Assessment of design and implementation of a smart wearable safety jacket

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ABSTRACT

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| **Aims:** Smart clothing aims to balance fashion, engineering, interaction, user experience, cybersecurity, design, and science to create technologies that can anticipate needs and desires.  **Study design:** The study aims to develop and systematically test a wearable smart safety vest to enhance industrial worker safety by monitoring environmental and physiological conditions in real time.  **Place and Duration of Study:** Conducted at [The Higher Institute of Engineering and Technology in New Damietta.] over [January 2024 to December 2024].  **Methodology:** Possibility of employing smart textiles that can communicate with smartphones to process biometric information like heart rate, temperature, respiration, stress, movement, acceleration, or even fingerprints. hormone levels, indicating the start of a new age in retail. The main requirement for developing smart, Internet of Things-enabled apparel is covered in this article, along with the possible long-term impacts of smart clothing on business strategies.  **Results:** The miner receives alert messages from several sensors via the app, and various beep sounds are produced for each sensor. The app allows you to view the automations, DataStream, events, and other sensor data. Additionally, it displays the various sensors' readings.  **Conclusion:** The fundamental kinds and elements of smart IoT clothing and wearables are explained, along with their main requirements and some of the most recent uses for smart clothing. There is also a global IoT architecture available. In order to provide suggestions for the creators of a network that would eventually link apparel to other Internet of Things devices, this article explores the background and present status of smart clothing: Smart Clothing on the Internet. |

*Keywords: Internet of Things, humidity, Internet Protocol, Temperature, sensors, smart clothes, wireless communication, smart garments and wearables.*

1. INTRODUCTION

In the current era, where security and well-being are the most important needs in various basic cycles, people in coal ventures essentially promise the same thing. The Worldwide Coalition has accounted for approximately one episode while focusing on the most recent reality. in support of Iranian laborers (Suttitatee et al., 2024). This incident occurred at the Sanjdi coal mine near Quetta, Baluchistan, and resulted in the deaths of six persons due to toxic gasses. Although the Pakistan Central Mines Labor Federation and the Industrial Global Union are well aware of this problem, there isn't a perfect answer. Thousands of lives could be spared at the appropriate moment if the suggested method were implemented in a coal mine even though it can't be put into practice after being monitored on a wireless sensor network. Additionally, this is a first-of-its-kind approach due to the number of effective sensors recommended in this research (Lee & Baek, 2021). There are other potential solutions to the same issue, many of which have been tried previously, but monitoring them following a coal mine collapse for any reason is a significant challenge (Azhan et al., 2024). The disaster management authority starts a protracted excavation of the entire site in such a situation. Most of the time, the rescue crew cannot find victims with the right pulse rate, therefore they are unable to save all of the victims. This technology will continuously update the miner's pulse rate and determine the exact depth and GPS location of the miner (De Fazio et al., 2022). Using this technique, the rescue crew can excavate exactly where the miners are stuck and at the ideal depth to bring them back to the ground.[3]

**1.1. Literature Review**

In (Narasimha et al., 2013), Numerous health-related parameters are detected by the prototype, such as the miner's global geolocation, the present temperature and humidity, the miner's pulse rate, and the exact depth location. A semi-conductor gas sensor is described in (Pandey et al., 2016) as one of the most effective ways to identify the presence of toxic gases. It is possible to install these sensors in the area of coal mineshafts. In other cases, the sensor gadget was often accidentally damaged. Another alternative is to deploy a robot. Meanwhile, because of their ability to monitor the environment in a wide range of locations, ZigBee-based wireless sensor networks have recently been the focus of research.

A significant amount of research has been done on the creation of health monitoring devices, as stated in (Jubadi & Sahak, 2009) .Heart Beat Monitoring Via Alert is a new technology that may be used soon, according to War-suzarina Mat Jubadi and her colleagues. The purpose of this warning system is to monitor a patient's heart rate in order to avert cardiac arrest. This technique is called electrocardiography (PPG) and it uses the photoplethysmography principle to monitor heart rate with excellent precision. After a PIC16F87 microcontroller received and processed the PPG signal, the data could be utilized to determine the heartbeat rate per minute.

