Intelligent Health Sensing Safety Jacket for Construction Workers

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Abstract: Construction sites are among the most hazardous work environments, exposing workers to extreme physical conditions, fatigue, and unpredictable accidents. This project proposes the development of an Intelligent Health-Sensing Safety Jacket designed to continuously monitor the vital signs and environmental conditions affecting construction workers in real time. The jacket is embedded with sensors capable of measuring Heart Rate, Body Temperature, SpO_2 (oxygen level), and motion patterns. It also includes environmental sensors to detect harmful gases, excessive heat, or humidity. These readings are processed and transmitted using IoT technology to a central monitoring system accessible by site supervisors and health personnel. In case of abnormal readings—such as signs of heat stress, fatigue, or sudden falls—the system triggers Automatic Alerts Via Buzzer, vibration, or mobile notifications for immediate action. This smart jacket not only enhances worker safety but also promotes a proactive health management approach in construction. It offers a practical and innovative solution for reducing on-site injuries, improving emergency response times, and promoting worker well-being through preventive monitoring.

***Keywords: Heart Rate and Temperature Sensor*, *Automatic Alerts Via Buzzer*.**

I. INTRODUCTION

Construction sites expose workers to a range of physiological and environmental hazards that can quickly escalate into medical emergencies. Prolonged heat exposure and high humidity increase the risk of heat stress and heat stroke, toxic or flammable gas pockets (CO, VOCs) create acute respiratory or explosion hazards, and sudden health events such as tachycardia or fainting can lead to falls and severe injury. Traditional personal protective equipment protects against impact and visibility but does not provide continuous monitoring or automated alerting for these concealed threats.

An Intelligent Health Sensing Safety Jacket addresses this gap by combining a focused set of sensors—temperature and humidity, gas, and pulse (PPG)—with an ESP8266-based IoT module to enable real-time monitoring and rapid notification. The temperature and humidity sensor tracks microclimate conditions near the worker's torso to detect heat-stress risk and trigger preventive alerts. The gas sensor continuously monitors concentrations of hazardous gases and raises alarms when thresholds are exceeded. The pulse sensor provides continuous heart-rate monitoring to identify abnormal physiological responses or distress during exertion.

The ESP8266 serves as the communication backbone, collecting conditioned sensor data, performing lightweight preprocessing (threshold checks and short-term trend detection), and publishing telemetry to a cloud service or supervisor mobile app via Wi-Fi using MQTT/HTTP. On-device alerts.

An intelligent health sensing safety jacket is designed to monitor construction workers' vital signs and environmental conditions in real time, enhancing on-site safety. It helps prevent accidents by providing early alerts for health risks and hazardous situations, ensuring better protection and quick response.

II.LITERATURE SURVEY

The user requires a well-structured literature survey focusing on specific sensor technologies and their applications within IoT-based wearable systems. To meet this need, the survey will be organized into clear, coherent sections that provide comprehensive coverage of the topic. It will begin with an overview of wearable safety technologies, followed by dedicated sections discussing temperature and humidity sensors, gas detection sensors, and pulse or vital- sign monitoring sensors, highlighting their operating principles, accuracy, and suitability for construction-site environments.

Additional sections will examine the role of IoT modules such as ESP8266, emphasizing their connectivity features, power efficiency, and integration in real- time monitoring systems. The survey will also address system-level considerations such as data transmission, sensor fusion, and implementation challenges including calibration, latency, and environmental noise.

Finally, the literature survey will conclude with a summary of research gaps, identifying the limitations in current wearable technologies and the opportunities for improving worker safety through enhanced sensing and IoT- based solutions.

II. SYSTEM ANALYSIS

The Intelligent Health Sensing Safety Jacket is designed to provide continuous, real- time monitoring of a construction worker's immediate environment and physiological condition through an integrated network of advanced sensors. Temperature and humidity sensors help assess the worker's microclimate, enabling detection of heat stress or dehydration risks, while gas sensors identify the presence of hazardous substances such as carbon monoxide, methane, or other toxic fumes commonly encountered on construction sites. Additionally, pulse sensors track vital parameters like heart rate and oxygen saturation, allowing early recognition of fatigue, cardiac irregularities, or sudden physiological distress.

