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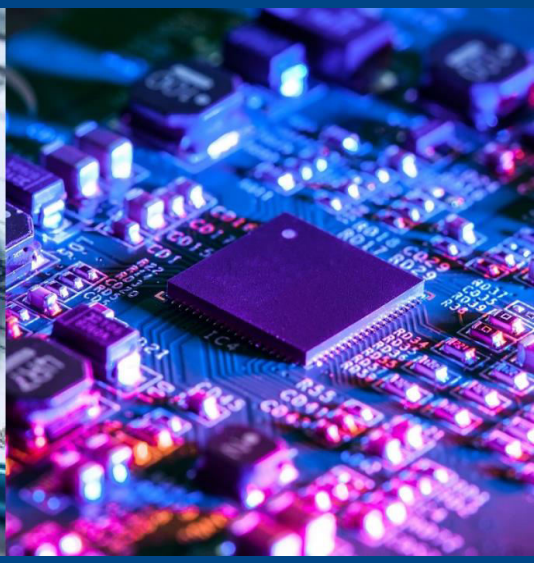

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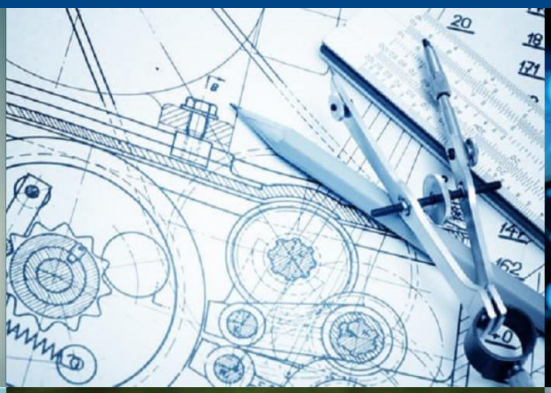

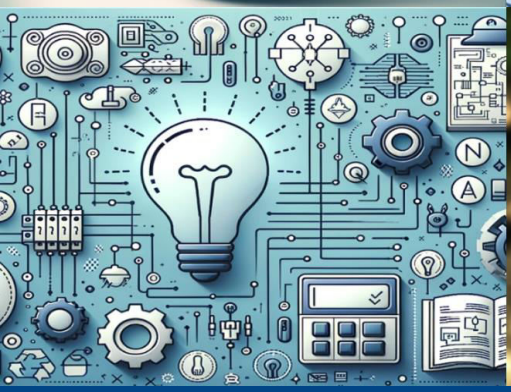

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IoT Based Smart Wearable Sensor for Safer Construction Work Environment

Dr. S.S. Lavhate[1], Pramil Gunjal[2], Shivtej Kobarne[3], Datta Dhakne[4]

Professor, Department of Electronics and Computer Engineering, PREC, Loni, Maharashtra, India[1]

Student, Department of Electronics and Computer Engineering, PREC, Loni, Maharashtra, India[2, 3, 4]

ABSTRACT: Construction workers face many dangers on the job falls, exposure to harmful gasses, heat stress, and unexpected illnesses/medical conditions. Traditionally, construction safety is mostly achieved by relying on manual supervision of workers rather than providing continuous monitoring. This paper presents an IoT-based wearable safety system for construction workers. Sensors assess a worker's heart rate, oxygen level, body movement, temperature, and harmful gasses. ESP32 microcontroller uses the above measurements to process data from the sensors and when an emergency happens, it sends an alert via GSM module and GPS coordinates will be included within that message. The system provides real-time monitoring without requiring an active Internet connection and can provide monitoring of workers' safety at remote locations where construction projects may take place.

KEYWORDS: IoT, Wearable Safety System, Construction Safety, ESP32, GSM Alert System

I. INTRODUCTION

Construction job sites are some of the most hazardous work environments due to heavy machinery operation, spans above ground level, dust, heat, and exposure to combustible or other toxic gases. Workers can experience accidents as a result of falling from heights, fatigue, or unsafe working conditions. The delay in recognizing an emergency can increase the severity of worker injuries and limit the availability of immediate medical assistance. Standard safety procedures still primarily rely on the use of personal protective equipment and human supervision. Although these procedures may lessen the chance of certain injuries, they do not provide continuous monitoring or protection to workers due to their reliance on personal judgment or manual observation. Recent advances in Internet of Things (IoT) technology and wearable technology are allowing for the commercial production and implementation of compact monitoring systems capable of collecting data and processing it in real-time. The proposed system has been developed to improve safety of workers by continuously monitoring three separate physical characteristics, health parameters, environmental conditions (e.g., temperature, humidity) and how a worker moves. The system utilizes multiple sensors that connect to an ESP32 microcontroller for processes such as data processing and decision-making related to emergency situations for workers. In the event of an unsafe condition, the system will transmit an emergency signal along with the worker's location back to the appropriate authority using General System Mobile (GSM) communication technology. The system is especially valuable on remote constructions sites that lack internet connectivity.

