L-LEAKAGE DETECTION AND PREVENTION OF ITS THREATS USING IoT IN SMART HOME AUTOMATION SYSTEMS

A PROJECT REPORT

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BONAFIDE CERTIFICATE

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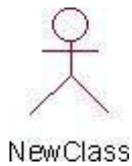
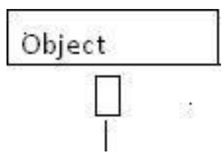
ABSTRACT

These days gas spillage and gas identification is a significant issue in our day by day lives. Additionally gas wastage is a significant issue that should be countered. LPG gas is exceptionally combustible and can dispense harm to life and property. To maintain a strategic distance from such circumstances, a extensive measure of exertion has been given to the improvement of dependable systems for recognizing gas spillage. As thinking about the presence of a break isn't in every case enough to dispatch a remedial action, some of the break location procedures were intended to permit the chance of finding the hole. Our point is to decrease the dangers in Kitchen utilizing Internet of Things. The primary point is to propose the structure and development of a wi-fi based Gas Leakage Alert System. Gas sensor are utilized to distinguish gas spillages in a kitchen with the assistance of the controller ARDUINO MEGA (ATmega2560), with the assistance of an infrared sensor the issue of gas wastage is additionally observed. A caution goes off at whatever point the sensor doesn't distinguish any vessel over the burner past a specific timespan.

LIST OF SYMBOLS

S.NO	SYMBOL NAME	NOTATION	DESCRIPTION
1.	Initial Activity		This shows the Starting point or first activity of flow.
2.	Final Activity		The end of the Activity diagram is shown by a bull's eye symbol.
3.	Activity		Represented by a rectangle with rounded edges.
4.	Decision		A logic where a decision is to be made.
5.	Use Case		Describe the interaction between a user and a system.
6.	Actor		A role that a user plays with respect to system.
7.	Object		A Real time Entity.
8.	Message		To send message between the life of an object.

LIST OF FIGURES

LIST OF ABBRIVATIONS

S. No	Abbreviation	Expansion
1	IR	Infra Red
2	LED	Light Emitting Diode
3	LCD	Liquid crystal display
4	IoT	Internet of Things
5	GPS	Global Positioning System
6	GSM	Global System for Mobile commnication
7	GSI	Global Standards Initiative
8	LPG	Liquified Petrolium Gas
9	DC	Direct Current
10	IDE	Integrated Development Environment
11	RTOS	Real Time Operating System
12	USB	Universal Serial Bus
13	AC	Alternating Current
14	EEPROM	Electrically Erasable programmable Read-Only Memory
15	IO	Input and Output

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION TO INTERNET OF THINGS

The internet of things (IoT) is the network of physical devices, vehicles, buildings and other items embedded with electronics, software, sensors, actuators, and network connectivity that enable these objects to collect and exchange data. In 2013 the Global Standards Initiative on Internet of Things (IoT-GSI) defined the IoT as "the infrastructure of the information society. The IoT allows objects to be sensed and controlled remotely across existing network infrastructure, creating opportunities for more direct integration of the physical world into computer-based systems, and resulting in improved efficiency, accuracy and economic benefit. When IoT is augmented with sensors and actuators, the technology becomes an instance of the more general class of cyber-physical systems, which also encompasses technologies such as smart grids, smart homes, intelligent transportation and smart cities. Each thing is uniquely identifiable through its embedded computing system but is able to interoperate within the existing Internet infrastructure. Experts estimate that the IoT will consist of almost 50 billion objects by 2020.

1.2 OVERVIEW OF PROJECT

The LPG gas is highly ignitable and can inflict damage to life and property. The main aim is to construct the wireless fidelity based Gas outflow Alert System. Gas detector area units won't notice gas leakages in an exceedingly room with the assistance of the controller ARDUINO MEGA (ATmega2560), when the gas leakage detected the evacuation starts. At the moment any fire exists in the surrounding the servo motor generates the fire extinguisher and this action clear the chance of an accident situation. The entire system function can be displayed in the LCD display and can be controlled by the IoT. These data can be stored in the cloud. With the help of an IR sensor detector the problem of gas wastage is additionally monitored. An alarm explodes whenever the detector doesn’t notice any vessel over the burner on the far side for a selected period of time.

1.3 PROJECT SCOPE

Product reviews are valuable for upcomming buyers in helping them make decision to the end different opinion. Techniques have been prepard where judging a review orientation is one of this key challenge. Recently, IoT has emerge as an effective means for solving the problem .

IoT evolves a useful representation automatically without human efforts. However the success of IoT relies on the availability of the storage of large scale of data and automation of the system. We propose a framework for the leakage of the gas. The framework consist

- Find the gas leakage and prevention of its threats
- All the datas are stored in the cloud.

1.4 SOFTWARE QUALITY ATTRIBUTES

Functionality: are the required functions available, including Interoperability and security

Reliability: maturity, fault tolerance and recoverability.

Usability: how easy it is to understand, learn and operate the software system.

Efficiency: performance and resource behavior.

Maintainability: how easy it is to modify the software.

Portability: can the software easily be transferred to another environment, including install ability.

1.5 OBJECTIVE OF THE PROJECT

The main aim is to propose the design and construction of a wi-fi based Gas Leakage Alert System and to reduce the risks in Kitchen using Internet of Things. This system can be operated automatically along with the alarm system.

CHAPTER 2

LITERATURE SURVEY

1. Luay Fraiwan, Khaldon Lweesy, Aya Bani-Salma proposed the paper, A wireless safety device for gas leakage detection is proposed. The device is intended for use in household safety where appliances and heaters that use natural gas and liquid petroleum gas (LPG) may be a source of risk. The system also can be used for other applications in the industry or plants that depend on LPG and natural gas in their operations. The system design consists of two main modules: the detection and transmission module, and the receiving module. The detection and transmitting module detects the change of gas concentration using a special sensing circuit built for this purpose. This module checks if a change in concentration of gas(es) has exceeded a certain pre-determined threshold. If the sensor detects a change in gas concentration, it activates and audiovisual alarm and sends a signal to the receiver module. The receiver module acts as a mobile alarm device to allow the mobility within the house premises. The system was tested using LPG and the alarm was activated as a result of change in concentration.**published in 978-1-4244-7000-6/11/$26.00 ©2011 IEEE**

2. T.Soundarya, J.V. Anchitaalagammai, G. Deepa Priya, S.S. Karthick kumar proposed that Home Fires have taken a growing toll in lives and property in recent years. LPG is highly inflammable and can burn even at some distance from the source of leakage. Most fire accidents are caused because of a poor-quality rubber tube or when the regulator is not turned off. The supply of gas from the regulator to the burner is on even after the regulator is switched off. By accident, if the knob is turned on results in the gas leaks. This paper deals with the detection, monitoring and control system of LPG leakage. Using relay DC motor the stove knob is automatically controlled. Along with safety measures the system has additional advantage of automatic rebooking of cylinder when the level of gas goes below the normal weight of cylinder. **IOSR Journal of Electronics and Communication Engineering (IOSR-JECE) e-ISSN: 2278-2834,p- ISSN: 2278-8735.Volume 9, Issue 1, Ver. VI (Feb. 2014), PP 53-58 www.iosrjournals.org**

3. Ganesh D, Anilet Bala.A , describes In the large petrochemical industry, one of the most concerning problem is the leakage of toxic gas. To solve this problem, it is necessary to locate the leak points and feed the possible location of leak points back to rescuers. Although some researchers have previously presented several methods to locate leak points, they ignored the impact of external factors, such as wind, and internal factors, such as the internal pressure of equipment, on the accurate detection of leak points. Thus here we are using the gas sensor which placed in the leak points, which senses the concentration value of toxic gases such as carbon mono-oxide and it imitates to the mobile device when the concentration value exceeds the normal value. The signal given to the PIC microcontroller which intimates the mobile device through zigbee communication module. This article proposes context-aware system architecture for leak point detection in the large scale petrochemical industry. This architecture is a new scheme for accurate leak point detection, which is more consistent with practical application in the large scale petrochemical industry. **© 2015 IJEDR | Volume 3, Issue 2 | ISSN: 2321-9939**

4. Lei Shu, Mithun Mukherjee,Xiaoling Xu, Kun Wang, XiaolingWu, have shown Gas leakage source detection and boundary tracking of continuous objects have received a significant research attention in the academic as well as the industries due to the loss and damage caused by toxic gas leakage in large-scale petrochemical plants. With the advance and rapid adoption of wireless sensor networks (WSNs) in the last decades, source localization and boundary estimation have became the priority of research works. In addition, an accurate boundary estimation is a critical issue due to the fast movement, changing shape, and invisibility of the gas leakage compared to the other single object detections. We present various gas diffusion models used in the literature that offer the effective computational approaches to measure the gas concentrations in the large-area. In this survey, we compare the continuous object localization and boundary detection schemes with respect to complexity, energy consumption, and estimation accuracy. Moreover, this survey presents the research directions for existing and future gas leakage source localization andboundary estimation schemes with WSNs. **This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/ACCESS.2016.2550033, IEEE Access**

5. Anindya Nag, Asif Iqbal Zia, Xie Li, Subhas Chandra Mukhopadhyay, proposed that Gas sensing technology has been among the topical research work for quite some time. This paper showcases the research done on the detection mechanism of leakage of domestic cooking gas at ambient conditions. Micro-electro mechanical systems-based interdigital sensors were fabricated on oxidized single-crystal silicon surfaces by the maskless photolithography technique. The electrochemical impedance analysis of these sensors was done to detect liquefied petroleum gas (LPG) with and without coated particles of tin oxide (SnO2) in form of a thin layer. A thin film of SnO2 was spin-coated on the sensing surface of the interdigital sensor to induce selectivity to LPG that consists of a 60/40 mixture of propane and butane, respectively. This paper reports a novel strategy for gas detection under ambient temperature and humidity conditions. The response time of the coated sensor was encouraging and own a promising potential to the development of a complete efficient gas sensing system.**IEEE SENSORS JOURNAL, VOL. 16, NO. 4, FEBRUARY 15, 2016**

6. E. Jebamalar Leavline, D. Asir Antony Gnana Singh, B. Abinaya,H. Deepika, developed Home fires have been taking place frequently and the threat to human lives and properties is growing in recent years. Liquid petroleum gas (LPG) is highly inflammable and can burn even at some distance from the source of leakage. Most fire accidents are caused because of a poor-quality rubber tube or the regulator is not turned off when not in use. Therefore, developing the gas leakage alert system is very essential. Hence, this paper presents a gas leakage alert system to detect the gas leakage and to alarm the people onboard. **International Journal of Electronics Engineering Research. ISSN 0975-6450 Volume 9, Number 7 (2017) pp. 1095-1097 © Research India Publications**

7. Ania Mukherjee and Ambarish Paul, organized and described There has been a growing need for portable gas detection device for gas leakage monitoring. Here, we report the developmentof dielectric breakdown-assistedionization (DBAI)-based on-chip gas sensor (GSEN) and temperature sensor (TSEN), which were integrated to serve as leakage gas (L-gas) identification and detection device.The TSEN with single microtip architecture provides high temperature sensitivity but renders itself chemically inert toward different L-gases. The GSEN with an array of microtips imparts high chemical specificity toward different L-gases together with high temperature sensitivity. High chemical and thermal responsiveness of GSEN make it suitable for the chemical identification of different L-gases in air through the temperature-driven DBAI process. The TSEN plays the role of the temperature monitor. The chemical recognizability of the integrated device for different Lgases was demonstrated using Ar, O2, and CO2 as L-gases in air. This chemical recognizability of GSEN for different L-gases was imparted through their characteristic molecular polarizability, resulting in different rates of DBAI and hence the output current. The device finds the application for the detection of a wide variety of ionizable L-gases. **IEEE TRANSACTIONS ON ELECTRON DEVICES, VOL. 65, NO. 11, NOVEMBER 2018**

8. Ravi Kishore Kodali, Greeshma, R.N.V., Kusuma Priya Nimmanapalli, Yatish Krishna Yogi Borra proposed that, Most of the fire-breakouts in industries are due to gas leaks. These cause dreadful damage to the equipment, human life leading to injuries, deaths, and environment. Currently available leakage detectors warn the people around using on-site alarms. So, this project proposes a leakage detector which sends the warning to the concerned people through SMS. This detector senses the presence of harmful gases particularly, LPG, Methane and Benzene. LPG and Methane gases catch fire easily resulting in blasts. Benzene is carcinogen effecting the health of workers, if inhaled in higher concentrations. Hence, detection of these gases is essential. This low cost project includes MQ6, MQ4 and MQ135 gas sensors which detect LPG, Methane and Benzene gas leaks respectively and uses ESP-32 as a Wi-Fi module. The concentration levels of the above mentioned gases are uploaded in the UBIDOTS cloud and the login details are included in the alert message so that the user can check, if needed. The prototype of the proposed system generates a sound alert using buzzer on detection of a dangerous leakage and sends an SMS to the concerned person using IFTTT web service. Different colour LEDS are used to specify the gas leaked for example, RED LED indicates the presence of LPG.
978-1-5386-6947-1/18/$31.00 ©2018 IEEE

9. Manaswi Sharma, Diksha Tripathi, Narendra Pratap Yadav, Parth Rastogi developed that, For the sake of lives safety and fulfillment of social duties, and keeping in focus the life-threatening instances of blasts and injuries due to leakage of gas in industries, vehicles and houses, a gas leakage system has been designed whereby application of embedded systems and involvement of Internet of things (IoT) in it, a system is obtained that enables us not only to notify the concerned person but also seize any leakage of gas. In the paper, a system has been proposed which lessen the chances of accidents and ensure safety by the virtue of existing electronics and technology. **International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 05 Issue: 02 | Feb-2018 www.irjet.net p-ISSN: 2395-0072**

10. Lei Shuyz, Yuanfang Cheny, Zhihong Suny, Fei Tongx, Mithun Mukherjeey proposed that, Petrochemical accidents, e.g., toxic gas leaking and explosion, result in serious damage, so the detection and visualization of the dangerous area of leaking toxic gases is an important research issue for large-scale petrochemical plants. There have been many efforts made to address this issue by using a large number of special monitoring devices. These special devices provide the gas concentration reports within their individual ranges. However, because of the continuity of gas diffusion and the invisibility of toxic gases, it is difficult to detect and visualize the continuous dangerous area of gas diffusion by only using the scattered concentration reports. This paper proposes a scheme to detect and visualize the dangerous area using Wireless Sensor Networks (WSNs). In this proposed scheme, a planarization algorithm is used to planarize a WSN, and based on the planarized network, the boundary area of gas diffusion is calculated to delimitate the dangerous area. This study also verifies the robustness of the proposed scheme in regards to the node failure. The node failure has a special kind of influence on the accuracy of dangerous area detection. This paper also analyses the impact of 5 planarization algorithms on the accuracy of dangerous area detection. **This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/TETC.2017.2700358, IEEE Transactions on Emerging Topics in Computing**

CHAPTER 3

SYSTEM ANALYSIS

3.1 EXISTING SYSTEM

In the existing system humans have to monitor the safety status of the gas manually. So it is difficult to check the safety parameters as well as no alarm system also.The property of gas sensor to detect LPG and Natural gas sense at the low level.The system automatically close the knob after it detect the gas leakage .

DISADVANTAGES:

- Leakage status of gas unknown until manual detection.
- Not possible to take Necessary action to avoid accident immediately.

3.2 PROPOSED SYSTEM

In the proposed system we can monitor as well as control safety status of the gas. The safety status of gas is up to date and the necessary action to be taken along with an alarm via data are controlled by IOT.

ADVANTAGES:

- The system can be operated automatically along with an alarm system.
- Necessary action to be taken to avoid the accident.
- All the data fetch from the controller has updated to cloud so that the owner can be monitor as well control along with notification message send.

3.3 REQUIREMENT ANALYSIS

The requirements specification is a technical specification of requirements for the software products. It is the first step in the requirements analysis process it lists the requirements of a particular software system including functional, performance and security requirements. The requirements also provide usage scenarios from a user, an operational and an administrative perspective. The purpose of software requirements specification is to provide a detailed overview of the software project, its parameters and goals. This describes the project target audience and its user interface, hardware and software requirements. It defines how the client, team and audience see the project and its functionality.

3.3.1 HARDWARE REQUIREMENTS

The hardware requirements may serve as the basis for a contract for the implementation of the system and should therefore be a complete and consistent specification of the whole system.

- ARDUINO MEGA
- IOT MODULE
- LCD MODULE
- GAS SENSOR
- HUMIDITY SENSOR
- FIRE SENSOR
- LED LIGHT
- DC FAN
- SERVO MOTOR
- RELAY(2)

3.3.2 SOFTWARE REQUIREMENTS

The software requirements are the specification of the system. It should include both a definition and a specification of requirements. It is a set of what the system should do rather than how it should do it. The software requirements provide a basis for creating the software requirements specification.

- EMBEDDED C
- ARDUINO IDE

CHAPTER 4

SOFTWARE AND HARDWARE DESCRIPTION

4.1 SOFTWARE DESCRIPTION:

4.1.1 INTRODUCTION TO ARDUINO (IDE)

The Arduino Integrated Development Environment - or Arduino Software (IDE) - contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino and Genuino hardware to upload programs and communicate with them.

4.1.2 WRITING SKETCHES:

Programs written using Arduino Software (IDE) are called sketches. These sketches are written in the text editor and are saved with the file extension .ino. The editor has features for cutting/pasting and for searching/replacing text. The message area gives feedback while saving and exporting and also displays errors. The console displays text output by the Arduino Software (IDE), including complete error messages and other information. The bottom right hand corner of the window displays the configured board and serial port. The toolbar buttons allow you to verify and upload programs, create, open, and save sketches, and open the serial monitor.NB: Versions of the Arduino Software (IDE) prior to 1.0 saved sketches with the extension .pde. It is possible to open these files with version 1.0, you will be prompted to save the sketch with the .ino extension on save.

4.1.3 COMMANDS:

Additional commands are found within the five menus: File, Edit, Sketch, Tools, and help. The menus are context sensitive, which means only those items relevant to the work currently being carried out are available.

4.1.4 EMBEDDED C:

Embedded C is most popular programming language in software field for developing electronic gadgets. Each processor used in electronic system is associated with embedded software.Embedded C programming plays a key role in performing specific function by the processor. In day-to-day life we used many electronic devices such as mobile phone, washing machine, digital camera, etc.

These all device working is based on microcontroller that are programmed by embedded C.The Embedded C code written in above block diagram is used for blinking the LED connected with Port0 of microcontroller.In embedded system programming C code is preferred over other language. Due to the following reasons:

- Easy to understand
- High Reliability
- Portability
- Scalability

BASIC EMBEDDED C PROGRAMMING STEPS:

Let's see the block diagram representation of Embedded C Programming Steps:

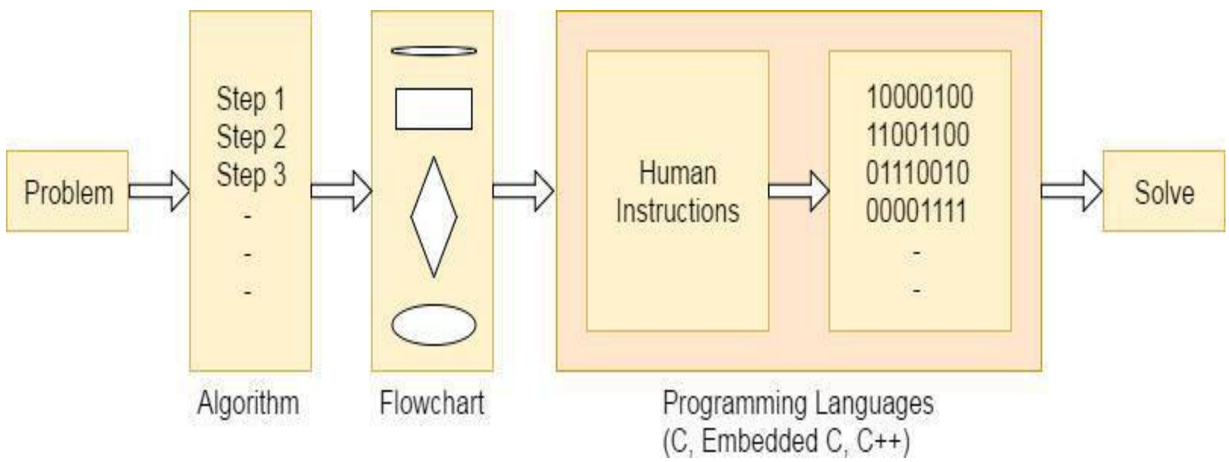


Fig 4.1: Basic embedded c programming steps

The microcontroller programming is different for each type of operating system. Even though there are many operating system are exist such as Windows, Linux, RTOS, etc but RTOS has several advantage for embedded system development.

