bSafe: A Framework for Hazardous Situation Monitoring in Industries

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Abstract Industrial accidents such as chemical spills, fires, and explosions. Can have serious consequences, including injuries and fatalities, environmental damage, and economic losses. To prevent industrial accidents, it is important for industries to implement safety measures such as proper training for employees, regular maintenance of equipment, etc. Furthermore, the installation of emergency response systems is the need of the era to minimize the impact of any accidents that do occur. In this paper, an IoT-based hazardous situation monitoring framework is presented to monitor and detect toxic releases from chemical companies. The proposed system actively records, processes, and analyses the ambient temperature in areas where molten metal is handled and manufacturing is done. Additionally, it keeps an eye out for two dangerous gases i.e., LPG and natural gas. Every time a parameter is breached, a set of predetermined lists of users are immediately alerted, and the system continuously collects the data for further suggestions to modify the industry's safety rules. The sensors used in this prototype model can be altered as needed to accommodate industrial requirements.

Keywords IoT · Temperature · Toxic gases · Sensor · Hazardous

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1 Introduction

Industrial risks are becoming an increasingly serious concern to both people and the environment. Industrial accidents can be initiated by a range of causes such as human error, equipment failure, inadequate training, and unsafe working conditions [1]. To prevent industrial accidents, it is important for companies to implement safety measures such as proper training for employees, regular maintenance of equipment, and strict adherence to safety regulations [2]. Furthermore, the installation of emergency response systems is the need of the era to lessen the impact of any accidents that do occur. Additionally, it is important for having knowledge of different types of hazards present at the workplace. It is also important for workers to be aware of the hazards present in their workplaces and to follow safety protocols and procedures. This includes wearing protective equipment, following proper handling procedures for hazardous materials, and being aware of emergency exits and evacuation procedures [3]. By taking these precautions, individuals can help to reduce the risk of industrial accidents and protect themselves, their colleagues, and the surrounding environment.

Internet of Things (IoT) based solutions to monitor and detect toxic releases from chemical companies can be an effective way to prevent or mitigate the impact of these kinds of disasters [1, 3]. By continuously collecting and analyzing data from sensors and other devices, it is possible to identify potential hazards and take appropriate action to prevent or minimize the release of toxic substances [3]. A framework that utilizes IoT technology to monitor and report on toxic releases could be designed to include a variety of sensors and devices that are proficient of detecting and assessing the presence and concentration of hazardous materials [4, 5]. These devices could be connected to a central network and configured to transmit data in real-time to a database, where it could be analyzed and used to identify potential hazards and alert relevant authorities [4–6]. In this paper, an IoT-based monitoring platform tailored specifically to the needs of the mining, refining, and manufacturing industries is presented in which the temperature of the environment is actively recorded, processed, and analyzed by the system. Temperature is a key safety factor in locations where molten metal is treated, manufacturing is done, or welds are formed. It also keeps an eye on the high levels of dangerous gases (LPG/Natural Gas) that are present in the air. The system continues to gather and monitor data for further analysis in order to suggest modifications s in the industry's safety standards if a parameter is exceeded, issuing an instant alert if a parameter is violated to a group of users on their cellphones from pre-determined lists of *s* people.

The work presented in this paper is structured as: The background study and some of the related systems are discussed in Sect. 2. The design of the proposed prototype is presented in Sect. 3. The various results obtained during the development of the prototype are discussed in Sect. 4. The work is concluded in Sect. 5.

2 Background

Industrial hazards refer to the potential dangers that can occur in a workplace or during the production of goods or services. These hazards can come in many forms, including physical, chemical, biological, and ergonomic hazards. Some examples of common industrial hazards include [1]:

- Physical hazards: These include physical injury or harm from equipment, machinery, or other objects in the workplace.
- Chemical hazards: These include harm from exposure to chemicals in the workplace such as chemical spills, toxic fumes, etc.
- Biological hazards: These refer to harm from exposure to biological agents in the workplace, such as bacteria, viruses, or fungi.
- Ergonomic hazards: These include harm from repetitive movements or poor posture while working such as carpal tunnel syndrome, back strain, or other musculoskeletal disorders.

It is important for employers to identify and mitigate these hazards in order to ensure the safety and health of their employees. This can involve things like training employees on safety procedures, implementing safety protocols and procedures etc. [7, 8].