In the case of a medical emergency, family members or medical professionals received an emergency text message alert (Bhagchandani & Augustine, 2019). In particular, this study makes use of the photoplethysmography (PPG) technology. This system uses the PIC16F87 microcontroller, which is available here. The results may be a little delayed because this approach just measures heart rate. As stated in (Akash & Shikder, 2020), the Patient Monitoring System (sometimes called PMS) uses GSM technology to achieve this objective. An ongoing surveillance system maintains.

**1.2. Impact of Internet of Things**

Our proposed method uses a wearable device or an external intelligent clothing for the convenience of the miners. Not at all like the existing frameworks that employs a cap which may place the digger in risk at the hour of brief out and effect the cerebrum, a coat is more helpful. A temperature and heartbeat sensor are used to measure the coal mineshaft workers' body temperature and heart rate. The gas spillage will be detected by gas sensor and insinuated through IOT utilizing Blynk application. The sound sensor will alert, and the flame sensor will detect the fire. To identify the location of coal mineshaft workers, GPS is used.

**1.3. Importance of the Project**

This project addresses a real and growing need in industrial safety. By providing asmart solution that combines health tracking, environmental monitoring, and location tracking, it offers enhanced protection for workers and peace of mind for supervisors. The system could significantly reduce workplace accidents, improve emergency response time, and increase productivity in hazardous work conditions.

2. METHODOLOGY

study one

Wearable technology can increase workplace safety, track an employee's health in real time while they are participating in dangerous activities, and analyze data to provide timely emergency action. Conversely, wearable technology must satisfy certain requirements, such as ease of use, cost, sensor setup, and data retrieval complexities. Wearable technology that employs various sensor types to gather data pertinent to various quantitative fields is of interest to scientists and companies. It has been shown that these technologies are especially successful in continuously monitoring a user's health as it is influenced by behavioral, physiological, psychological, and—most importantly—environmental factors. In addition to traditional wearables that can measure parameters in a single domain, hybrid solutions for monitoring several parameters have emerged, such as devices that can assess both biophysical and environmental elements.

Metallurgical, chemical, mining, and food industries are just a few of the industries where hybrid solutions are drastically altering workplace safety.

Workers are frequently exposed to hazardous conditions in these places, which can be detrimental to their health. Exposure to high temperatures and hazardous gas leaks from steel production additives or combustion operations are two of the most frequent risks in the metallurgical sector.

**2.1. Devices Used in the Entire System**

Node-MCU is an Elua-based firmware for ‘Espressif Systems' ESP8266 Wi-Fi SOC. The ESP-12 module is essential to the apparatus. The firmware is built on top of the ‘Espressif’ NON-OS SDK 2.1.0 and uses a spiffs-based file system. 98% of the code in the source repository is C code, which supports the SDK's thin Lua veneer. A model for asynchronous programming that is event-driven.

For the miners' convenience, the suggested solution uses a wearable gadget or an external intelligent clothing.

A coat is far more practical than the current constructions that use a cap, which may endanger the digger at the hour of short out and impact the frontal cortex. Coal mine shaft workers' pulse rates and temperatures are tracked using a temperature and heart rate sensor.

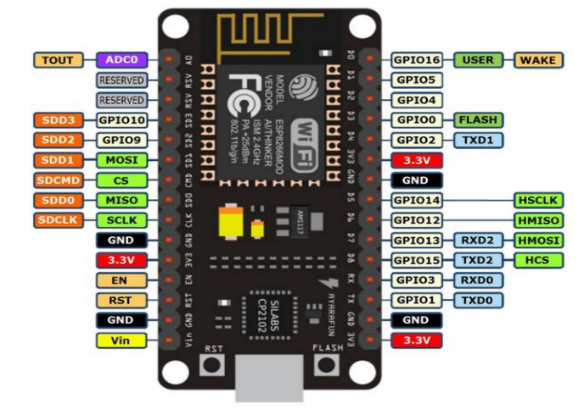


Fig. 1. ESP8266 datasheet

A gas sensor will detect the spill, and the Blynk application will use IOT to infer it. The flame sensor will detect the fire, and the sound sensor will notify the alert. GPS is used by coal mineshaft workers to pinpoint their location.

