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DEVELOPMENT OF A SMOKE SENSING SYSTEM WITH SMS ALERT USING ARDUINO UNO AND A GSM MODULE

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ABSTRACT

This report presents the development of an Arduino-based smoke detection system with SMS alert in conjunction with a GSM module . The system is much more efficient in terms of power consumption, durability, sensing smoke and is also inexpensive when compared to other models on the market, allowing it to be used even at the household level and thus preventing any casualties in the event of an accident with the least amount of maintenance. The system consists of a few electrical components that work together to detect the presence of fire and alert people. This portable smoke detection system is constructed in such a manner that the overall status of the room or location may be evaluated at any time. The aim of this project is to prevent major accidents caused by fires at residential or industrial premises. The main objective is to detect smoke at an early stage, which allows for the fire to be put out earlier and not cause any damage. It is accomplished by implementing a Metal Oxide Semiconductor (MOS) MQ2 type gas sensor. The sensor signal analog is converted to digital by the ADC and processed by a microcontroller Arduino Uno to command activation of the buzzer and SMS (short message service); the sensor system is also capable of displaying a smoke concentration detected by the LCD in parts per million (ppm). Aside from the gas sensor, the GSM module SIM900A is also used to interact between the sensor and the user via an interface provided by the microcontroller by delivering the specific at commands. Moreover, for this project, a bundle of joss sticks are used as testing. As a result, anytime the smoke level surpasses the sensor's calibrated threshold value of 300 ppm, the sensor's resistance decreases, causing the output voltage to rise as the concentration of smoke increases. In line with the microcontroller coding, the corresponding at commands are delivered to the GSM module by the Microcontroller Arduino UNO, which is connected to the gas sensor. The GSM module subsequently sends an alarm message to the household members for further action. Other than that, this report includes all the process during the project as well as the results that were obtained after carrying out the

project such as the user's will receive alert SMS, value of Rs/Ro and sensor’s output voltage when concentration increased, the distance of the system with source fire and the best position to place the system. Basically the input and output of the sensor, analysis of the system and the connection of the circuit will be exploited towards the success of the smoke detection system.

ABSTRAK

Laporan ini membentangkan reka bentuk pengesan asap yang sangat cekap dari segi penggunaan kuasa, ketahanan, pengesanan asap dan juga harganya murah jika dibandingkan dengan model lain di pasaran, membolehkan ia digunakan walaupun di peringkat isi rumah. Dengan itu sistem ini mengelakkan sebarang kematian sekiranya berlaku kemalangan dengan jumlah penyelenggaraan yang paling sedikit. Sistem ini terdiri daripada beberapa komponen elektrik yang bekerjasama untuk mengesan segala kejadian kebakaran yang berlaku dan dan seterusnya memberi amaran kepada orang ramai. Sistem pengesanan asap mudah alih ini dibina sedemikian rupa untuk mengesan status keseluruhan bilik atau lokasi pada bila-bila masa. Matlamat projek ini adalah untuk mengelakkan kemalangan besar yang disebabkan oleh kebakaran di premis kediaman atau industri. Objektif utama adalah untuk mengesan asap pada peringkat awal, ia membolehkan api dapat dipadamkan lebih awal dan tidak menyebabkan sebarang kerosakan. Ia dicapai dengan penggunaan sensor gas jenis Metal Oxide Semiconductor (MOS) MQ2. Isyarat analog sensor ini ditukar kepada digital oleh ADC dan diproses oleh mikropengawal Arduino Uno untuk mengarahkan pengaktifan buzzer dan SMS (perkhidmatan pesanan ringkas); sistem sensor juga mampu memaparkan kepekatan asap yang dikesan oleh gas sensor pada skrin LCD dalam unit bahagian per juta (ppm). Selain daripada gas sensor, modul GSM SIM900A juga digunakan untuk berinteraksi antara sensor dan pengguna melalui antarmuka yang disediakan oleh mikropengawal dengan menyampaikan arahan At khusus. Selain itu, untuk projek ini, satu berkas kayu joss digunakan untuk menjalankan eksperimen. Oleh itu, apabila kepekatan asap melepasi nilai maksimum 300 ppm yang telah ditentukan pada koding sensor, nilai rintangan pada sensor akan berkurangan, menyebabkan nilai voltan meningkat kerana lebih banyak voltan yang boleh mengalir apabila

kepekatan asap meningkat. Selaras dengan pengekodan mikropengawal, arahan At yang sepadan dihantar ke modul GSM oleh Microcontroller Arduino UNO, yang disambungkan kepada sensor gas. Modul GSM kemudiannya menghantar mesej amaran kepada ahli isi rumah untuk tindakan selanjutnya. Selain itu, laporan ini juga merangkumi semua proses yang dilakukan ketika projek dijalankan serta keputusan yang diperolehi selepas menjalankan projek. Sebagai contoh, pengguna akan menerima SMS amaran, nilai Rs/Ro dan nilai voltan sensor apabila kepekatan meningkat, jarak dan kedudukan terbaik antara sistem dengan sumber api. Pada asasnya input dan output sensor, analisis sistem dan sambungan litar akan dieksploitasi ke arah kejayaan sistem pengesanan asap ini.

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Abbreviations	Definition
GSM	Global System for Mobile communication
SMS	Short Message Service
Ro	Resistance of sensor in clean air
Rs	Resistance of sensor when exposed to gas
IDE	Integrated Development Environment
dBm	Power ratio in decibels (dB) of the measured power referenced to one milliwatt
V	Volt
Pin A0	Pin Analog
VS	Versus
s	Second
IoT	Internet of Things
LoRa	Long Range
ppm	Parts per million
VDS	Video Detection System
SPL	Sound Pressure Level

CHAPTER 1

INTRODUCTION

1.1 Background

1.1.1 Smoke from Incomplete Combustion

There are three components required in proper combination before ignition and combustion can take place, which are (a) heat, (b) oxygen and (c) fuel. These three components are known as the “fire triangle”, and by removing any one of these three components, the fire will cease to burn (Blazquez et al., 2010). Sarkar (2017) stated that, combustion of materials in air mixtures are not toxic if the material goes through a complete combustion. Complete combustion occurs when sufficient oxygen is present in the surrounding, which helps the material to burn entirely and only produces water and carbon dioxide (Lackner ,2011). However, when there is not enough oxygen to burn the fuel completely, incomplete combustion form, and smoke will produce and release potentially toxic byproducts (Speight, 2020). The byproducts of this incomplete combustion will spread to the surroundings in the form of smoke, which contains many toxic compounds such as (a) carbon monoxide (CO), (b) excessive water vapour, and (c) soot. Smoke from incomplete combustion is not only harmful to property, but it is also dangerous to the lives of those stuck in it.

Furthermore ,it is not often the fire that does the most significant damage to the occupants, but rather the smoke that could spread faster, block the passageways, and suffocate the victims (Munawer, 2018). Besides that, smoke from incomplete combustion is harmful when breathed because it contains noxious gases that can lead to fatalities and injure a person if present in a high enough concentration. One of the most potentially dangerous byproducts of incomplete combustion is carbon monoxide (Hampson NB, 2018). This poisonous gas is tasteless, odourless, and colourless, and victims are usually rendered unconscious before they realise they are being poisoned (Otterness K & Ahn C, 2018). Carbon monoxide can only enter the human body via the respiratory system and when breathed in, it travels through the bloodstream and binds with haemoglobin to exclude oxygen. As a result, it inhibits the blood's ability to transport oxygen throughout the body and causes the fire victims to die from carbon monoxide poisoning due to a lack of oxygen.

Other than that, a significant injury may occur in a short period with the exposure of carbon monoxide in smoke as little as 10% of carboxyhemoglobin (COHb) or in a concentration of 60 parts per million (ppm) (McCall JE & Cahill TJ ,2017). However ,when the COHb level in the body exceeds 60% or 300 ppm, unconsciousness and death may ensue without warning. Symptoms like migraines, drowsiness, nausea, vomiting, and cherry-red skin may occur at any range of concentrations, depending on the individual's dosage and exposure. The pace of breathing and the time exposure of the fire victims should also be considered. The impacts of CO exposure ,however , might vary widely from person to person depending on age, general health, the concentration and period of exposure. Table 1 shows the symptoms developed if being exposed to smoke for approximate inhalation time .

Table 1.1: Effects of smoke inhalation to human body

Concentration of smokes	Approximate Inhalation Time and Symptoms Developed
0 - 50 ppm	The maximum allowable concentration for continuous exposure for healthy adults in any 8-hour period ,according to OSHA.
50 - 200 ppm	Slight headache ,fatigue ,dizziness ,and nausea after 2-3 hours .
200 - 400 ppm	Frontal headaches for 1-2 hours . Life threatening after 3 hours .
> 800 ppm	Dizziness ,nausea ,and convulsions within 45 minutes . Unconsciousness within 2 hours . Death within 2-3 hours .
> 1600 ppm	Headache ,dizziness and nausea within 20 minutes . Death within 1 hour .

Inhaling this hazard gas might result in smoke inhalation injury, which is a major cause of mortality among victims of indoor fires (Jonghong, 2012). This form of injury is described as “damage produced by breathing in toxic gases, fumes, and particulate material contained in smoke.”(Gill P & Martin RV, 2015) . According to ISBI Practice Guidelines Committee (2016) ,the injury can be classified as 1) thermal, which usually involves damage to the upper respiratory tract caused by the high temperature of smoke and gases, or 2) chemical, which usually involves damage to the lower respiratory system caused by inhalation of irritant fire byproducts and particulate matter deposition. 3) asphyxiation and systemic toxicity induced by inhaling harmful gases created by burning, most often carbon monoxide and hydrogen cyanide; or 4) a combination of the above mentioned. This injury increases the mortality rate by 24 times in fire-related injuries and is highlighted as one of the most critical risk factors increasing morbidity and mortality (You K,2016).

1.1.2 Smoke Detector

Smoke detectors that are not equipped with an alert message have also become one of the main factors in fatal fires . According to the Fire and Rescue Department of Malaysia (2019) , about 5500 fire accidents were recorded in 2016 alone,and the majority of them are residences followed by transportation, electrical appliances, and gas leakage. There are many various aspects that contribute to home fires such as cooking equipments, smoking in the house, electrical appliances, candles, careless and unsupervised children, poor wiring, and many more. If the fire starts while the residents are at home, there is a chance that it can be extinguished. However, this project focuses on when the residents are unaware of fire since they may not be present when a fire starts, may not effectively raise the alarm, or may not be in perfect health to recognise fire signatures (Ismail et al., 2016). Thus ,early detection and early warning of fires are two fundamental criterias in smoke detectors, in order to effectively extinguish the fire and reduce catastrophic lives and property damage.