II. LITERATURE REVIEW

There has been an increasing focus on using wearable IoT technology for monitoring the safety of workers in hazardous working conditions within the construction industry. Putra et al. [1] reviewed the effect of wearable technologies on real-time monitoring and the reduction of work-related accidents via continuous data collection. The authors also documented a recent trend in wearable device use that involves edge computing technologies for processing sensor data locally, thereby minimizing communication delays and maximizing the effectiveness of emergency response use and performance. Artificial Intelligence techniques are also being integrated into wearable safety systems. Al-Emran et al. [3] proposed an AI-enabled wearable model for detecting worker fatigue and fall conditions through multi-sensor data analysis. Zhang et al. [4] developed a fall detection framework based on deep learning approaches that enhance the accuracy of motion analysis and reduce false detection rates. Many researchers have investigated IoT-based health and environmental monitoring systems. Mehata & Shankar [5] proposed a wearable health monitoring system designed to monitor worker health status in real time. Awolusi et al.

[6] provided field implementation case studies illustrating the use of wearable safety devices and the challenges associated with power consumption and long-term usability. Research by Ahmed et al. [7] has shown evidence that smart wearable devices provide a means to improve safety management within the construction industry by offering continuous monitoring of worker status and warning users of potential hazards prior to their occurrence. Wang et al. [8] proposed a new approach using 'multi-sensor fusion' specifically for wearables that can detect falls, thereby increasing their reliability and reducing false alarms. Chen et al.'s [9] study on flexible gas detection devices were demonstrated to be capable of functioning in hazardous industrial settings; whereas Patel et al.'s study focused on monitoring heat stress among construction workers whose work environments are subject to extreme conditions through IoT technology ([10]).

Although both pieces of prior research provide evidence for the safety function of wearable devices (e.g., fall detection, gas detection/monitoring, and health analysis), there still remains a significant opportunity for research/test development into developing a single compact and low-cost wearable device that combines all of the major safety functions into one (i.e., health monitoring, environment sensing, fall detection, and emergency communication using GSM technology); thus, achieving the goal set forth.

III. METHODOLOGY OF PROPOSED SURVEY

The proposed system serves as a wearable safety monitoring device based on IoT for construction workers. The device will be continuously monitoring the worker's physiological state, as well as the parameters of their surrounding environment and general movements, using multiple sensors linked into a central microcontroller. The complete methodology is formed on Real-Time Data Acquisition, Intelligent Processing, Hazard Detection, Emergency Communication with the worker. The block diagram for the proposed system consists of sensing modules, communication modules, cloud monitoring interface and an Emergency Alert mechanism that is to be controlled by the Controller Device. The various sensing devices will be used for monitoring various conditions of safety at the same time, through the controllers. The MAX30102 heart rate and SP02 sensor are used to monitor the worker's heart rate and SPO_2 levels. MAX30102 works on the Optical Sensing Principle to continuously measure physiological parameters by interpreting the blood flowing through the body via the changes within it. The values collected from the sensor will be used to identify workers that may need to seek medical assistance for abnormal heart rates, fatigue, shortness of breath, or sudden medical emergencies. Additionally, should the measured values exceed predetermined safety limits; the system will determine that the worker(s) and/or given working environment is a hazard and begin the alert process.

To be able to identify dangerous gasses and smoke that exist in an environment, the MQ-2 gas sensor has been designed with off-the-shelf components. At construction sites, many dangerous, toxic gasses and dust particles can have a negative impact on the health and well-being of workers. To ensure that they are monitored on a regular basis, this sensor will continue to monitor air quality within the working atmosphere and return analog values back to the controller. If the concentration of an existing gas exceeds an acceptable threshold LIMIT, the controller will be made aware of the hazardous condition and be activated to sound a warning alarm. The DS18B20 is a digital temperature sensor that measures the body temperature of workers by monitoring their body heat while working. Continuous monitoring of worker temperature allows for early identification of fever, and/or heat stress due to overexertion while working in extreme temperatures or due to excessive workloads in the environment. This sensor produces reliable, accurate digital temperature readings that can be used in applications that are in the form of wearable devices.

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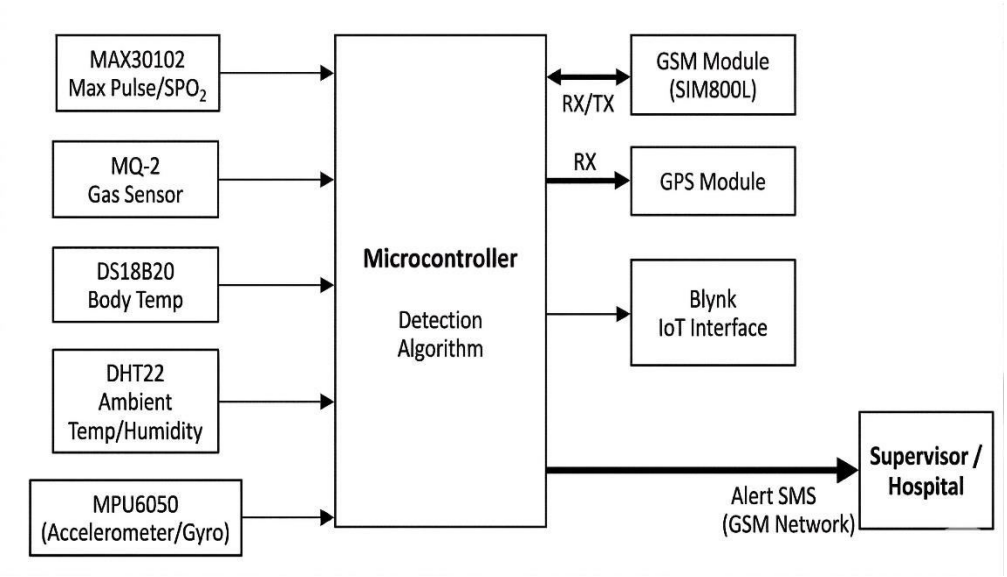