4.1.5 EMBEDDED SYSTEMS:

Embedded System is a system composed of hardware, application software and real time operating system. It can be small independent system or large combinational system.

Our Embedded System tutorial includes all topics of Embedded System such as characteristics, designing, processors, microcontrollers, tools, addressing modes, assembly language, interrupts, embedded c programming, led blinking, serial communication, lcd programming, keyboard programming, project implementation etc.

4.1.6 EMBEDDED SYSTEM TOOLS AND PERIPHERALS:

COMPILER:

Compiler is used for converting the source code from a high-level programming language to a low-level programming language. It converts the code written in high level programming language into assembly or machine code. The main reason for conversion is to develop an executable program.

Let's see the operations performed by compiler are:

- Code generation
- Code optimization
- Parsing
- Syntax direct translation
- Preprocessing

CROSS-COMPILER:

If a program compiled is run on a computer having different operating system and hardware configuration than the computer system on which a compiler compiled the program, that compiler is known as cross-compiler.

DECOMPILER:

A tool used for translating a program from a low-level language to high-level language is called a decompiler. It is used for conversion of assembly or machine code to high-level programming language.

ASSEMBLER:

Assembler is embedded system tool used for translating a computer instruction written in assembly language into a pattern of bits which is used by the computer processor for performing its basic operations. Assembler creates an object code by translating assembly language instruction into set of mnemonics for representing each low-level machine operation.

4.1.7 LIBRARIES:

Libraries provide extra functionality for use in sketches, e.g. working with hardware or manipulating data. To use a library in a sketch, select it from the **Sketch > Import Library** menu. This will insert one or more **#include** statements at the top of the sketch and compile the library with your sketch. Because libraries are uploaded to the board with your sketch, they increase the amount of space it takes up. If a sketch no longer needs a library, simply delete its **#include** statements from the top of your code.

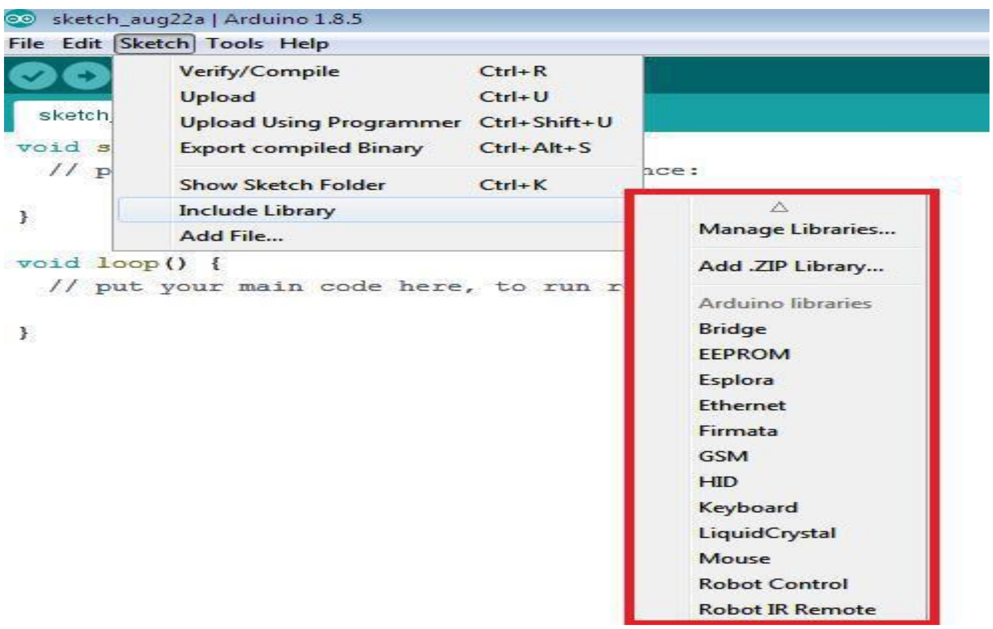


Fig 4.2:libraries

There is a list of libraries in the reference. Some libraries are included with the Arduino software. Others can be downloaded from a variety of sources or through the Library Manager. Starting with version 1.0.5 of the IDE, you do can import a library from a zip file and use it in an open sketch. See these instructions for installing a third-party library

4.2 HARDWARE DESCRIPTION:

4.2.1 ARDUINO MICRO-CONTROLLER

Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online. You can tell your board what to do by sending a set of instructions to the microcontroller on the board.Over the years Arduino has been the brain of thousands of projects, from everyday objects to complex scientific instruments. A worldwide community of makers - students, hobbyists, artists, programmers, and professionals - has gathered around this open-source platform, their contributions have added up to an incredible amount of accessible knowledge that can be of great help to novices and experts alike.

Arduino was born at the Ivrea Interaction Design Institute as an easy tool for fast prototyping, aimed at students without a background in electronics and programming. As soon as it reached a wider community, the Arduino board started changing to adapt to new needs and challenges, differentiating its offer from simple 8-bit boards to products for IoT applications, wearable, 3D printing, and embedded environments. All Arduino boards are completely open-source, empowering users to build them independently and eventually adapt them to their particular needs. The software, too, is open-source, and it is growing through the contributions of users worldwide.

4.2.2 POWER:

The Mega 2560 can be powered via the USB connection or with an external power supply. The power source is selected automatically.External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) .

The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the GND and Vin pin headers of the POWER connector.The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may become unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

4.2.3 MEMORY:

The ATmega2560 has 256 KB of flash memory for storing code (of which 8 KB is used for the bootloader), 8 KB of SRAM and 4 KB of EEPROM (which can be read and written with the EEPROM library).

4.2.4 INPUT AND OUTPUT:

Below is the pin mapping for the Atmega2560. The chip used in Arduino 2560. There are pin mappings to Atmega8 and Atmega 168/328 as well.

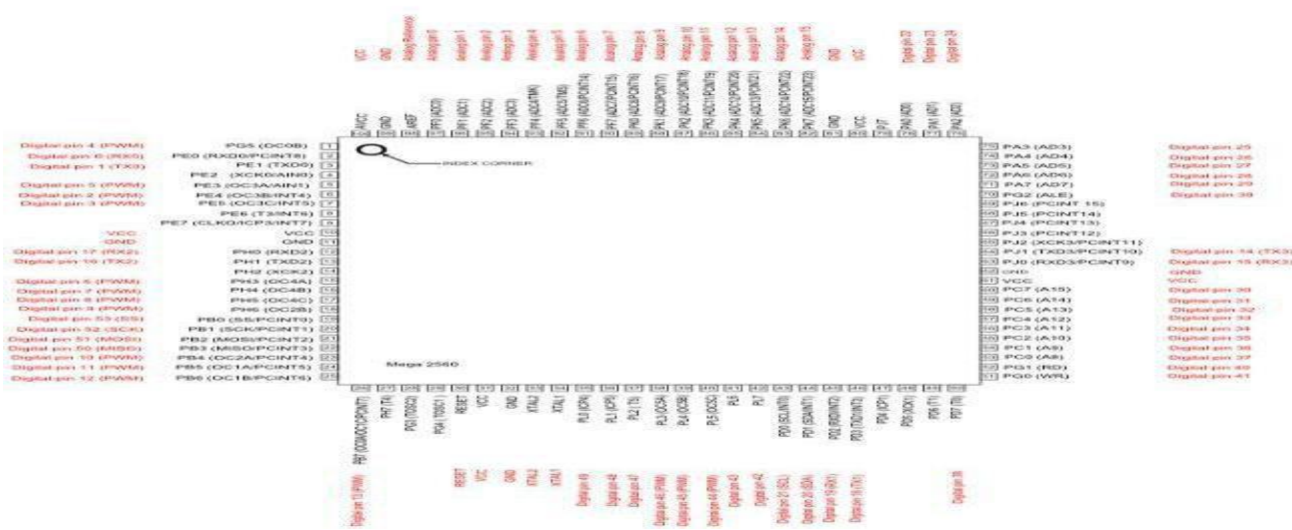


Fig 4.3: Arduino Mega 2560 PIN mapping table

Pin Number	Pin Name	Mapped Pin Name
1	PG5 (OC0B)	Digital pin 4 (PWM)
2	PE0 (RXD0/PCINT8)	Digital pin 0 (RX0)
3	PE1 (TXD0)	Digital pin 1 (TX0)

4	PE2 (XCK0/AIN0)	
5	PE3 (OC3A/AIN1)	Digital pin 5 (PWM)
6	PE4 (OC3B/INT4)	Digital pin 2 (PWM)
7	PE5 (OC3C/INT5)	Digital pin 3 (PWM)
8	PE6 (T3/INT6)	
9	PE7 (CLKO/ICP3/INT7)	
10	VCC	VCC
11	GND	GND
12	PH0 (RXD2)	Digital pin 17 (RX2)
13	PH1 (TXD2)	Digital pin 16 (TX2)
14	PH2 (XCK2)	
15	PH3 (OC4A)	Digital pin 6 (PWM)
16	PH4 (OC4B)	Digital pin 7 (PWM)
17	PH5 (OC4C)	Digital pin 8 (PWM)
18	PH6 (OC2B)	Digital pin 9 (PWM)
19	PB0 (SS/PCINT0)	Digital pin 53 (SS)
20	PB1 (SCK/PCINT1)	Digital pin 52 (SCK)
21	PB2 (MOSI/PCINT2)	Digital pin 51 (MOSI)
22	PB3 (MISO/PCINT3)	Digital pin 50 (MISO)
23	PB4 (OC2A/PCINT4)	Digital pin 10 (PWM)
24	PB5 (OC1A/PCINT5)	Digital pin 11 (PWM)
25	PB6 (OC1B/PCINT6)	Digital pin 12 (PWM)
26	PB7 (OC0A/OC1C/PCINT7)	Digital pin 13 (PWM)
27	PH7(T4)	
28	PG3 (TOSC2)	
29	PG4 (TOSC1)	
30	RESET	RESET
31	VCC	VCC
32	GND	GND
33	XTAL2	XTAL2
34	XTAL1	XTAL1
35	PL0 (ICP4)	Digital pin 49
36	PL1 (ICP5)	Digital pin 48
37	PL2(T5)	Digital pin 47

38	PL3 (OC5A)	Digital pin 46 (PWM)
39	PL4 (OC5B)	Digital pin 45 (PWM)
40	PL5 (OC5C)	Digital pin 44 (PWM)
41	PL6	Digital pin 43
42	PL7	Digital pin 42
43	PD0 (SCL/INT0)	Digital pin 21 (SCL)
44	PD1 (SDA/INT1)	Digital pin 20 (SDA)
45	PD2 (RXDI/INT2)	Digital pin 19 (RX1)
46	PD3 (TXD1/INT3)	Digital pin 18 (TX1)
47	PD4 (ICP1)	
48	PD5 (XCK1)	
49	PD6(T1)	
50	PD7(T0)	Digital pin 38
51	PG0(WR)	Digital pin 41
52	PG1(RD)	Digital pin 40
53	PC0(A8)	Digital pin 37
54	PC1(A9)	Digital pin 36
55	PC2 (A10)	Digital pin 35
56	PC3 (A11)	Digital pin 34
57	PC4 (A12)	Digital pin 33
58	PC5 (A13)	Digital pin 32
59	PC6 (A14)	Digital pin 31
60	PC7 (A15)	Digital pin 30
61	VCC	VCC
62	GND	GND
63	PJ0 (RXD3/PCINT9)	Digital pin 15 (RX3)
64	PJ1 (TXD3/PCINT10)	Digital pin 14 (TX3)
65	PJ2 (XCK3/PCINT11)	
66	PJ3 (PCINT12)	
67	PJ4 (PCINT13)	
68	PJ5 (PCINT14)	
69	PJ6 (PCINT 15)	
70	PG2 (ALE)	Digital pin 39
71	PA7 (AD7)	Digital pin 29

72	PA6 (AD6)	Digital pin 28
73	PA5 (AD5)	Digital pin 27
74	PA4 (AD4)	Digital pin 26
75	PA3 (AD3)	Digital pin 25
76	PA2 (AD2)	Digital pin 24
77	PA1 (AD1)	Digital pin 23
78	PA0 (AD0)	Digital pin 22
79	PJ7	
80	VCC	VCC
81	GND	GND
82	PK7 (ADC15/PCINT23)	Analog pin 15
83	PK6 (ADC14/PCINT22)	Analog pin 14
84	PK5 (ADC13/PCINT21)	Analog pin 13
85	PK4 (ADC12/PCINT20)	Analog pin 12
86	PK3 (ADC11/PCINT19)	Analog pin 11
87	PK2 (ADC10/PCINT18)	Analog pin 10
88	PK1 (ADC9/PCINT17)	Analog pin 9
89	PK0 (ADC8/PCINT16)	Analog pin 8
90	PF7 (ADC7)	Analog pin 7
91	PF6 (ADC6)	Analog pin 6
92	PF5 (ADC5/TMS)	Analog pin 5
93	PF4 (ADC4/TMK)	Analog pin 4
94	PF3 (ADC3)	Analog pin 3
95	PF2 (ADC2)	Analog pin 2
96	PF1 (ADC1)	Analog pin 1
97	PF0 (ADC0)	Analog pin 0
98	AREF	Analog Reference
99	GND	GND
100	AVCC	VCC

Each of the 54 digital pins on the Mega can be used as an input or output, using pinMode(), digitalWrite(), and digitalRead() functions.

They operate at 5 volts. Each pin can provide or receive 20 mA as recommended operating condition and has an internal pull-up resistor (disconnected by default) of 20-50 k ohm. A maximum of 40mA is the value that must not be exceeded to avoid permanent damage to the microcontroller.

4.2.5 INTERNET OF THINGS MODULE:

The **internet of things** (**IoT**) is the network of physical devices, vehicles, buildings and other items embedded with electronics, software, sensors, actuators, and network connectivity that enable these objects to collect and exchange data. In 2013 the Global Standards Initiative on Internet of Things (IoT-GSI) defined the IoT as "the infrastructure of the information society. The IoT allows objects to be sensed and controlled remotely across existing network infrastructure, creating opportunities for more direct integration of the physical world into computer-based systems, and resulting in improved efficiency, accuracy and economic benefit. When IoT is augmented with sensors and actuators, the technology becomes an instance of the more general class of cyber-physical systems, which also encompasses technologies such as smart grids, smart homes, intelligent transportation and smart cities. Each thing is uniquely identifiable through its embedded computing system but is able to interoperate within the existing Internet infrastructure. Experts estimate that the IoT will consist of almost 50 billion objects by 2020.

4.2.6 ESP-12E BASED NODEMCU

The ESP8266 is the name of a micro controller designed by Espressif Systems. The ESP8266 itself is a self-contained Wi-Fi networking solution offering as a bridge from existing micro controller to Wi-Fi and is also capable of running self-contained applications. This module comes with a built in USB connector and a rich assortment of pin-outs. With a micro USB cable, you can connect NodeMCU devkit to your laptop and flash it without any trouble, just like Arduino. It is also immediately breadboard friendly.

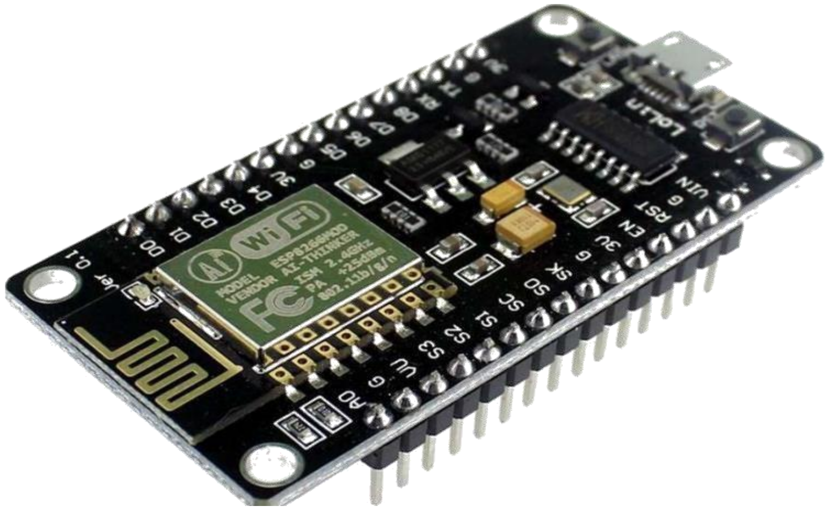


Fig 4.4: Esp-12e based nodemcu

ESP-12E Wi-Fi module is developed by Ai-thinker Team. core processor ESP8266 in smaller sizes of the module encapsulates Tensilica L106 integrates industry-leading ultra-low power 32-bit MCU micro, with the 16-bit short mode, Clock speed support 80 MHz, 160 MHz, supports the RTOS, integrated Wi-Fi MAC/BB/RF/PA/LNA, on-board antenna. The module supports standard IEEE802.11 b/g/n agreement, complete TCP/IP protocol stack. Users can use the add modules to an existing device networking, or building a separate network controller. ESP8266 is high integration wireless SOCs, designed for space and power constrained mobile platform designers. It provides unsurpassed ability to embed Wi-Fi capabilities within other systems, or to function as a standalone application, with the lowest cost, and minimal space requirement.

ESP8266EX offers a complete and self-contained Wi-Fi networking solution; it can be used to host the application or to offload Wi-Fi networking functions from another application processor. When ESP8266EX hosts the application, it boots up directly from an external flash. In has integrated cache to improve the performance of the system in such applications. Alternately, serving as a Wi-Fi adapter, wireless internet access can be added to any micro controller based design with simple connectivity (SPI/SDIO or I2C/UART interface). ESP8266EX is among the most integrated Wi-Fi chip in the industry; it integrates the antenna switches, RF balun, power amplifier, low noise receive amplifier, filters, power management modules, it requires minimal external circuitry, and the entire solution, including front-end module, is designed to occupy minimal PCB area.

4.2.7 LIQUID CRYSTAL DISPLAY:

LCD screen is an electronic display module and find a wide range of applications. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits. These modules are preferred over seven segments and other multi segment LEDs. The reasons being: LCDs are economical; easily programmable; have no limitation of displaying special & even custom characters (unlike in seven segments), animations and so on.

A **16x2 LCD** means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. This LCD has two registers, namely, Command and Data. The command register stores the command instructions given to the LCD. A command is an instruction given to LCD to do a predefined task like initializing it, clearing its screen, setting the cursor position, controlling display etc. The data register stores the data to be displayed on the LCD. The data is the ASCII value of the character to be displayed on the LCD. Click to learn more about internal structure of a LCD.

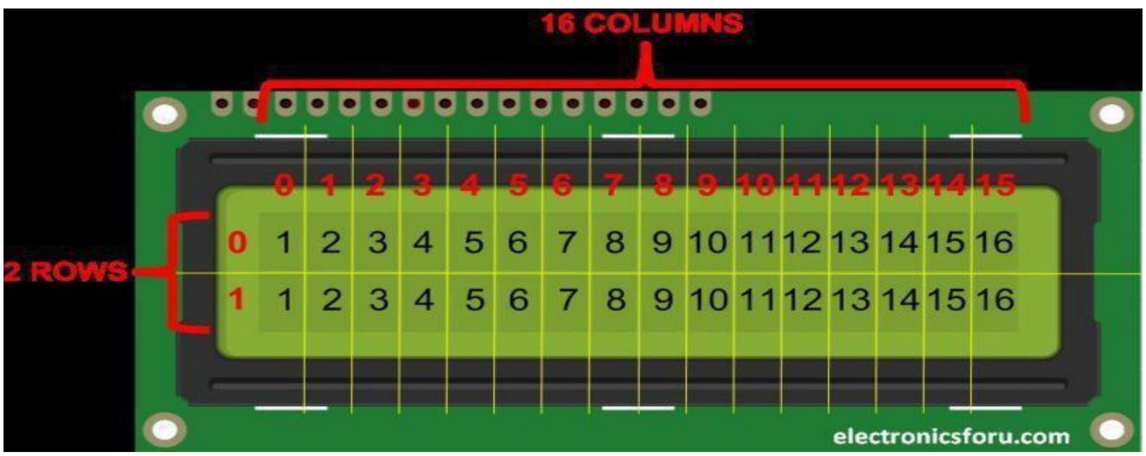


Fig 4.5: Liquid crystal display

We come across LCD displays everywhere around us. Computers, calculators, television sets, mobile phones, digital watches use some kind of display to display the time. An LCD is an electronic display module which uses liquid crystal to produce a visible image. The 16×2 LCD display is a very basic module commonly used in projects. The 16×2 translates to a display 16 characters per line in 2 such lines. In this LCD each character is displayed in a 5×7 pixel matrix.