For that reason ,the smoke alarm system in this study is mainly composed of sensors and microcontrollers such as MQ2 gas sensor, Arduino Uno and GSM Module SIM800 as they serve better performance in detecting smoke . Choosing a high quality sensor that can deliver accurate smoke reading is crucial for every safety device . Thus, the MQ2 gas sensor is used because of its high sensitivity to smoke compared to other metal oxide gas sensors (Chamorro-Atalaya & Arce-Santillan, 2020). Besides its excellent sensitivity ,MQ2 was chosen for its low cost and applicability for a wide range of applications .The smoke detector is also developed using the Arduino board as the primary controller board, which interacts with the GSM module SIM800 that functions as a message transmitter. The purpose of having a message transmitter is to inform the user if there is a possibility of a fire tragedy occurring in their premises. The GSM module receives instructions from the Arduino on where to send the data and what data that needs to be sent. GSM Module SIM800 communicates with the Arduino through serial communication and requires Hayes compliant AT instructions to operate. Moreover ,the microcontroller within the Arduino board serves as the circuit's mastermind where it controls circuit flows and executes all of the instructions. For the smoke alarm system to function effectively, the user needs to register the recipient's phone number into the project codes during the installation process. Once the MQ2 gas sensor detects excessive smoke and the threshold value is attained, a SMS will be sent to the registered phone number to notify the user of a fire that occurs in their premises. Therefore ,installing a smoke alarm system that is equipped with GSM Modem is important since it is proven to reduce the chance of mortality from residential fires by 50 to 70 percent (Miller, 2014) .

1.2 Problem Statement

Before the smoke detector first developed, we relied on human intervention to recognize a fire, evacuate the building and pull the call box to notify the nearest fire brigade. However ,much has changed since that time, and now smoke detectors have become an essential safety device in every home. Most of the smoke detectors in use today are based on sensor technology invented more than four decades ago. Since then, numerous incremental improvements have been made to the implementation of these technologies. Advances in smoke detection technology hold the promise of improving the protection of people and property, which has encouraged the community to install this safety device in their home.

According to the National Fire Protection Association (2014) , house smoke alarm use increased dramatically from less than 10% in 1975 to at least 95% in 2000, with the number of house fire fatalities nearly halved . A working smoke alarm has been proven to reduce the risk of death from a house fire by 50% to 70% (Mohamad Adenan et al., 2021). According to the US Fire Administration (2018) , over 88% of American households have at least one smoke alarm, with 60% of residential fire fatalities occurring in homes without one. Based on the data from the United States Fire Administration's National Fire Incident Reporting System (2010) , it was revealed that from 2003 to 2006, no smoke alarms were installed in 31% of reported house fires and 40% of house fire fatalities. Regardless of whether some of these fatalities were caused by explosions or other close physical encounters with fire, the presence of a smoke alarm is most useful if it is activated quickly by the presence of smoke, such that people in the residence are notified of the fire and have more time to evacuate from the building as soon as possible .

Moreover, the dangers of fire are not limited to only fatal heat levels. During a house fire, there is a rise in carbon monoxide and harmful amounts of chemical and thermal irritants. This will cause the sufferer to more likely inhale those irritants, which may result in difficulty breathing due to the damage in the respiratory tract's mucous membranes and lining. Other than that, when fire smoke is too thick, it becomes more difficult for individuals to evacuate the fire due to limited vision during the fire.

Besides that, one of the common issues in most of the gas sensors is their sensitivity. If the sensor of a smoke detector is highly sensitive towards smoke, it will result in false alarms or unwanted fire alarm activations. When false alarms occur too frequently, it has the potential to lead people to disregard legitimate warnings .In the case where actual fire accidents happen, following warnings may be dismissed or disregarded entirely. This kind of situation can be described as the "Cry Wolf Effect", which could lead to lives loss and property damage.

1.3 Objectives of the study

1) To determine smoke hazard level based on the relationship between concentration of smoke in ppm and the measured output voltage in Volts.
2) To evaluate the performance of MQ2 smoke sensor in flaming and smouldering fire .
3) To develop a MQ2 Sensor smoke alarm system utilising Arduino-GSM technology.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter overviews various methods and techniques that have been employed for use in smoke alarm systems. It also reviews the principles of components and the principles of Internet of Things (IoT). This was done with the aim of providing guidance to certain design decisions for later use throughout the project.

2.2 Review of Previous Work

2.2.1 Raspberry Pi based Smoke Detector

In the previous study carried out by Kulkardni et. al (2018) ,they designed a smoke alarm system that is capable of detecting the presence of smoke in air by capturing images of a region when a fire occurs . The design that was proposed by the authors consists of five components which are Raspberry Pi ,Arduino UNO ,QM-NG1 gas sensor ,GSM module and webcam . When the smoke alarm is triggered, the system will capture the image of the building state and send it to the occupants via GSM for confirmation before reporting the fire accident to the nearby firefighter brigade . This confirmation technique is a good approach since it will reduce the false alarm rate reported to the firefighter. However ,the presence of Raspberry Pi seems unnecessary in the system as it is not capable of processing analog signals input from a gas sensor by itself . This is because Raspberry Pi is not equipped with an internal analog-digital converter (ADC) chip and it can only handle digital signals but not analog . Thus, it needs addition of an ADC component to convert the analog signal from the sensor to digital signal before it can be interpreted by Raspberry Pi . Other than that ,the gas sensor that is used in this study, which is MQ-NG1 ,needs about 5 volts of power in order to operate . If 5 volts is applied to the Raspberry Pi GPIO pins, Raspberry Pi has a high chance of permanent damage because it can only handle input of 3.3 volts but not higher than that . Thus, to use this sensor ,an additional component is needed and will lead to an increase in cost ,as the voltage needs to be converted to 3.3 volts using a logic level converter . The total cost ,however ,can be reduced if Raspberry Pi is replaced with Arduino UNO . Unlike the Raspberry Pi ,the Arduino board has its own analog-to-digital converter and it can operate 5 volts of sensor without problem .

2.2.2 Video Smoke Detection (VDS) techniques

There was research conducted by (Chiu ,2004) entitled "Study on the Video Smoke Detection System" . The author proposed a new technique which is implementing video smoke detection technology (VSD) in smoke alarm systems. It is basically a system that is made up of video-based analytical smoke identification algorithms by incorporating cameras into smoke detectors. The detection algorithm works by using various methodologies in identifying smoke characteristics which include spatial ,spectral, and temporal properties . This technique can effectively monitor fire in large-scale areas, high-rise buildings and meet outdoor fire detection demands . Although it can be used outdoors and detect the signs of disaster even before the fire starts, many factors need to be considered . One of the factors that will affect the VSD operation is the quality of the camera lens . Low quality of camera lens will result in false alarm . A poorly maintained camera can cause the image to be blurred and lose its clarity . If a blurred image is formed ,it will become an indicator of smoke as smoke is grey and translucent . Moreover, most video smoke detection systems will lose their function with different forms of precipitation such as during rain, snow or mist as it loses their visibility to capture and detect smoke presence in the air. Therefore ,it only performs best in indoor or roofed areas but not outdoors . The system also has its own set of requirements and costs. Unlike other detection systems, VID is based on software that needs to be programmed and maintained to reduce false alarms . Specialized cameras and numerous cameras to adequately cover an extensive area increase the cost, as the expert does the installation.

2.2.3 LoRa Based Internet of Things (IoT)

Sendra et al. (2020) proposed a smoke alarm system with a low-cost network based on Long Range (LoRa) technology that can autonomously assess the amount of fire danger and the presence of smoke in a given location. The system is made up of numerous LoRa nodes and connected with MQ4 gas sensors. If the gas sensor senses excess smoke, the sensor will collect data and transmit it to LoRa nodes . Then ,the data is saved and processed on a The Things Network (TTN) server before being sent to a website for graphic representation of the gathered data. The system is then tested in a real-world context, and the findings reveal that a single gateway can cover a circular region with a radius of 4 km. Although LoRa has a broad coverage area, it is extremely reliant on the environment and the premise materials that comprise it. The range for rural areas is around 20 kilometres. In metropolitan areas, however, it is lowered to 5 kilometres. Other than that ,limitations on the used frequency band can cause high latency on delivered messages . Therefore, implementing LoRa technology in the smoke detector would not be the best due to the slow response in delivering alert messages.

2.2.4 Method Fuzzy Logic

Next is the findings conducted by Sarwar et al. (2018). The author designed an intelligent smoke detector based on Fuzzy Logic that can detect the presence of a hazardous fire and transmit an alarm to the Fire Management System (FMS). The purpose of this work is to explain the design and implementation of a Fuzzy Logic in smoke alarm system that also delivers an alarm message to recipients through Global System for Mobile Communication (GSM) technology. The system is built on tiny, low-cost, and extremely compact sensors to guarantee that the solution is duplicatable. Moreover ,the simulation work is done in MATLAB and the outcomes of experiment findings are excellent in terms of identifying the false-fire accident and reporting only true fire incidents . The system has resulted in a great reduction of false alarm rate compared to other smoke alarm systems . However ,one of the major drawbacks of implementing Fuzzy Logic in smoke detectors is the system is entirely reliant on human knowledge and competence. Fuzzy logic rules are the core part of this smoke alarm system. It plays a vital role in determining and differentiating between false and true fire accidents.Thus ,it requires deep understanding and the system must be updated regularly to eliminate false alarms from occurring .

2.2.5 Audible Improvement based Sound Pressure Level (SPL) techniques

According to Dinaburg (2019) ,the traditional smoke detectors may not be loud enough to alert those who already have cognitive impairment to the possibility of a fire . Thus, the authors carried out a research in aiming to choose a sound alarm with a suitable sound pressure level (SPL) to be applied in smoke detectors for elders with hearing loss. The authors experimented with various SPL to determine which one would be a better fit for an age-sensitive smoke alarm signal. A series of potential sounds were delivered to pairs of individuals aged 65 and older with varying degrees of hearing problems in their own homes to determine which SPL worked best in terms of detection, localization, and perceived attention-getting value. During listening sessions, subjects were placed in different location-and masking-based settings inside their houses and listened to sound played at a constant volume. The results show that almost 50 percent of respondents rated the average SPL of 75 dBA as ‘low’ and others rated it as ‘suitable '. SPL of 75 dBA is actually a standard sound pressure level recommended by National Fire Protection Association (NFPA) in all premises . Thus ,it is clearly shown that the technique to change the SPL is not the best approach to be applied in smoke detectors as it is not effective for everyone . Other than that, changing the SPL of the smoke alarm system would not make any improvements because, according to Chris (2013), 6dB loss every time, doubles the distance from the alarm smoke system . Moreover ,the material of the room also will affect the intensity of sound . If the room has more sound absorbing material like curtains and carpets ,more sound will be lost compared to a room with ceiling and floors .

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this study ,the measurement will be conducted in a closed area, where a material undergoes two different phases of combustion which is flaming and residual (smouldering) phase . The amount of smoke produced in these two phases will be captured by the MQ2 sensor ,then it will be processed in an arduino program that can display data in LCD ,emit sound and send a warning message to the phone number specified in the program.

There are two major parts that need to be taken into account in the development of smoke alarm systems ,which are the hardware and the software details . The smoke detector's hardware architecture includes the design of the circuit as well as the creation of the project's prototype . While for the software development, the entire prototype is developed for programming codes to operate in Arduino.