Fig. 1. Block diagram of proposed System

The DHT22 is a Digital Temperature and Relative Humidity Sensor that measures the ambient temperature and relative humidity around the worker. Monitoring the conditions of the environment is essential as high temperatures and high humidity levels can lead to dehydration, heat exhaustion and lower levels of worker efficiency. The DHT22 sensor will continue to return updated values of the temperature and relative humidity to the controller, which can be used to monitor conditions in real-time for worker safety. The MPU6050 accelerometer and gyroscope sensor provides motion monitoring and fall detection. The sensor continuously measures the worker's body acceleration and orientation in all three dimensions. When the worker is moving regularly, their movement is stable; however when there are sudden changes in acceleration or body position, it may indicate that they have had a fall. The microcontroller analyses the motion data it receives from the sensor through detection algorithms that distinguish between normal movement patterns and those indicative of risky behaviors (i.e., falls).

All of the sensors are connected to the ESP32 microcontroller, which acts as the central processing unit (CPU) for the entire system, receiving sensor data via I2C digital input and analog input communication interfaces. After the CPU receives sensor data, it processes them and compares them to predefined threshold limits. The CPU will continuously run detection algorithms to determine if unsafe conditions exist (i.e., abnormal heart rate, low oxygen level, dangerous gas exposure, extreme temperature, or fall of the worker). Once the CPU has detected that a hazardous condition exists, it will activate the emergency communications process. Using the GPS module, the real-time geographic location of the worker is transmitted in latitude and longitude coordinates; this data will allow supervisors or rescue teams to find the exact location of the worker in the event of an emergency.

There is a GSM (Global System Mobile Communication) module as a SIM800L to send SMS (Short Message Service) notifications of emergency alerts to people using a cellular network. The microcontroller connects to the GSM module via serial RX/TX (Receive/Transmit) communications; once the controller confirms that an emergency exists, it generates an alert SMS with the identified emergency hazard along with GPS (Global Positioning System) coordinates. This SMS will be sent to a pre-defined contact, for example, the supervisor, safety officer, or a hospital within the immediate area of the emergency. Because this project uses GSM communications, it will also function well in areas of construction where there is no internet connectivity. In addition to sending emergency alerts via GSM, the system can also send remote monitoring (from the Blynk IoT platform) and collecting data from the sensors. For example, the ESP32 microcontroller will upload information from the connected sensors to the Blynk cloud server via wireless communications, allowing different measured parameters from different sensors (heart rate, oxygen level, temperature, humidity, gas concentration, and motion status) to be seen in real-time using a mobile device application, or a computer web interface dashboard. This allows supervisors to remotely monitor worker conditions and maintain historical information for analysis in the future.

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The entire wearable system is powered by rechargeable batteries built for low energy use and continual operation. The entire system is very compact in size and can thus be used for practical applications in a wearable format in a construction environment. The use of multiple sensing modules, intelligent processing algorithms, emergency communication via GSM, location tracking via GPS, and IoT monitoring provide a highly effective approach to improving the safety of workers, decreasing the time for an emergency response, and allowing continuous monitoring of hazardous construction sites.

IV. CONCLUSION AND FUTURE WORK

The developed wear-able sensor system utilizing IoT provides a real-time robust solution for improving occupational safety of construction workers via vital signs monitoring and environmental hazards detection. Using an ESP32 microcontroller interfaced with an MPU6050 accelerometer for fall detection, plus specialised sensors measuring SpO2, heart rate, and ambient conditions allows this system to connect the physical work of construction with digital health monitoring. The use of GSM and GPS modules will provide emergency alerts sent with exact coordinates thus, greatly improved response times to critical incidents. Experimental testing shows the wearable prototype maintains high accuracy data and low power usage, allowing for a compact, cordless, wearable solution designed for the demands of harsh working environments. Ultimately, this study shows how leveraging affordable IoT hardware and intelligent processing algorithms can help reduce workplace fatalities and provide a scalable model to modernise safety procedures in the global construction industry by allowing for proactive, automated monitoring with speed of communication in emergencies.

Future improvements will focus on incorporating edge-based machine-learning for predictive health analytics and moving to flexible PCB technology.

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