16X2 LCD PINOUT DIAGRAM:

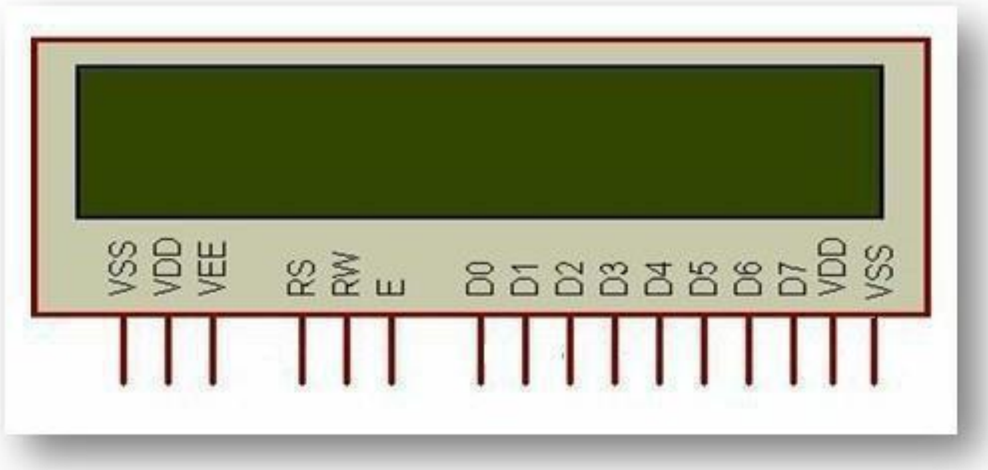


Fig 4.6:16*2 Lcd pinout diagram

COMMAND REGISTER:

The command register stores the command instructions given to the LCD. A command is an instruction given to LCD to do a predefined task like initializing it, clearing its screen, setting the cursor position, controlling display etc. Processing for commands happens in the command register.

DATA REGISTER:

The data register stores the data to be displayed on the LCD. The data is the ASCII value of the character to be displayed on the LCD. When we send data to LCD it goes to the data register and is processed there. When RS=1, data register is selected.

4.2.8 GAS SENSOR:

Sensitive material of MQ-2 gas sensor is SnO2, which with lower conductivity in clean air. When the target combustible gas exist, The sensor's conductivity is more higher along with the gas concentration rising. Please use simple electro circuit, Convert change of conductivity to correspond output signal of gas concentration. MQ-2 gas sensor has high sensitivity to LPG, Propane and Hydrogen, also could be used to Methane and other combustible steam, it is with low cost and suitable for different application. Sensor is sensitive to flammable gas and smoke. Smoke sensor is given 5 volt to power it. Smoke sensor indicate smoke by the voltage that it outputs .More smoke more output. A potentiometer is provided to adjust the sensitivity. But when smoke exist sensor provides an analog resistive output based on concentration of smoke. The circuit has a heater. Power is given to heater by VCC and GND from power supply. The circuit has a variable resistor. The resistance across the pin depends on the smoke in air in the sensor. The resistance will be lowered if the content is more. And voltage is increased between the sensor and load resistor.

4.2.9 HUMIDITY SENSOR:

This DHT11 Temperature & Humidity Sensor features a temperature & humidity sensor complex with a calibrated digital signal output. By using the exclusive digital-signal-acquisition technique and temperature & humidity sensing technology, it ensures high reliability and excellent long-term stability. This sensor includes a resistive-type humidity measurement component and an NTC temperature measurement component, and connects to a high-performance 8-bit microcontroller, offering excellent quality, fast response, anti-interference ability and cost-effectiveness. Each DHT11 element is strictly calibrated in the laboratory that is extremely accurate on humidity calibration. The single-wire serial interface makes system integration quick and easy.

4.2.10 FIRE/FLAME SENSOR

A **flame detector** is a sensor designed to detect and respond to the presence of a flame or fire. Responses to a detected flame depend on the installation, but can include sounding an alarm, deactivating a fuel line (such as a propane or a natural gas line), and activating a fire suppression system. There are different types of flame detection methods. Some of them are: Ultraviolet detector, near IR array detector, infrared (IR) detector, Infrared thermal cameras, UV/IR detector etc.

When fire burns it emits a small amount of Infra-red light, this light will be received by the Photodiode (IR receiver) on the sensor module. Then we use an Op-Amp to check for change in voltage across the IR Receiver, so that if a fire is detected the output pin (DO) will give 0V(LOW) and if the is no fire the output pin will be 5V(HIGH). It is based on the YG1006 sensor which is a high speed and high sensitive NPN silicon phototransistor. It can detect infrared light with a wavelength ranging from 700nm to 1000nm and its detection angle is about 60°. Flame sensor module consists of a photodiode (IR receiver), resistor, capacitor, potentiometer, and LM393 comparator in an integrated circuit. The sensitivity can be adjusted by varying the on board potentiometer. Working voltage is between 3.3v and 5v DC, with a digital output. Logic high on the output indicates presence of flame or fire. Logic low on output indicates absence of flame or fire.

Flame sensor is the most sensitive to ordinary light that is why its reaction is generally used as flame alarm purposes. This module can detect flame orwavelengthin760nmto1100nmrangeoflightsource.Smallplateoutputinterfacecan andsingle-chip can be directly connected to the microcomputer IO port. The sensor and flame should keep a certain distance to avoid high temperature damage to the sensor. The shortest test distance is 80cm, if the flame is bigger test it with far distance. The detection angle is 60 degrees so the flame spectrum is especially sensitive. The detection angle is 60degrees so the flame spectrum is especially sensitive.

4.2.11 LIGHT EMITTING DIODE:

The Light emitting diode is a two-lead semiconductor light source. In 1962, Nick Holonyak has come up with an idea of light emitting diode, and he was working for the general electric company. The LED is a special type of diode and they have similar electrical characteristics of a PN junction diode. Hence the LED allows the flow of current in the forward direction and blocks the current in the reverse direction. The LED occupies the small area which is less than the **1 mm^2**. The applications of LEDs used to make various electrical and electronic projects. In this article, we will discuss the working principle of the LED and its applications.

4.2.12 RELAY:

Relays are the primary protection as well as switching devices in most of the control processes or equipment. All the relays respond to one or more electrical quantities like voltage or current such that they open or close the contacts or circuits. A relay is a switching device as it works to isolate or change the state of an electric circuit from one state to another.

4.2.13 SERVO MOTORS

A Servo Motor is a small device that has an output shaft. This shaft can be positioned to specific angular positions by sending the servo a coded signal. As long as the coded signal exists on the input line, the servo will maintain the angular position of the shaft. If the coded signal changes, the angular position of the shaft changes. In practice, servos are used in radio-controlled airplanes to position control surfaces like the elevators and rudders. They are also used in radio-controlled cars, puppets, and of course, robots.

servo motors use feedback to determine the position of the shaft, you can control that position very precisely. As a result, servo motors are used to control the position of objects, rotate objects, move legs, arms or hands of robots, move sensors etc. with high precision. Servo motors are small in size, and because they have built-in circuitry to control their movement, they can be connected directly to an Arduino. Tiny and lightweight with high output power.

Servo can rotate approximately 180 degrees (90 in each direction), and works just like the standard kinds but smaller. You can use any servo code, hardware or library to control these servos. Good for beginners who want to make stuff move without building a motor controller with feedback & gear box, especially since it will fit in small places. It comes with a 3 horns (arms) and hardware.

4.3 INFRASTRUCTURE:

The Internet of Things will become part of the fabric of everyday life. It will become part of our overall infrastructure just like water, electricity, telephone, TV and most recently the Internet. Whereas the current Internet typically connects fullscale computers, the Internet of Things (as part of the Future Internet) will connect everyday objects with a strong integration into the physical world.

PLUG AND PLAY INTEGRATION

If we look at IoT-related technology available today, there is a huge heterogeneity. It is typically deployed for very specific purposes and the configuration requires significant technical knowledge and may be cumbersome. To achieve a true Internet of Things we need to move away from such small-scale, vertical application silos, towards a horizontal infrastructure on which a variety of applications can run simultaneously.

INFRASTRUCTURE FUNCTIONALITY

The infrastructure needs to support applications in finding the things required. An application may run anywhere, including on the things themselves. Finding things is not limited to the start-up time of an application. Automatic adaptation is needed whenever relevant new things become available, things become unavailable or the status of things changes. The infrastructure has to support the monitoring of such changes and the adaptation that is required as a result of the changes.

PHYSICAL LOCATION AND POSITION

As the Internet of Things is strongly rooted in the physical world, the notion of physical location and position are very important, especially for finding things, but also for deriving knowledge. Therefore, the infrastructure has to support finding things according to location (e.g. geo-location based discovery). Taking mobility into account, localization technologies will play an important role for the Internet of Things and may become embedded into the infrastructure of the Internet of Things.

SECURITY AND PRIVACY

In addition, an infrastructure needs to provide support for security and privacy functions including identification, confidentiality, integrity, non-repudiation authentication and authorization. Here the heterogeneity and the need for interoperability among different ICT systems deployed in the infrastructure and the resource limitations of IoT devices (e.g., Nano sensors) have to be taken into account.

4.4 DATA MANAGEMENT

Data management is a crucial aspect in the Internet of Things. When considering a world of objects interconnected and constantly exchanging all types of information, the volume of the generated data and the processes involved in the handling of those data become critical. A long-term opportunity for wireless communications chip makers is the rise of Machine-to-Machine (M2M) computing, which one of the enabling technologies for Internet of Things. This technology spans abroad range of applications. While there is consensus that M2M is a promising pocket of growth, analyst estimates on the size of the opportunity diverge by a factor of four [16]. Conservative estimates assume roughly 80 million to 90 million M2M units will be sold in 2014, whereas more optimistic projections forecast sales of 300 million units. Based on historical analyses of adoption curves for similar disruptive technologies, such as portable MP3 players and antilock braking systems for cars, it is believed that unit sales in M2M could rise by as much as a factor of ten over the next five years, see Figure 2.29 [16]. There are many technologies and factors involved in the “data management” within the IoT context. Some of the most relevant concepts which enable us to understand the challenges and opportunities of data management are:

- Data Collection and Analysis
- Big Data
- Semantic Sensor Networking
- Virtual Sensors
- Complex Event Processing.

CHAPTER 5

SYSTEM DESIGN

Systems design is the process of defining the architecture, modules, interfaces, and data for a system to satisfy specified requirements. Systems design could be seen as the application of systems theory to product development. There is some overlap with the disciplines of systems analysis, systems architecture and systems engineering.