All sensor data is transmitted using an ESP8266 Wi-Fi module, which provides reliable wireless connectivity for seamless telemetry and rapid alert communication. The system is engineered to deliver both local notifications— such as alarms or vibration feedback to the worker—and remote alerts to supervisors via cloud dashboards or mobile applications, ensuring swift and coordinated response during emergencies.

The overall design emphasizes wearability, durability, and low power consumption, making it practical for long working hours in harsh outdoor or industrial environments. By combining health monitoring with environmental sensing, the jacket aims to enhance worker safety through early detection, timely intervention, and continuous situational awareness.

III. SYSTEM IMPLEMENTATION

4.1 Hardware Integration

Temperature and humidity sensor: mounted in a breathable chest pocket near the sternum with a fine mesh cover to allow airflow and reduce particulate ingress. Gas sensor (CO/VOC): housed in a vented enclosure on the outer shoulder or upper chest to sample ambient air while avoiding occlusion by clothing. Pulse sensor (PPG): placed on an inner chest strap or upper-arm pouch with soft silicone backing and an adjustable strap to maintain firm, stable skin contact. Electronics pod: detachable, water-resistant pod (lower-back or hip) containing ESP8266, power management, buzzer/LEDs, and connectors for easy removal before washing

4.2 Mechanical and connector design

Use standard waterproof snap or magnetic quick-disconnects for power/data to enable safe removal. Sensor modules built as replaceable cartridges with a single 4-pin connector (Vcc, GND, Data, Status). Electronics and Circuit Design

4.3 Core components and layout

ESP8266 (NodeMCU/WeMos) for Wi-Fi and IoT connectivity. Analog front-end for PPG: low- noise amplifier, bandpass filter (0.5–4 Hz), and peak detector; external multi-channel ADC if multiple analog sensors are used. Gas sensor interface: MOS driver with heater-control MOSFET or electrochemical interface with low-noise amplifier. Temperature & humidity: digital I2C sensor (e.g., SHTxx) for direct digital readout. Power: Li-ion battery (2000–4000 mAh), charging IC (TP4056 or equivalent), boost/regulator as required, fuel-gauge/ADC for battery monitoring.

4.4 Noise and signal integrity

Star-ground layout for the pod; separate analog ground plane for PPG front- end. Short shielded cable between PPG sensor and analog front end; ferrite beads on radio power lines to reduce EMI during Wi-Fi transmission.

4.5 Duty-cycling and domain separation

Keep ESP8266 in deep-sleep where possible; use a low-power companion MCU (e.g., Cortex-M0 or ATTiny/STM32L0) to monitor sensors continuously and wake ESP8266 only for transmissions or critical events. Duty-cycle MOS gas heater (short warm bursts) or select a low- power electrochemical gas sensor to reduce continuous heater draw.

4.6 Battery and charging

Provide clear charging port and LED status. Implement low-battery pre-alert and safe shutdown policy that preserves event-logging and local alarm capability.

4.7 Software architecture and modes

State machine: Normal (periodic reads + summary publish), Event (local alert+ immediate publish), Buffering (store events), Sleep (power saving). Modular firmware layers: HAL for sensors, signal processing library (filters, peak detection), event manager (fusion rules), comms manager (MQTT/HTTP), HMI controller, persistence layer (circular flash buffer)

4.8 Sensor sampling and processing

Temp/Humidity: sample at 1–2 Hz, moving-average smoothing, short-term delta detection. Gas: apply baseline subtraction, low-pass filtering, heater-control schedule (if MOS), threshold hysteresis to avoid chattering. PPG: sample 25–100 Hz, bandpass filter (0.5–4 Hz), adaptive peak detection, compute inter-beat intervals, apply short-term smoothing for BPM; use accelerometer correlation if available

4.9 Event detection and fusion rules

Per-sensor thresholds with configurable hysteresis and confirmation windows (e.g., require condition for N seconds).Simple fusion: e.g., HR rise + temperature rise → escalate to heat-stress alert;gas threshold breach → immediate alarm irrespective of other sensors. Worker acknowledgement: single-press to mute local alarm; long-press for manual SOS that forces immediate remote alert.

4.10 Data handling and reliability

JSON telemetry with minimal fields: deviceID, workerID, timestamp, sensor values, event code. Buffer events in circular flash when offline; implement exponential-backoff retry and heartbeat messages to indicate health. Network, Security and Cloud Interface.