**2.2. Advantages**

* A wearable coat will protect the workers' safety and well-being.
* Blynk will be utilized to inform staff members about health concerns.
* GPS will be utilized to ascertain their whereabouts.

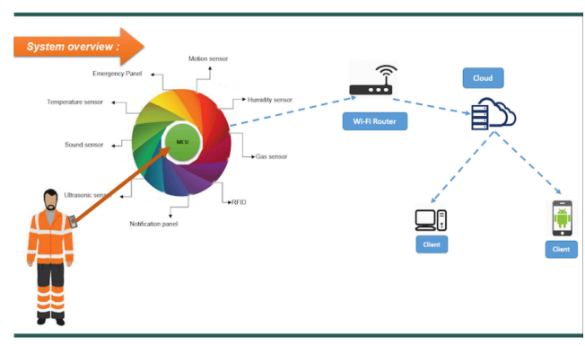


Fig. 2. System overview

**2.3. Working**

The temperature of an object or environment is estimated via a temperature sensor. Temperature sensors come in a variety of forms, including RTDs (obstruction temperature identification), thermistors, and thermocouples. These sensors detect changes in resistance or voltage in response to temperature variations. Using sound waves, an ultrasonic sensor calculates the distance between an item and the sensor. The sensor records the time it takes for a high-frequency sound wave to return after it has been released. This information can then be used to calculate the distance between the sensor and the item. An individual's heartbeat or pulse rate is measured via a pulse sensor. In order to identify the variations in blood volume brought on by the heartbeat, the sensor usually shines through the skin using a light source, such as an LED. A sound sensor measures the amount of sound in an area. Examples of several types of sound sensors include piezoelectric sensors and microphones. These sensors transform sound waves into electrical signals that may be measured and examined. Each sensor's operational system will depend on its specific design and use. Nonetheless, these sensors typically work by transforming variations in electrical or auditory signals into a quantifiable format that may be utilized for a number of parameter detection, monitoring, and control applications. To enable computerization, observation, and control in a wide range of applications, these sensors can be integrated into various frameworks and devices.

3. study two

The photoplethysmography principle serves as the foundation for the heartbeat sensor's measurement of the heart's rate. A blood pressure change (avascular area) occurs when the amount of blood flowing through an organ in the body varies due to a change in the intensity of light passing through that organ. When it comes to applications where heart rate monitoring is necessary to make sure that the pulses are delivered at the right time, it is more crucial than anything else. Because the blood absorbs light, the signal pulses are equal to the heart's beating rate, which in turn determines the volume of blood that is circulated.

Two categories can be used to group photoplethysmography: The detector picks up light emission from the light-emitting device when it passes through the avascular area of the body, like the earlobes. Reflection is the process by which light from a light source is reflected by the areas of the image. Centigrade temperature can be precisely determined with the LM35 temperature sensor. In this instance, the linearity of the sensor is determined by measuring the change in its output.

A diagram of a computer component

Description automatically generated

FIG. 3. IOT BASED MEDICAL MONITORING SYSTEM

Its output voltage is proportional to the Celsius temperature, and it is linearly proportional to the integrated circuit sensor's temperature. This gadget can function between -55 and +150 volts without overheating due to its wide operating voltage range and low self-heating temperature. This gadget can run on voltages between 4 and 30 volts, depending on the model. The electronic devices that are most commonly employed in daily life are operations amplifiers, also referred to as differential amplifiers. They belong to the differential amplifier category. One output pin on the temperature sensor circuit is not reversed. The operational amplifier IC741 is used to implement the non-inverting amplifier IC741.

