Autonomous Risk and Hazard Management System for Smart Cities

Arivukkarasan Raja and E. Pavithra

Abstract A smart city is a well-planned, self-sustainable urban area which is capable of managing its own resource and assets intelligently and efficiently with the help of the data derived out of various sensing elements. A hazard can be defined as an external or internal agent, which has some unrealized ability to cause harm. Some of the identified potential hazards in industrial and residential environment include, but not limited to, air quality, air temperature, humidity, noise levels, vibration, radiation, fire, electric short circuit, water leakage, etc. In the context of smart cities, the management of these potential hazards is very important in both industrial and residential environments to assure superior quality of living, reduce the cost of health care and for improving the morale, productivity, and job satisfaction of the employees. The proposed risk and hazard management system includes multiple sensors, which are programmed to receive data like carbon monoxide, formaldehyde, lead, nitrogen dioxide, butane, LPG, and radon levels in real-time. The end-users can visualize the data through Internet of things (IoT) open-source platform. The services for device integrations are done through Embedded C, loaded in Teensy 3.2. Similarly, the services for data validations, intelligent actions, and the data storage, display using Python, loaded in Raspberry Pi3 Model B+. The remedial or control actions like automated door, exhaust fan, and solenoid valve operations are carried out based on real-time data analysis using artificial intelligence.

Keywords Smart home · IoT · Teensy 3.2 · Air quality

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1 Introduction

Safety will be valid only if any individual or society in-charge takes a lead role in handling hazard and safety mechanism. Many industrial establishments have proven the benefits of safety and hazard management. A good hazard and safety compliance process or system can avoid injuries among employees and reduce the number of accidents within the industrial environment. It can greatly reduce the number of hours spent on manufacturing process, thus can improve the financial growth of an organization [1].

A hazard is just a disorder or a set of conditions that leads to a possible destruction. We can classify hazards into two groups like hazards which can cause occupational illness and hazards which can cause physical injuries.

The key principle of health and safety compliance is the prerequisite for a methodical risk and hazard management process, which can categorize the probable and definite causes of harm. Only by when the risks and vulnerabilities are documented, the corresponding departments are able to put preventive mechanisms [1] in place to avoid harm. The significant hazards in an industrial or residential environment are air quality, noise, vibration, radiation, fire, temperature, and humidity.

Why hazard, health, and safety management system are important? [2]

- To have a fewer injuries among workforce
- To reduce the health care/insurance costs
- To improve the employees' morale
- To increase the productivity and job satisfaction.

2 Objective

Indoor and outdoor contaminants in both residential and industrial properties can be a significant environmental health problem. Numerous health issues have been linked with occupant exposure to several toxic and hazardous substances [3]. The overall objective of this exploration is to prepare an IoT-based smart hazard management, health and safety compliance system. The following areas have been focused on this project.

- To identify the possible environmental hazards
- To assess the risks which can be possible outcome of hazards
- To manage the risks to avoid further damage due to hazards
- To monitor the control methods for continuous improvement.

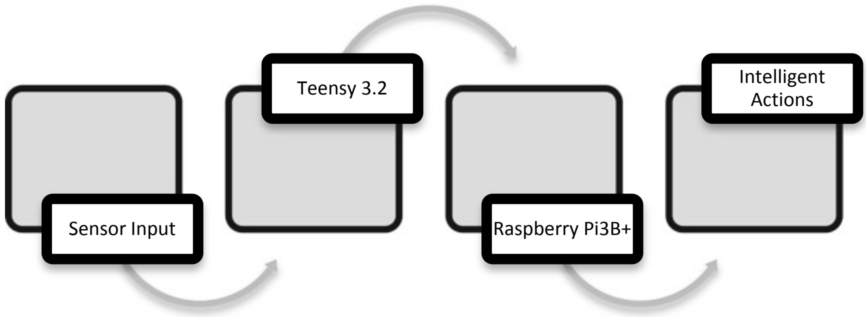

Fig. 1 Flow diagram

3 Methodology

Several sensors are inter connected to gather carbon monoxide, formaldehyde, lead, butane, nitrogen dioxide, radon levels in real time, then the collected data is displayed through an open-source UI platform. The services for device and controller integration are written in Embedded C and the services for UI integration are written in Python, Raspberry Pi3 Model B+ is acting as a secondary controller. MySQL database is used to store the historical data [1] (based on the explorer's request). The hierarchical representation of sensor architecture is mentioned in Fig. 1.