5.1 ARCHITECTURE DIAGRAM

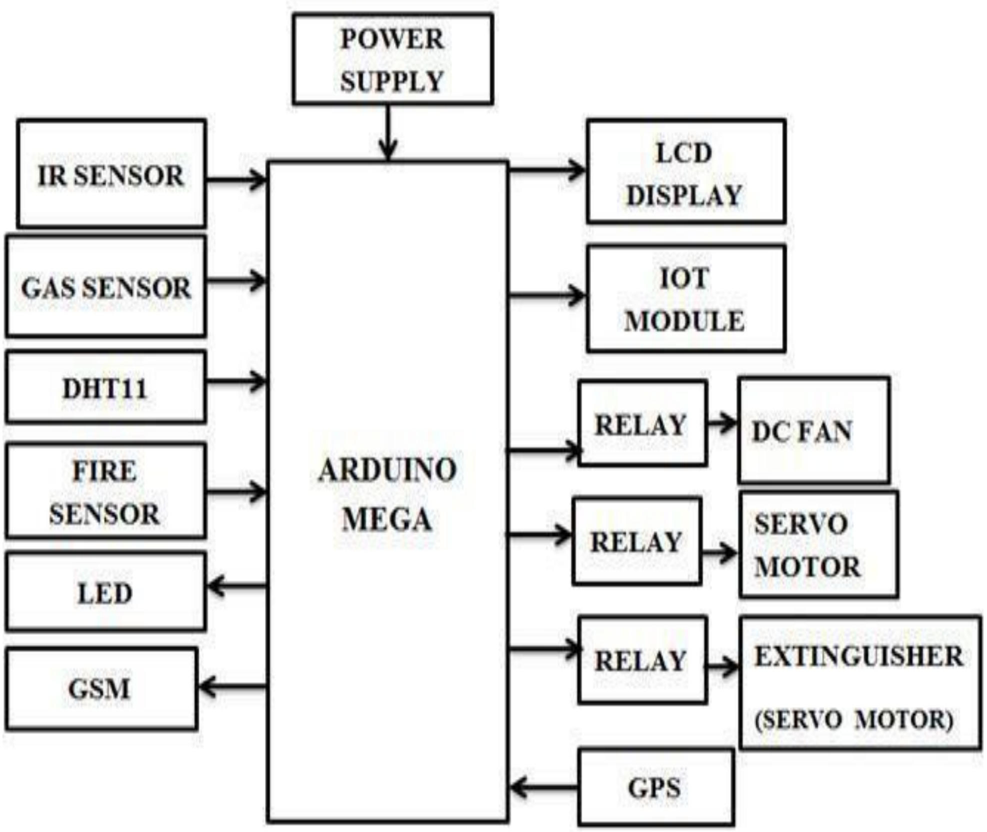


Fig 5.1:Architecture diagram

5.2 SEQUENCE DIAGRAM

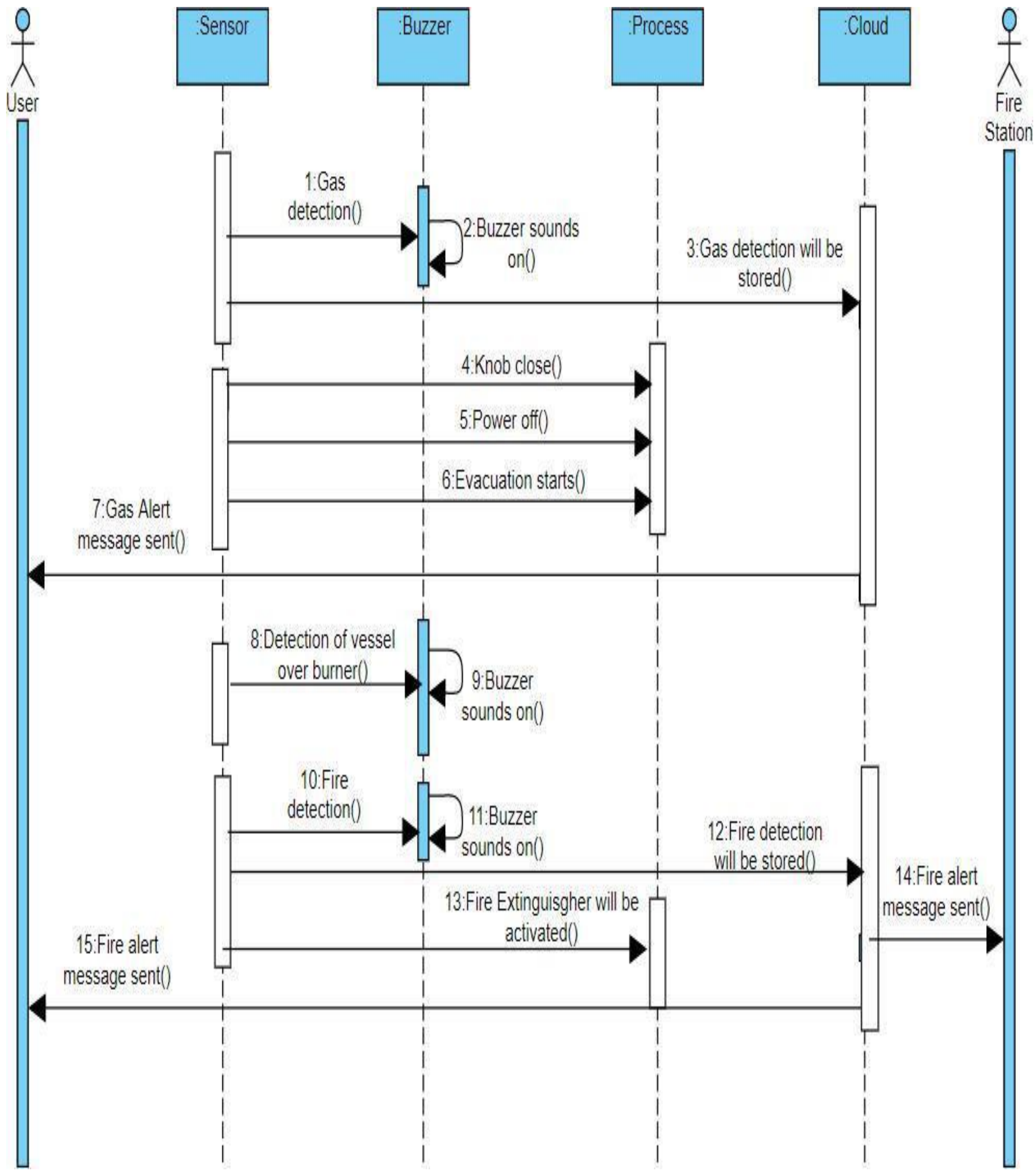


Fig 5.2:Sequence diagram

5.3 USE CASE DIAGRAM

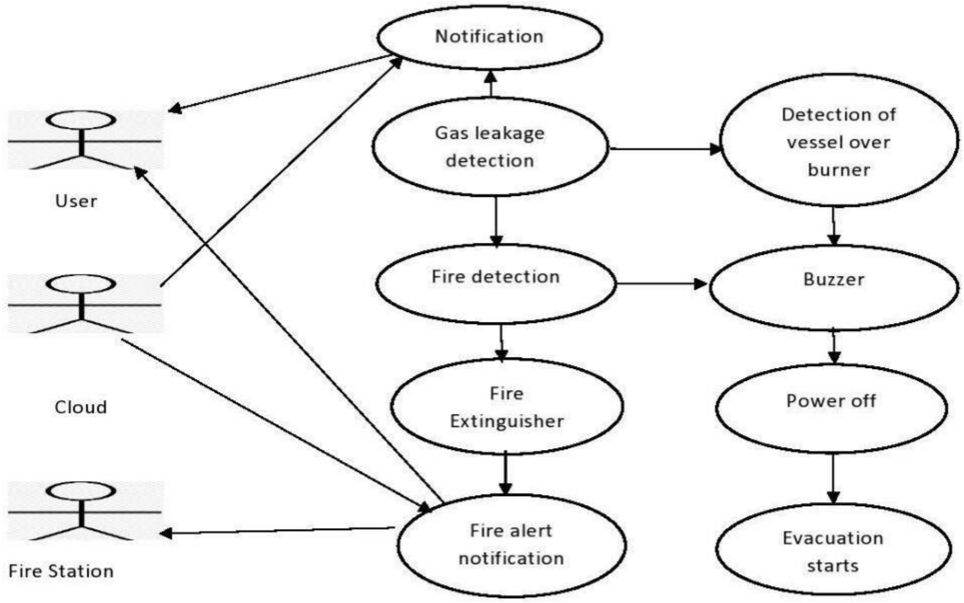


Fig 5.3:Use case diagram

5.4 ACTIVITY DIAGRAM

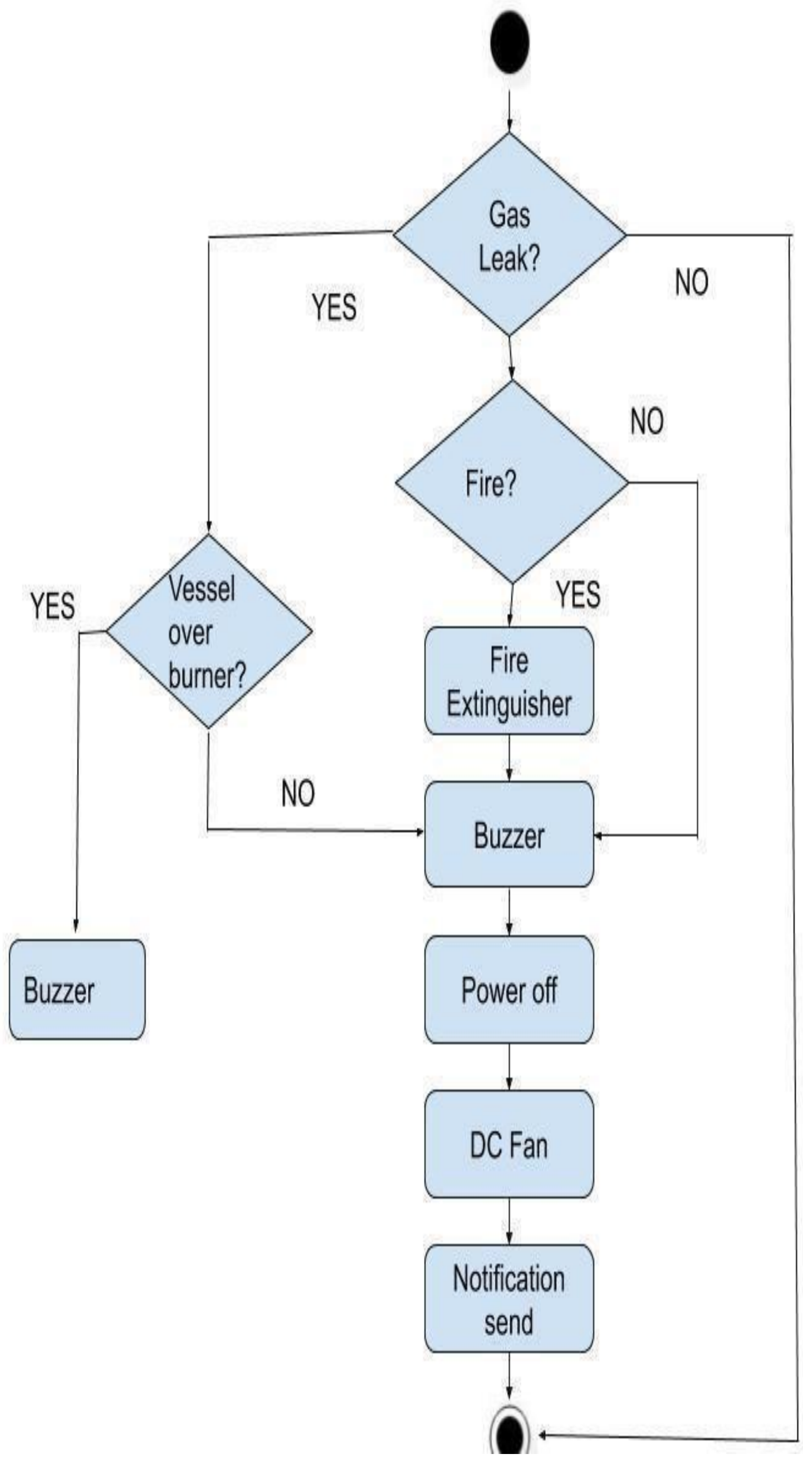


Fig 5.4:Activity diagram

5.5 COLLABORATION DIAGRAM

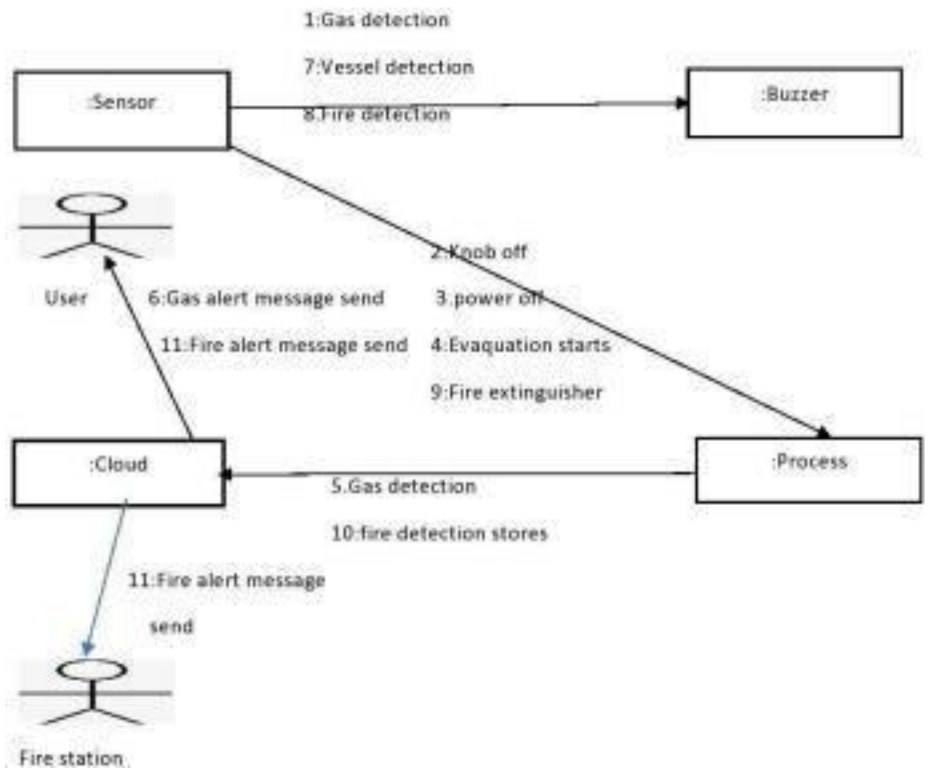


Fig 5.5:Collaboration diagram

5.6 FLOW CHART

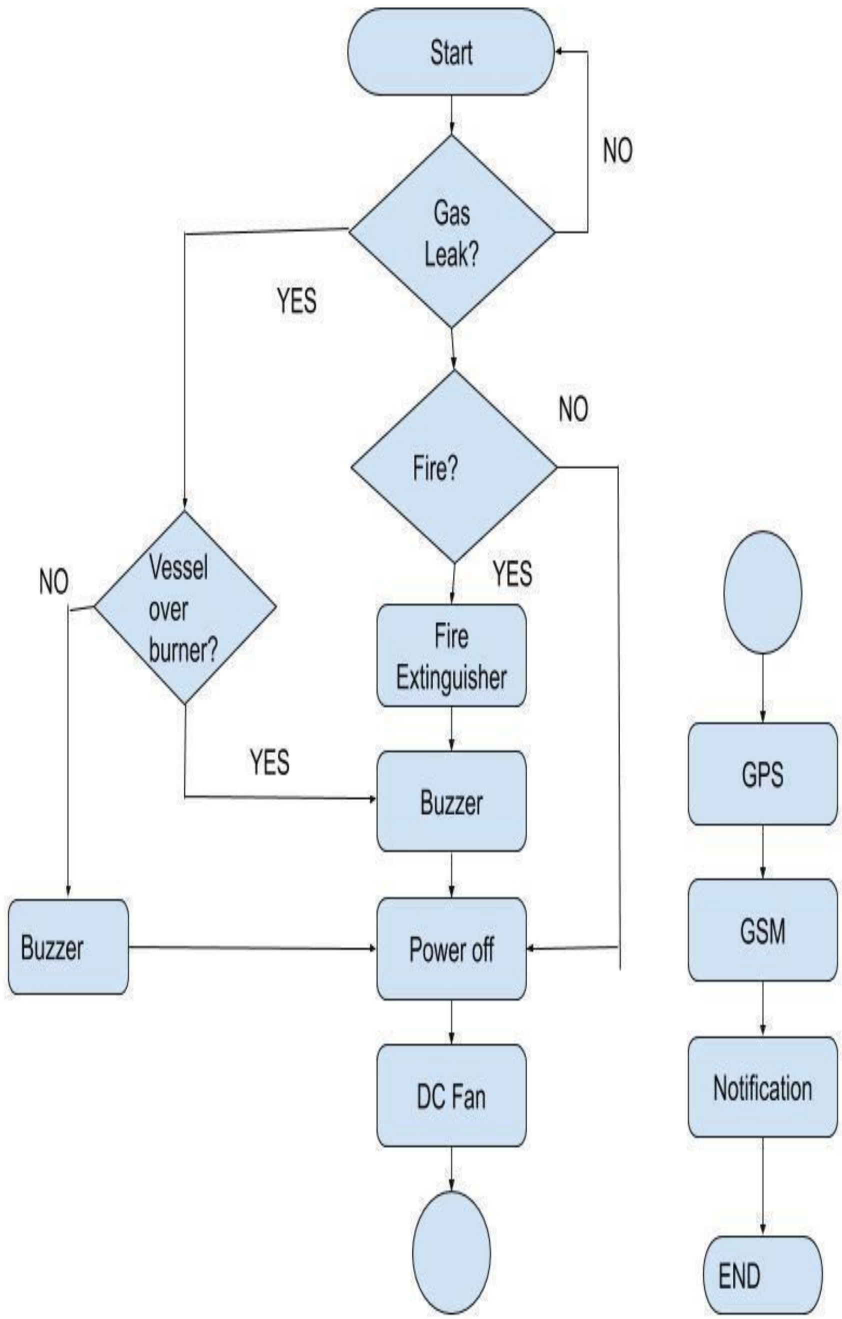
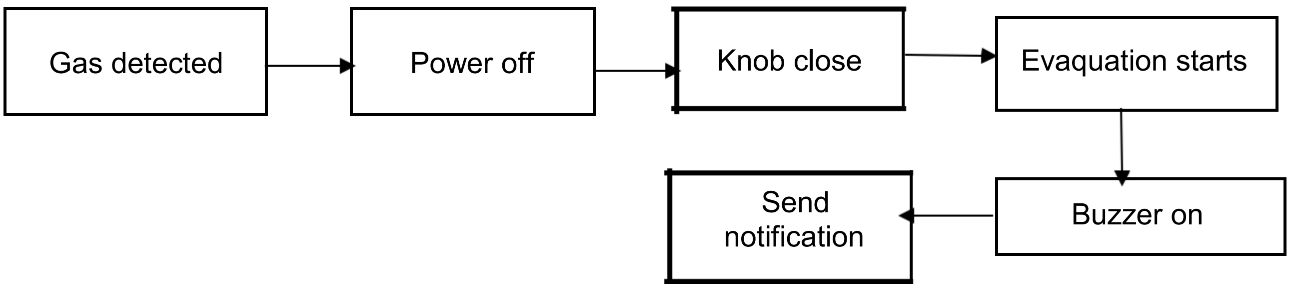


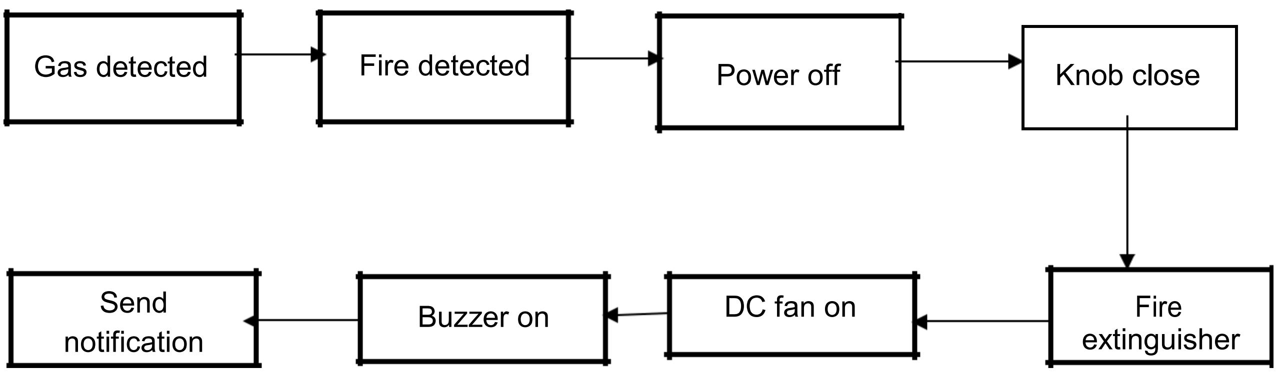
Fig 5.6:Flow chart

5.7 DATA FLOW DIAGRAM:

LEVEL 0



LEVEL 1



LEVEL 2

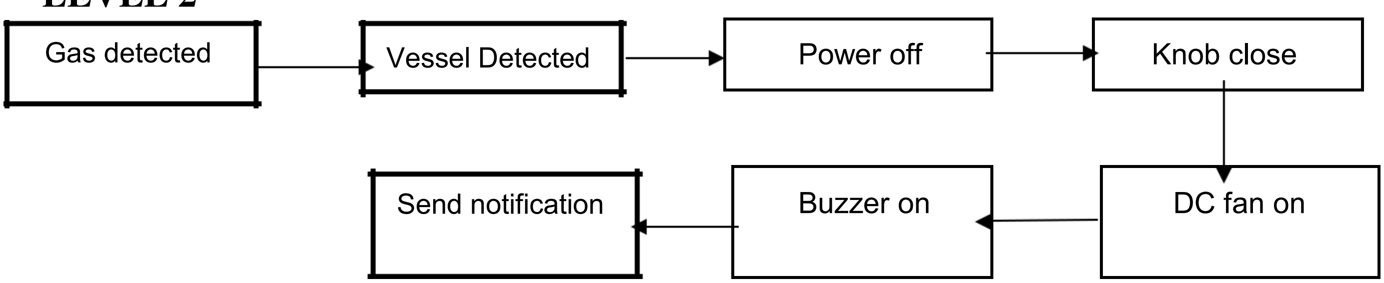


Fig 5.7:Data flow diagram

CHAPTER 6

MODULE DESCRIPTION

A modular design reduces complexity, facilitates change (a critical aspect of software maintainability), and results in easier implementation by encouraging parallel development of different parts of the system. Software with effective modularity is easier to develop because function may be compartmentalized and interfaces are simplified. Software architecture embodies modularity, that is software is divided into separately named and addressable components called modules that are integrated to satisfy problem requirements. Modularity is the single attribute of software that allows a program to be intellectually manageable.

6.1 LIST OF MODULES

The four important criteria that enable us to evaluate a design method with respect to its ability to define an effective modular design are: gas leakage detection, fire detection and evacuation, infrared sensor detection, communication module.

6.2 MODULE DESCRIPTIONS

6.2.1 GAS LEAKAGE DETECTION:

The main function of this module is to detect the gas leakage in the kitchen. It consists of the Arduino Mega microcontroller shown in figure6.1, gas sensor shown in figure6.2, DC fan, LED, Buzzer. Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button, and turn it into an output - activating a motor, turning on an LED, publishing something on the cloud. Arduino act as the heart of the entire system. It consists of an ATMEL 8 bit AVR microcontroller with varying amounts of flash memory, pins and features.

Fig 6.1:Arduino Mega Fig 6.2:Gas Sensor The gas detection is done by using a gas sensor that is sensitive to LPG, natural gas and other gases such as CO and H2. It is made up of Tin dioxide(Sno2).The gas sensor detects the small change in the concentration of the gas. The Power supply can be noticed with the help of LED. The Light Emitting Diode is forward biased PN junction Diode. It makes the complete atom and more stable and it gives a little burst of energy in the photon of light, when the whole action takes place the buzzer starts the function and intimate the gas is detected in the room. The kitchen exhaust fan can be a vitally important part of our kitchen.

The kitchen exhaust fans are extremely effective when it comes to the extraction of air and any possible pollution or other substance that may be present. Some exhaust fans employ sensors that allow them to automatically activate when they send the gas that there's a stream in the room.

6.2.2 FIRE DETECTION AND EVACUATION:

The fire sensor shown in figure6.3, is designed to detect the fire. The fire sensor consists of sounding an alarm, deactivating a fuel line(such as propane or natural gas) and activating a fire suppression system. When the fire burns it emits a small amount of Infrared light that will be received by the photodiode on the sensor module. Arduino Mega checks the logic level on the output pin of the sensor and performs further tasks such as activating the buzzer and LED sending an alert message. The fire sensor circuit is too sensitive and can detect a rise in temperature of 10 degree or more in its vicinity. When the fire detected the fire extinguisher starts its function.

Fig 6.3:Fire Sensor

Fig 6.4:Buzzer

A fire extinguisher is an active fire protection device used to control small fires often in an emergency situation. A fire extinguisher consists of a hand held cylindrical pressure vessel containing an agent that can be discharged to extinguish a fire. In stored pressure units, expellant is stored in the same chamber as the fire sighting agent itself. Depending on the agent used, different propellants are used. With a dry chemical extinguisher "Nitrogen" is typically used; Water and Foam extinguisher typically used in air; When the fire is detected the buzzer starts its action to intimate the message to the user.

6.2.3 INFRARED SENSOR DETECTION:

An Infrared sensor shown in figure6, is an electronic device that emits in order to aspects of its surrounding. An Infrared sensor can measure the heat of the object as well as detects the motion. A passive infrared sensor is an electronic sensor that measures infrared light radiating from an object in its field of view. The PIR sensor is commonly used in security alarm and automatic lighting applications. A Servo motor is an electrical device which can push or rotate an object with great precision. It rotates the objects from some specific angles or distance. It is just made up of a simple motor which runs through a servo mechanism.

Fig 6.5:IR Sensor Fig 6.6:Servo Motor

A servo shown in figure5, consists of a motor(DC(or)AC),a potentiometer, gear assembling and a controlling circuit connected to the output shaft. The position of a servo motor is decided by electrical pulse and its circuitry is placed beside the motor. It is a closed loop system where it uses a positive feedback system to control motion and positive position of the shaft. Here the device is controlled by the feedback signal generated by comparing output signal and reference input signal. The servomotor is used in Robotics, RC helicopters ,planes and automatic doors open.

6.2.4 COMMUNICATION MODULE:

Global System For Mobile Communication is a mobile communication modem. GSM is an open cellular technology used for transmitting mobile voice and data services. GSM digitizer compresses the data, then sends it down a channel with two other streams of user data, each in its own time slot. GSM was developed using digital technology. It has an ability to carry 64kbps to 120mbps of data rates. GSM operates in the bands 850MHZ and 1900MHZ.DHT 11 is a low cost digital sensor for sensing temperature and humidity.

This sensor can be easily interfaced with a microcontroller such as Arduino, Raspberry pi, etc...to measure humidity and temperature instantaneously. By using the exclusive digital signal acquisition technique, humidity and temperature sensing technology it ensures high reliability and long term stability. Each DHT11 element is strictly calibrated in the laboratory that is extremely accurate on humidity calibration.

Fig 6.7 : IoT Module

Fig 6.8 : GSM

An IoT module is a small electronic device embedded in objects, machines and things that connects to the wireless networks to send and receive datas. In the industry of IoT, wireless technology plays a significant role. Any device can be connected to the internet through any wireless technologies like wifi,bluetooth.ESP8266EX is often integrated with external sensor and other applications specific devices through its GPIos ;codes for such applications can be provided as examples in the SDK.ESP8266 itself is a self combined Wi-fi network solution offering as a bridge from existing microcontroller to wi-fi and is also capable of running self contained applications.

LCD screen is an electronic display module and find a wide range of applications. A 16*2 LCD display is very basic module and it is commonly used in various devices and circuits. The data is the ASCII value of the character to be displayed on the LCD. The LCD technology works by blocking light. GPS shown in figure7, is the satellite navigation system used to determine the group position of the object. The GPS receiver gets the signal from the satellite. The satellite transmits the exact time, the signal is send. Many GPS receivers can relay position data to a PC using NIM O&B protocol.

CHAPTER 7

CODING AND TESTING

7.1 CODING

Once the design aspect of the system is finalizes the system enters into the coding and testing phase. The coding phase brings the actual system into action by converting the design of the system into the code in a given programming language. Therefore, a good coding style has to be taken whenever changes are required it easily screwed into the system.

7.2 CODING STANDARDS

Coding standards are guidelines to programming that focuses on the physical structure and appearance of the program. They make the code easier to read, understand and maintain. This phase of the system actually implements the blueprint developed during the design phase. The coding specification should be in such a way that any programmer must be able to understand the code and can bring about changes whenever felt necessary. Some of the standard needed to achieve the above-mentioned objectives are as follows:

Program should be simple, clear and easy to understand.

- Naming conventions
- Value conventions
- Script and comment procedure
- Message box format
- Exception and error handling

NAMING CONVENTIONS

Naming conventions of classes, data member, member functions, procedures etc., should be self-descriptive. One should even get the meaning and scope of the variable by its name. The conventions are adopted for easy understanding of the intended message by the user. So it is customary to follow the conventions. These conventions are as follows:

CLASS NAMES

Class names are problem domain equivalence and begin with capital letter and have mixed cases.

MEMBER FUNCTION AND DATA MEMBER NAME

Member function and data member name begins with a lowercase letter with each subsequent letters of the new words in uppercase and the rest of letters in lowercase.

VALUE CONVENTIONS

Value conventions ensure values for variable at any point of time. This involves the following:

- Proper default values for the variables.
- Proper validation of values in the field.
- Proper documentation of flag values.

SCRIPT WRITING AND COMMENTING STANDARD

Script writing is an art in which indentation is utmost important. Conditional and looping statements are to be properly aligned to facilitate easy understanding. Comments are included to minimize the number of surprises that could occur when going through the code.

MESSAGE BOX FORMAT

When something has to be prompted to the user, he must be able to understand it properly. To achieve this, a specific format has been adopted in displaying messages to the user. They are as follows:

- X – User has performed illegal operation.
- ! – Information to the user.

7.3 TEST PROCEDURE

SYSTEM TESTING

Testing is performed to identify errors. It is used for quality assurance. Testing is an integral part of the entire development and maintenance process. The goal of the testing during phase is to verify that the specification has been accurately and completely incorporated into the design, as well as to ensure the correctness of the design itself. For example the design must not have any logic faults in the design is detected before coding commences, otherwise the cost of fixing the faults will be considerably higher as reflected. Detection of design faults can be achieved by means of inspection as well as walkthrough.