3.2 Hardware Architecture

3.2.1 Arduino UNO

Arduino Uno is known as an open source ,that manufactures single-board microcontrollers and microcontroller kits for developing digital devices and interactive tools that can sense and control objects via programming code (David ,2017) . The term 'open source' means that it is designed to be publicly accessible where everyone can view, modify, and share the Arduino codes and schematic designs as they want . It is made particularly friendly to new and experienced users. Generally ,it is a piece of software that can be programmed with any set of instructions to interact with numerous types of input and output (J Boxall ,2013). The microcontroller on the Arduino board, which is ATmega328 ,serves as the main controller which functions to operate the whole circuit correspondingly (Leo Louis ,2016) . It has a set of analogue and digital pins that may be incorporated into a number of boards and circuits that have different functionalities in a design . As for coding, Arduino has created its own software called the integrated development environment (IDE), which fully supports the C and C++ programming languages . The language used is categorized as an intermediate-level language which is a readable programming language to humans (H. Schildt ,2003). Therefore, before using Arduino ,users are required to create their own coding in Arduino IDE first before uploading it to the board that needs to be programmed . The reason behind it is to ensure no errors occur in the coding, for Arduino to run . If there are any errors in the Arduino code a warning message will flag up prompting the user to make changes. After the changes are made ,users can load the codes from the computer to the Arduino board through a USB serial communication interface provided by Arduino . Once the code has successfully compiled ,it's then uploaded to the board's memory for it to function.

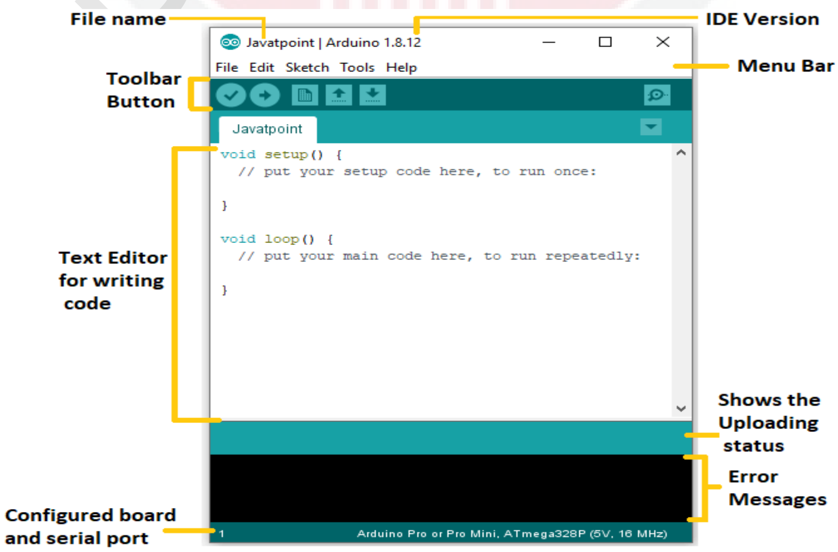

Figure 3.1 : Arduino IDE which contains a text editor for Arduino coding.

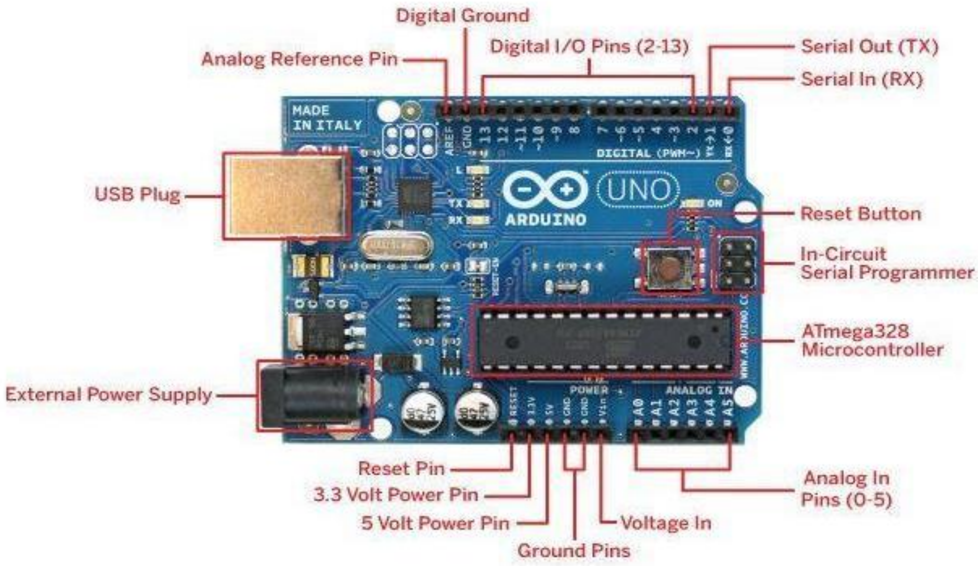

Figure 3.2: The Arduino UNO with ATmega328 microcontroller onboard.

3.2.2 GSM Module SIM900A

For the GSM module in the smoke detector, the GSM SIM900A type is chosen to carry out all the operations in the communication section because the price is more affordable. GSM SIM900A is dual band GSM modem which operate in 900 and 1800 MHz bands. Besides that , GSM SIM900A can only be used in Asia as it is region locked in Asia area. Most of the AT commands that makes call or sending and receiving SMS can be used with the SIM900A modem. Figure 3.3 shows the GSM Module SIM900A that is used in the project.

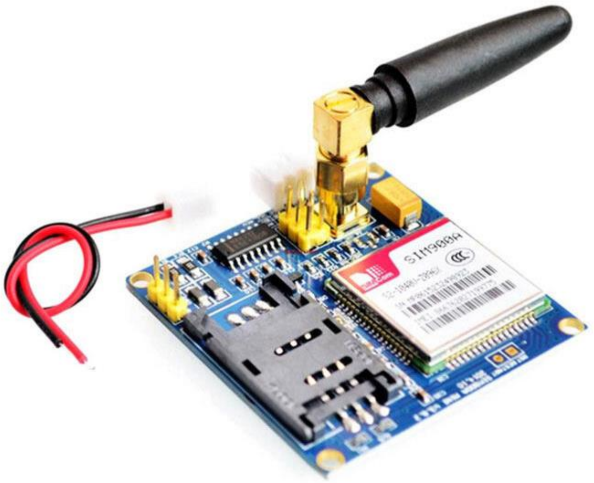

Figure 3.3: The GSM SIM900A module which handles communication with the Arduino board.

3.2.3 MQ2 Gas Sensor

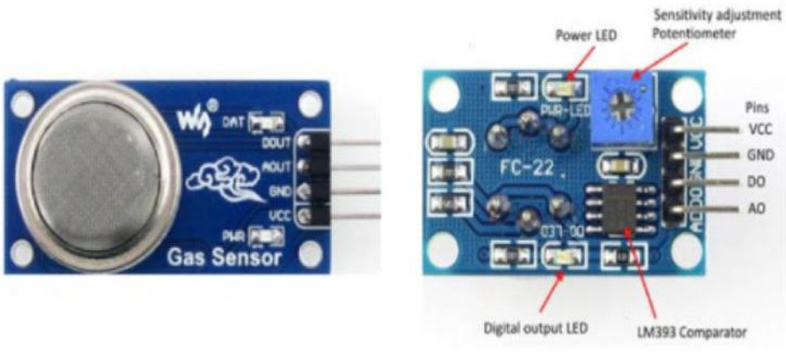

Figure 3.4 : MQ2 gas sensor to detect excess smoke

Another component that is essential in this project is the MQ2 gas sensor . MQ2 is chosen for many reasons including high sensitivity to smoke , fast response time, wide detection range, and long life (Al-Haija ,2013) . The function of this sensor is to detect the presence and concentration of smoke in the environment . The MQ2 gas sensor works on 5V DC and can measure smoke anywhere from 300 to 10,000 ppm making it such a compatible device to use in smoke detectors . In addition ,the sensor generally works by generating a corresponding potential difference based on the concentration of the gas by altering the resistance of the sensing material (SnO_2) inside the sensor, which may be detected as output voltage. The sensor's output voltage however ,varies depending on the amount of smoke present. The greater the smoke concentration ,the higher is the output voltage; while lesser the smoke concentration results in low output voltage. Table 3.1 shows the output voltage of the sensor with levels of smoke exposure .

Table 3.1 : The level of smoke according to the output voltage and concentration of smoke

<table>
<tr><th>Level of Smoke</th><th>Output Voltage (V) (0V - 5V)</th><th>Concentration of Smoke</th></tr>
<tr><td>Low</td><td>< 0.3V</td><td>< 50 ppm</td></tr>
<tr><td>Moderate</td><td rowspan="3">0.3V - 5V</td><td>50 - 200 ppm</td></tr>
<tr><td>High</td><td>200 - 400 ppm</td></tr>
<tr><td>Dangerous</td><td>> 400 ppm</td></tr>
</table>

In addition ,calibrating a smoke sensor is such an important step before putting it into use to avoid the safety of occupants being jeopardized . Therefore, to prevent this from happening ,a calibration code made available by Sandbox Electronics Company is used to calibrate the gas sensor. By applying this calibration algorithm, systematic inaccuracy can be avoided and more accurate results are produced. Aside from that, the MQ2 smoke sensor has a built-in potentiometer that allows users to adjust the sensor’s sensitivity. This can be done by turning the screw in a clockwise direction to increase the sensitivity or anticlockwise to decrease its sensitivity ,according to how accurates the user wants to detect smoke. Other than that ,the comparator on the smoke sensor continuously checks if the analog pin (A0) has hit the threshold value set by potentiometer. When it exceeds the threshold value, the digital pin (D0) will go HIGH and the signal LED turns on. This threshold value can be changed in the Arduino Code ,depending on the type of gases wanted to be measured. Thus, for this study, the threshold value is set to 50ppm since it is the maximum allowable concentration for continuous exposure for healthy adults in any 8-hour period,according to OSHA. .

3.2.4 Buzzer as Output

Other electronic parts used in this project setup are buzzer, LCD 16*2 and connecting wires . Buzzer is used to produce a sound whenever the smoke level crosses the threshold value. The operating voltage of the buzzer is 4 V to 8 V direct current (DC) while the current is less than 30 mA.The buzzer can be operated at temperature of -25°C to +80°C and the tone is continuous.

3.2.5 Liquid Crystal Display

LCD 16*2 is used ,which functions to display the concentration of smoke detected. The data transfer is much faster compared to serial communication LCD. It can support I^2C, UART, SPI protocol communication. The 16 x 2 LCD is also capable to display 224 different characters and symbol.