The identified potential hazards are in our industrial/residential environment as a part of this exploration are air quality, air temperature, humidity, noise levels, vibration, radiation, fire, electric short circuit, and water leakage.

4 Work Plan

Table 1 consist of various sources of hazard along with the health issues associated with each hazardous environment. The remedial actions also suggested ***if the density of hazardous gases are more than the limit prescribed by the National Air Quality Safety Bereau*** as per Table 2. The remedial actions are going to be triggered mechanically through AI. The state of affairs is reverted based on the conventional values.

5 Technical Architecture

Based on the request triggered through the Web interface [4], the hazard management, health and safety compliance data will be stored in a MySQL database. The frequency of data storage will be purely depending on the Web interface configuration done by

Table 1 Health issues and remedial actions

Source of hazard	Health issues	Remedial actions
Carbon monoxide	High density of carbon monoxide will stop the body from obtaining oxygen. Also causes nausea, associated with headache and dizziness, sleepiness, weakness of entire body. In general, high density of carbon monoxide will cause loss of consciousness, brain damage which leads to death [3]	Doors and windows will be opened through a stepper motor interface and the gas connection will be turned off through a smart solenoid valve. Exhaust fan will also be switched ON
Formaldehyde	Since it is classified as carcinogen, long-term exposure may lead to respiratory issues, eczema and nasopharyngeal cancer. The short-term exposure may lead to skin and eye irritation. The general symptoms of formaldehyde exposure include, watery eyes, coughing, chest spasm, wheezing, burning sensation, throat infection and head ache [3]	Doors and windows will be opened through a stepper motor interface. Exhaust fan will be switched ON
Lead	The short-term exposure to lead can affect the children with behavioural problems and learning disabilities. The prolonged exposure to lead may lead to serious issues like anaemia, constipation, abdominal pain, tingling in the hands and/or feet, nervous system damage and impaired brain. Further to this, exposure to high levels of lead causes weakening of kidney and nervous system. Finally, the continuous exposure to lead may cause death	Doors and windows will be opened through a stepper motor interface. Exhaust fan and air filter will be switched ON
Butane	Butane in liquid kind will cause severe cold burns to the skin because of its speedy vaporization. Butane as liquefied petroleum gas forms an inflammable mixture with air in concentrations of between a pair of and 100%. It can, therefore, be a hearth and explosion hazard if keep or used incorrectly [3]	Gas connection will be turned off through a smart solenoid valve. Doors and windows will be opened through a stepper motor interface and the exhaust fan will be switched ON

(continued)

Table 1 (continued)

Source of hazard	Health issues	Remedial actions
Nitrogen dioxide	In general, it causes respiratory issues. Short-term exposure to nitrogen dioxide may cause bronchitis, flu, wheezing and coughing. The long-term exposure to nitrogen dioxide may reduce the immunity drastically, thus causes severe lung infections. The nitrogen dioxide used to form as a particulate matter, which is the main cause for allergies	Doors and windows will be opened through a stepper motor interface and the gas connection will be turned off through a smart solenoid valve
Radon	Since radon is an inert gas, will get exhaled immediately after breathing. But it will form as an aerosol along with other dust particles and reduce the inhalation capacity. Hence, the radon inhalation may lead to chest pain, pneumonia, rigorous cough and difficulty in breathing	Doors and windows will be opened through a stepper motor interface. Exhaust fan will be switched ON

Table 2 National air quality data

Parameters to be measured	Unit	Limit
Carbon monoxide	mg/M^3	≤ 04
Formaldehyde	mg/M^3	≤ 0.1
Lead	PPM	≤ 400
Butane	mg/M^3	≤ 05
Nitrogen dioxide	mg/M^3	≤ 55
Radon	pCi/L	≤ 04

the administrator. The stored data can be exported in a form of reports, as in when required. The historical data can be compared with the current one to do the trend analysis.

