A Smart System for the University Chemical Laboratory Using IoT

Soha A. Shaban

Department of Computer Science, Faculty of Specific Education, Mansoura University, Mansoura, Egypt
Email: prof_soha@mans.edu.eg

***Abstract*—University chemical laboratories are constantly exposed to multiple kinds of threats, including frequent explosions, theft of high-value equipment, sensitive data, dual-use chemicals that can be used in weapons, and high energy consumption. Therefore, the purpose of this paper is to develop an automated system for the university's chemical laboratory while also providing it with safety and security using IoT. The proposed system is divided into three parts. The first part is security, which employs a Passive Infrared (PIR) sensor and Radio-Frequency Identification (RFID) module to keep the laboratory secure at all times. The second part is automation, which uses the "Google Assistant" embedded into the Android smartphone, HC-05 Bluetooth module, an Arduino Uno, and a relay module. It is intended to allow the laboratory supervisor to remotely monitor and control different laboratory electrical appliances. The third part is safety, which monitors the laboratory environment using a flame sensor, MQ3 smoke sensor, DHT22 temperature and humidity sensor, and MQ135 air quality sensor. The data from the sensors is transferred to the Arduino Uno, which then takes the necessary action in the event of an emergency. The results showed that the proposed system works 98% correctly under the conditions of the investigation, which indicates that it is trustworthy, dependable, and efficient.**

***Keywords*—chemical laboratory, Internet of Things (IoT), Google assistant, Arduino Integrated Development Environment (IDE), MIT app inventor 2**

I. Introduction

Chemical laboratory is an essential facility for every university, especially one with faculties of exact sciences. It is used for teaching, research, and community service, which are all functions of higher education [1]. Experimental activities in the chemical lab are closely related to the use of chemicals. These chemicals can be corrosive, carcinogenic, flammable, irritants, and toxinous and are associated with lab equipment usage, which may result in an explosion due to high pressure or temperature. As a result, accidents and even life-threatening hazards occur [2, 3]. So, lab safety must be prioritized, especially in chemical laboratories, so that there is no danger or worry of an accident occurring in a lab [4, 5]. Currently, the system of laboratory management is a human-based system that has human errors and threats [6]. Moreover, laboratories are seldom examined due to a lack of resources, including competent employees, and an underestimation of lab safety [4]. Additionally, some people conducting experiments lack sufficient knowledge concerning the harmful effects of chemicals and methods for experimentation [7]. The chemical lab's security is just as vital as its safety; it protects the lab against theft, loss, accidents, and other issues [8]. Labs may include some electrical appliances such as lights, fans, etc. In order to save electricity, human efforts, and functioning time, all these appliances need to be controlled remotely to switch off when not in use. This is done with the help of a mobile application installed on any smartphone [9, 10]. Allowing anyone to stay in the lab after the official study lab hours have finished is also prohibited. IoT comprises of things in the real world and sensors attached to them that are connected to the Internet via wired and wireless networks. IoT-enabled things can share information with humans, software, and other devices about the condition of things and the surrounding environment [11]. IoT has several uses in medical, transportation, farming, manufacturing, and automation [12]. As a result, this technology may be effectively used to make laboratories smarter, safer, and more automated. Smartphones are mobile phones that use the Android operating system [13]. Google Assistant is an artificial intelligence-based software that is accessible on almost all Android mobile phones. Users utilize it to access smart devices and applications by using voice commands [14]. Smartphones support one or more short-range wireless technologies, such as Bluetooth and infrared, making it easy to transfer data via these wireless connections. Bluetooth HC-05 is a module that allows Arduino and Android smartphone to communicate [15, 16]. Arduino Uno receives voice commands from a smartphone via Bluetooth and transmits them to relays, which subsequently switch the appliances on and off [17]. Sensors are devices that monitor environmental changes, continuously capture data, and transmit that data to a microcontroller (Arduino Uno) [18]. Radio-Frequency Identification (RFID) technology and Arduino are utilized to create an automated access control system that grants authorized persons access while denying unauthorized persons access [19]. In combination with other sensors, Passive Infrared (PIR) sensors are commonly employed in a variety of applications to create smart environments and security systems [20]. In this paper, IoT technology has

Manuscript received June 6, 2023; revised July 30, 2023; accepted September 4, 2023; published January 18, 2024.

doi: 10.12720/jait.15.1.104-117

been used in the university chemical laboratory to provide it with safety and security in addition to automation. For lab security, the RFID module is installed on the lab entrance next to the door to prevent unauthorized individuals from entering. Additionally, the PIR sensor is used to detect any movement in the lab outside of its official working hours. For lab automation, voice commands using the "Google Assistant" inbuilt with the android smartphone, are used. It allows the lab supervisor to remotely monitor and control lab appliances such as lights, fans, etc. to conserve energy when not in use. For lab safety, flame, smoke, temperature, humidity, and air quality sensors data is monitored, and in the event of an emergency, the lab supervisor is alerted, and control actions are taken to prevent accidents.

