitoring loop, continuously checking the environment and the worker's health. This cycle repeats endlessly unless the system is manually stopped or powered off.

Overall, the flowchart explains a reliable, real-time, and multi-layered safety mechanism that enhances situational awareness and emergency response capabilities in industries. It ensures proactive hazard detection, reducing the risk of accidents significantly.

V. METHODOLOGY

The core functionality of the RF-enabled smart glove begins with the sensing module, which serves as the primary data acquisition unit. This module is embedded into the glove and includes various sensors that help detect potentially hazardous conditions. The temperature sensor is designed to monitor the ambient temperature surrounding the worker. When the temperature exceeds a safe threshold, it alerts the control system to trigger a safety response. Similarly, a gas sensor continuously samples the air for harmful gases such as carbon monoxide or methane. Upon detecting toxic gases above permissible levels, it initiates an alert. In addition, a pulse sensor is included to track the worker's heart rate in real-time. This is crucial for identifying physical stress or health anomalies. The collected sensor data is vital for real-time decision-making and ensures that the system can proactively respond to unsafe conditions.

At the heart of the glove lies the processing and control module, which utilizes the ESP32 microcontroller. The ESP32 is a compact and efficient processor well-suited for IoT applications due to its integrated Wi-Fi and Bluetooth capabilities, as well as its low power consumption. The microcontroller reads input from all sensors and processes this information to check if any parameter crosses its safety threshold. It acts as the decision-making unit of the system and governs the functioning of communication and alert mechanisms. Logic is implemented within the ESP32 to reduce false positives by validating sensor readings over intervals. It also ensures that any abnormal condition triggers the appropriate alert mechanisms without delay, making the glove intelligent and responsive.

The communication aspect of the project is handled by the RF transmission module, which forms a wireless bridge between the worker and the supervisor. When a hazard is detected, the ESP32 sends a signal through the RF transmitter integrated into the glove. This signal is picked up by an RF receiver placed at a remote monitoring station. The RF module is specifically chosen for its effectiveness in industrial environments where Wi-Fi or mobile signals may not be reliable. This method ensures real-time, low-latency communication and functions even in isolated or enclosed areas, enhancing the overall safety of the worker.

To ensure that the worker is also immediately made aware of dangerous conditions, a coin-type vibration motor is attached to the glove. This motor provides tactile feedback by producing short bursts of vibrations when triggered by the control system. This local alert mechanism ensures that even if the worker cannot visually or audibly perceive the hazard, they will be notified through a physical sensation. It acts as a personal warning system and allows the worker to take immediate action, such as moving away from a hazardous area.

The supervisor's end of the system is equipped with an Arduino microcontroller connected to the RF receiver and a buzzer. Upon receiving an emergency signal, the Arduino activates the buzzer to notify the supervisor. The buzzer acts as an audible alarm that draws immediate attention to the worker in distress. This quick alert allows the supervisor to intervene or initiate emergency protocols, thereby minimizing potential harm. In enhanced versions of the system, the ESP32 can also send a message or notification to the supervisor's mobile phone using Wi-Fi, enabling remote monitoring even when the supervisor is not at the control station.





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Powering the entire system is a lightweight Lithium Polymer (Li-Po) battery. This type of battery is selected due to its compact size, low weight, and high energy density, making it ideal for wearable applications. The battery supports the functioning of sensors, the microcontroller, RF modules, and the vibration motor. Voltage regulation is handled through onboard circuitry to ensure consistent and safe power supply to all components. This ensures that the glove can operate for extended periods without frequent charging, enhancing user convenience and system reliability.

Overall, the methodology revolves around continuous environmental and biometric monitoring, fast and effective communication, and immediate alerts. All components work together in an integrated fashion, ensuring the safety of the worker in real-time. The modular nature of the system allows for scalability, making it adaptable to various industrial scenarios where safety and quick response are critical.

VI. SCOPE OF THE PROJECT

The scope of this project revolves around enhancing workplace safety through the implementation of smart wearable technology. The RF-enabled smart glove aims to provide a cost-effective, reliable, and real-time safety solution for workers, particularly those employed in hazardous industrial environments such as manufacturing units, construction sites, chemical factories, and small-scale industries. This glove is not just a wearable—it acts as a first line of defense against potential dangers, making it a proactive tool in accident prevention.