Testing is one of the important steps in the software development phase. Testing checks for the errors, as a whole of the project testing involves the following test cases: Static analysis is used to investigate the structural properties of the Source code. Dynamic testing is used to investigate the behavior of the source code by executing the program on the test data.

7.4 TEST DATA AND OUTPUT

UNIT TESTING

Unit testing is conducted to verify the functional performance of each modular component of the software. Unit testing focuses on the smallest unit of the software design (i.e.), the module. The white-box testing techniques were heavily employed for unit testing.

FUNCTIONAL TESTS

Functional test cases involved exercising the code with nominal input values for which the expected results are known, as well as boundary values and special values, such as logically related inputs, files of identical elements, and empty files.

Three types of tests in Functional test:

- Performance Test
- Stress Test
- Structure Test

PERFORMANCE TEST

It determines the amount of execution time spent in various parts of the unit, program throughput, and response time and device utilization by the program unit.

STRESS TEST

Stress Test is those test designed to intentionally break the unit. A Great deal can be learned about the strength and limitations of a program by examining the manner in which a programmer in which a program unit breaks.

STRUCTURED TEST

Structure Tests are concerned with exercising the internal logic of a program and traversing particular execution paths. The way in which White-Box test strategy was employed to ensure that the test cases could Guarantee that all independent paths within a module have been exercised at least once.

- Exercise all logical decisions on their true or false sides.
- Execute all loops at their boundaries and within their operational bounds.
- Exercise internal data structures to assure their validity.
- Checking attributes for their correctness.

INTEGRATION TESTING

Integration testing is a systematic technique for construction the program structure while at the same time conducting tests to uncover errors associated with interfacing. i.e., integration testing is the complete testing of the set of modules which makes up the product. The objective is to take untested modules and build a program structure tester should identify critical modules. Critical modules should be tested as early as possible. One approach is to wait until all the units have passed testing, and then combine them and then tested. This approach is evolved from unstructured testing of small programs. Another strategy is to construct the product in increments of tested units. A small set of modules are integrated together and tested, to which another module is added and tested in combination. And so on. The advantages of this approach are that, interface dispenses can be easily found and corrected.

The major error that was faced during the project is linking error. When all the modules are combined the link is not set properly with all support files. Then we checked out for interconnection and the links. Errors are localized to the new module and its intercommunications. The product development can be staged, and modules integrated in as they complete unit testing. Testing is completed when the last module is integrated and tested.

TESTING TECHNIQUES / TESTING STRATEGIES

TESTING

Testing is a process of executing a program with the intent of finding an error. A good test case is one that has a high probability of finding an as-yet – undiscovered error. A successful test is one that uncovers an as-yet- undiscovered error. System testing is the stage of implementation, which is aimed at ensuring that the system works accurately and efficiently as expected before live operation commences. It verifies that the whole set of programs hang together. System testing requires a test consists of several key activities and steps for running a program, string, system and is important in adopting a successful new system. This is the last chance to detect and correct errors before the system is installed for user acceptance testing. The software testing process commences once the program is created and the documentation and related data structures are designed. Software testing is essential for correcting errors. Otherwise the program or the project is not said to be complete. Software testing is the critical element of software quality assurance and represents the ultimate the review of specification design and coding. Testing is the process of executing the program with the intent of finding the error. A good test case design is one that as a probability of finding an yet undiscovered error. A successful test is one that uncovers an yet undiscovered error. Any engineering product can be tested in one of the two ways:

WHITE BOX TESTING

This testing is also called as Glass box testing. In this testing, by knowing the specific functions that a product has been design to perform test can be conducted that demonstrate each function is fully operational at the same time searching for errors in each function. It is a test case design method that uses the control structure of the procedural design to derive test cases. Basis path testing is a white box testing.

Basis path testing:

- Flow graph notation
- Cyclometric complexity
- Deriving test cases
- Graph matrices Control

BLACK BOX TESTING

In this testing by knowing the internal operation of a product, test can be conducted to ensure that "all gears mesh", that is the internal operation performs according to specification and all internal components have been adequately exercised. It fundamentally focuses on the functional requirements of the software.

The steps involved in black box test case design are:

- Graph based testing methods
- Equivalence partitioning
- Boundary value analysis
- Comparison testing

SOFTWARE TESTING STRATEGIES:

A software testing strategy provides a road map for the software developer. Testing is a set activity that can be planned in advance and conducted systematically. For this reason a template for software testing a set of steps into which we can place specific test case design methods should be strategy should have the following characteristics:

- Testing begins at the module level and works "outward" toward the integration of the entire computer based system.

- Different testing techniques are appropriate at different points in time.
- The developer of the software and an independent test group conducts testing.
- Testing and Debugging are different activities but debugging must be accommodated in any testing strategy.

INTEGRATION TESTING:

Integration testing is a systematic technique for constructing the program structure while at the same time conducting tests to uncover errors associated with. Individual modules, which are highly prone to interface errors, should not be assumed to work instantly when we put them together. The problem of course, is "putting them together"- interfacing. There may be the chances of data lost across on another's sub functions, when combined may not produce the desired major function; individually acceptable impression may be magnified to unacceptable levels; global data structures can present problems.

PROGRAM TESTING:

The logical and syntax errors have been pointed out by program testing. A syntax error is an error in a program statement that in violates one or more rules of the language in which it is written. An improperly defined field dimension or omitted keywords are common syntax error. These errors are shown through error messages generated by the computer. A logic error on the other hand deals with the incorrect data fields, out-off-range items and invalid combinations. Since the compiler s will not deduct logical error, the programmer must examine the output. Condition testing exercises the logical conditions contained in a module. The possible types of elements in a condition include a Boolean operator, Boolean variable, a pair of Boolean parentheses A relational operator or on arithmetic expression. Condition testing method focuses on testing each condition in the program the purpose of condition test is to deduct not only errors in the condition of a program but also other a errors in the program. SECURITY TESTING:

Security testing attempts to verify the protection mechanisms built in to a system well, in fact, protect it from improper penetration. The system security must be tested for invulnerability from frontal attack must also be tested for invulnerability from rear attack. During security, the tester places the role of individual who desires to penetrate system.

VALIDATION TESTING

At the culmination of integration testing, software is completely assembled as a package. Interfacing errors have been uncovered and corrected and a final series of software test-validation testing begins. Validation testing can be defined in many ways, but a simple definition is that validation succeeds when the software functions in a manner that is reasonably expected by the customer. Software validation is achieved through a series of black box tests that demonstrate conformity with requirements. After the validation test has been conducted, one of two conditions exists.

- The function or performance characteristics confirm to specifications and are accepted.
- A validation from specification is uncovered and a deficiency created.

Deviation or errors discovered at this step in this project is corrected prior to completion of the project with the help of the user by negotiating to establish a method for resolving deficiencies. Thus the proposed system under consideration has been tested by using validation testing and found to be working satisfactorily. Though there were deficiencies in the system they were not catastrophic.

USER ACCEPTANCE TESTING

User acceptance of the system is key factor for the success of any system. The system under consideration is tested for user acceptance by constantly keeping in touch with prospective system and user at the time of developing and making changes whenever required. This is done in regarding to the following points.

- Input screen design.
- Output screen design

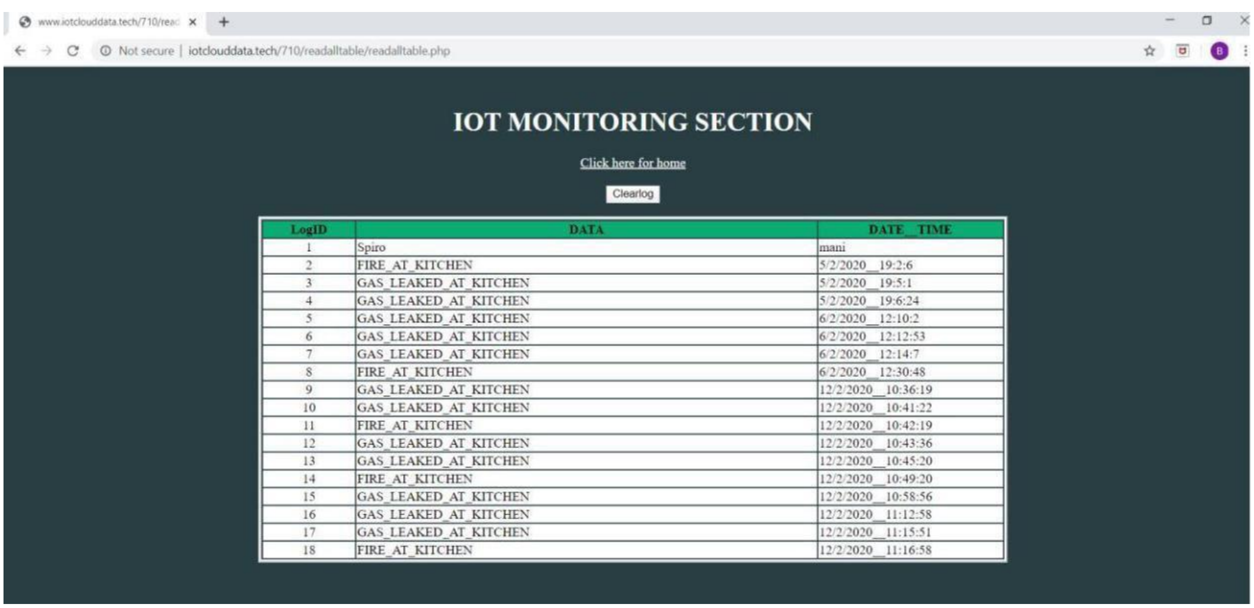
CHAPTER 8

RESULTS AND DISCUSSION

Homepage: The User has to enter into cloud Homepage

Fig 8.1:Home page

Go to Click here for Monitoring System



LogID	DATA	DATE__TIME
1	Spiro	mani
2	FIRE_AT_KITCHEN	5/2/2020__19:2:6
3	GAS_LEAKED_AT_KITCHEN	5/2/2020__19:5:1
4	GAS_LEAKED_AT_KITCHEN	5/2/2020__19:6:24
5	GAS_LEAKED_AT_KITCHEN	6/2/2020__12:10:2
6	GAS_LEAKED_AT_KITCHEN	6/2/2020__12:12:53
7	GAS_LEAKED_AT_KITCHEN	6/2/2020__12:14:7
8	FIRE_AT_KITCHEN	6/2/2020__12:30:48
9	GAS_LEAKED_AT_KITCHEN	12/2/2020__10:36:19
10	GAS_LEAKED_AT_KITCHEN	12/2/2020__10:41:22
11	FIRE_AT_KITCHEN	12/2/2020__10:42:19
12	GAS_LEAKED_AT_KITCHEN	12/2/2020__10:43:36
13	GAS_LEAKED_AT_KITCHEN	12/2/2020__10:45:20
14	FIRE_AT_KITCHEN	12/2/2020__10:49:20
15	GAS_LEAKED_AT_KITCHEN	12/2/2020__10:58:56
16	GAS_LEAKED_AT_KITCHEN	12/2/2020__11:12:58
17	GAS_LEAKED_AT_KITCHEN	12/2/2020__11:15:51
18	FIRE_AT_KITCHEN	12/2/2020__11:16:58

Fig 8.2:cloud page

Fig 8.3:gas leakage message

Fig 8.4:fire detected message

CHAPTER 9
CONCLUSION AND FUTURE ENHANCEMENT

CONCLUSION

The detection of gas leakage is mainly proposed to avoid fire accidents because of gas leakage. This system can be operated along with the alarm system. The gas sensor is used to detect the gas leakage with the help of an ARDUINO MEGA microcontroller.The Infrared sensor is used to detect the vessel at the gas top.The fire sensor and the fire extinguisher can also be used to avoid unexpected accident. All the data fetch from the controller is updated to cloud. So that the user can be monitor as well as controlled along with notification messages.

FUTURE ENHANCEMENT

In Future, mobile robots can be developed for detecting multiple gas concentrations.. Addition to that in future the pressure of the gas in the cylinder pipes can also be detected and send the alert message to the user.

CHAPTER 10
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CHAPTER 11

APPENDICES

APPENDIX A:SAMPLE SOURCE CODE

```
///////////GAS LEAKAGE PRIVENTION/////////////////////
#include<LiquidCrystal.h>
#include <Servo.h>
#include "DHT.h"
#define DHTPIN A15
#define DHTTYPE DHT11   // DHT 11 // DHT12 INDUSTRI

DHT dht(DHTPIN, DHTTYPE);//
LiquidCrystal lcd(8,9,10,11,12,13);
Servo s1;
Servo s2;

void ggg();
void gps();
void gsm(String data,String data1);
void gsm1(String data,String data1);
void iot(String msg);

char *test = "$GPGGA";
String gpsstr = "";
String lat = "No Range     ";
String lon = "No Range   ";
String lat2 = "13.054452";
String lon2 = "80.075227";
```

```
boolean flag=0;
int loc,i,j;

 int  ir=22;
 int gs=24;
 int fr=26;
 int alm_lt=28;
 int pwr_lt=30;
 int bz=32;
 int rl=7;

 unsigned int stat;
 int pos,pos1;

void setup()
{
  Serial.begin(9600);//iot
  Serial1.begin(38400);//gsm
  Serial2.begin(9600);//gps
  dht.begin();//DHT INI
  //////////PIN SETUP///////////////////////
  pinMode(ir,INPUT);
  pinMode(gs,INPUT);
  pinMode(fr,INPUT);
  pinMode(alm_lt,OUTPUT);
  pinMode(pwr_lt,OUTPUT);
  //////////////////////
  digitalWrite(pwr_lt,HIGH);
  ////////////////////
  pinMode(bz,OUTPUT);
  pinMode(rl,OUTPUT);
  s1.attach(4);//gas nobe
  s2.attach(5);//fire extin
  //////////LCD SETUP////////////////////////
  lcd.begin(16,2);
```

```
 lcd.setCursor(0,0);
 lcd.print("GAS LKG DETECTIO");
 lcd.setCursor(0,1);
 lcd.print("& PREVENTION KIT");
 delay(3000);
}
void loop()
{
 lcd.clear();
 lcd.setCursor(0,1);
 digitalWrite(pwr_lt,HIGH);

 int h =dht.readHumidity();//READ DATA
 int no_vassel=digitalRead(ir); int on_fire
 =digitalRead(fr);

 if(no_vassel == 1 && on_fire == 1)//vassel no fire
   stat=1;
 else if(on_fire== 0 && no_vassel == 0)//only fire when vassel
   stat=2;
 else if(on_fire== 0 && no_vassel == 1)// fire when no vassel
   stat=3;
 else;


   lcd.print("HUMIDITY:" + String(h));//humidity
   delay(1500);

  switch(stat)
  {
    case 1:
      if(digitalRead(gs)== 0)
      {
        Serial.println("case 1");//SHOULD DELET
```

```
lcd.setCursor(0,0);
lcd.print("GAS LKG DETECTED");
lcd.setCursor(0,1);
lcd.print("STAT :POWER OFF ");

//////////POWER OFF//////////////
digitalWrite(pwr_lt,LOW);
//////////BUZZER ALARM//////////
digitalWrite(bz,HIGH);
//////////ALARM LIGHT////////////
digitalWrite(alm_lt,HIGH);

delay(2000);
lcd.setCursor(0,1);
lcd.print("STAT:KNOBE CLOSE");

//////////cylinder nobe close////////////////
for (pos = 90; pos <= 180; pos += 1)
{
  s1.write(pos);
  delay(20);
}
  delay(1000);
for (pos = 180; pos >= 90; pos -= 1)
{
  s1.write(pos);
  delay(20);
}
///////EVACUATION //////////////
delay(2000);
lcd.setCursor(0,1);
lcd.print("STAT :EVACUATION");

digitalWrite(rl,HIGH);
////////////IOT & GSM//////////////////////
```

```
    iot("*GAS LEAKED AT KITCHEN#");
    gsm("GAS LEAKED","LOCATION HAS SENT");
    delay(2000);
    lcd.setCursor(0,1);
    lcd.print("STAT :SMS SEND ");

    ///////////WAIT FOR GAS//////////
    while(digitalRead(gs)== 0);////until gas not detect

    delay(2000);
    lcd.setCursor(0,1);
    lcd.print("STAT :ATM SECURE");

    digitalWrite(bz,LOW);
    digitalWrite(alm_lt,LOW);
    digitalWrite(rl,LOW);
    }
    break;

case 2:
    Serial.println("case 2");

    lcd.clear();
    lcd.setCursor(0,0);
    lcd.print("FIRE AT KITCHEN ");
    lcd.setCursor(0,1);
    lcd.print("STAT : ALRM !!!!");

    ///////////ALARM LIGHT///////////////////
    digitalWrite(alm_lt,HIGH);
    ///////////POWER OFF///////////////////
    digitalWrite(pwr_lt,LOW);
    ///////////BUZZER ALARM////////////////
    digitalWrite(bz,HIGH);
```

```
delay(2000);
lcd.setCursor(0,1);
lcd.print("STAT:FR EXSTNGHR");

////////FIRE EXSTINGUISHER ON/////////////
for(pos1 = 90 ; pos1 <=180; pos1 += 1) {
  s2.write(pos1);
  delay(20);
}
/////////IOT,GSM AND LOCATION///////////////
iot("*FIRE AT KITCHEN#");
gsm("FIRE AT KITCHEN","LOCATION HAS SENT");
gsm1("FIRE AT KITCHEN","LOCATION HAS SENT");

delay(2000);
lcd.setCursor(0,1);
lcd.print("STAT: SMS SEND  ");

//////////WAIT FOR FIRE/////////////////
while(digitalRead(fr)==0);

lcd.clear();
lcd.setCursor(0,0);
lcd.print(" FIRE CLEARED ");
lcd.setCursor(0,1);
lcd.print("EXTINGUISHER OFF");

////////FIRE EXSTINGUISHER OFF////////////////////
for(pos1 = 180 ; pos1 >=90; pos1 -= 1) {
  s2.write(pos1);
  delay(20);
}
digitalWrite(alm_lt,LOW);
```

```
    digitalWrite(bz,LOW);
    delay(2000);
    break;
  case 3:
    Serial.println("case 3");

    lcd.clear();
    lcd.setCursor(0,0);
    lcd.print("FIRE AT KITCHEN ");
    lcd.setCursor(0,1);
    lcd.print("STAT : ALRM !!!!");

    ///////////ALARM LIGHT///////////////////
    digitalWrite(alm_lt,HIGH);
    ///////////POWER OFF///////////////////
    digitalWrite(pwr_lt,LOW);
    ///////////BUZZER ALARM////////////////
    digitalWrite(bz,HIGH);

    delay(2000);
    lcd.setCursor(0,1);
    lcd.print("STAT:FR EXSTNGHR");

    ////////FIRE EXSTINGUISHER ON/////////////
    for(pos1 = 90 ; pos1 <=180; pos1 += 1) {
      s2.write(pos1);
      delay(20);
    }
    /////////IOT,GSM AND LOCATION///////////////
    iot("*FIRE AT KITCHEN#");
    gsm("FIRE AT KITCHEN","LOCATION HAS SENT");
    gsm1("FIRE AT KITCHEN","LOCATION HAS SENT");

    delay(2000);
```

```
        lcd.setCursor(0,1);
        lcd.print("STAT: SMS SEND ");

        //////////WAIT FOR FIRE/////////////////
        while(digitalRead(fr)==0);

        lcd.clear();
        lcd.setCursor(0,0);
        lcd.print(" FIRE CLEARED ");
        lcd.setCursor(0,1);
        lcd.print("EXTINGUISHER OFF");

        ////////FIRE EXSTINGUISHER OFF////////////////////
        for(pos1 = 180 ; pos1 >=90; pos1 -= 1) {
          s2.write(pos1);
          delay(20);
        }
        digitalWrite(alm_lt,LOW);
        digitalWrite(bz,LOW);
        delay(2000);
        break;
      default:
        break;
  }
   stat=0;
  delay(2000);

  lcd.clear();
  lcd.setCursor(0,1);
  lcd.print("HUMIDITY:" + String(h));//humidity
  gps();
}
/////////////////GPS-1////////////////
void gps()
```

```
{
  flag = 0;
  int x = 0;
  while (flag == 0)
  {
    ggg();
    flag = 1;
    int str_lenth = i;
    lat = "";
    lon = "";
    int comma = 0;
    while (x < str_lenth)//
    {
      if (gpsstr[x] == '.')
      {
        x++;
        continue;
      }
      if (comma == 2)
        lat += gpsstr[x];

      else if (comma == 4)
        lon += gpsstr[x];

      if (gpsstr[x] == ',')
        comma++;
      x++;
    }

    int l1 = lat.length();
    lat[l1 - 1] = ' ';
    l1 = lon.length();
    lon[l1 - 1] = ' ';

    i = 0; x = 0;//, j = 0;
```

```
    str_lenth = 0;
    loc = 1;
  }
}
//////////GPS-2///////////////////
void ggg()
{
  gpsstr = "";
  while (1)
  {
    while (Serial2.available() > 0)
    {
      char inChar = (char)Serial2.read();//CHECKS WITH THE
VALUE($GPGGA) RECIEVES FROM GPS
      gpsstr += inChar;
      i++;
      if (i < 7)
      {
        if (gpsstr[i - 1] != test[i - 1])
        {
          i = 0;
          gpsstr ="";
        }
      }
      if (inChar == '\r')
      {
        if (i > 65) //73
        {
          flag = 1;
          break;
        }
        else
        {
          i = 0;
        }
```

```
     }
    }
    if (flag)
      break;
  }
}
/////////////////GSM////////////////
void gsm(String data,String data1)
{
  Serial1.println("AT");
  delay(1000);
  Serial1.println("AT+CMGF=1");
  delay(1000);
  Serial1.println("AT+CMGS=\"+918825592211\"\r");
  delay(1000);
  Serial1.println(data);
  Serial1.println(data1);
  Serial1.println("lat:"+String(lat2)+" "+"lon:"+String(lon2)+"\n");
  delay(1000);
  Serial1.println((char)26);
  delay(1000);
}
/////////////////GSM-1////////////////only for fire
void gsm1(String data,String data1) {

  Serial1.println("AT");
  delay(1000);
  Serial1.println("AT+CMGF=1");
  delay(1000);
  Serial1.println("AT+CMGS=\"+919445652135\"\r");
  delay(1000);
  Serial1.println(data);
  Serial1.println(data1);
  Serial1.println("lat:"+String(lat2)+" "+"lon:"+String(lon2)+"\n");
  delay(1000);
```

```
  Serial1.println((char)26);
  delay(1000);
}
/////////IOT///////////////////
void iot(String msg)
{
 for (int i = 0; i < msg.length(); i++)
 {
   Serial.write(msg[i]);
 }
 delay(3000);
}
```