The Internet of Things (IoT) is a network of physical items, including machines, cars, buildings, and other things, that have connectivity, software, and sensors to collect and exchange data [9]. By enabling new types of automation, efficiency, and convenience, the IoT has the potential to completely transform several industries [10–12]. Some common examples of IoT applications include smart homes, which allow homeowners to control and monitor their home's security, lighting, and temperature remotely through a smartphone or other device [3, 8, 10, 11]. IoT might dramatically increase safety and lower the likelihood of industrial disasters by enabling real-time monitoring and control of equipment and processes, and by providing early warning of potential hazards. One way that the IoT can improve safety in industrial settings is by enabling the remote monitoring and control of equipment and processes [13]. They can be used to monitor environmental conditions in industrial settings, such as temperature, humidity, and air quality [2, 4]. Sensors and other IoT-enabled devices can be used to gather data on the performance and condition of equipment, alerting operators to potential problems or malfunctions that could lead to accidents or other hazards [14–16]. In addition to monitoring equipment and environmental conditions, the IoT can be used to track a worker's whereabouts and mobility in real-time [17–19]. This can be particularly useful in industries with hazardous working conditions, such as construction, mining, and oil and gas exploration, where workers may be exposed to risks such as falls, machinery accidents, and other hazards. By tracking worker movements, supervisors can quickly respond to potential accidents or other emergencies, and can also use the data to identify and address potential safety issues [20].

Motivated by the popularity of IIoT [10], this paper presents the use of IoT to actively monitor and analyze various factors in the typical heavy industrial zone like temperature and levels of gases in the environment. If the above parameters exceed the recommended safe values, the system can track the same and issue alerts. Also, the data generated in real time can provide information about how smoothly the work is going on in different zones.

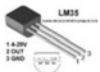
3 System Requirements

The proposed system is built using open-source hardware and software platforms, which aligns with current software development trends and the principles of Industry 4.0. This means that the system is designed to be flexible and adaptable, allowing it to be customized and modified as needed to meet the specific needs of different users. Various hardware and software components to develop the system are explained below.

3.1 Hardware Requirements

Different hardware used for the development of proposed prototype are listed in Table 1 and explained below.

Table 1 Hardware requirements

Product	Image
Arduino	
Temperature sensor	
Gas sensor	
Humidity sensor	
Power supply	

Microcontroller ATmega328 serves as the foundation for Arduino UNO. It is a component of the Arduino platform, an open-source platform for developing microelectronics projects. The Arduino UNO contains a 16 MHz crystal oscillator, 6 analogue inputs, 14 digital input/output pins, a USB port, a power jack, an ICSP header, and a reset button. It is programmed with the use of the user-friendly software tool known as the Arduino Integrated Development Environment (IDE), which enables users to write and upload code to the Arduino UNO. In comparison to other microcontroller boards on the market, it is widely offered from online retailers and electronics stores for a reasonable price. Overall, the Arduino UNO is a popular and versatile choice for a wide range of electronic projects.

The temperature sensor LM35 is popular and utilized in many different applications. Since it is a linear temperature sensor, the relationship between its output voltage and temperature is clear. The LM35 has a temperature range of – 55–150 °C with a room-temperature precision of 1 °C. It is relatively easy to use, as it requires only a single supply voltage and has a simple linear output. The LM35 can be used to measure temperature in a variety of environments, including air, water, and other liquids.

One sort of sensor used to identify the presence of specific gases in the atmosphere is the MQ-6 gas sensor. It is commonly used to detect the presence of flammable gases, such as propane, butane, and methane, as well as other gases such as carbon monoxide and hydrogen. The MQ-6 gas sensor works by using a chemical reaction to detect the presence of gases. When a gas comes into contact with the sensor, it reacts with the chemicals on the surface of the sensor, causing a change in the electrical resistance of the sensor which is used to determine the concentration of the gas in the air.

A common temperature and humidity sensor is the DHT11 sensor. It is a digital sensor that can be easily connected to a microcontroller or computer through a digital input/output (I/O) pin. The DHT11 sensor consists of a humidity sensing element and a thermistor (a temperature-sensitive resistor).

A high-accuracy digital barometric pressure and temperature sensor called the BMP180 can be used to measure atmospheric pressure and temperature. It uses I2C protocol to communicate with microcontrollers like Arduino. The BMP180 sensor is a low-power, high-precision sensor that can measure atmospheric pressure and temperature. The sensor can measure pressure with an accuracy of ± 1 hPa and temperature with an accuracy of ± 1 °C.

KY037 sound sensor is a type of microphone sensor that detects sound waves and converts them into electrical signals. The KY037 sound sensor is a small, low-cost module that can detect sound levels in the range of 48–66 dB. The sensor module consists of a small microphone and an amplifier circuit. The output of the sensor is an analog signal that can be delivered by a microcontroller, such as Arduino. The sensor operates on a supply voltage of 3.3–5 V.