3.3 Connections for project setup

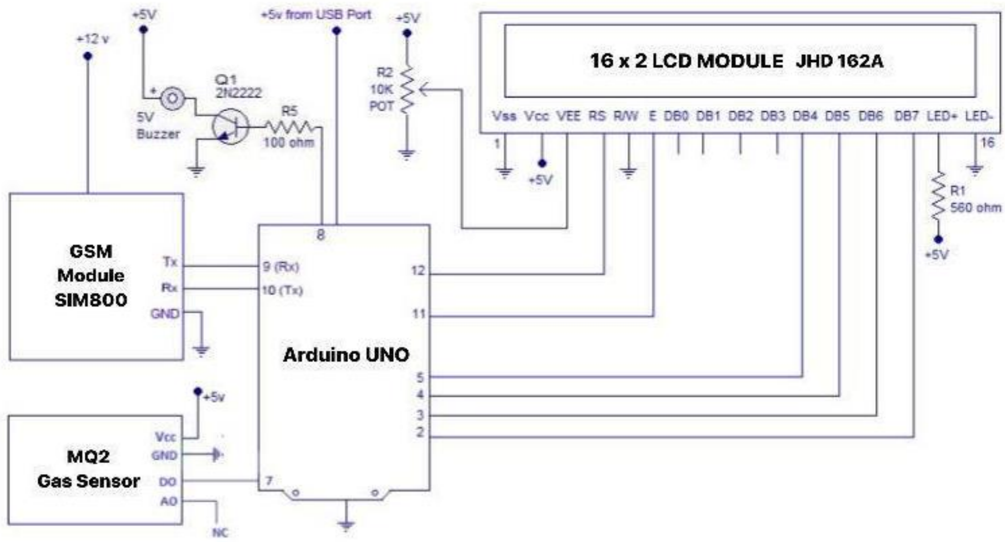

Figure 3.5 : Physical connection of smoke alarm circuit

Table 3.2 : Connection of MQ2 Gas Sensor to Arduino UNO

a)

	Gas Sensor	**to**	**Arduino pin**
MQ2 Gas Sensor To Arduino UNO	GND	to	GND
	D0	to	D7
	A0	to	A0
	Vcc	to	+5V

Table 3.3 : The connections of GSM Module to Arduino UNO

b)

	GSM	**to**	**Arduino pin**
GSM To Arduino UNO	TX	to	D9
	RX	to	D10
	GND	to	GND

c) LCD is connected to pin no 7,6,5,4,3,2 of Arduino UNO and 5V of power supply. The contrast of the LCD can be adjusted using a 10K potentiometer .

3.3.1 Schematic Diagram

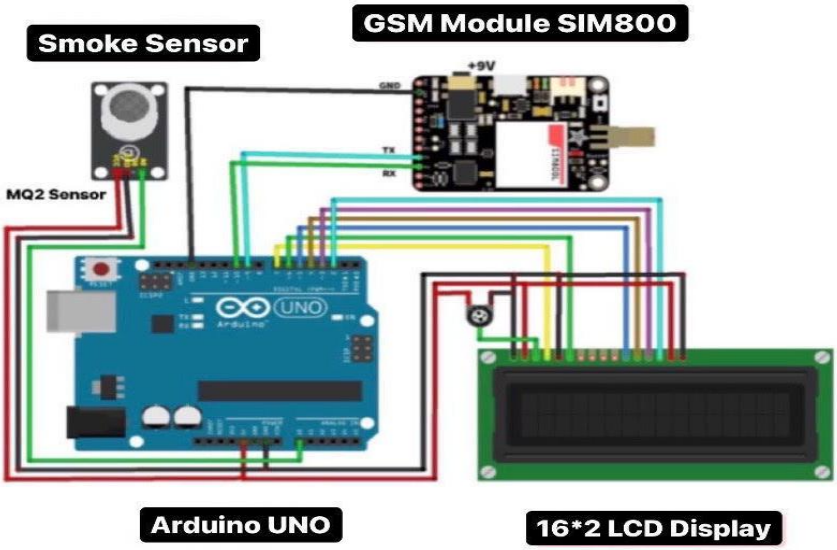

Figure 3.6 : Schematic Diagram of smoke alarm system

3.4 System Architecture Design

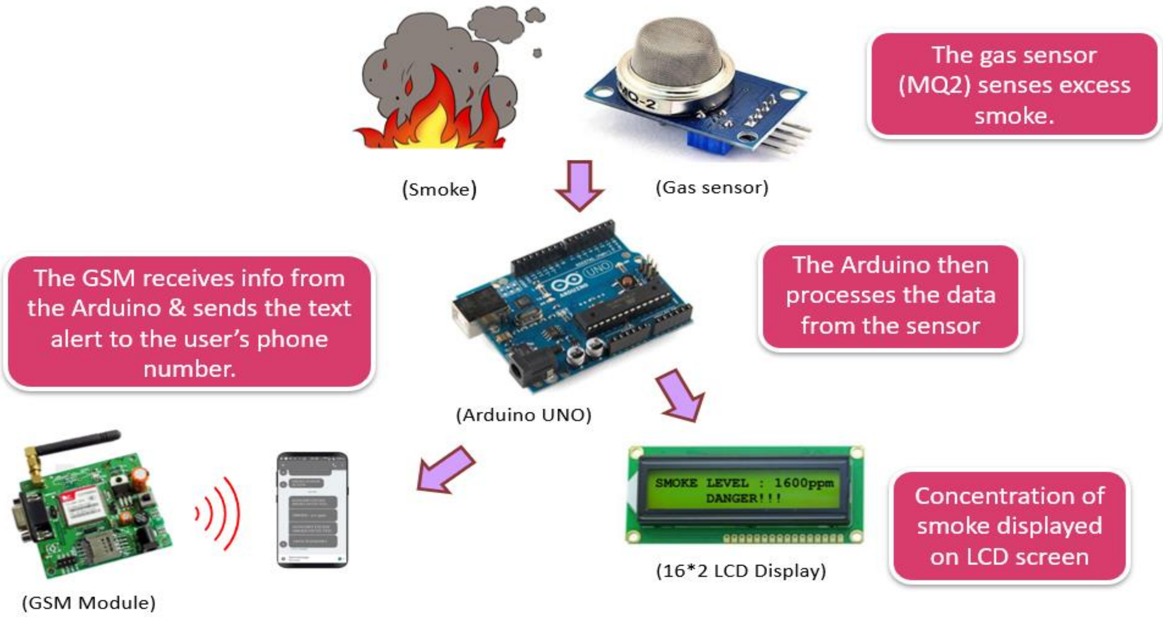

Figure 3.7 : Hardware architecture of the smoke alarm system

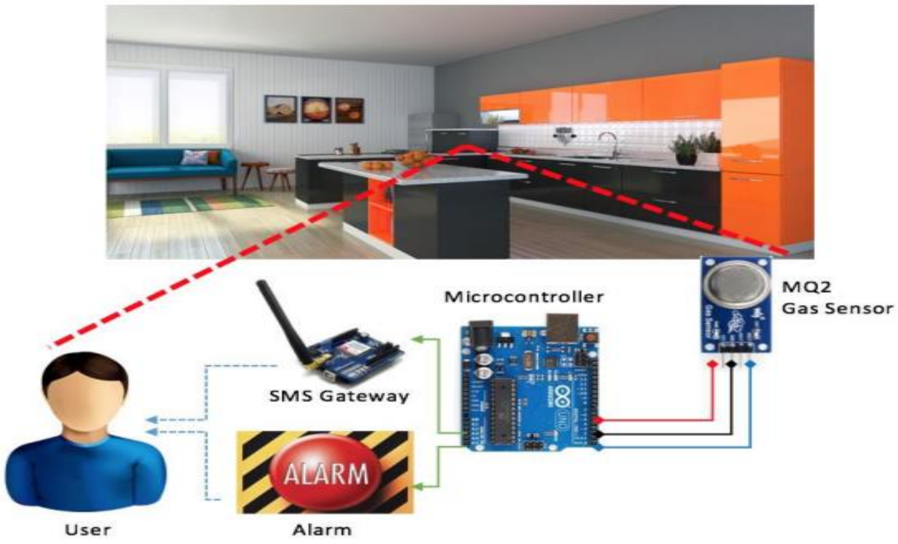

Figure 3.8 : System Architecture Design for smoke alarm system.

When a fire occurs, the MQ2 sensor detects smoke in the air by reading the part per million (ppm) smoke ratio parameter in the air, which is known as raw data. The MQ2 sensor then converts the raw data into digital signals that include HIGH or LOW. This parameter is then transmitted to the Arduino Uno (Microcontroller) for processing. The mechanism in the Microcontroller then determines if the input smoke parameter is HIGH, indicating that smoke has happened. The system then directly delivers the information to the user through Sim800 SMS Gateway. The alarm will continue to sound until it reaches 180,000 milliseconds or 3 minutes

3.5 Software Development

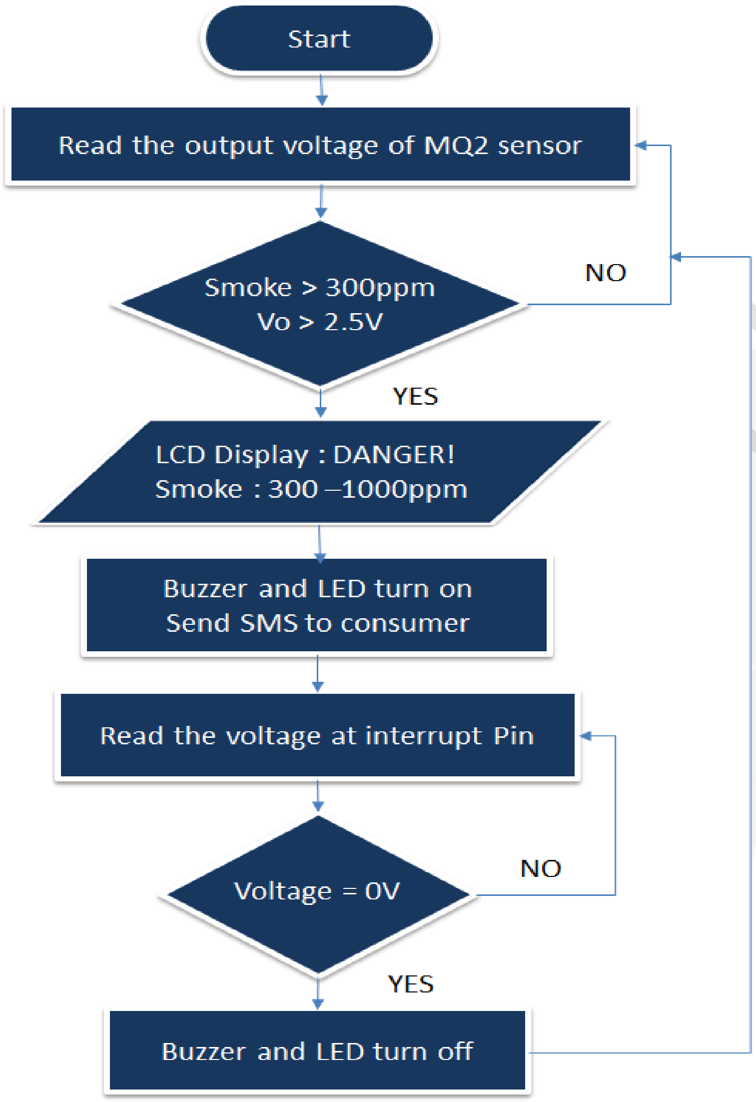

Figure 3.9 : Flowchart for smoke detector program .