The Gas Leak Detection Based on a Wireless Monitoring System

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***Abstract*—Industrial gas leaks cause accidents and pose threats to the environment and human life. Thus, it is essential to detect gas leaks in time. Usually, the abnormal concentration signals are defined by a fixed concentration value, such as 25% of the lower explosive limit. However, it is difficult to accumulate to the fixed point quickly when the leak is small. In addition, the actual leak signals are seldom available, making many data classifications inoper-able. To solve these problems, this paper proposes a detec-tion approach using the auto-correlation function (ACF) of the normal concentration segment. The feature of each nor-mal segment is obtained by calculating the correlation coefficients between ACFs. According to the features of statistical analysis, a nonconcentration threshold is determined to detect the real-time signals. In addition, the weighted fu-sion algorithm based on the distance between the sensors and virtual leak source is used to fuse multisensory data. The proposed method has been implemented in a field by building a wireless sensor network. It is confirmed that the system detection rate reaches as high as 96.7% and the av-erage detection time delay is less than 30 s on the premise of low false alarm rate.**

***Index Terms*—Auto-correlation function (ACF), correlation coefficient, gas leak detection, weighted fusion, wireless sensor network (WSN).**

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I. Introduction

GLOBALLY, the gas, petroleum, chemical, metallurgy, and other industries produce a large number of flammable and toxic gases as well as benzene and other organic vapors every year. Due to improper man-made operation or equipment aging, a large number of gas leaks have occurred. Some leaks that are not detected or repaired in time have caused great economic losses, environmental pollution, and even huge casualties. Sta-tistically, 778 safety accidents occurred in China from January 2016 to January 2017. The explosions and poisonings resulted from the gas leakage accounted for 6.17% and 5.4% reference to the total accidents, respectively [1]. The usages of hazardous materials are strictly restricted for safety by the State Admin-istration of Work Safety. However, the usage of chemical and hazardous materials increases year by year. At present, a large number of commercial companies and research institutions are engaged in researching the detection of dangerous gas leaks. In the market, the handheld devices are most commonly used. These devices have high accuracy and accurate positioning. However, the users need to go to the detected areas where the leaks are prone to occur while their safety and real-time detec-tion cannot be ensured [2]. The mobile robot with vision and gas sensors can replace the workers to detect gas leaks and send the data to a remote control center; this is a novel detection method and protects the lives of workers [3]. However, this detection system is limited by the mobility of the robot and is not suitable for monitoring areas with uneven terrain and wide range. In addition, the wire monitoring system that is composed of high resolution sensors and control centers solves the problems of the security and real-time issues by using the cables to transfer data and compromises on the inflexible installation and expensive maintenance [4].

Recently, sensor technology, wireless communication, and embedded technology are developing rapidly. The wireless sensor network (WSN) with low cost, flexible installation, real-time continuous detection, and other advantages is used widely in the monitoring of environmental parameters, structural health [5], and gas leaks. Somov *et al*. [6] deployed a ZigBee WSN to mon-itor gas leaks in a boiler facility. The system consists of nine battery-powered wireless sensor nodes and one network ZigBee coordinator while the system also has access to the Ethernet and GSM network to send messages. Generally, the system of detecting gas leak by gas sensors sets a few fixed leak concentration to confirm gas leak or not. Jelicic *et al*. presented a WSN for monitoring indoor air quality. The sensor node is designed with very low sleep current consumption and the network is multimodal. It exploits information from auxiliary sensors and neighbor nodes about gas concentration to modify the behavior of the node and the measuring frequency of the gas concen-tration [7]. Rossi *et al*. exploited the transient response of the sensing element, so that indoor air quality assessment power re-quired is reduced to 1/20 of the original [8]. In the paper [9], two alert levels that are high alert and low alert are set. According to the setting specifications for safety monitoring and controlling equipment in dangerous chemicals major hazard installations, two fixed points are set at 25% of the lower explosive limit (LEL) and 50% LEL usually. However, the leaks cannot be de-tected by setting a fixed concentration threshold generally when the leakage is small or just starts to happen.

Different from the common detection method of gas concentration for the leaks, the methods of infrared and ultrasonic detection developed rapidly in recent years. The former method uses thermal imaging and infrared image processing to detect leaks [10]. For example, a low cost infrared camera called SENSIA's Gas Imaging System [11] developed by Universidad Carlos III de Madrid is a low-cost infrared camera based on spectrally adapted and high sensitivity imaging technology. It can easily detect and identify fugitive gas emissions. Additionally, Leis *et al.* proposed improvements in the detection time [12] and the optical flux variation due to using solid-state IR sources to heat [13], respectively, which promoted the development of infrared sensors in leak detection. The ultrasonic method detects the leaks by analyzing the ultrasound that is generated under pressure. The approach is not affected by inclement weather, wind direction, and can respond quickly without physical contacts. The GDU-Incus ultrasonic gas leak detector released by the United States Emerson Group can detect gas leaks in the range from 2 to 40 m [14]. Also, it is unnecessary to wait until the gas concentration accumulates to a dangerous threshold. In the actual environment, the two kinds of devices are often set on the towers in order to monitor a larger area. Both of them have difficulty detecting the leaks with low leakage pressure, environmental obstacles, or interference from heat sources.

In order to solve the small leak detection, many algorithms have been used in the field of pipeline leak detection. The probabilistic and data classification methods are the common approaches. Akouemo *et al*. [15] used a linear regression model and a geometric probability distribution of the residuals to de-termine the anomalous probability of a data, and then trained a Bayesian maximum likelihood classifier to distinguish between false positives and true anomalies. Gupta *et al*. [16] proposed a probabilistic method which used Bayesian probabilistic framework and the steady-state flow and pressure values of gas to detect the presence of a leak event. In addition, Wang *et al.* [17] proposed a pipeline leak detection approach by using time-domain statistical features from normal sample signals, and built the support vector data description (SVDD) model to finish the leak detection. For the small leaks, some results have been achieved. Xiao *et al.* [18] used the variational mode decomposition (VMD) to do the components reconstruction and proposed the ambiguity correlation classification (ACC) based on the correlation coefficient to detect small pipeline leaks. A novel denoise algorithm based on dual tree complex wavelet transform and singular value decomposition (DTCWT-SVD) is applied for small leak detection [19]. Similarly, the harmonic wavelet based pipeline small leakage detection method is proposed by Hu *et al.* [20]. Furthermore, Kang *et al*. [21] presented a water leakage monitoring architecture using the one-dimensional convolutional neural network and a support vector machine (1-D-CNN-SVM) that utilized the feature maps of CNN as input to the classifier, and the approach does not need data transformation.

For small leaks, it is difficult to use the concentration threshold to distinguish small leakage. So the features should be extracted in the term of time-domain or frequency-domain so that the abnormal signals are distinguished. In the field of pathological analysis of electrocardiogram (ECG), an approach is proposed which extracted the auto-correlation functions (ACFs) of segments and analyzed the similarity between the ACFs of normal and abnormal to define the ECG signals [22]. The essence of this method is the concept of random signal processing [23]. However, the approach is to analyze whether the historical data contains anomalies after the sampling of signals has been completed. Therefore, the approach cannot be directly used for the online leak detection. Pister *et al.* [24] proposed a method combining the ECG concept and the likelihood function to detect industrial gas leaks. By establishing the concentration distribution model, the likelihood function is obtained, and then the result of leak detection is obtained by the method mentioned for the ECG. However, the threshold is obtained through constantly trying, and the impact of the sensor node's position was not considered.

To tackle these limitations, this work further advances the previous method from the following perspectives:

1) Implement an automatic procedure to select sensor nodes that participate in leak detection, considering the location of sensors.
2) Explicitly define the degree of the ACF as the feature for leak detection.
3) Propose a general procedure for the threshold that distin-guishes between abnormal and normal.

In the proposed method, normal data are sampled under the normal operation environment. The sample is first divided into fixed length segments. Then, the ACF of each segment is obtained and the degree of each segment is calculated as the time-domain feature by computing the correlation coefficient between each pair of ACF. It is employed as the discriminative feature for leak detection. Furthermore, the threshold, which is defined as the baseline to detect the abnormal signal, is obtained by analyzing the distribution of the degrees of the normal signals.

In this work, first the data collected by sensor nodes are initially analyzed and classified. The concentration is divided into three levels: the first level is greater than 50% LEL, the second level is within 25–50% LEL, and the third level is less than 25% LEL. The first two cases are defined as concentration abnormal while the third level is undefined. In addition, the temperature, pressure, and humidity are divided into normal and abnormal according to fixed alarm values, respectively. The system in this

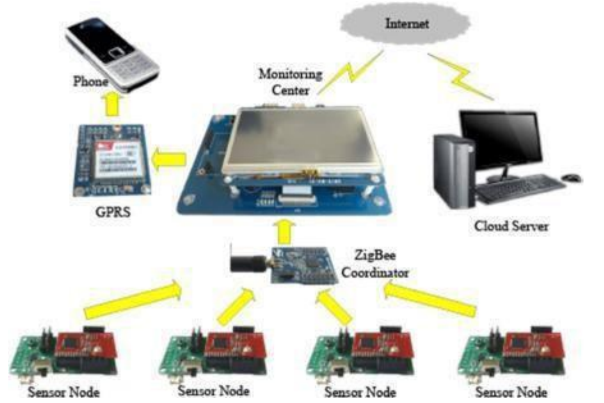


Fig. 1. Overall architecture of the monitoring system based on the WSN for the detection of gas leak.

study will sound alarms immediately when the abnormal results are obtained. The undefined concentration data will be defined by the method proposed in this paper. The reliability is verified by comparing the measurement data of the professional sensor equipment with the data in our system.

The rest of the paper is organized as follows. The wireless monitoring system for the gas leak detection is introduced in Section II. Section III describes the method of the gas leak detection including the selection of the multisensory data and the feature extraction in time-domain mainly. The experimental results are presented in Section IV. The paper is summarized and concluded in Section V.

II. WSN-Based Detection System

Fig. 1 illustrates the overall architecture of the monitoring system based on the WSN for the detection of gas leaks in an open environment. In order to detect the gas leak, a number of ZigBee nodes with gas sensors and a ZigBee coordinator need to be deployed to form a WSN in the monitored area. After converting and filtering, the data of gas concentration will be sent to the ZigBee coordinator. Then, the sensor nodes which send the third level data are selected to form a set by the ZigBee coordinator. The ZigBee network uses the 2.4-GHz band. The data of the sensor nodes in the set is fused into one concentration sequence (CS). Then the CS is transferred to the monitoring center of the system and judged whether there is a gas leak by the detection algorithm. The method used by this work is described in Section III. Once the concentration signals are detected as abnormal by the detection algorithm, the GPRS module will send out an audible alarm and warning messages to the maintenance person. It works in the 900-MHz band. It will also send the collected data and the diagnostic result to the cloud server via Internet.

A. Wireless Sensor Nodes Design

All the data analyzed by the detection system is acquired by the sensor nodes. So the impact of the environmental factors on the sensor data will be mapped to the result of the detection system. At this point, the temperature, humidity, and pressure sensors (THPs) are included in the nodes. The sensor nodes in this work are designed by MCU, ZigBee wireless transceiver module, sensors module, and power supply module.

Considering the feasibility and safety of experimental operations, ethanol is used as the test gas and the sensor TGS2620 was selected, with a 50–5000 part per million (ppm) measurement range and a 0.3–0.5 sensitivity (resistance ratio). The sensor is comprised of a metal-oxide-semiconductor layer formed on an alumina substrate together with an integrated heater. In the presence of a detectable gas, the sensor's conductivity increases as the gas concentration increases. A simple electrical circuit can convert the change in conductivity to an output signal which corresponds to the gas concentration. For the test, it consumes an average of 42 mA current at 5 V. The power consumption of gas sensor is approximately 210 mW. To meet the power requirement of the sensor node, it would be possible to utilize a solar scavenger with a rechargeable battery, combined with ad-justable sampling frequency according to gas leak or not, and unnecessary alarms report to minimize the energy consumption. As efficient microcontrollers become cheaper and less power hungry, the only component left to be improved is the sensor [24]. The main weakness of the metal-oxide-semiconductor gas sensor used in this work is its large energy consumption, which is also a common shortcoming of current gas sensors. Low-power gas sensors are currently less commercially available, but the gas sensors reported in the literature have been able to achieve very low power consumption. For example, Y. H. Kim *et al.* [25] demonstrated a self-activated transparent all-graphene gas sensor, with power consumption of 12 μW to 14.2 mW for the applied voltage of 1 to 60 V. The power consumption of low power wireless gas sensors used by A. Som *et al.* [26] is 75 mW in the continuous measurement. Its low power consumption is achieved by applying a heater implemented as 10-μm platinum microwire in glass insulation. H. Long *et al.* [27] realized a gas sensor by integrating a novel 3-D hybrid aerogel on a low-power microheater platform, and when the temperature of the microheater is 200 °C, the power consumption is only 4 mW. In the future, the commercial application of these low-power gas sensors will greatly improve the continuous working time of wireless gas sensor nodes.

Other strategies have also been researched to solve the en-ergy consumption and power supply problems of wireless sensor nodes. The literature [28] studied the system- and circuit-level optimization of power supply systems for WSNs, and renew-able power-supply systems. M. Chen *et al.* [29] presented a self-powered wireless sensor node powered by an electromag-netic energy harvester, and the results show that designing chip architecture with less components is also good strategy.

The algorithm mentioned in this paper is suitable for low sampling rates to conserve the AD sampling's power consumption and when detecting a sudden gas leak, then increase sampling frequency to ensure the sensor data accuracy. To increase the continuous working time of the wireless gas sensor node, choosing large capacity lithium cells is also one compromise method. For example, when the gas sensors work intermittently, it works 10 s every 20 s for data acquisition when there is no gas leak-age. Based on the 10 000-mAh size lithium cells available on

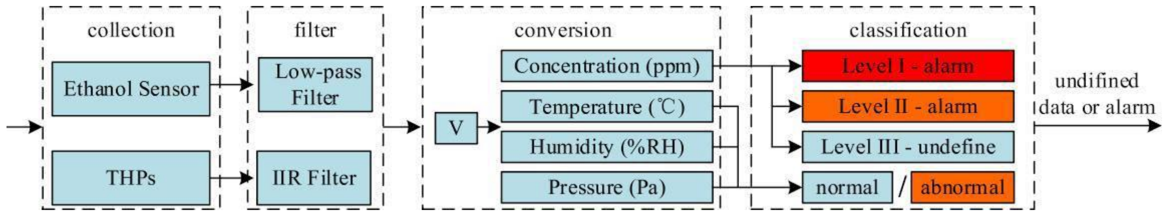


Fig. 2. Flow diagram of the data processing in the sensor nodes.

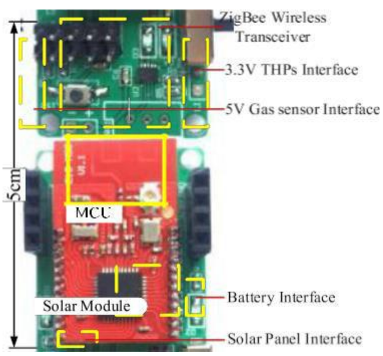


Fig. 3. Physical diagram of the sensor node.

the market, the gas sensor can work for about 40 days. If the photovoltaic solar panel and future low power consumption gas sensors with a few microWatts to milliWatts order of power consumption will be used in the sensor nodes, a longer working time can be reached.

For the THPs, the BME280, which is a MEMS sensor integrated temperature, humidity, and pressure, is adopted. The sensor has a built-in IIR filter to filter short-term disturbances. It consumes 11.88 μW when it works and 0.33 μW when it is dormant. For the MCU and wireless transceiver module, the highly integrated CC2530F256 chip is used as the node processor and transceiver. In order to achieve the minimum power consump-tion of the node, we reduce its transmission power under the condition of satisfying the normal monitoring of the system, where the transmission distance is 70 m. The peak of working current specified for CC2530F256 chip is 79 mA at 3.3-V supply in continuous measuring mode. The major function of this chip includes the collection of signals, filtering, voltage/indicators conversion, classification, and the signal transmission. The flow diagram of the data processing is shown in Fig. 2.

In addition, the sensor node is powered by a lithium battery and the BP24210 solar charging module produced by TI. A photograph of the sensor node is shown in Fig. 3.

B. Deployment of Sensor Nodes

The placement of the sensor is critical to the detection result. It affects the collection of data directly, even if the sensor is located near the gas source. The sensor nodes can be distributed randomly, deterministically, or uniformly. On the premise of being familiar with the monitoring area, the deployment of sensors is deterministic. The sensor nodes should be deployed at the location where the concentration data is prone to be collected. The simulations for the leak of volatile ethanol by Fluent are performed to analyze the distribution of the concentration and further determine the position of the sensor under different conditions. Fig. 4(a) presents that the leaking gas is influenced by the wind direction, the source nozzle size is 6 mm and the wind direction is set from left to right. It is observed that the gas diffusion is divided into four stages: first, the gas diffuses in the initial injection direction; second, the gas spreads mainly in the downwind direction under the influence of the wind; then the gas sinks and accumulates as the density of ethanol is greater than the air's; third, the buoyancy force plays a leading role and the gas diffuse upward; finally, the gas concentration is negligi-ble when the gas is diluted in air. And Fig. 4(b) illustrates the concentration distribution in presence of an obstacle near the leak source. The leaking gas bypasses the obstacle or accumu-lates nearby the obstacle. There is higher concentrations at both front and back of the obstacle.

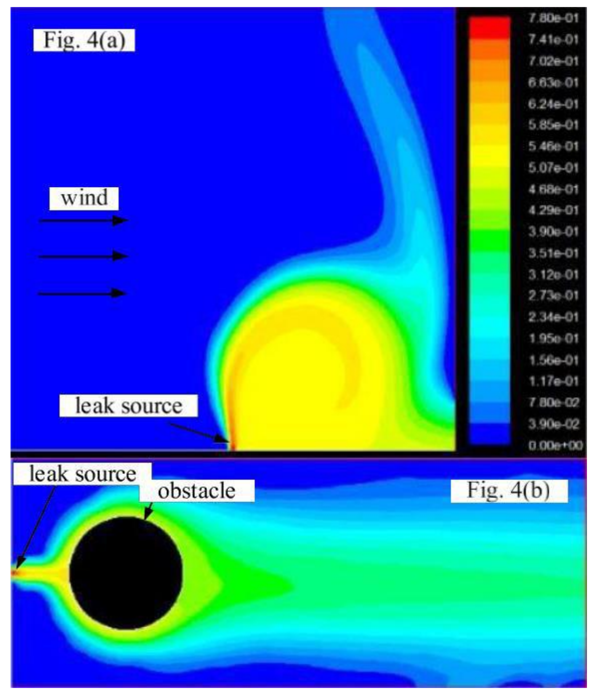


Fig. 4. (a) Gas diffusion simulation under the influence of the wind direction and gas characteristics. (b) Concentration distribution in presence of an obstacle near the source of the leak.