There are several ways to power an Arduino microcontroller board. The most common method is to use a USB connection to a computer or external power supply. The Arduino board can also be powered through a barrel jack or VIN pin, which allows to use a DC power supply or a battery as the power source. The USB connection provides a stable 5 V power supply to the Arduino board, which is sufficient for most systems.

3.2 Software Requirements

To develop the proposed prototype, an open source platform "ThingsBoard" is used to perform collection, visualization and processing of data. A robust and adaptable IoT platform, ThingsBoard offers a variety of features and tools for creating and managing IoT applications. Various features of ThingsBoard includes:

- Device management: ThingsBoard provides a web-based user interface for managing IoT devices and their configurations. It supports various communication protocols, such as MQTT, CoAP, and HTTP.
- Data collection and processing: The platform can collect and process data from various sources, including sensors, devices, and external systems
- Visualization and dashboarding: ThingsBoard provides a customizable dashboarding system that allows users to create and manage custom dashboards and visualizations.
- Security: The platform provides various security features, including user authentication and authorization, data encryption, and access control.
- Integration and interoperability: ThingsBoard provides APIs and connectors for integrating with various external systems and platforms, such as cloud services and databases.
- Scalability and performance: The platform is designed to be scalable and can handle large amounts of data and devices.
- Open-source and community-driven: ThingsBoard is an open-source project with an active community of developers and users.

A lightweight publish/subscribe messaging protocol called MQTT Protocol (Message Queuing Telemetry Transport) was created for Internet of Things (IoT) and M2M (machine-to-machine) communication. Publishers transmit messages to a broker using the publish/subscribe messaging mechanism used by MQTT, and subscribers receive those messages from the broker. This model allows for asynchronous and decoupled communication between devices. It provides three levels of QoS, which allows the sender to ensure that a message is delivered at least once, exactly once, or multiple times. MQTT is a widely used messaging protocol for IoT and M2M communication, due to its lightweight, efficient, and reliable nature.

Web Sockets are a protocol that enables real-time, bidirectional communication between a client and a server over a single TCP (Transmission Control Protocol) connection. It is made to give web applications with real-time updates with low-latency, high-performance connectivity. Web Sockets provides a persistent connection between the client and server, allowing for real-time, bidirectional communication. It provides low-latency communication, as it eliminates the need for the overhead of HTTP requests and responses.

Firebase Firestore is a cloud-based NoSQL document database provided by Google. It is designed to store and synchronize data between multiple clients and the cloud with real-time updates. Firestore is part of the Firebase suite of products, which provides a comprehensive backend infrastructure for building web and mobile applications. Because Firestore offers real-time updates, any database modifications are instantly synchronized between clients and the cloud. It is highly scalable and can handle large amounts of data and high traffic loads.

4 System Design and Implementation

The proposed workplace monitoring prototype "bSafe" is designed on Arduino, which can be deployed in workplace to make the workplace more protected and work friendly. This prototype is completely independent and not a part of any larger system. The connection of various hardware components is presented in Fig. 1.

4.1 Designing Approach

The step by step approach of the designing of proposed prototype is explained below.

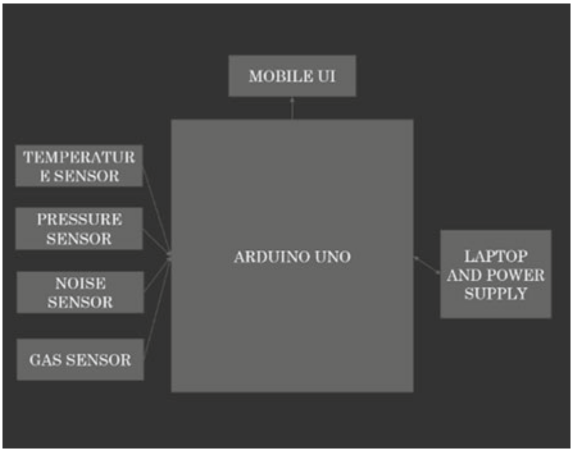


Fig. 1 System design

- Hardware setup: Connecting the sensors to the Arduino board and make sure everything is properly wired and powered.
- Installing necessary libraries: Installation of required libraries for the sensors (e.g. DHT11, MQ2, BMP180, LM393) and for paho.mqtt and ThingsBoard communication.
- Data Serialization: Serialization of data is done before publishing it to ThingsBoard or any other IoT platform because most IoT platforms accept data in a specific format, and that format is usually JSON. Serializing data into JSON format also makes it easier to parse and analyze the data later on.
- Arduino Coding: Developing the code in python to read data from the sensors and publish the sensor data to ThingsBoard using MQTT. This will involve setting up the MQTT client, connecting to the broker, publishing the sensor data, and handling any errors or exceptions that may arise.
- Configure ThingsBoard: Creating a dashboard on ThingsBoard to visualize the sensor data and configure the rules engine to trigger alarms when hazardous conditions are detected.
- Secure the system: To prevent unauthorized access to the system, use JWT tokens for authentication and web sockets for secure communication between the Arduino board and ThingsBoard.
- Sending data to Firebase: Using Web Socket(API) data fetching is done in the local system from the things board and after it parses the JSON data and sends it to the firebase firestore database.
- Fetching The Data in Mobile UI: When Data is Available on Firebase then make visualize it on app using firebase config.
- System Testing: To ensure that whether all sensors are working properly, testing of system is performed by publishing the data to ThingsBoard.