3.6 Performance Analysis of the System

3.6.1 Accuracy

To analyse the accuracy of the system, the readings that obtained from GasLab and multimeter will compared with the readings taken from MQ2 gas sensor. The percentage error will then be calculated to determine the accuracy of MQ2 gas sensor. The number of joss sticks are varied in this section, while the distance between joss sticks and the entire system is fixed. Firstly, no joss sticks are used to obtain the readings of the room from the gas sensor at the normal condition. Each set of the experiment takes 5 minutes. Then, the number of joss sticks are slowly increased to 5, 10, 15, 20, 25,and 30. The readings for the concentration of smoke and the output voltage of the sensor can be taken and analysed in the next section. The same steps are repeated for the condition with 5, 10, 15, 20, 25 and 30 joss sticks and the experiment is repeated 10 times for each of the conditions with a different number of joss sticks.

Figure 3.10 : Sensor connecting to digital multimeter and GasLab

3.6.2 Distance

For the analysis of distance, two different materials which are newspapers and joss sticks will undergo combustion to produce flaming and smouldering fire. Both materials were used as fuel components during the combustion. The number of joss sticks is fixed which is 15 because the smoke produced from 15 joss sticks is not that much but might be sufficient for the system to detect. Each of the experiments also takes 5 minutes. Then, the readings of the concentration of smoke in both fires will be taken for analysis. The experiment is repeated 10 times so that the accurate readings can be obtained.

Figure 3.10 (a) shows the determination of concentration of smoke with the change of distance in flaming fire and Figure 3.10 (b) in smouldering fire.

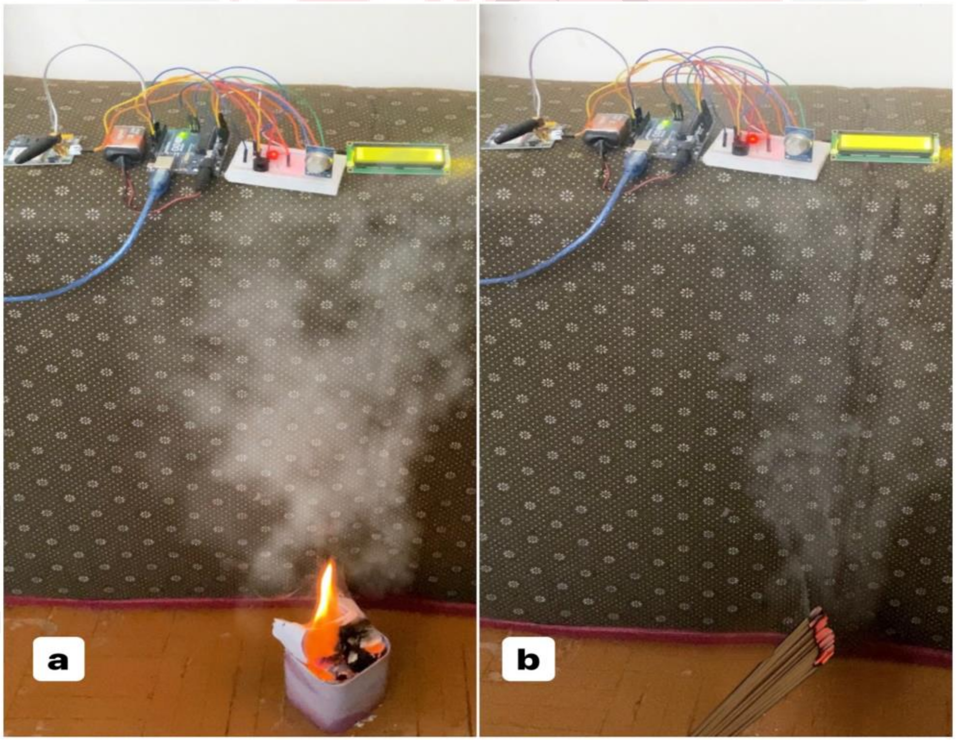

Figure 3.11 :

(a) : Newspapers are burned to produce flaming fire

(b) : Joss sticks are used to produce smouldering fire

3.6.3 Position

The analysis of the position of the system also would be made. The number of joss sticks that are used are fixed to 15. Three different positions are varied for this part, which is the left and right corner of the room and also the centre of the room. The joss sticks are placed at the centre throughout the experiment. As mentioned in previous, the experiment also takes 5 minutes. Then, the readings from the gas sensor are obtained and analysed. Figure 3.11 is the layout for the room. The blue dot indicates the left corner of the room, the red dot is the centre of the room and the green dot is the right corner of the room. The joss sticks are placed at a fixed place which is at the center of the room while the position of the system is changed to test which one is the best position to place the smoke detection system. From Figure 3.12, the system is unable to be placed at each of the corners since there are many obstacles that limit the experiment to be carried out.

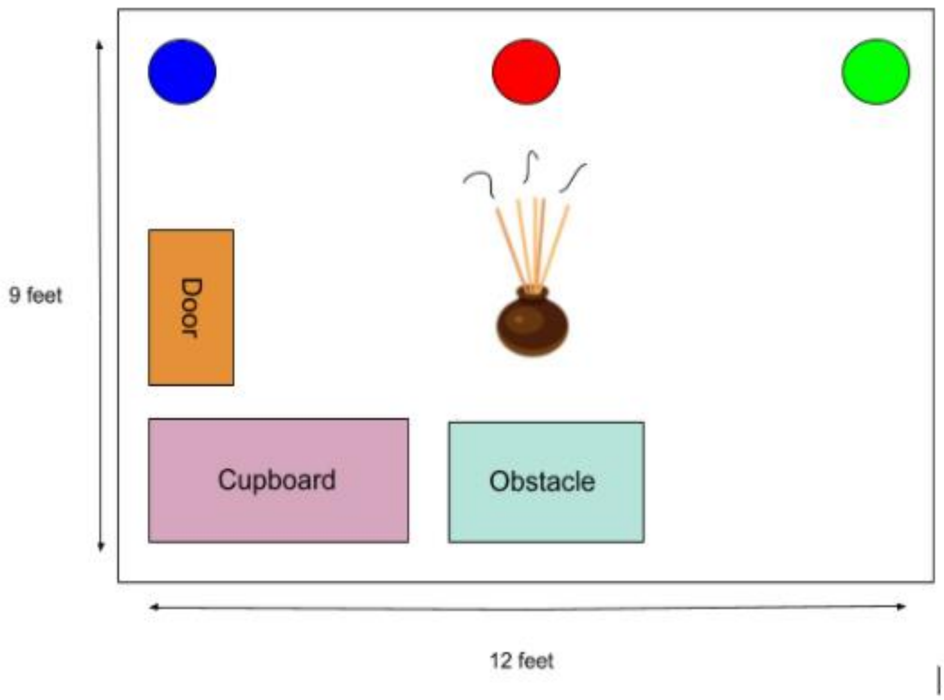

Figure 3.12 : The layout of the room

CHAPTER 4

RESULT AND DISCUSSION

4.1 Smoke detection system

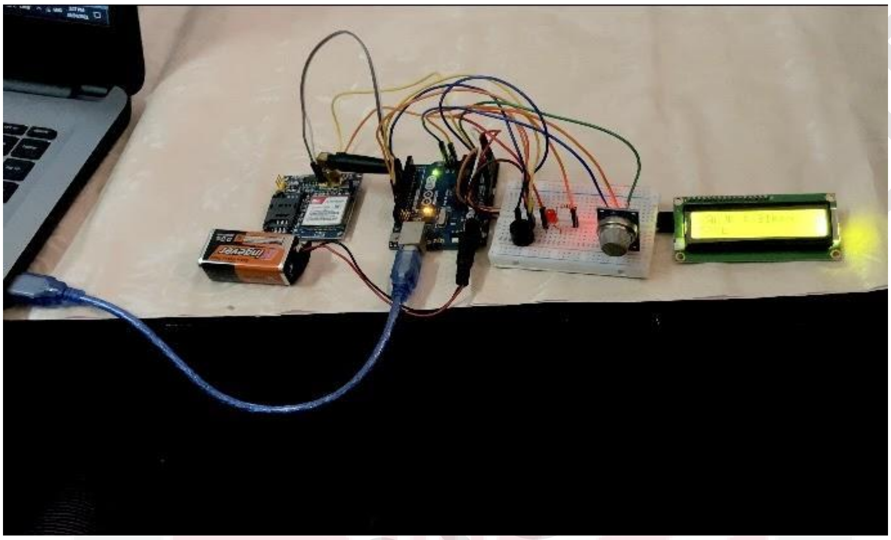

Figure 4.1 (a) : Condition of gas sensor when no smoke is detected

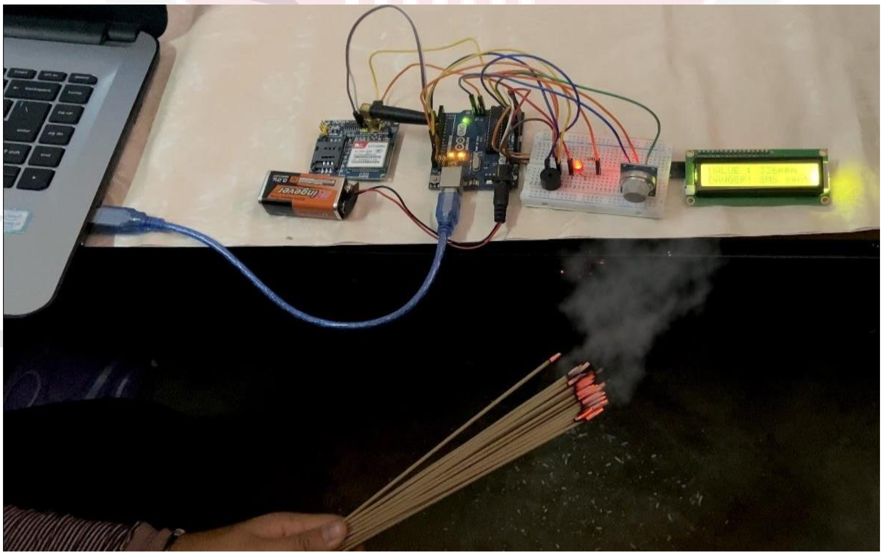

Figure 4.1 (b) : Condition of gas sensor when smoke is detected

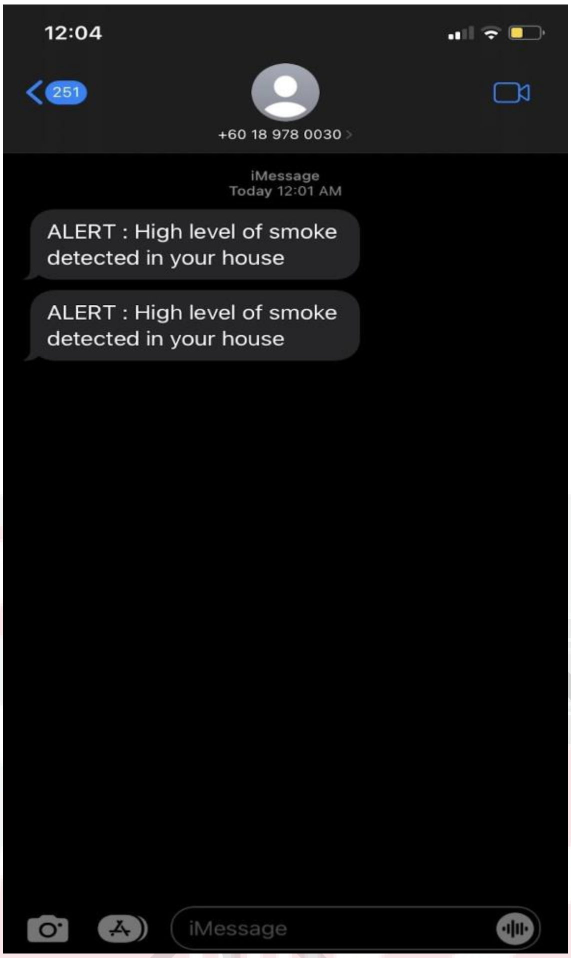

Figure 4.2 : Alert SMS received by the user

Figure 4.1 shows how the gas sensor works in the system. In Figure 4.1 (a), the red LED does not light up when no smoke is detected. The red LED will only light up when there is smoke detected from the joss sticks as shown in Figure 4.1 (b). The buzzer will start beeping afterwards, and an alert SMS will be sent to the user's phone using the GSM module, as shown in Figure 4.2.