IV. METHODOLOGY

The methodology diagram illustrates the complete workflow followed in developing the Intelligent Health-Sensing Safety Jacket. Each block represents a sequential step that contributes to designing, integrating, and implementing the IoT-based worker-safety system. The process begins with Literature Survey and Research Gap Identification, where existing studies on worker-safety technologies, IoT-based wearables, and health-monitoring devices are reviewed. By analyzing the limitations of previous systems—such as lack of real-time alerts, limited sensing capabilities, or absence of cloud connectivity—the research gap is identified. This step helps in defining the system objectives, selecting appropriate sensors, and planning system features for enhanced worker protection. Next, the Worker Wearing Safety Jacket block represents the scenario in which a construction worker uses the smart jacket. The jacket serves as the main platform into which all sensing and communication components are embedded. It is designed to be lightweight, durable, and comfortable so that it does not interfere with the worker's routine activities while providing continuous health and environmental monitoring.

The flow then proceeds to Sensor Integrated, indicating the installation of bio- sensors and environmental sensors into the jacket. This includes heart-rate monitoring sensors (pulse sensors), temperature sensors, and air-quality sensors. Integration ensures that all sensors are positioned appropriately on the jacket to capture accurate physiological and environmental data. The sensors operate continuously, collecting data every second to ensure the system can detect abnormalities instantly. Following integration, the system captures specific real-time parameters such as Body Temperature (DHT11), Pulse Rate, and Air Quality levels. These three sensing elements are essential for detecting worker health risks like heat strokes, abnormal heart activity, or inhalation of toxic gases at construction site.

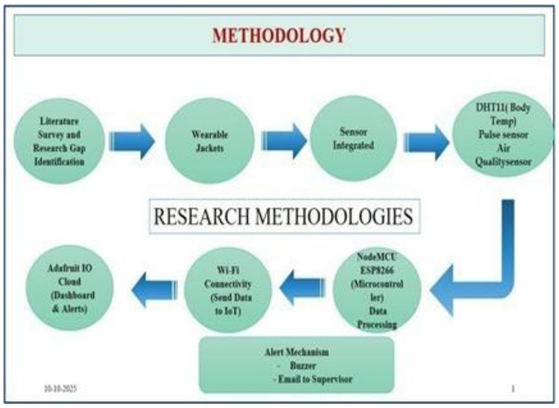

fig 1: Methodology of the proposed System

The sensors are chosen due to their low-power operation, reliability, affordability, and compatibility with microcontrollers. The next block, NodeMCU ESP8266 (Microcontroller) – Data Processing, plays a central role in the system. The NodeMCU receives raw sensor data, processes it, filters noise, and performs threshold checks. If any reading crosses preset safety limits, the ESP8266 prepares an alert packet. The microcontroller also handles communication, power management, and real-time decision- making. Once data is processed, it is forwarded through Wi-Fi Connectivity (Send Data to IoT). The ESP8266's built-in Wi-Fi module enables seamless wireless transmission of sensor data to cloud platforms. Wi-Fi connectivity is crucial for enabling real-time visibility of worker health and environmental conditions, allowing safety officers to monitor multiple workers simultaneously.

The transmitted data reaches the Adafruit IO Cloud (Dashboard & Alerts). This IoT cloud platform stores incoming data, displays live values on dashboards, and triggers automatic alerts when abnormal conditions are detected. Supervisors can view graphs, analyze patterns, and receive warnings instantly through mobile or web dashboards. The cloud also enables remote monitoring, making the system highly scalable for large construction site.

Finally, the Research Methodologies box summarizes the entire workflow, emphasizing the systematic approach—from literature review to sensor integration, data processing, cloud monitoring, and real-time alerting. This structured methodology ensures a reliable, effective, and user-centered safety solution.

V.EXPERIMENTAL OR MATERIALS AND METHODS

This chapter provides a comprehensive explanation of the experimental procedures, materials, components, and methodologies used in the development of the Intelligent Health- Sensing Safety Jacket for Construction Workers. The system integrates a variety of biomedical and environmental sensors, microcontrollers, power modules, and IoT communication components to enable continuous monitoring of a worker's physiological condition and surrounding environmental hazards. The core purpose of the experimental work is to design, assemble, program, and validate a wearable safety device capable of detecting abnormal conditions such as elevated body temperature, reduced oxygen saturation, irregular heart rate patterns, hazardous gas exposure, and accidental falls or impacts.