As shown in Fig. 2, the component architecture of proposed model consists of carbon monoxide, formaldehyde, lead, nitrogen dioxide, butane and radon sensor. The analogue to digital conversion is taken care of by Teensy 3.2, the data storage is being handled by MySQL database, and L298N is the motor driver used as an interface between controller and the stepper motor. The technical details of the components used for this exploration are listed in Table 3,

The smoke sensor MQ2 used in this exploration for detecting butane uses SnO_2 as a semiconducting material. The higher exposure to liquefied petroleum components like CH_4 and Butane, the resistance of the semiconducting material will increase. Hence, it affects the flow of output voltage. The concentration of liquefied petroleum components in air is directly proportional to output voltage. With the help of iterative

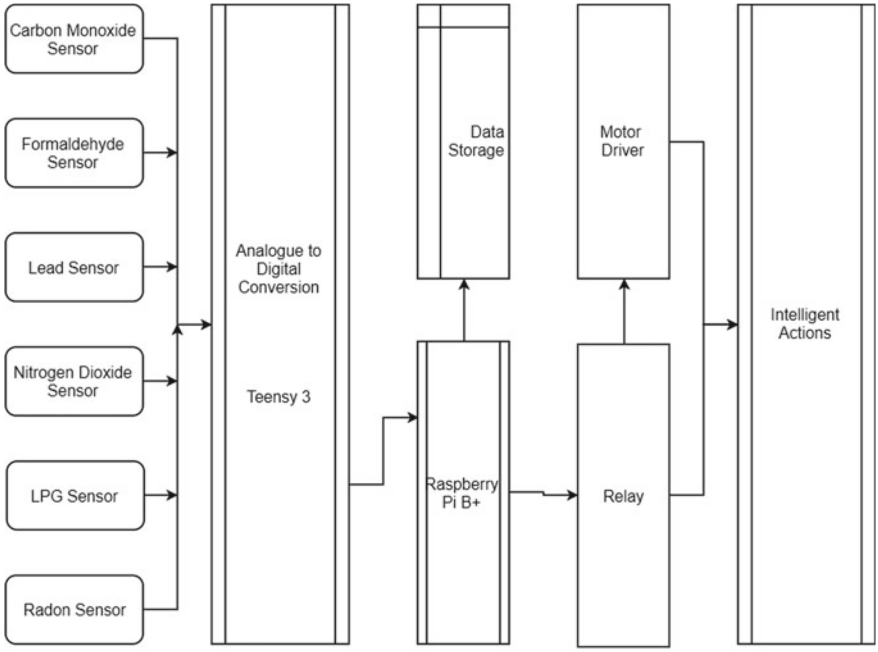

Fig. 2 Architecture diagram

Table 3 Product details

Component description	Product details
Processor	Raspberry Pi3 Model B+
Data storage	MySQL community edition
Web interface	Open-source IoT development platform
Device interface	Embedded C
Driver	L298N
Drive	Gear mechanism
Analogue to digital conversion	Teensy 3.2
Sensors	MQ7 for carbon monoxide MQ 138 for formaldehyde MQ3 for lead MQ2 for butane MQ131 for nitrogen dioxide MQ135 for radon

calibration, the nearest match of liquefied petroleum components concentration value will be arrived. Similarly, for the other MQ family of sensors MQ4, MQ7, MQ135 use combination of ceramic and SnO_2 as a semiconducting material. In some cases, the ceramic SnO_2 leads are connected through nickel–chromium pins at the outer core, which enables quick eating and accurate sensing.

L298N is a dual bridge driver which is capable of connecting two motors. The speed and direction also can be controlled for two motors simultaneously. The voltage range for this driver is between 5 and 35 V. The peak current can be up to 2 A. The driver consists of two output sockets for connecting two motors concurrently. In addition to that, it contains a jumper for voltage regulation, power source and ground. The integrated circuit available in the board uses only 2 V for operation.