A diagram of a circuit

Description automatically generated

Fig. 4. LM35 Circuit Diagram

**3.1. Working**

The output power of the chip increases by 10 mV when the temperature of I2C raises by one degree Celsius. This fluctuating voltage is applied to a comparator IC741, which is in charge of making comparisons. This is one of the most popular technological gadgets in the world right now. One example of a differential amplifier is the IC 741 operational amplifier, sometimes known as an op-amp. The IC741 non-inverting amplifier's input and output are connected to pin 3, and it's important to keep in mind that the output is not inverted when utilizing this device. The difference between the two input terminals is amplified by a factor of two in the LM35 temperature sensor circuit. Some benefits of using a temperature sensor include the following. As a result, it has no adverse effect on the medium and is more accurate, flexible, and sensitive to environmental changes—all of which it accomplishes almost instantly. An infusion pump is a medical device that helps patients receive prescribed drugs and nutrients in precise dosages into their bodies. Medication can be given in a number of ways both at home and in clinical settings like nursing homes and hospitals. You can regulate the rate and duration of fluid administration using the infusion pump's software interface if you have a skilled user. When it comes to fluid administration, infusion pumps perform better than manual administration. These developments enable, among other things, the delivery of fluids in small volumes at precisely regulated rates or at automated intervals. This kind of gadget can provide patients antibiotics, chemotherapeutic medications, painkillers, insulin, and other hormone treatments. Automated operation is made possible by the micro-controller. The representative receives an alert message if the intravenous fluid or gas level drops below a preset threshold.

4. study three

An Arduino microcontroller is used to identify and monitor the variables in a coal mine. Real-time readings are provided by the gas, temperature, humidity, and infrared flame sensors. A microcontroller and a transceiver connect them all together. The microcontroller receives the information, and the gateway and the specific node communicate via Xbee WPAN IEEE 802.15.4. As previously mentioned, the data is sent to the control room via the XBee protocol. When something is unusual, an alert message is sent to the system and shown on an LCD screen at the coalfield entrance that is connected to an Arduino. A buzzer is also programmed and controlled by Arduino, and it sounds when any unusual reading is picked up by the sensors above. A smart helmet is controlled by a microcontroller that is just connected to a push button. The microcontroller also includes a ZigBee transceiver. This step has been taken in order to guarantee the highest level of worker safety in the coalfield. Every time an employee touches a panic button, an emergency message detailing the worker's situation is transmitted to the control center, enabling prompt medical attention.

**4.1. System Description**

As seen in Fig. 5, this block design of a prototype integrates the sensors needed in a coalfield and is connected to a microprocessor to identify environmental factors. The Arduino Uno microcontroller was attached to the LM35 temperature sensor, DHT11 humidity sensor, MQ2 gas sensor, and an infrared flame sensor. The Arduino board has been configured so that any deviation from the previously stated parameters would trigger an alarm and sound the buzzer. The temperature, humidity, air density, and gasses present in the coalfield may all be continuously measured thanks to these sensors. An additional 16x2 LCD panel will display all of the readings. This LCD will be placed at the entrance to the coalfield so that employees can keep an eye on the circumstances there in real time and respond accordingly. Reliable and secure communication with the control room has been established using the ZigBee Protocol. To ensure that the right steps are taken quickly in an emergency, the XCTU software connects the X-Bee transmitter and receiver, which are used to send the coalfield's environmental characteristics. A block diagram, Fig. 6, is shown below. Another safety gadget is a smart helmet equipped with a buzzer, push button, and ZigBee transmitter. Any employee who feels uneasy or needs medical treatment at any time can press the emergency button to activate the bell and send a ZigBee emergency message to the control center.

**A diagram of a computer system

Description automatically generated**

Fig. 5. Block diagram of smart helmet

Three sensors—the DHT11, vibration, and ultrasonic sensors—are used here. The ATmega328P microcontroller is linked to all three of these sensors. After being received by the microcontroller, the data is transmitted to the monitored Firebase cloud and then received by the application. That data can be interpreted as a notification from the mine that utilizes the application. Inside the coal mine, the DHT11 Sensor measures the temperature and humidity and notifies the miners when the humidity range exceeds a certain threshold. By detecting the subsurface vibrations, a vibration sensor warns miners when landslides are imminent. An ultrasonic sensor inside the mine measures the distance to an object using ultrasonic sound waves.

A diagram of a firebase cloud

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Fig. 6. Architecture diagram

The DHT11, vibration, and ultrasonic sensors are all connected by the microcontroller. When something is strange, the Node MCU, which uses Wi-Fi to send the data to the fire-based cloud, notifies the miner. The microcontroller receives the information later, sounds an alert, and sends a warning message to the mine workers using the Blynk app.