4.2 Analysing of Gas Sensor

Figure 4.3 : Result of smoke detection printed on serial monitor of Arduino IDE

Figure 4.3 shows the result of smoke detection system that displayed on the serial monitor of Arduino IDE. The results show pin A0, which is the analog value of the sensor, along with the sensor_volt, RS_ratio and Rs/Ro. Pin A0 represents the concentration value when exposed to smoke . Sensor_volt is the sensor's output voltage when exposed to smoke, RS_ratio is the resistance of the sensor when exposed to smoke and Rs/Ro is the ratio of resistance of the sensor when exposed to smoke and the resistance of sensor in the clean air. The smoke detected by the sensor is the smoke produced from joss sticks; this causes the buzzer to be activated, and an alert SMS will be sent when the concentration of smoke exceeds the threshold value, which is 300.

In normal conditions, where no smoke exists in the air, the resistance of the sensor is high and this causes the voltage across the sensor to be low. The voltage increases when the sensor is exposed to smoke due to the decrease of the resistance and thus more current flows from load resistance. The higher the concentration of smoke causes the sensor's output voltage to become higher. Therefore, the analog value of the sensor in Arduino also increases when the concentration of smoke is increased.

The resistance of the sensor in clean air is 3.39Ω which is measured by the Arduino and the resistance of the sensor when exposed to the smoke is varying depending on the concentration of the smoke . The higher the concentration of the smoke caused the resistance of the sensor when exposed to the smoke become lower. This means the ratio between the resistances of the sensor in clean air and when exposed to the gas, Rs/Ro will be decreased as the concentration of smoke increases.

Table 4.1 : Results of sensor's output voltage and Rs/Ro

Sensor's Output Voltage (V)	Rs/Ro
0.45	4.82
0.49	4.40
0.63	3.30
0.89	2.19
1.04	1.82
1.09	1.70
1.21	1.50
1.58	1.03
1.59	1.02
2.23	0.59
3.21	0.27
3.65	0.18

Table 4.1 shows the results of the sensor's output voltage and Rs/Ro when being exposed to the smoke produced from joss sticks . The output voltage sensor is increasing while the Rs/Ro is decreasing when the concentration of smoke increases. From the beginning of the result, the reading is not following the trend due to the instability of the gas sensor. Usually a gas sensor requires some time to preheat in order to achieve the stable state and get a more accurate result.

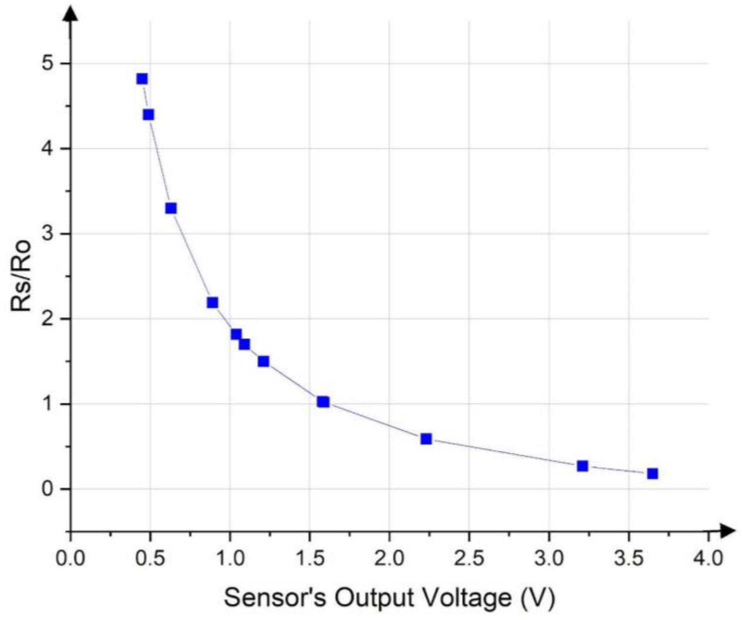

Figure 4.4 : Experimental results of Rs/Ro against sensor's output voltage

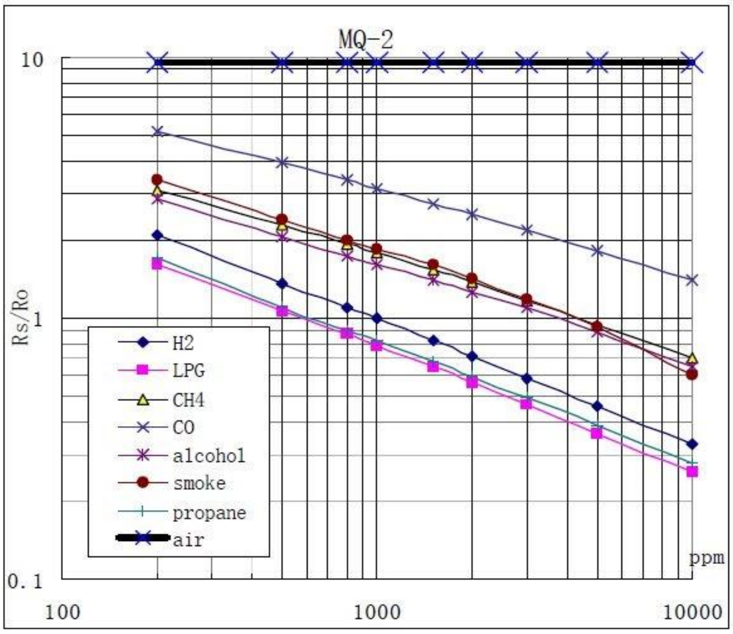

Figure 4.5 : Theoretical results of Rs/Ro against gas concentration. (n.d.). Retrieved from

http://www.haoyuelectronics.com/Attachment/MQ-2/MQ-2.pdf)

Figure 4.4 shows the experimental result of Rs/Ro against the sensor's output voltage and Figure 4.5 shows the theoretical result of Rs/Ro against smoke concentration. According to the datasheet of the MQ2 gas sensor, the analog value of the sensor only represents the approximated trend of smoke concentration which is not the exact value of smoke concentration. Due to this reason, the analyzing part only to compare the trend of experimental and theoretical results of Rs/Ro against smoke concentration but not to calculate the exact value of smoke concentration. The gas concentration is represented by the analog value of the sensor (pin A0) for the experimental result as the gas concentration increase will also make the analog value increase.

From the experimental result, the sensor's output voltage increased as the Rs/Ro decreased. This also means that the gas concentration increased when the Rs/Ro decreased. The experimental trend is similar to the theoretical trend in which the gas concentration increased when Rs/Ro decreased.

This experiment has proven the gas sensor used in this project is working under the correct principle. The experimental reading of the gas concentration does not have the same exact trend to the theoretical result. This is because the pre heating time of the gas sensor is not enough and caused the result to become less accurate.

4.3 Analysing of GSM Signal

The SIM card used in this project which is required by the GSM module is from CELCOM XPAX TELCO. The objective of this experiment is to study how the GSM signal affects the average time a user's phone receives SMS. The user will test the system by activating the gas sensor and then observe the time for the phone to receive the alert SMS. The GSM signal was measured by the smartphone application "Network Monitor" which downloaded from the App Store and the time to receive SMS was measured by the stopwatch. The experiment was conducted in two different locations, one location is in good signal and another one is in poor signal. The experiment was conducted 5 times in each location to get the average time to receive the alert SMS.

4.3.1 Good GSM Signal Condition

Table 4.2 : Result of GSM signal in good signal condition which measured by 'Network Monitor" application

ID	SIGNAL STRENGTH (dBm)	DATE	TIME
1	-109	2021.11.30	10:00:33
2	-105	2021.11.30	10:01:33
3	-109	2021.11.30	10:01:53
4	-109	2021.11.30	10:02:13
5	-109	2021.11.30	10:02:33
6	-111	2021.11.30	10:03:34
7	-109	2021.11.30	10:03:54
8	-109	2021.11.30	10:04:14
9	-109	2021.11.30	10:04:34
10	-109	2021.11.30	10:04:54

Table 4.3 : Result of average time to receive alert SMS in good signal condition

Experiment	Time message received (s)
1	5
2	6
3	6
4	7
5	8
average	6.4

Table 4.2 shows the result of the GSM signal in good signal condition which is measured by the "Network Monitor" application. The experiment was conducted from 10:00 am to 10:04 am which is about 4 minutes. The signal strength is varying from 105 dBm to -111dBm. Table 4.3 shows the result of average time for the phone to receive alert SMS. The average time is about 6.4 seconds for the phone to receive the alert SMS from the system.

4.3.2 Poor GSM Signal Condition

Table 4.4 : Result of GSM signal in poor signal condition which measured by the "Network Monitor" application

ID	SIGNAL STRENGTH (dBm)	DATE	TIME
1	-127	2021.11.30	13:00:03
2	-127	2021.11.30	13:01:23
3	-129	2021.11.30	13:01:53
4	-133	2021.11.30	13:02:13
5	-133	2021.11.30	13:02:33
6	-135	2021.11.30	13:03:34
7	-135	2021.11.30	13:03:54
8	-142	2021.11.30	13:04:14
9	-140	2021.11.30	13:04:34
10	-135	2021.11.30	13:04:54

Table 4.5 : Result of average time to receive alert SMS in poor signal condition

Experiment	**Time message received / s**
1	62
2	74
3	65
4	68
5	70
average	68

Table 4.4 shows the result of GSM signal in poor signal condition which is measured by the "Network Monitor" application. The experiment was conducted from 1:00 pm to 1:04 pm which is about 4 minutes. The signal strength is varying from -127 dBm to -142 dBm. Table 4.5 shows the result of average time for the phone to receive alert SMS. The average time is about 68 seconds for the phone to receive the alert SMS from the system.