The Teensy 3.2 controller consists of 32-bit ARM processor, 64 k inbuilt memory, 256 K flash memory, 21 analogue and 34 digital input/output pin and a USB connectivity. It can be programmed using Embedded C. The voltage requirement for this controller is 3.3 V. The current requirement is 100 mA. All digital pins of Teensy 3.2 are having tolerance limit up to 5 V for interoperability.

6 Working Principle

Teensy 3.2 controller is used for analogue to digital conversion and device integration. It is programmed using Embedded C. The relevant sensors are connected to the circuit and the circuit is connected with power supply. Once the power supply is switched on, the sensors will take a few seconds for heating up. The delay for heating up is already been configured through our programming. Once the sensor senses any deflection in voltage, it will be sent to the controller in an analogue format. Then the sensing variable output of the sensors is converted into digital format and sent to Raspberry Pi3 Model B+ for further processing. In Raspberry Pi3 Model B+, through PHP services, the sensor variables are stored in a MySQL database. The stored data will also be displayed in the Web page through an open-source IoT platform. The program for analysing the sensor digital values is written in Python. Based on the Python services, the intelligent remedial actions will be carried out based on Python and Embedded C programs.

7 Results and Analysis

When the circuit is switched on, then all associated sensors sense and transmit the data to the controller board. The delay is useful for the sensors which take longer time to respond. The analogue signals are converted into digital format through the controller itself and sent to Raspberry Pi3 Model B+. Then, the variables data of carbon monoxide, formaldehyde, lead, butane, nitrogen dioxide, radon are stored in a structured MySQL database. Once the data is stored, then, the intelligent actions were triggered based on the data reference value given in the programming. If the value of butane is more than 5 mg/M^3, the door and windows were opened through a stepper motor interface and Gas connection was turned off through a smart solenoid valve. If the concentration of Lead is more than 400 PPM in side our premises, the door and windows were closed through a stepper motor interface and the air filter, exhaust fan were switched on. Similarly, for the other sensor variables, the intelligent actions were taken place with respect to the limiting factors.

Figure 3 displays the value of radon gas stored in the Web page/database over the analysis period in a structured manner for our easy reference. The data stored in the database can be accessed at any time and the historical data comparison can be carried out.

Figure 4 displays the level of formaldehyde in the testing premises area at any given moment. The data displayed here will also be available in the database for future

Fig. 3 Radon-level graphical representation

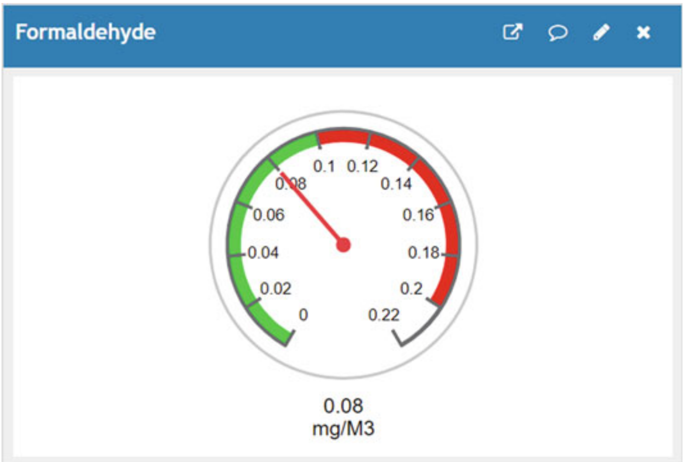

Fig. 4 Formaldehyde-level graphical representation

reference. The warning levels are highlighted in red colour, after which the scope for triggering intelligent actions will be initiated. The normal values are highlighted in green.

Figure 5 displays the value of nitrogen dioxide stored in the Web page/database over the period of time from October–December 2018 in a structured manner for our easy reference. The data stored in the database can be retrieved and displayed in the Web page for our comparative studies.

Figure 6 displays the level of carbon monoxide inside our testing premises at any moment. The data displayed here will also be available in the database for future reference. The display method can be easily configured in our Web page through a user interface. For example, the display widget can be of a dial or graph or number display, etc.