4.2 Working of System

Smartphone is used as a visualization medium for the proposed system, which utilizes the data from the firebase connection over the Internet. The provided user interface may deal with the real-time presentation of the device's filtered data. All data is recorded in a cloud-hosted database called firebase real-time database.

When a device connects to a cellular/Wi-Fi network, data is stored as JSON and instantly synchronized to all connected clients. A smartphone's sensors were used as the second set of sensors. The several networked sensors offer real-time measurements. When the parameters cross the threshold value or approach the threshold value, it indicating a dangerous state marked it as an emergency situation by generating alarm to the user. Various threshold values used in the proposed prototype are presented in Fig. 2. Various steps followed during the working of the proposed prototype are listed below and presented in Fig. 3.

Fig. 2 Threshold values for different parameters

Parameter	Thresholds value
Temperature	20°-23°C (normal) >24°C (threshold)
Smoke	<300 (cool environment) >300tpm (gas detected)
Light	<=10000 (light is on) >10000 (light is off)
Fire	<100 (fire detected) >100 (no fire)
Humidity	40-50% (normal) <40 & >50% (threshold)

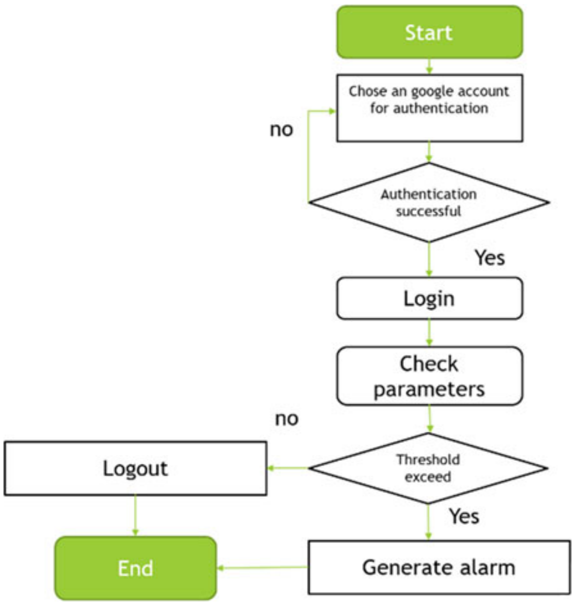


Fig. 3 Flow chart of the proposed hazardous activity detection system

Steps
Start
Connect the sensors using Arduino with PC or Laptop
Function to choose a google account for authentication
Function to see the values of the parameters in Application
Function to check if the parameter exceeds the threshold value or not
Function to Sign out
Exit

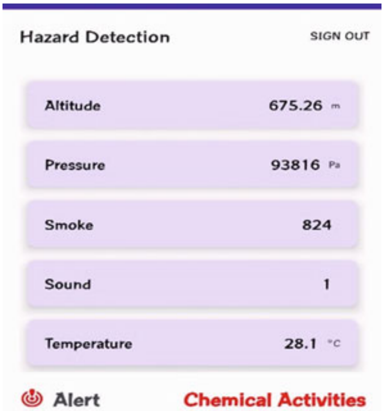


Fig. 4 Notification for hazardous activity

The threshold values indicate the acceptable range of values for each parameter under normal conditions. If the values for any of these parameters exceed the threshold value, it may indicate an abnormal or dangerous condition that requires immediate attention or corrective action. For example, if the temperature exceeds 24 °C, it may indicate that the air conditioning system is not functioning properly, and corrective measures should be taken to avoid overheating. The successful detection of hazardous situations is presented in Fig. 4.

5 Conclusion

The effort presented in this paper is focused on the development of an automated system for monitoring and controlling various industrial parameters, such as temperature, gas, fire, and humidity. The goal of this system is to reduce the manual overhead required for monitoring industrial situations, which was previously done using CCTV cameras. The work presented here shows that the proposed measurement system is highly cost-effective compared to other solutions in the market and is less time-intensive to implement. The proposed prototype has the potential to improve the efficiency and safety of industrial processes, while also being more affordable and easier to implement than other existing solutions.

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