The experimental workflow begins with sensor calibration, ensuring that each module—such as the temperature/humidity sensor, pulse sensor (PPG), gas sensor, and accelerometer—produces accurate and stable readings. This is followed by circuit assembly, where the sensors are interfaced with the microcontroller and supporting electronics, including voltage regulation, battery management, and alert modules (buzzer, LED, vibration motor). Firmware development is carried out using the Arduino IDE, which includes writing, compiling, and uploading code for data acquisition, preprocessing, threshold detection, fall detection algorithms, and communication routines.

Cloud and network integration is implemented through MQTT-based IoT communication, enabling seamless real-time data transmission via the ESP8266 Wi-Fi module to cloud dashboards or mobile monitoring platforms. This architecture allows supervisors to remotely track workers' health status and environmental conditions, ensuring rapid response during emergencies. The algorithms incorporated into the system include threshold-based detection for physiological abnormalities, fall detection logic using accelerometer data to classify sudden movements or impacts, and data preprocessing techniques such as filtering, noise reduction, and artifact removal to enhance measurement accuracy. Through these experimental procedures and system validations, the jacket is optimized to function reliably in real- world construction environments.

6.1 Hardware Requirements

6.1.1 NodeMCU ESP8266 Microcontroller

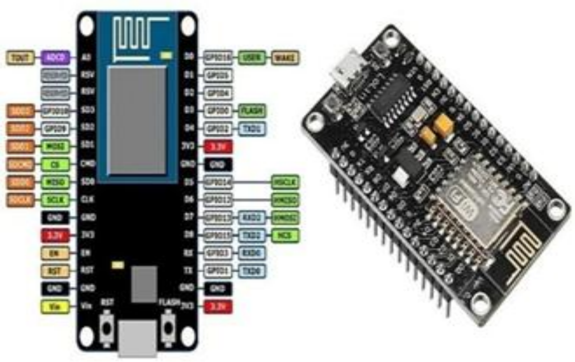

Fig 2:ESP8266 Microcontroller

Acts as the main processing and Wi-Fi communication unit. Handles sensor readings, threshold logic, and data transmission.

6.1.2 Max30100 Heart Rate Monitor Sensor

Fig 3:MAX30100 Sensor

This sensor is used to measure the Heart Rate.

6.1.3 Temperature Sensor (DHT11)

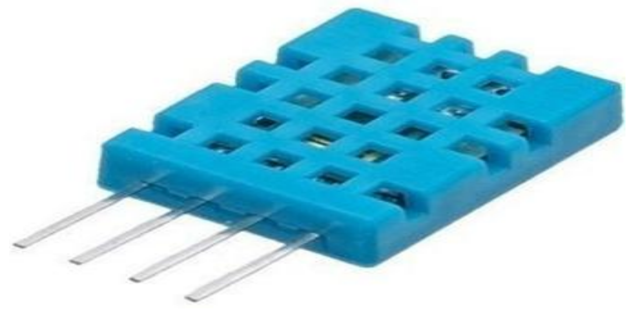

Fig 4:DHT11 Sensor

Measures body temperature and/or ambient temperature. Used to detect heat stress and fever-like symptoms.

6.1.4 Gas Sensor (MQ-135)

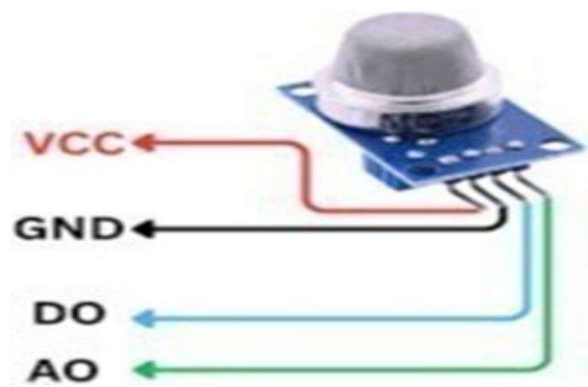

Fig 5:Gas Sensor

Detects hazardous gases (CO, CH_4, smoke). Powers the entire system. Should be lightweight and rechargeable for wearable use. Connection Wires, PCB/Perf Board, Jacket Mounting Accessories Used for constructing the circuit and integrating components into the jacket.