Figure 7 displays the level of lead inside our testing premises at any moment. The data displayed here will also be available in the database for future reference. The values are configured using an open-source IoT platform which is available on Internet as well. Hence, the data can be accessed in a real-time manner across the globe.

Figure 8 displays the warning light sign for the liquefied petroleum gas concen-

Fig. 5 Nitrogen dioxide-level graphical representation

Fig. 6 Carbon monoxide-level graphical representation

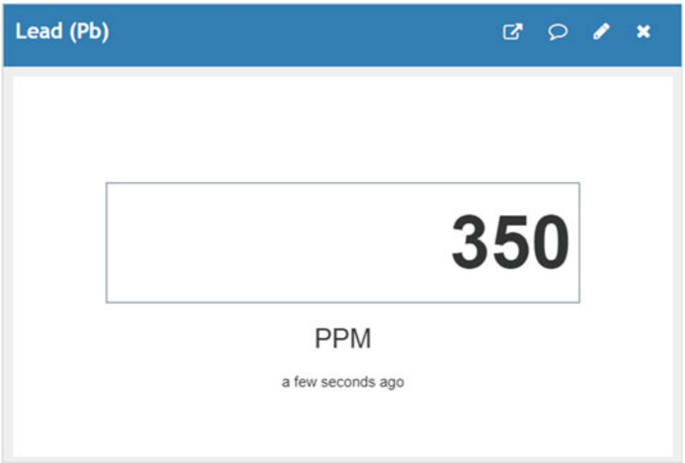

Fig. 7 Lead-level graphical representation

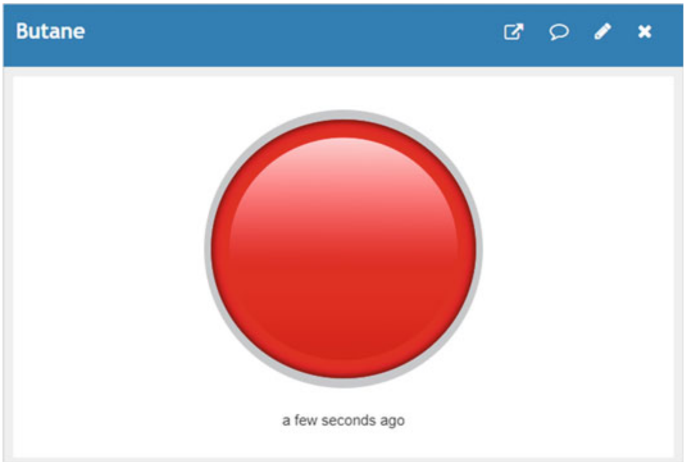

Fig. 8 Butane-level graphical representation

tration in a particular testing area. Along with the warning sign, the actual data will also be captured in the database for our future reference with easy accessibility.

8 Conclusion

In a smart city, Indoor contaminants in both residential and industrial possessions can be a substantial environmental health problem. Various health issues have been linked with occupant's exposure to various toxic and hazardous substances. With the help of interlinked sensors, the carbon monoxide, sulphur, ammonia, butane, propane, temperature and relative humidity levels are identified in real-time basis, then the collected data is available for fellow students and researchers through an open-source user interface platform. The historical data is available for the indented audience through a MySQL database. The remedial actions for each hazard are taken with the help of artificial intelligence.

Here are the benefits because of the intelligent remedial actions triggered by our exploration [5],

- The number of injuries among employees is reduced
- Health care/insurance costs for the organizations are reduced
- Employees morale has improved is an intangible benefit
- Productivity and job satisfaction are increased, and it is a win-win situation for employees and the organization [6].

For future enhancements and research, with the help of the same platform, additional potential hazards can be added as a measurement parameter. The same apparatus can be used to conduct the experiment in multiple locations and record the hazard management, health and safety compliance data is a centralized manner, which enables the historical data comparison. The intelligent remedial actions for the newly identified hazards can also be added. The same circuit can be fabricated using different controllers based on future invention and the programming languages can also have based on future trends and cutting edge technologies.

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