4.4 System Accuracy

4.4.1 Mean Relative Error

From the experiment, the result is compared with each other and the error is found out using error formula which is

$$Error\ (\%) = \frac{Theoritical\ Value - \ Experimental\ Value}{Theoritical\ Value} \text{ x } 100\%$$

This formula is standardised in calculating the error. For the relative mean error, all of the errors of each result are summed up and then the average is calculated. Therefore the mean error can be calculated using the formula of

$$Mean\ Relative\ Error\ (\%) = \frac{Total\ of\ error}{Total\ number\ of\ experimental\ value}$$

4.4.1.1 Comparison in theoretical and experimental value

The purpose of this experiment is to test if the system gets accurate readings from the MQ2 gas sensor. The experiment was carried out in an enclosed room by placing the system inside and the readings are recorded for analysis. The distance is fixed to 20cm because the system accuracy is tested in this case. In this experiment, the concentration of smoke and sensor's output voltage changed accordingly to the number of joss sticks used. The reading at normal room condition has been taken beforehand as a comparison with the condition of different numbers of joss sticks. The experiment also repeated ten times to make sure the readings obtained from the sensors are more accurate. For the first section, the readings of smoke concentration that obtained from the MQ2 gas sensor is compared with the reading on GasLab at different conditions. Theoretical value of the concentration of smoke is taken from GasLab and the experimental value is measured by MQ2 gas sensor.

Table 4.6. Mean Relative Error for concentration of smoke between the value obtained from GasLab and MQ2 gas sensor.

Condition (Number of joss sticks)	Theoretical Value, ppm (GasLab)	Experimental Value, ppm (MQ2 gas sensor)	Error (%)
0	110	112	1.818
5	147	148	0.680
10	195	193	1.026
15	308	306	0.649
20	384	381	0.781
25	460	455	1.087
30	505	501	0.792
		Mean Relative Error	**0.976 %**

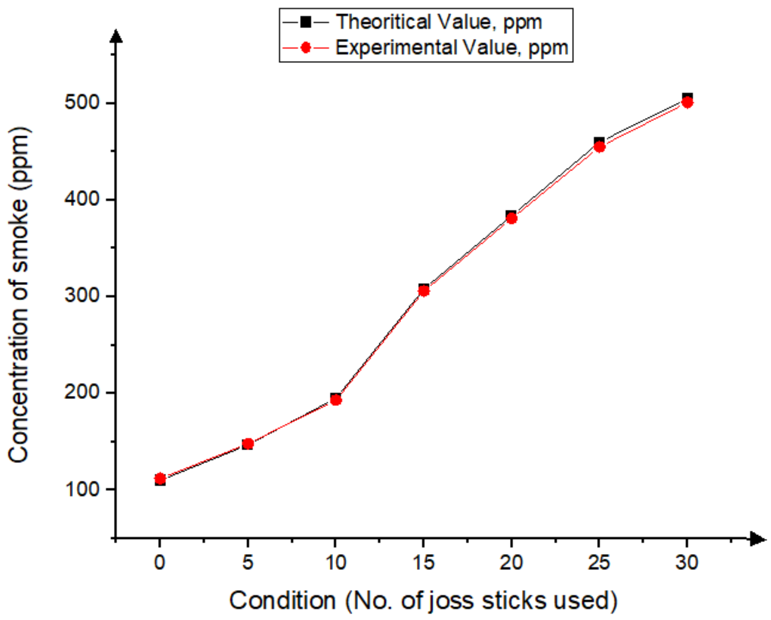

Figure 4.6. Graph of concentration of smoke versus number of joss sticks at a fixed distance for theoretical and experimental value

Figure 4.6 showed the data taken from the GasLab and Arduino Uno at different conditions. From Figure 4.6, both theoretical and experimental values showed a linear relationship which when the number of joss sticks increased, the concentration of smoke also increased. From Table 4.6, the buzzer rings when the condition of the room has reached the threshold value which has been set to 300 ppm. Therefore, the buzzer starts to trigger for conditions with 15 joss sticks or more. The accuracy of the MQ2 gas sensor also can be determined from Table 4.1, where only 0.976% is calculated for mean relative error. The percentage error that is obtained is very close to zero, this means the concentration values recorded by MQ2 gas sensor are almost accurate from the true value. However, the sensor value only reflects the approximated trend of gas concentration in a permissible error range, it does not represent the exact gas concentration.

As for the next section, the readings of the sensor's output voltage that are obtained in MQ2 gas sensor are compared with the readings obtained in the multimeter at different conditions. Theoretical value of the sensor’s output voltage is measured by multimeter and the experimental value is taken from MQ2 gas sensor

Table 4.7. Mean Relative Error for sensor's output voltage between the value obtained from MQ2 gas sensor and multimeter.

Condition (Number of joss sticks)	Theoretical Value, V (Multimeter)	Experimental Value, V (MQ2 Gas Sensor)	Error (%)
0	0.55	0.56	1.754
5	0.82	0.81	0.012
10	0.94	0.95	1.064
15	1.54	1.55	0.649
20	1.87	1.85	1.070
25	2.20	2.22	0.909
30	2.58	2.55	1.163
		Mean Relative Error	**0.946 %**

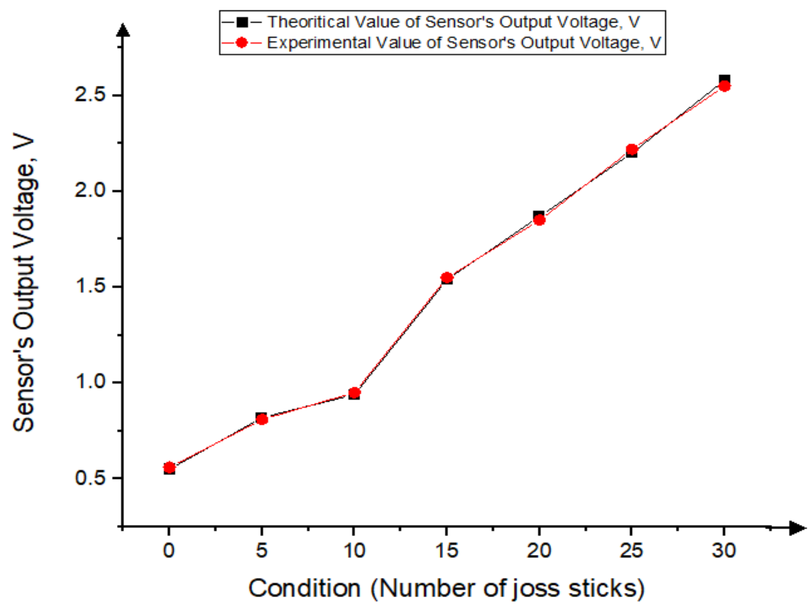

Figure 4.7. Graph of sensor's output voltage versus number of joss sticks at a fixed distance for theoretical and experimental value

Figure 4.7 showed the data taken from MQ2 gas sensor and multimeter. From the graph, the data for both theoretical and experimental value showed a linear relationship in which when the number of joss sticks increased, the sensor’s output voltage also increased. The system also is set to trigger the buzzer when the threshold value is greater than or equal to 300 ppm or when the sensor’s output voltage is more than 1.5 V. Therefore, the system triggers the buzzer when 15 joss sticks are used because from the previous graph, the buzzer starts to trigger when the concentration is at 306 ppm, and for this part, it is when the output voltage reaches 1.55 V. Other than that, as shown in Table 4.7, the error obtained is in the range of 0% - 2% and the mean relative error is below than 1 which is 0.946%.

The error for both concentration and the output voltage of the sensor cases include the performance of the sensors. The performance of the sensors reduces or is less accurate after use for an extended period. Furthermore, a smoke detector's ability to sense fire depends on the rise, spread, rate of burn, coagulation, and air movement of the smoke itself. Other than that, the limitation of this experiment is the smoke produced is not as much as a real fire, and the smoke tends to move randomly in the air. Therefore, the experiment is repeated to make the reading more reliable.

4.5 Distance of the system

The system is also tested with two different types of fire which are smouldering and flaming fire at different distances. Fuel is needed for combustion to occur therefore joss sticks were used to produce smouldering fire and newspapers were burned to produce flaming fire. The room used for this experiment is measured by feet therefore feet is used as the unit for distance. This experiment is carried out to test the ability of the entire system to detect the concentration of smoke in both fires with the change of distance. The reading obtained from smouldering fire is compared to the flaming fire. Figure 4.8, is the graph of concentration of smoke versus distance in smouldering and flaming fire. From Figure 4.4, the trend of the graph in both fires is different. The concentration of smoke in flaming fire increasing up to 3 feet; however, the concentration of smouldering fire continuously dropped as the distances increased.

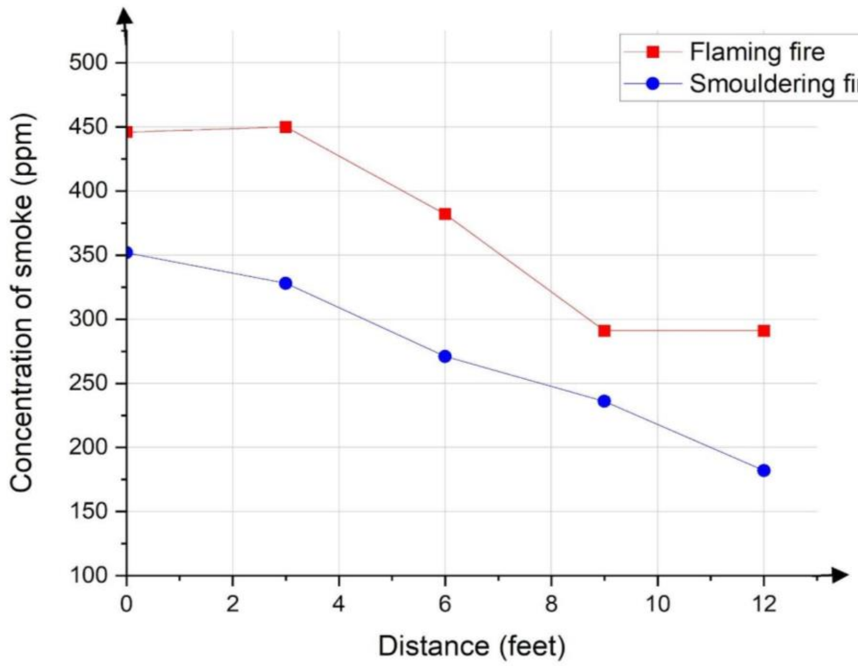

Figure 4.8 : Graph of the concentration of smoke versus distance with smouldering and flaming fire.

The unit of feet is used instead of the standard unit meter because the room in which the experiment is carried out is using the unit of feet. Basically, 1 feet is equal to 0.3048m. However, if the unit is converted into metres there will be a lot of decimals for the value that is used for plotting the graph . Table 4.8. is the result of the concentration of smoke in smouldering and flaming fire versus the distance.