As shown in Fig. 4(a), the sensor is mainly collected during the second stage of gas diffusion, since the initial injection direction is unpredictable and the concentration is too low in the latter two stages.

Therefore, combined with the simulation results and the safety specification of combustible gas detection, the deployment rules of the sensor nodes are summarized as follows:

1) The more sensor nodes should be installed at the downstream of the high frequency wind direction relative to the potential leak source.
2) When the density of the gas is greater than 0.97 kg/m^3, the sensor nodes should be deployed below the level of the potential leak source.
3) Considering the presence of the obstacle, the sensor should be placed in the vicinity of the obstacle (e.g., columns or walls).
4) A suitable obstacle will be placed near the sensor nodes to increase the gas residence time when the monitored area is open or the wind speed is high.

III. Method of the Gas Leak Detection

A. Time-Domain Features Extraction

Time-domain features such as variance, mean, kurtosis, or skewness are not suitable as a basis for judging between normal and abnormal. The main drawback of mean is that it is easy to be affected by extreme values. By increasing the time window of each average, the effect of extreme values can be reduced, but the monitoring delay of the system is increased. Variance can indicate the deviation of all samples from the mean value to a certain extent, but it cannot be used as a parameter for rapid detection of gas leakage. Kurtosis are statistics describing the overall extent of the slow distribution of all forms steep values, which is not suitable as a statistical parameter for gas leakage. Skewness is a measure of the skewness and extent of statistical data distribution. It is a numerical feature of the degree of asymmetry of statistical data distribution, and is not suitable for dynamic feature statistics. Mean and variance is used in ACFs. They are part of the algorithm. These parameters, such as mean, variance, is not suitable for determining whether a gas is leaking or not. The algorithm is supposed to detect the leaking as soon as possible, but these parameters are time-consuming.

When no leaks occur, the concentration of the monitored gas approximates to zero. And if leaks happen, the amplitude of concentration will fluctuate and deviate from zero. Therefore, a common detection method of gas leak is to set fixed alarm concentration point (such as 25%LEL and 50%LEL). The prob-lem is that the concentration is difficult to accumulate to the alarm points when the leak aperture is small. Thus, the non-concentration threshold need to be set.

The measurement curves of gas sensors in the process of gas leakage and nonleakage, as well as the sampled normal and abnormal signal of concentration in 3 min are shown in Fig. 5. According to product information of TGS 2620, this sensor is insensitive to low level ppm of ethanol. When the gas concentration is lower than 50 ppm, the sensor has a lower precision because of the insensitivity. The sampling rate of the sensor is 1 Hz during the experiment. There is no need for high sampling rate in the detection process of the system, which is helpful to reduce the power consumption. The abnormal signal was generated with a man-made ethanol gas leak, whose aperture

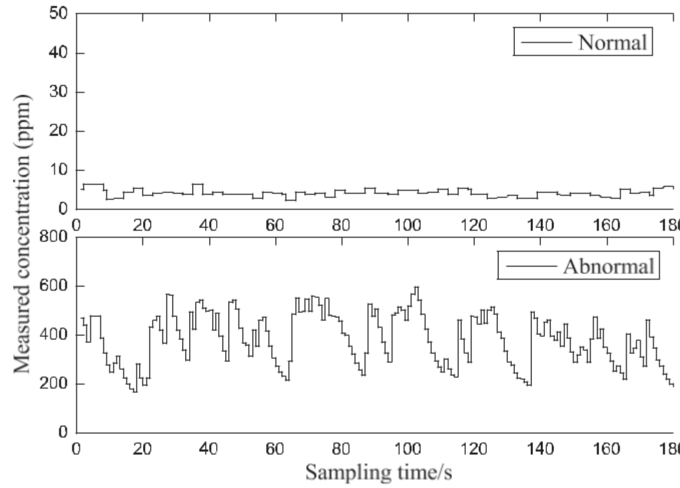


Fig. 5. Top: normal concentration data (without leak); bottom: abnormal concentration data (with leak).

is about 6 mm. The ethanol sensor is placed downwind at a distance of 20 cm from the leak source made by our laboratory.

The signals of normal and abnormal are divided into three segments respectively, and then the ACF of each segment is calculated. The result is shown in Fig. 6.

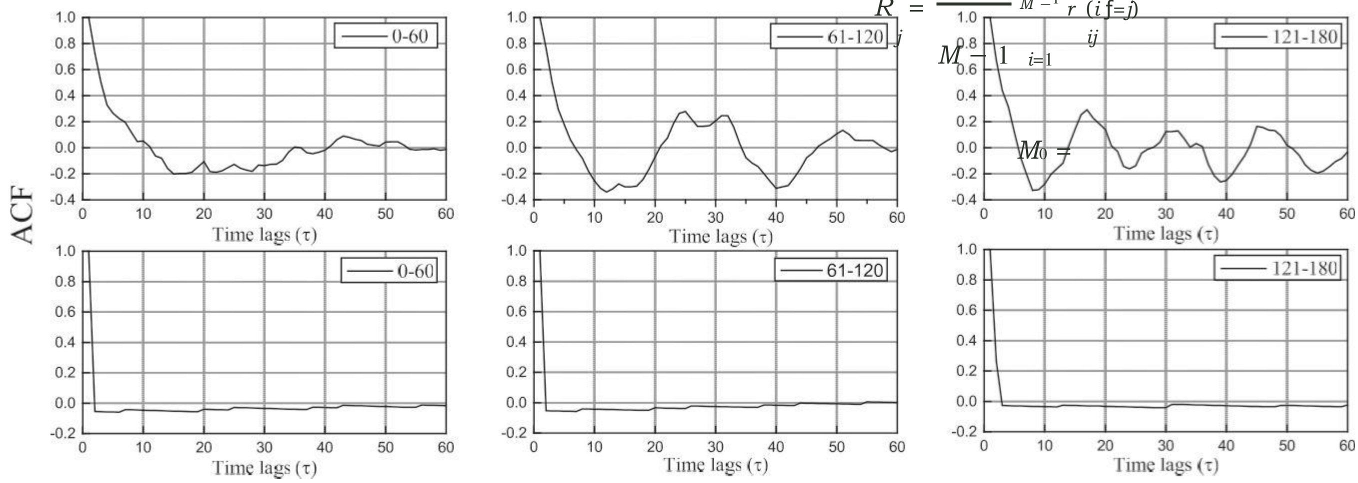
The similarity between ACFs is determined by the correlation coefficient, which is quantified by

$$r_{ij} = \frac{\mathrm{Cov}\,(A_i, A_j)}{\sigma_i \cdot \sigma_j} = \frac{E\,[(A_i - \mu_i)\,(A_j - \mu_j)]}{\sigma_i \cdot \sigma_j} \tag{1}$$

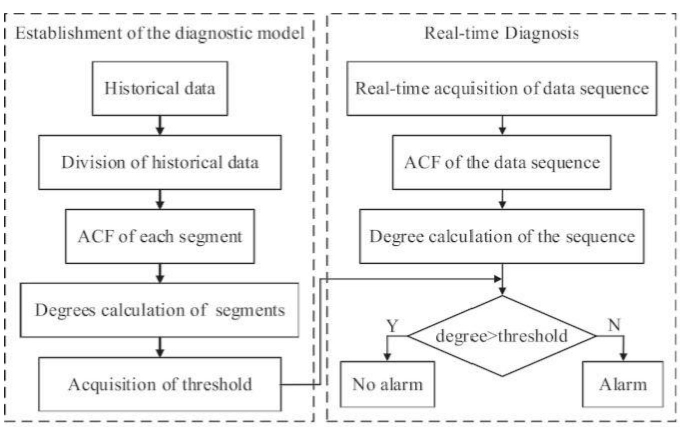
where A_i and A_j are two ACF, μ_i and μ_j are the means of A_i and A_j, σ_i and σ_j are the standard deviations of A_i and A_j. In this way, the correlation coefficients r_{ij} are normalized to the range of 0 to 1 firstly and then a correlation matrix composed of r_{ij} is formed. Each segment is characterized by a degree value, which is obtained by calculating the mean of the coefficients for each column of the matrix. When the segments are all normal, the degrees of them are high. And when the segments contain many normal segments and an abnormal segment, the degree of the abnormal segment is low. The degree feature is independent of the absolute amplitude and reflects the similarity between an undefined segment and normal ones. Therefore, the degree can be used as the feature to differentiate the normal and abnormal signals.

B. Implementing Leak Detection With Time-Domain Features

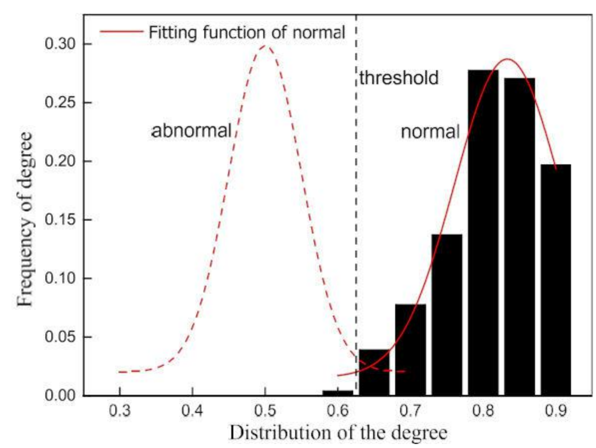
1) *The general procedure:* For the system implementation, the leak detection model is established with the normal concentration data and applied to the real-time gas leak detection. Fig. 7 illustrates the leak detection procedure used by this study.
2) *Feature extraction:* The training historical data took two hours to complete the sampling continuously when no leak. The time-domain features, which described in Section III-A, can be extracted by the following steps.
   a) Divide the historical data into M segments with a step value N (with $N = 30$).



l) Fig. 6. ACFs of six different concentration segments of one minute. When the signal is normal, their ACFs are similar and stable while the abnormal ACFs have large fluctuations which are different strongly from the normal ACFs. This can be seen in Fig. 10 where the ACFs of three normal segments (bottom) and three abnormal segments (top) are plotted together.



m) Fig. 7. Procedure for real-time leak



n) Fig. 8. Statistical distribution curve of

j) b) Then the ACF of each segments is

k) c) Next, the correlation matrix is formed

h)

g) i) Finally, the degrees R_i of ACFs are computed by averaging each column of the

$$R_j = \frac{1}{M-1}\sum_{i=1}^{M} r_{ij} \quad (i \neq j)$$

e) 3) Threshold determination: In the previous step, nearly three hundred degrees have been obtained. These degrees are used to do the demonstration of the method and more historical data is needed in practice. The histogram of the degrees' distribution can obtained by the following steps: a) Divide the value of degrees into M_0 groups with a

f) step value A_{step}, which can be

$M_0 =$

c) R

d)

b) where R_{max} and R_{min} are the maximum and minimum of the degrees, respectively. The value ratio can be used to detect the leak [30]. However, it is almost impossible to get actual leak samples. So the threshold should

second place after the decimal point, so the step A_{step} is set to 0.05.

b) Count the number of degrees whose value fall in the range of the kth(k = 1 , ..., M_0) group and scale it as frequency.

c) Calculate the fitting function of the histogram distri-

(2)

bution based on the statistics of the degrees.

Plot the statistical distribution curve of the degrees and the fitting function.

Through the process of the fitting, the probability density function (PDF) of the degrees is obtained, as shown in Fig. 8.

In other words, the probability $P(R_i \mid \theta = 0)$ against the de-gree R_i is obtained when no leak ($\theta = 0$). According the pre-vious theories described in Section III-A, the degrees of the abnormal segment are less than the degrees of normal, gener-ally, as shown in the Fig. 9.

If enough leak data is available, the probability $P(R_i|\theta = 1)$

(3)

against the degree R_i also can be obtained when leak which is shown by the dashed line in Fig. 8. The sequential probability

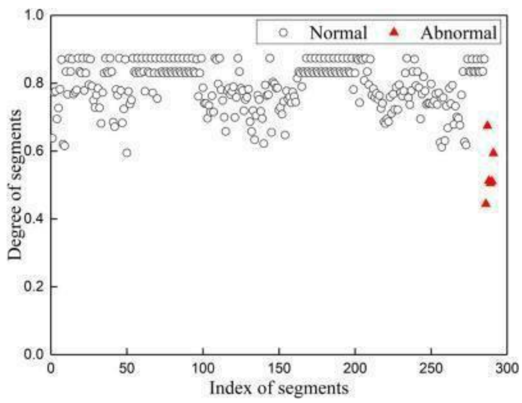


Fig. 9. Circle symbols represent normal degrees, while the triangle symbols represent abnormal degrees.

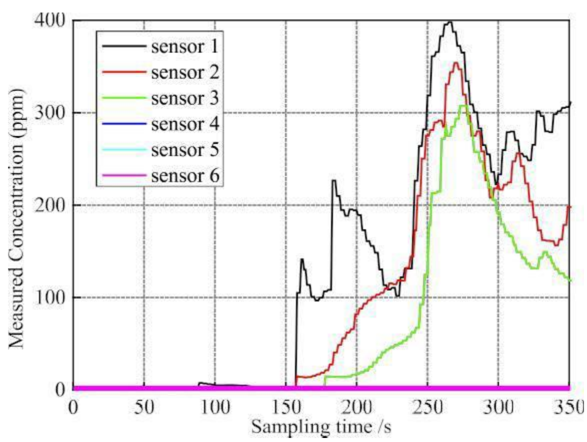


Fig. 10. Concentration curve of sensors at different distances from the leak source.

be set so that the probability $P(R|_i\,\theta = 0)$ is low under the premise of higher detection rate and lower false positive. When the degree is the threshold, the probability $P(R|_i\,\theta = 0) = P_{th}$.

The threshold is a critical parameter. The false negative judgment increases when the threshold is too low, while the false positive one rises when the threshold is too high. So a suitable balance between them needs to be confirmed.

4) *Selection of sensor nodes and fusion of the real-time data:* Generally, the WSN uses a large number of sensors to obtain data. As the deployment grows in size, a faraway sensors from the leak source will probably not be able to detect any change. The response of the sensors to the plume of gas will depend on its location with respect to this plume, to confirm it, a test is completed by placing six sensors at different distances from the source of the leak in the downwind direction. It is found that the concentration decreases and phase of the detected concentration curve delay away from the source of the leak, as shown in Fig. 10.

The several sensors closest to the leak source should make up a set to participate in the detection of gas leak such as sensor 1–3. However, the location of the source leak is uncertain. The general rule is that the closer the distance to the leak source, the greater the gas concentration. So, the sensor with the largest mean concentration over a period of time was assumed to be the virtual leak source (VLS).

In this work, the concentration data collected by the ith sensor at time t is expressed as $x_i(t)$ where $i \in \{1, 2, \ldots, n\}$, n is the total number of sensors that detected the third level data. The distance $d_{iVLS}(t)$ between the VLS sensor and sensor i can be written as

$$d_{iVLS}(t) = \exp\left(-(x_i(t) - x_{VLS}(t))^2\right). \tag{4}$$

The smaller the $d_{iVLS}(t)$, the greater the distance. In addition, the distance $d_{iVLS}(t)$ is also fluctuant since the concentration is fluctuant. At a moment, a sensor is close to the VLS sensor, and it may be far away from the VLS sensor at the next moment. So when the mean of $d_{iVLS}(t)$ is large and its variance is small, the sensor i is considered close to the leak source in the period of time T. The distance D_{iVLS} is given as

$$D_{iVLS} = \left(1 - 0.05\sigma_i^2\right) \cdot \overline{d_{iVLS}}. \tag{5}$$

And there are

$$\overline{d_{iVLS}} = \frac{1}{N}\left(d_{iVLS}(t_1) + d_{iVLS}(t_2) + \cdots + d_{iVLS}(t_N)\right) \tag{6}$$

$$\sigma_i^2 = \frac{1}{N}\sum_{k=1}^{N}\left(\overline{d_{iVLS}} - d_{iVLS}(t_k)\right)^2 \quad k \in (1, N) \tag{7}$$

where N is the step value and the number of sampling points in the period of time T.

Thus, a set of distance is given as

$$D_n = \{D_{1VLS}, D_{2VLS}, \ldots, D_{nVLS}\}. \tag{8}$$

According to the value of D_{iVLS}, the top m sensors are selected into the new set D_m that is given as

$$D_m = \{D_{1VLS}, D_{2VLS}, \ldots, D_{mVLS}\}. \tag{9}$$

Correspondingly, the set S_m including s sensors is obtained as

$$S_m = \{s_1, s_2, \ldots, s_m\}. \tag{10}$$

The weighting coefficient c_i of each sensor in the set S_m is calculated according the D_{iVLS} in the set of D_m as

$$c_i = \frac{D_{iVLS}}{\sum_{i=1}^{m} D_{iVLS}}. \tag{11}$$

Hence, the data from the sensors close to the VLS play a more important role in the leak judgment. Finally, the value $X(t)$ in the CS, the result of fusion, is given as

$$X(t) = \sum_{i=1}^{m} c_i x_i(t). \tag{12}$$

The CS is recognized as the real-time data sequence and is used as the input of the diagnostic model.

5) *Leak detection:* Once the real-time CS is obtained, its ACF is computed first. According to the flow in Fig. 11, the real-time degree needs to be obtained. At the same

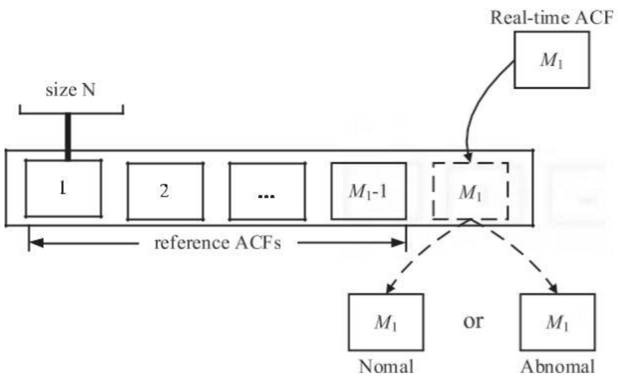


Fig. 11. Diagram of the real-time detection.

Fig. 12. Experimental devices.

time, several ACFs of the normal sequence are required for the calculation of the real-time degree. The length of data in one detection, denoted as L, is divided into M_1 segments (named window 1). As a result, the length of each segment is $N = L/M_1$ (named window 2) which is the same as the value mentioned in the step 2. The first M_1-1 ACFs are taken as the reference values and the M_1 th is the real-time ACF. So its degree is obtained according to (1) and (2). If the new degree is less than the threshold, it means the input concentration is abnormal; otherwise, the concentration is normal.

IV. Experimental Validation

A. Verification of the Effect of Ambient Temperature on the Output Response of the Sensor

As MOX sensor, the output of the gas sensor also depends on the temperature of the internal heater, we have done some exper-iments on the gas to analyze the effect of ambient temperature on the output response of the sensor. We have measured internal heater temperature and the response of the gas sensor at multi-ple temperatures in the temperature box. Experimental devices are shown in Fig. 12. Experimental device structure diagram is shown in Fig. 13.

The effect of working environment temperature on MOX gas sensor is shown in Fig. 14 with a red line. When the gas sensor

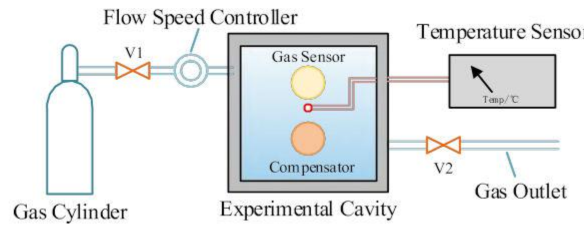


Fig. 13. Experimental device structure diagram.

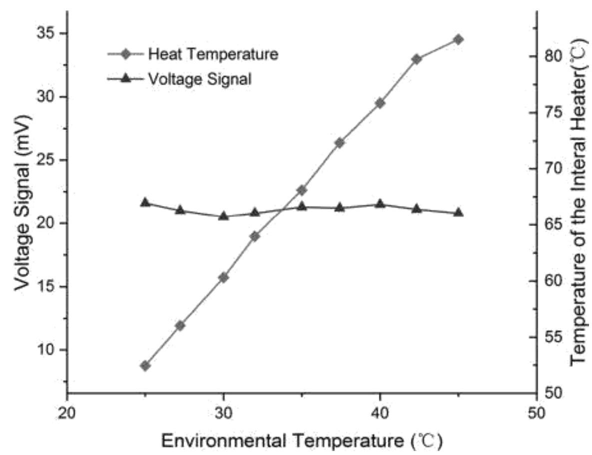


Fig. 14. Effect of ambient temperature on temperature of internal heater.

is placed in the thermostat, the temperature of the gas sensor heater rises as the temperature of the thermostat rises, when the ambient temperature reaches 47.5 °C, the heater temperature rises to 82.5 °C. The output voltage of the sensor corresponding to the test temperature is shown in Fig. 14 with a blue line. The experimental results show that the output variance of the sensor is 0.126 in the working environment temperature range of 25 °C–47.5 °C.