6.2 Software Requirements

Arduino IDE Used to write, compile, and upload the firmware to the ESP8266 board.ESP8266 Board libraries wire `hPubSubClient.h (MQTT communication) Sensor-specific libraries (MAX3010x, DHT, ADXL345) Adafruit IO / MQTT Cloud Platform, Displays real-time data dashboards. Sends notifications through emails/SMS/push alerts.=Mobile Application / Web Dashboard.

VI. RESULTS AND DISCUSSIONS

The development and testing of the Intelligent Health Sensing Safety Jacket for Construction Workers yielded promising results in terms of functionality, reliability, and real- time responsiveness. The system was evaluated under simulated construction site conditions to assess its ability to monitor vital signs, detect environmental hazards, and communicate alerts effectively. The MAX30100 sensor successfully captured heart rate data with minimal noise, thanks to its built-in filtering and amplification features. The DHT11 sensor reliably measured body temperature and humidity, providing consistent readings within its operational range. The posture detection module, based on Gas sensors such as MQ- 135 detected the presence of harmful gases like carbon monoxide and ammonia, demonstrating the system's capability to monitor air quality in real time.

The NodeMCU ESP8266 microcontroller played a central role in data acquisition and transmission. It processed inputs from all sensors and communicated with the Adafruit IO cloud platform using MQTT protocol. The data was displayed on a real-time dashboard accessible via mobile and web interfaces. Supervisors could monitor multiple workers simultaneously and receive instant notifications in case of abnormal readings. Performance analysis showed that the system responded to critical events within seconds, ensuring timely intervention. The wireless communication was stable across a typical construction site range, and the battery-powered setup sustained operation for several hours without interruption. The mobile dashboard was intuitive and allowed supervisors to acknowledge alerts and take necessary actions promptly.

Overall, the intelligent safety jacket demonstrated high effectiveness in enhancing occupational safety. It provided continuous health surveillance, environmental monitoring, and emergency alerting—all integrated into a wearable form factor. The system's modular design allows for future upgrades, such as GPS tracking or integration with centralized safety management systems. These results affirm the feasibility of deploying smart wearable technology in high- risk industrial environments to reduce accidents and improve worker well-being.

VII. CONCLUSION

The development of the Intelligent Health Sensing Safety Jacket for Construction Workers clearly demonstrates the transformative potential of wearable IoT technologies in enhancing worker safety, early risk identification, and emergency response in high-risk industrial environments. By integrating biomedical monitoring sensors, environmental detection modules, embedded processing capabilities, and wireless cloud connectivity, the system establishes a continuous, real-time safety network that far surpasses the limitations of conventional protective equipment. Instead of relying solely on helmets, reflective clothing, or supervisor oversight, this intelligent jacket provides an automated, data-driven approach to worker protection.

The project validates the effectiveness of a compact, energy-efficient, and affordable microcontroller platform—specifically the ESP8266 NodeMCU—for handling multisensor data acquisition, on-board preprocessing, and seamless communication with IoT cloud services. Through continuous monitoring of critical health parameters such as heart rate, SpO_2 levels, and body temperature, alongside environmental indicators such as toxic gas concentration and ambient temperature, the jacket is capable of identifying early signs of heat stress, hypoxia, fatigue, or exposure to harmful gases.

The addition of a fall detection algorithm using accelerometer data further enhances worker safety by detecting sudden impacts, slips, or loss of balance, and promptly generating emergency notifications. The cloud-based monitoring platform offers supervisors a comprehensive dashboard for visualizing worker health metrics, analyzing trends, and receiving instant alerts. This capability supports data-driven decision-making, proactive safety interventions, and faster emergency response, ultimately reducing the likelihood of severe injuries and fatalities. AI-powered predictive analytics for forecasting risks, integration with enterprise safety management systems, or edge-computing enhancements for faster local processing.

In conclusion, the Intelligent Health Sensing Safety Jacket emerges as a highly practical and impactful innovation aimed at modernizing occupational safety practices in construction and other industrial sectors. Its ability to deliver continuous protection, real- time situational awareness, and rapid communication makes it a valuable addition to personal protective equipment (PPE). The success of this project not only demonstrates the capabilities of smart wearable technologies but also lays a strong foundation for future advancements in intelligent PPE, contributing to safer, more efficient, and more technologically empowered work environments.

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