**4.2. Working**

**4.2.1. IC voltage regulators**

One of the most commonly used ICs in the VA family is the voltage regulator. The regulator IC unit contains a single integrated circuit (IC) that houses the circuitry for the reference source, comparator amplifier, control device, and overload protection. IC devices can regulate a fixed positive voltage, a fixed negative voltage, or an adjustable set voltage. In terms of power ratings, the regulators can handle load currents ranging from hundreds of milliamperes to tens of amps, or milliwatts to tens of watts. The power supply unit is composed of the following units: A step-down transformer B. Unit of rectifier C. Input filter D. Unit of regulator E. Filter for the output.

5. results and discussion

**5.1. Study one**

**A person wearing a safety suit

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Fig. 7. Smart safety jacket with monitoring and communication features

The temperature, oxygen content, depth of the mine, and presence of dangerous gases are some of the variables that affect the health of those working in coal mineshafts. Many accidents involving this type of labor have already been documented. Salvage organizations spend a lot of time and money trying to remove the victim from the accident scene. To solve this issue, a system has been created. In addition to offering a GPS finder, exact location, and depth, it also tracks the miner's heart rate so that, should the need arise, it can deliver immediate, top-priority medical treatment.

**5.2. Study Two**

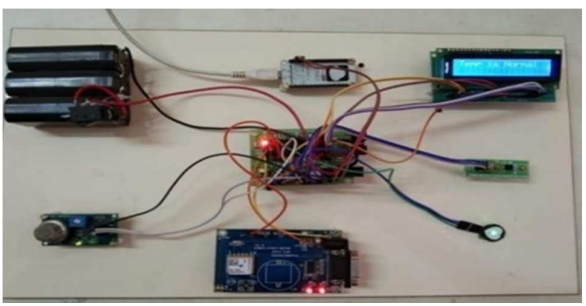
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Fig. 8. Hardware output: Temperature is normal

Figure 8 shows the hardware kit of the proposed system. Here, the Arduino controller process the data from the sensors and displays the output in the LCD display.

**5.3. Study Three**

The miner receives alert messages from several sensors via the Blynk app, and various beep sounds are produced for each sensor. The Blynk app allows you to view the automations, DataStream, events, and other sensor data.

6. Conclusion and Future Direction

To validate the effectiveness of our proposed real-time smart jacket, the literature survey incorporates insights from various studies that have evaluated similar approaches through simulations and real-world testing. These evaluations shed light on the benefits, challenges, and potential limitations of integrating advanced safety features into wearable technology. In conclusion, our proposal presents a novel approach that combines wearable personal safety technology with state-of-the-art technology in a seamless fashion. Our smart jacket improves user safety and situational awareness in a variety of scenarios by utilizing cloud computing and cutting-edge sensor technologies. With its real-time alerts and user support, this model is a major development in personal safety solutions. In the future, we want to achieve continuous progress through ongoing research and development activities, and we are dedicated to perfecting and putting our model into practice for real- world applications.

The smart wearable safety jacket may be expanded in the future by adding sensors to the Arduino board. Other sensors, such as an alcohol sensor or a heart rate monitor, can be utilized to confirm the worker's condition. A carbon monoxide and methane gas sensor can also be added to the mining site to monitor the environment. The pedestrian worker can be warned of the danger if a high concentration of dangerous gasses is found. To ensure safety, the worker may then follow the required protocols. Additionally, the jacket can be equipped with a wireless communication system, allowing the worker to quickly connect with the safety team.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

References

Balaji, M., Monika, S., Akshaya, N., Priya, R. S., & Swathi, A. (2023). Smart wearable safety jacket design for coal miners. International Research Journal of Engineering and Technology (IRJET), 10(5), 315. <https://www.irjet.net>

Ananth, C., Anitha, A., Revathi, B. S., & Kumar, T. A. (2022). Wearable smart jacket for coal miners using IoT. In 2022 2nd International Conference on Technological Advancements in Computational Sciences (ICTACS) (pp. 669–673). IEEE. <https://doi.org/10.1109/ICTACS55075.2022.9987834>