Table 4.8 : Results of the concentration of smoke vs distance in smouldering and flaming fire.

Distance (feet)	**Concentration of smoke (ppm)**	
	Flaming fire	**Smouldering fire**
0	446	342
3	450	328
6	382	271
9	291	236
12	291	182

From Table 4.8, the concentration value for both fires exceeds the threshold value for distance at 0 feet; where the smoke detector gives the reading of 446 ppm for flaming and 342 ppm for smouldering fire. This is because the source of fires were placed nearer to the system, therefore, more smoke can be detected and alert messages can be sent. When the distance is increased by 3 feet, the concentration of smoke for smouldering fire drops to 328 ppm compared to flaming fire which slightly increases to 450 ppm. Even though the concentration of smoke for smouldering is dropping, the danger in both fires can be still detected by the system because the concentration obtained exceeds 300 ppm. It means that the system is able to detect smoke even when the distance is increased. However when the distance is increased by another 3 feet for flaming fire, the concentration of smoke decreases where 382 ppm is obtained compared to the distance of 3 feet. As for the smouldering fire, the concentration of smoke kept on decreasing where a big increment is recorded for distance of 6 feet at which 271 ppm is obtained. In this case, the system will send alert messages when it detects smoke produced from flaming fire only. The concentration of smoke in smouldering fire kept on decreasing where 236 ppm is obtained for 9feet and 182 ppm for 12feet . The reading dropped because only 15 joss sticks are used to produce smoke. From the previous section ,only 15 joss sticks needed to produce smoke ,therefore 15 joss sticks are used in this case. Yet, the smoke produced by joss sticks is considered too little if the distance is further. Therefore, more joss sticks should be burned. However the room has poor ventilation which is not good therefore the amount of fuel component in combustion cannot be increased otherwise people in the room might have smoke inhalation problems. As for flaming fire, at the distance of 9 feet, the concentration of smoke starts to drop to 291 ppm. But for the distance of 12 feet, the reading remains unchanged compared to 9 feet, this happens due to the systematic error of the components and human error as well. The reading is supposed to be dropped when the distance is increased to 12 feet but due to the error so the reading remains the same. Thus, no alert message is received at the distance of 9 and 12 feet in both fires as the concentration of smoke is below the threshold value.

4.6 Position of the system

For this section, the position of the system is varied and the changes in the concentration of smoke are observed. Table 4.9 is the results of the concentration of smoke versus position of the system with a fixed number of joss sticks.

Table 4.9 : Results of the output voltage sensor versus position with fixed number of joss sticks

Position of the system	Concentration of smoke (ppm)
Centre of the room	420 ppm
Left side of the room	287 ppm
Right side of the room	231 ppm

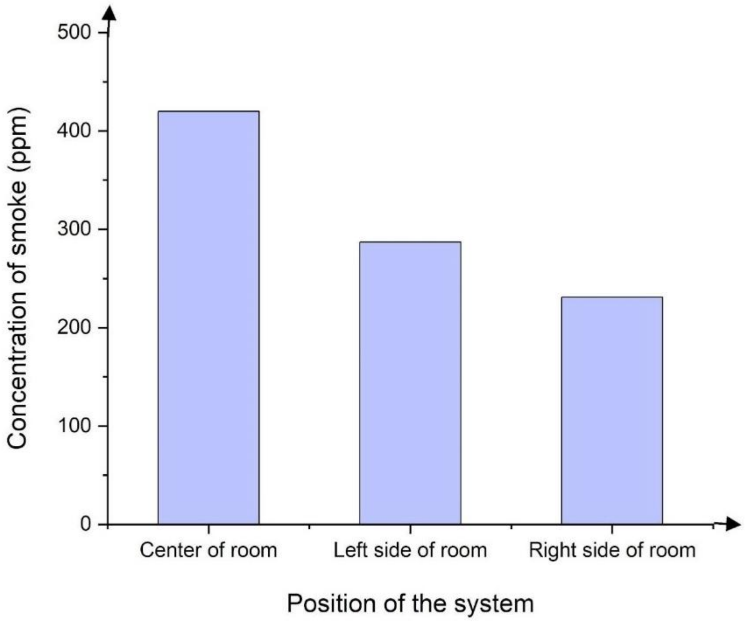

Figure 4.9 : Graph of the concentration of smoke versus position of the system with fixed number of joss sticks

From Figure 4.9 the concentration of smoke when the system is placed in the center of the room is the highest which is 420 ppm as the system is the nearest from the joss sticks. When the system is placed at the left corner of the room ,the smoke detector only gives the reading of 287 ppm because the direction of the smoke produced moves in the left side therefore the concentration of smoke for the position at the right corner is the lowest. The concentration of the smoke for the position at the right corner is 231 ppm as the smoke moves in the opposite direction. Another reason that caused the reading for position at the left and the right corner is because the system is placed at the bottom part of the left and right corner . However, the smoke tends to move to the upper part of the room, therefore, the system is not able to detect the smoke.

From the concentration readings the best position for the entire system to be placed is at the centre of the room. However, the best position for the entire system also depends on where the fire starts. For example, if a real fire is happening in the room but the fire started from the left or right corner, therefore the best position for the system should be placed nearer to where the fire occurs. The best way to overcome this problem is to place more than one smoke detection system in the room.

CHAPTER 5

CONCLUSION

5.1 Conclusion

At the end of the project, smoke detection system with GSM module was designed and the circuit was successfully connected. The circuit was tested and found to be run perfectly. However, there are some weaknesses of this system. This system is more suitable to be allocated at an enclosed place such as a room because the sensor in this project is considered educational type sensors. The gas sensor has successfully interfaced to the computer by using Arduino UNO with GSM Module. When the gas sensor detects smoke, the indicator LED will light up and the buzzer will turn on meanwhile the alert SMS was successfully sent to the user's mobile phone.

The smoke detection system has been analyzed in terms of Rs/Ro VS sensor’s output voltage, the effect of network latency in receiving alert messages, accuracy of the gas sensor, along with the impact of the distance between fire source and to the system with different types of fire, and the best position to place the system.

MQ 2 gas sensor is a metal oxide semiconductor (MOS), also known as a chemiresistor. This type of sensor requires the gas to encounter the sensor for a chemical reaction to occur. This chemical reaction causes a change in resistance, which is then measured to detect the presence or concentration of the gas. Thus, in the first section, the Rs/Ro value decreased as the sensor’s output voltage increased. Other than that, the GSM signal which will affect the time for the phone to receive alert SMS has been analyzed. An application “Network Monitor” which downloaded from AppStore is used to measure and record the GSM signal of the SIM card. The average time for the phone to receive SMS in two different locations which have different GSM signals has been recorded. The average time to receive SMS with a good GSM signal is faster than a poor GSM signal which is 6.4s and 68s.

Other than that, the graph of concentration of smoke vs number of joss sticks has a similar trend to the graph of sensor's output voltage vs number of joss sticks. Therefore, it is proven that the greater the gas concentration, the higher is the output voltage; while lesser gas concentration results in low output voltage. Other than that, the system will trigger the buzzer and an alert SMS will be sent, if the system detects a smoke level that exceeds the threshold value of 300 ppm or when the sensor's output voltage is greater than 1.5V. The performance of the MQ2 gas sensor in flaming and smouldering fire has also been evaluated. The sensor was still capable of detecting smoke produced from both fires, however, when the distance is farther from the source of fire, the system is not able to send alert messages to the user's mobile phone as the concentration of smoke decreases when the distance increases. Furthermore, the best position to place the smoke detection system is somewhere nearer to the source of fire or at empty spaces as the sensor will be exposed more with smoke compared to spaces that have many obstacles.

5.2 Recommendations / Future Work

The system can be implemented in the industrial field but the sensor used should be replaced by industrial type sensors. Basically, educational type sensors are sensors that are used for education level which are low in cost while industrial type sensors are more suitable for industry as the sensors have maximum reliability and can prevent dust, acidity and temperature effects. Other than that, more sensors or techniques should be used in order to increase the quality of the system such as temperature sensors where it can detect fires based on sudden change in temperature or techniques like Video Image Smoke and Fire Detection (VISD) where it can monitor fire that occur in outdoor or large volume spaces.

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APPENDIX

PROGRAM CODING FOR SMOKE DETECTOR WITH SMS ALERT

```
#include <LiquidCrystal_I2C.h>
LiquidCrystal_I2C lcd(0x27, 16, 2); //for 16x2 lcd display
#include <SoftwareSerial.h>

SoftwareSerial mySerial(7, 8);

#define MQ2pin (0)
int buzzer = 11;
int ledPin = 13;
int sensorValue;
int data = 0;

void setup()
{
  Serial.begin(9600);
  randomSeed(analogRead(0));
  lcd.init(); // initiate the lcd
  lcd.backlight();
  mySerial.begin(9600);
  Serial.begin(9600);
  pinMode(sensorValue, INPUT);
  pinMode(buzzer, OUTPUT);
  pinMode(ledPin, OUTPUT);
  lcd.print("Gas Leakage");
  lcd.setCursor(1,1);
  lcd.print("Detector Alarm");
  delay(3000);
}
 void loop() {

  float sensor_volt;
  float RS_gas; // Get value of RS in a GAS
  float ratio; // Get ratio RS_GAS/RS_air
  int sensorValue = analogRead(A0);
  sensor_volt=(float)sensorValue/1024*5.0;
  RS_gas = (5.0-sensor_volt)/sensor_volt;

  /*-Replace the name "R0" with the value of R0 in the First Test -*/
  ratio = RS_gas/2.10;  // ratio = RS/R0
  /*-----------------------------------------------------------------------*/
```

```
 Serial.print("pin A0 = ");
 Serial.println(sensorValue);
 Serial.print("sensor_volt = ");
 Serial.println(sensor_volt);
 Serial.print("RS_ratio = ");
 Serial.println(RS_gas);
 Serial.print("Rs/R0 = ");
 Serial.println(ratio);
 Serial.print("\n\n");

lcd.clear();
sensorValue = analogRead(MQ2pin); // read analog input pin 0
lcd.setCursor(0,0);
lcd.print("VALUE : ");
lcd.print(sensorValue);
lcd.print("ppm");

// Checks if it has reached the threshold value
if (sensorValue >= 300)
{
 SendMessage();
 lcd.setCursor(0,1);
 lcd.print("DANGER! SMS sent");
 digitalWrite(buzzer, HIGH);
 digitalWrite(ledPin, HIGH);
}
else
{
 lcd.setCursor(0,1);
 lcd.print("SAFE");
 digitalWrite(buzzer, LOW);
 digitalWrite(ledPin, LOW);
}
delay(500);
lcd.clear();
}
void SendMessage()
{
 Serial.println("SMS alert has been sent");
 mySerial.println("AT+CMGF=1"); //Sets the GSM Module in Text Mode
 delay(1000);
 mySerial.println("AT+CMGS=\"+60183813468\"\r");
 delay(1000);
 mySerial.println("DANGER! Smoke Detected");
 delay(100);
 mySerial.println((char)26);
 delay(1000);

}
```