It can be seen from the diagram that the heater temperature in gas sensor increases with the environment temperature, but the effect of environment temperature on the gas sensor is relatively small. This is because of the existence of compensator inside the sensor, the external temperature has little interference on the sensor. As we can see from Fig. 12, the compensator that is wrapped in an aluminum shell has the same physical structure as the detector. So the only difference between them is the composition of the gas around the two detectors. The influence of external factors on test results could be reduced by such structure.

According to working mechanism of MOX gas sensor [27], heating the sensing material of MOX sensor with a heater can en-hance the reversibility of the sensor and accelerate the response and recovery rates. The response and recovery time might be faster at higher temperature than room temperature, therefore, the performance of MOX gas sensor is affected by the heater temperature in gas sensor. But according to the tested results, the working environment temperature changes will has little ef-fect on sensor performance for MOX gas sensors with one good temperature compensating structure.

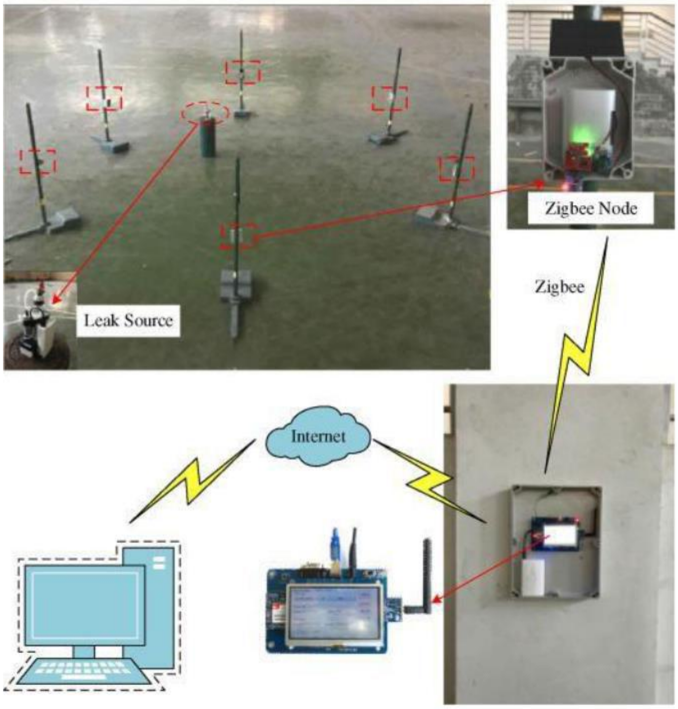


Fig. 15. Site of the experiment.

The effect of humidity on the performance of MOX gas sensor has not been tested due to the lack of testing setup. According to literature [31], humidity effects maybe neglected as they are usually an order less significant than temperature effects which is due to temperature change in the sensor heating element.

B. Field Tests of Leak Detection System

In order to verify our system, the experiment was carried out, as shown in Fig. 15. For safety, the volatile and nontoxic alcohol (95% alcohol purity) is selected as the source of gas. The source of the leak consists of air pump, power supply, alcohol bottle, and nozzle. In the leak process, the gas concentration is constant. Hence, the leakage only depends on the size of the nozzle. In the experiments, the nozzle sizes are 6, 11, and 20 mm. 30 leaks were created and each one lasted 3 min. It takes about 5 min to initialize the gas sensor before testing (sensor resistance preheating), and the node will work well after a preliminary classification and Zigbee restart needs time until become active, it is all about 10 s to start measuring in the system.

C. Parameters Selection for Gas Leak Detection

Several parameters have significant effects on the judgment in the proposed method. They are analyzed respectively. As shown in Fig. 16(a), the general trend observed show that the true positive rate of the detections increases as the length of the window 2 size increases greatly. And the impact of the size of window 2 on the true positive rate tends to be stable beyond a particular point (around 18). The length of window 1 shows little influence on the true positive rate of the detections. The

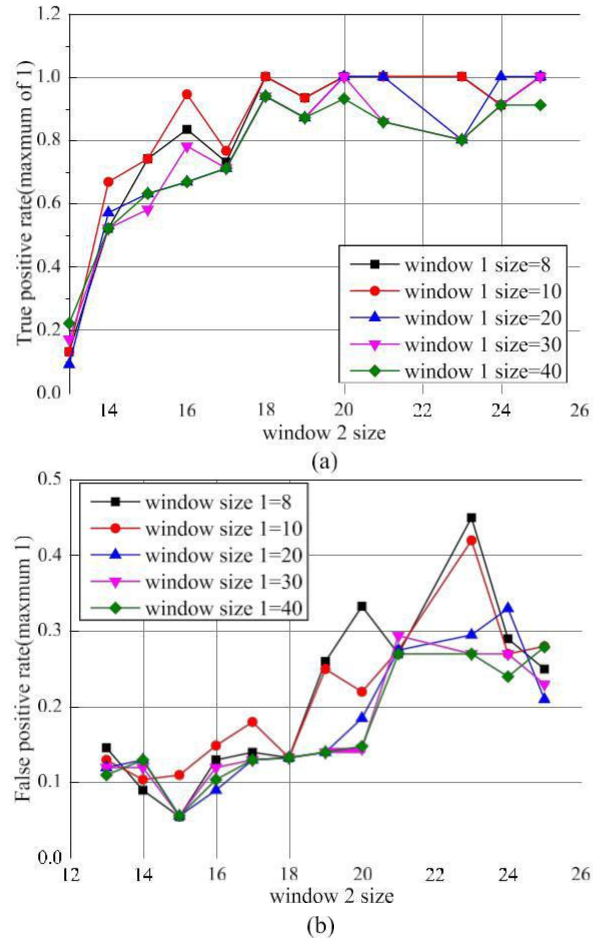


Fig. 16. Effect of the window size on both the true and false positive rate. (a) The effect of the window size on the true positive rate. (b) Effect of the window size on the false positive rate.

impact of changing the window 1 size and window 2 size on the false positive rate is shown in Fig. 16(b). It demonstrates that the false positive rate fluctuates at a lower level when the size of window 2 is small and then increases significantly when the length of window 2 exceeds a value (about 18). The trend shows that increasing the window 1 size does not affect the false positive rate obviously, except when it reduces to a small value (such as 8 or 10).

Besides the window sizes, the threshold is an important parameter that determines the performance of the detection method. The effect of the threshold on both the true and false positive rate can be seen in Fig. 17.

According the general trend, the true and false positive rate increase drastically. Furthermore, there are no detectable leaks and false positive judgment when the threshold is particularly small (set to 0). In addition, almost all of the segments will be misjudged (false positive rate of 100%) in another extreme case in which the threshold set to 1. The true positive rate is close to 100% at the same time because any degrees of the leak segments are certainly smaller than 1. However, false positive rate of 100% is unacceptable. Therefore, the threshold should be set to decrease the false positive rate on the premise of ensuring

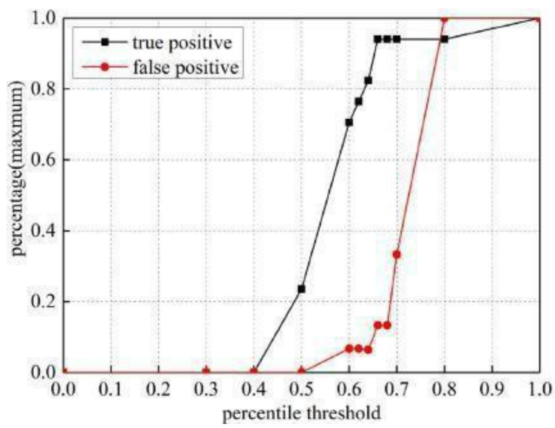


Fig. 17. Effect of the threshold on both the true and false positive rate.

TABLE I
COMPARISON OF TEST RESULTS BETWEEN COMPARATIVE AND PROPOSED METHODS

Signal type	Comparative method	Proposed method
Artificially leak signal	50	50
True positive alarm	42	47
Experimental group of no leakage	50	50
False positive alarm	7	5
Delay time	≥100	≤30

high true positive rate. In Fig. 17, the threshold is set at around 0.68 and the corresponding probability P_{th} is 0.02.

D. Results

According to the parameters selection rules presented in Section IV-C, the parameters are set as $N = 18$, $M_1 = 40$. In this test, historical data were collected for one day offline and more than four thousand segments were got as training sam-ples when no leaks. Then the statistical distribution curve of degrees. After fitting, the PDF curve $P(R_i|\ \theta = 0)$ is obtained. So the threshold is set as 0.68 when the probability P_{th} is 0.02. By using real-time data processing methods, real-time degrees are obtained and the results of leak detection are shown in the column of Table I. Based on the field operation and correspond-ing inspection records, during the monitoring of the set of 50 sets of leakage test group and 50 sets of non-leakage test group, the method of this paper successfully detected 47 sets of leak-age data. When detecting the non-leakage data, 5 sets of false alarms occurred, and the delay was within 30 s. Furthermore, the method of likelihood function [24] is used for comparison. A pipeline small leak detection by harmonic wavelet is used in the contrast experiment. The experimental setup of comparative approach is as follows:

1) Stage 1 window size: 20.
2) Stage 2 window size: 150.
3) Percentile threshold: 15%.

The PDF in comparative approach is obtained based on the statistics distribution of the historical data in preparation stage. And the likelihood of sensor data is obtained. By dividing the segments, the similarity of the segments is calculated. The per-centile threshold are determined by observing the general trend and keeping trying. The detection result are given in the Table I. There are 42 true positive alarms and 7 false alarms. It is obvious that the proposed method in this work is better than the com-parative method in the term of detection efficiency. Moreover, the quite good performance is obtained in the detection delay. The time of the proposed approach is within 30s while the com-parative approach is more than 100s averagely. In general, the method proposed by this study is more efficient.

V. CONCLUSION

In this paper, a concentration-based leak detection method with statistical feature extraction is proposed. The detection model is built with the feature extracted from normal con-centration signals. The approach obtained the nonconcentration threshold using the distribution of the correlation between ACFs of normal concentration segments. Moreover, an automatic pro-cedure is described to select sensor nodes that participate in leak detection considering the location of sensors. And the real-time concentration is the last segment in the real-time diagnosis process, which reduced greatly the detection delay and calcu-lation. Additionally, the analysis of the position of the sensors by the simulations of Fluent is performed in consideration of the influence of wind direction and obstacles during the de-ployment of the sensor network. Modeling simulation results provide recommendations for node installation. And the sen-sors are placed at the points where the concentration of gas is more easily collected. Based on the field operation (with 8 sensors and a monitoring area of 50 m^2) and corresponding in-spection records (with an average delay of 30 s), there were 47 true positive alarms, 5 false positive alarms with the proposed method. The experimental results demonstrate that the proposed method in this work can effectively detect the gas leaks.

In the future, many topics remained for research and gas leak detection will make great progress. The noise in the original signals has great impact on the detection of small leaks and should be considered. With the improvement of wireless com-munication reliability, and as efficient microcontrollers become cheaper and less power consumer, the only component need to be improved is the sensor. The power consumption of gas sen-sors is a huge obstacle to the application of WSN in the field of gas leak detection and a gas sensors can only measure one gas; Detection of multiple gas types will result in increased energy consumption of nodes, which provides an opportunity for de-velopment of the energy harvesting and MEMS process. Better sensor hardware can provide more accurate data for algorithms.

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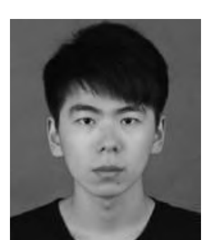

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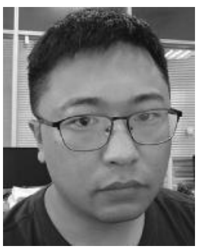

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L-Leakage Detection and Prevention of its Threats Using IoT in Smart Home Automation Systems

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***Abstract*: These days' gas spillage and gas identification is a significant issue in our day by day lives. Additionally, gas wastage is a significant issue that should be countered. LPG gas is exceptionally combustible and can dispense harm to life and property. To maintain a strategic distance from such circumstances, an extensive measure of exertion has been given to the improvement of dependable systems for recognizing gas spillage. As thinking about the presence of a break isn't in every case enough to dispatch a remedial action, some of the break location procedures were intended to permit the chance of finding the hole. Our point is to decrease the dangers in Kitchen utilizing Internet of Things. The primary point is to propose the structure and development of a wi-fi based Gas Leakage Alert System. Gas sensor are utilized to distinguish gas spillages in a kitchen with the assistance of the controller Arduino Mega (ATmega2560), with the assistance of an infrared sensor the issue of gas wastage is additionally observed. A caution goes off at whatever point the sensor doesn't distinguish any vessel over the burner past a specific timespan.**

***Keywords*: Arduino Mega, GPS, GSM, IoT module.**

1. Introduction

The LPG gas is highly ignitable and can inflict damage to life and property. Our main aim is to construct the wireless fidelity based gas outflow alert system. Gas detector area units won't notice gas leakages in an exceedingly room with the assistance of the controller Arduino Mega (ATmega2560), when the gas leakage detected the evacuation starts. At the moment any fire exists in the surrounding the servo motor generates the fire extinguisher and this action clear the chance of an accident situation.

The entire system function can be displayed in the LCD display and can be controlled by the IoT. These data can be stored in the cloud. With the help of an IR sensor detector the problem of gas wastage is additionally monitored. An alarm explodes whenever the detector doesn't notice any vessel over the burner on the far side for a selected period of time.

2. Literature survey

[1], [4] describes the property of gas sensor to detect LPG and natural gas sense at the low level. The system automatically closes the knob after it detect the gas leakage is represented in [2], [9]. [5] describes the detection based on the ambient temperature and humidity condition. [8] indicates the generation of sound alert using buzzer. [8], [9] refers the wi-fi module will send SMS using the cloud to the user. [9] refers the exhaust fan will fan out all enclosed gas from the environment. The relay will cut off the main power supply within 2 to 4 seconds.

3. Proposed work

In this system, Arduino Uno (ATmega328P) microcontroller are used, which acts as brain of the system, because the entire system program instruction stored in it. Gas, temperature and humidity sensor are used to monitor the leakage status of gas. The detection of gas result of power off the all power supply of system along with immediate evacuation take place by using DC fan. Here, IR sensor is used to detect the vessel at gas top.

The fire sensor used to detect the fire so that the servo motor Implement the fire extinguisher, following action clear the chance accident situation. Once the fire detected means the location get by GPS is sent to the fire station through GSM, All the operation as well as the entire system function status can be displayed in LCD and monitored and control by IOT.

A. Gas leakage detection

The main function of this module is to detect the gas leakage in the kitchen. It consists of the Arduino Mega microcontroller, gas sensor, DC fan, LED, Buzzer. Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button, and turn it into an output - activating a motor, turning on an LED, publishing something on the cloud. Arduino act as the heart of the entire system. It consists of an ATMEL 8 bit AVR microcontroller with varying amount of flash memory, pins and features. The gas detection is done by using a gas sensor that is sensitive to LPG, natural gas and other gases such as CO and H2. It is made up of Tin dioxide(Sno2). The gas sensor detects the small change in the concentration of the gas. The Power supply can be noticed with the help of LED. The Light Emitting Diode is forward biased

PN junction Diode. It makes the complete atom more stable and it gives a little burst of energy in the photon of light, when the whole action takes place the buzzer starts the function and intimate the gas is detected in the room. The kitchen exhaust fan can be a vitally important part of our kitchen. The kitchen exhaust fans are extremely effective when it comes to the extraction of air and any possible pollution or other substance that may be present. Some exhaust fans employ sensors that allow them to automatically activate when they send the gas that streams in the room.

B. Fire detection and evacuation

The fire sensor is designed to detect the fire. The fire sensor consists of sounding an alarm, deactivating a fuel line (such as propane or natural gas) and activating a fire suppression system. When the fire burns it emits a small amount of Infrared light that will be received by the photodiode on the sensor module. Arduino Mega checks the logic level on the output pin of the sensor and perform further task such as activating the buzzer and LED sending an alert message. The fire sensor circuit is too sensitive and can detect a rise in temperature of 10 degree or more in its vicinity. When the fire detected the fire extinguisher starts its function. A fire extinguisher is an active fire protection device used to control small fire often in an emergency situation. A fire extinguisher consists of hand held cylindrical pressure vessel containing an agent that can be discharge to extinguish a fire. In stored pressure units, expellant is stored in the same chamber as the fire sighting agent itself. Depending on the agent used, different propellants are used. With dry chemical extinguisher, nitrogen is typically is used; Water and Foam extinguisher typically used in air; When the fire detected the buzzer starts its action to intimate the message to the user.

C. Infrared sensor detection

An Infrared sensor is an electronic device that emits in order to aspects of its surrounding. An Infrared sensor can measure the heat of the object as well as detects the motion. A passive an infrared sensor is an electronic sensor that measures infrared light radiating from object in it field of view. The PIR sensor is commonly used in security alarm and automatic lighting applications. A Servo motor is an electrical device which can push or rotate an object with great precision. It rotates the objects from some specific angles or distance. It is just made up of simple motor. which run through a servo mechanism.

A servo consists of a motor(DC(or)AC), a potentiometer, gear assembling and a controlling circuits connected to the output shaft. The position of a servo motor is decided by electrical pulse and its circuitry is placed beside the motor. It is a closed loop system where it uses a positive feedback system to control motion and positive position of the shaft. Here the device is controlled by the feedback signal generated by comparing output signal and reference input signal. The servomotor is used in Robotics, RC helicopters, planes and automatic door open.

D. Communication module

Global System for Mobile Communication is a mobile communication modem. GSM is an open cellular technology used for transmitting mobile voice and data services. GSM digitizer compresses the data, then sends it down a channel with two other stream of user data, each in its own time slots. GSM was developed using digital technology. It has an ability to carry 64kbps to 120mbps of data rates. GSM operates in the bands 850MHZ and 1900MHZ.DHT 11 is low cost digital sensor for sensing temperature and humidity.

This sensor can be easily interfaced with a microcontroller such as Arduino, Raspberry pi, etc., to measure humidity and temperature instantaneously. By using the exclusive digital signal acquisition technique, humidity and temperature sensing technology it ensures high reliability and long term stability. Each DHT11 element is strictly calibrated in the laboratory that is extremely accurate on humidity calibration.

An IoT module is a small electronic device embedded in objects, machines and things that connects to the wireless networks to send and receive datas. In the industry of IoT, wireless technology plays a significant role. Any device can be connected to the internet through any wireless technologies like wi-fi, bluetooth. ESP8266EX is often integrated with external sensor and other applications specific devices through its GPIos; codes for such applications can be provided as examples in the SDK.ESP8266 itself is a self-combined wi-fi network solution offering as a bridge from existing micro controller to wi-fi and is also capable of running self-contained applications. LCD screen is an electronic display module and find a wide range of application. A 16*2 LCD display is very basic module and it is commonly used in various devices and circuits. The data is the ASCII value of the character to be displayed on the LCD. The LCD technology works by blocking light. GPS, is the satellite navigation system used to determine the group position of the object. The GPS receiver gets the signal from the satellite. The satellite transmits the exact time; the signal is send. Many GPS receivers can relay position data to a PC using NIM protocol.

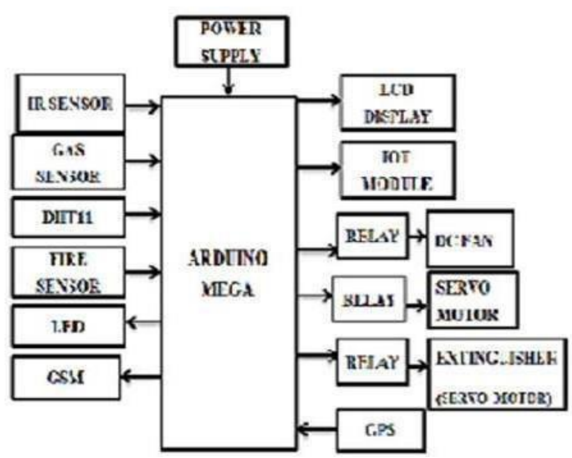

Fig. 1. Block diagram

4. Conclusion

This paper presents an overview on L-leakage detection and prevention of its threats using IoT in smart home automation systems.

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