Chandrasekaran, M. K., Akshaya, R., Ashwini, U., Kamali, V., & Mohana Sakthi, G. S. (2023). Smart wearable safety jacket design for coal miners. International Journal of Progressive Research in Engineering Management and Science (IJPREMS), 3(5), 709–713. <https://doi.org/10.58257/IJPREMS31309>

Narasimha, E., Kishore, Y. S., & V. (2013). Smart helmet for coal miners using ZigBee technology. International Journal for Research in Science & Advanced Technologies (IJRSAT), March-April. <https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=32224876371e42aca89a17d58bd19eb50d7ad304>

Pandey, P., Jha, B. K., & Sinha, N. (2016). Analyzing cognitive states using fMRI data. Procedia Computer Science, 90, 35–41. <https://doi.org/10.1016/j.procs.2016.07.084>

Jubadi, W. M., & Sahak, S. F. A. M. (2009). Heartbeat monitoring alert via SMS. In 2009 IEEE Symposium on Industrial Electronics & Applications (Vol. 1, pp. 1–5). IEEE.

Bhagchandani, K., & Augustine, D. P. (2019). IoT-based heart monitoring and alerting system with cloud computing and managing the traffic for an ambulance in India. International Journal of Electrical and Computer Engineering, 9(6), 50–68.

Akash, M. R., & Shikder, K. (2020). IoT-based real-time health monitoring system. In 2020 Research, Innovation, Knowledge Management and Technology Application for Business Sustainability (INBUSH) (pp. 167–171). IEEE.

Sakhare, S. A., Kale, A. A., More, D. G., Kumkar, P. A., Mirase, J. M., & Sahu, U. S. (2023). Smart wearable safety jacket. International Journal of Advanced Research in Science, Communication and Technology (IJARSCT), 3(5), 8. <https://ijarsct.co.in/Paper9311.pdf>

Raj, S. B. S. (2024). Advancing safety standards with real-time embedded smart jacket. International Advanced Research Journal in Science, Engineering and Technology (IARJSET), 11(5). <https://iarjset.com/wp-content/uploads/2024/05/IARJSET.2024.11565.pdf>

Zakir, Z. N. (2021). Blind man jacket with health monitoring system. International Journal of Creative Research Thoughts (IJCRT), 9(7), 456–460. <https://www.ijcrt.org/papers/IJCRT24A5369.pdf>

Reddy, V. B. S. K., & Prasad, P. (2021). IoT based smart wearable jacket for safety applications. Materials Today: Proceedings, 46, 9624–9629. <https://doi.org/10.1016/j.matpr.2021.04.463>

Nguyen, D. P., Nguyen, D. H., & Nguyen, T. T. (2021). Real-time fall detection system using MPU6050 and ESP32. In 2021 International Conference on Advanced Computing and Applications (ACOMP) (pp. 89–94). IEEE. <https://doi.org/10.1109/ACOMP53629.2021.00021>

Lee, H., & Baek, K. (2021). Developing a smart multifunctional outdoor jacket with wearable sensing technology for user health and safety. *Multimedia Tools and Applications*, *80*(21), 32273-32310.

Suttitatee, P., Juntarapack, M., Khuntisiri, K., Tiacharoen, S., Juntamas, S., Sorakunakorn, P., & Kerdvibulvech, C. (2024). DAT Jacket: Design and Technology Development of Smart Jacket for Outdoor Motorcyclists. *Transactions of the Indian National Academy of Engineering*, *9*(4), 819-832.

Azhan, N. A., Hasbollah, A. A., Jalil, N. A., & Riyanti, M. T. (2024). Design and Evaluation of a Smart Jacket for Enhancing Safety in Individuals with Hearing Loss and Non-Verbal Impairments. *Politeknik & Kolej Komuniti Journal of Engineering and Technology*, *9*(2), 151-159.

De Fazio, R., Al-Hinnawi, A. R., De Vittorio, M., & Visconti, P. (2022). An energy-autonomous smart shirt employing wearable sensors for users’ safety and protection in hazardous workplaces. *Applied Sciences*, *12*(6), 2926.