The glove is embedded with multiple sensors that continuously monitor environmental conditions such as temperature, toxic gas levels, and biometric data like heart rate. Its scope includes real-time analysis of these parameters to identify any anomaly or dangerous condition. When a threshold is crossed, the glove instantly alerts both the worker through a vibration mechanism and the supervisor via an RF signal and mobile notification. This dual-layered alert system ensures that both the individual and the management are aware of the situation, allowing for quick response and risk mitigation.

A significant aspect of the project's scope lies in its communication technology. RF communication is particularly useful in settings where internet access may be limited or unreliable. This makes the glove suitable for remote and confined industrial areas. The scope also includes future expansion possibilities, such as integrating cloud-based analytics for safety trend monitoring, GPS for location tracking, and advanced AI algorithms for predictive safety measures. This adaptability ensures that the project is not just limited to one application or scenario—it can evolve with the growing needs of the industry.

From an engineering and development perspective, the project encourages interdisciplinary application of electronics, embedded systems, sensor integration, wireless communication, and IoT technologies. It offers scope for academic growth as well, serving as a platform for research into wearable safety solutions, human-machine interaction, and industrial automation. Furthermore, the glove's design is lightweight, low-power, and user-friendly, supporting long-term wear without causing discomfort—making it suitable for day-long use by laborers and technicians.

In broader terms, the project aligns with current industrial safety standards and the global push toward smart industry and worker well-being. With increasing concern for employee safety and the adoption of Industry 4.0 practices, the scope of this glove includes not only immediate hazard alerts but also data collection that can help companies understand worksite risks better. This makes the solution relevant and scalable across various sectors where manual labor is involved.

In summary, the project's scope is vast and impactful. It addresses an essential problem with an innovative solution that is practical, affordable, and extensible. Whether used in small factories or large industrial plants, the RF-enabled smart glove has the potential to transform how worker safety is managed, making environments safer and responses quicker—ultimately saving lives and improving workplace productivity.





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VII. CONCLUSION

The RF-Enabled Smart Glove system represents a forward-thinking innovation in the field of industrial safety. Designed specifically for workers in hazardous environments, this system integrates advanced sensing, real-time alerting, and long-range wireless communication technologies to create a comprehensive safety mechanism. Its primary goal is to detect abnormal environmental and physiological conditions early and immediately inform both the worker and the supervisor, thereby reducing the possibility of injuries, accidents, or health-related emergencies.

This system addresses the most common industrial hazards excessive temperatures, toxic gas exposure, and abnormal heart rate by equipping gloves with temperature, gas, and pulse sensors. These sensors continuously monitor the surroundings and the wearer's vitals, sending the data to an ESP32 microcontroller. If any of the sensed parameters cross the safe threshold, the system immediately triggers a vibration motor inside the glove to alert the worker. Simultaneously, it activates a buzzer on the supervisor's end through LoRa communication, providing both local and remote alerts without delay.

One of the key features that enhances the system's effectiveness is the dual-layered alert mechanism. The LoRa module ensures long-range transmission of alerts, while Wi-Fi and cloud connectivity are used to send real-time data and notifications to the supervisor's mobile device. This multi-channel alert strategy ensures that no warning goes unnoticed, even in situations where one form of communication may fail. Additionally, cloud storage enables historical data logging, which can be useful for safety audits, predictive analytics, and improving workplace protocols over time.

The glove system is designed to be lightweight, power-efficient, and user-friendly. Its compact nature makes it suitable for continuous use without causing discomfort. Moreover, the system is affordable and scalable, making it especially beneficial for small and medium-scale industries that often lack access to sophisticated safety infrastructure. These industries can now adopt a high-standard safety mechanism without significant financial burden.

Furthermore, the inclusion of IoT and cloud technologies not only makes the system modern and intelligent but also adaptable to future expansions. Additional sensors, advanced data analytics, or AI-based health prediction modules can be incorporated later without overhauling the entire setup. This adaptability ensures the glove system remains futureready and relevant to evolving industrial safety demands.

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