II. Related Work

Many applications that people use in their daily lives depend on IoT technology, making their lives easier, safer, and smarter. This technology's main goal is to decrease human effort, save time and simplify a task. Smart cities, smart environment, smart agriculture, smart laboratories, and so on are examples of IoT applications [9]. With advances in technology and work processes, smart laboratories have come on the verge of improving laboratories workflow and reducing workloads for the staff within the laboratory. Smart laboratory built using IoT technologies and mobile communications supervises the overall general activities of the laboratory including energy consumption and application of devices, sensing environmental parameters, thus providing a smart environment with balanced energy consumption and comfort [12]. Accordingly, IoT-based smart automation laboratories are a significant topic on which some researchers have conducted studies. In Table I, a summary of the important characteristics of some relevant studies and the proposed system is provided.

TABLE I. Summary of the Important Characteristics of Some Relevant Studies and the Proposed System

Reference	The Important Characteristics of the Work
Bhandari *et al.* [21]	It included an RFID-enabled smart attendance system in a lab as well as a temperature monitoring system using LM35 sensor and Raspberry Pi board with fan control. It also had a smart teaching system that employed remote desktop technology using TeamViewer.
Basheer *et al.* [22]	It used multiple sensors to detect the event that occured in the computer lab. This model made use of motion, temperature, humidity, and luminosity sensors. A smoke sensor was also employed in the lab to detect smoke. When an event was identified, the GSM communication module was used to send an email.
Simanungkalit *et al.* [23]	It controlled the temperature of the computer lab's Air Conditioner (AC) using DHT11 sensor and Arduino. The Arduino adjusted the AC temperature based on the room temperature from the DHT11 sensor.
Khairnar *et al.* [24]	It enabled the user to remotely control the appliances connected to the laboratory from anywhere within the Wi-Fi range. Blynk application was used to control electrical appliances in a laboratory using a certain number of relays connected to an ESP32 wi-fi module.
Narhari *et al.* [25]	It monitored data from temperature, light, and motion sensors. Additionally, it has launched an operation based on what is needed, for example turning on the light when it gets dark. It also employed an RFID tag reader for door authentication.
Awaludin *et al.* [26]	It used a DHT11 sensor to measure temperature and humidity in a chemical lab. The NodeMCU ESP8266 microcontroller processed the sensor data, which was then displayed on the LCD. Also, there was a relay that functions to connect and cut off the electric current on the fan.
Kama *et al.* [27]	It used the MCUESP8266 node, the temperature sensor DHT11/ 22, and Python 3 flask to monitor and control the temperature in a chemical lab. Also, there was a software program that presents the temperature to the mobile platform and desktop system.
The Proposed System	It uses the RFID module and the PIR sensor, one outside and one inside the chemical lab, to ensure the lab's security at all times. Furthermore, the "Google Assistant" is used to provide voice commands for remotely managing (on/off) lab appliances such as lights, fans, water motor, and so on. The system also includes multiple sensors to monitor environmental factors, such as flame, smoke, humidity, temperature, and air quality. In the event of an emergency, it activates the buzzer sensor to alert the lab supervisor, displays an alert message on the Liquid Crystal Display (LCD), and proper safety steps are taken, such as turning on the fan in case of smoke, turning on the water motor in case of fire, etc.

III. The Proposed System

The proposed system makes use of IoT technologies to automate the university chemical lab environment while maintaining its safety and security. It is divided into three stages. The first is the security stage, which aims to maintain lab security at all times. It uses the RFID module to ensure lab security from outside and the PIR sensor to provide security from within the lab. The second is the automation stage, which seeks to conserve lab electricity when not in use. It uses a smartphone provided with the "Google Assistant," the Arduino Uno, the HC-05 Bluetooth module, the four-channel relay module, and the "MIT App Inventor 2" software. The "Google Assistant" is used to give voice commands to remotely control the lab appliances (on and off). Then, these voice commands are transferred to the Arduino Uno using the HC-05 Bluetooth module. After that, the Arduino Uno sends a signal to the relay module to execute the desired voice commands. The "MIT App Inventor 2" platform is used to develop the Android application. The developed application can be installed on an Android phone with a Bluetooth module. The third is the safety stage, which tries to maintain the lab's safety from accidents. It uses the flame sensor, the MQ3 smoke sensor, the MQ135 air quality sensor, and the DHT22 humidity and temperature sensor. These sensors data is monitored and transferred to the Arduino Uno. In an emergency, it activates the buzzer sensor to alert the lab supervisor, displays an alert message on the LCD, and performs safety actions. The circuit diagram, circuit simulation, and programming code for the proposed system were developed using Fritzing software, Proteus software, and the Arduino IDE, respectively. The proposed smart system framework for the university's chemical laboratory is shown in Fig. 1. The detailed analysis of the proposed system stages is as follows:

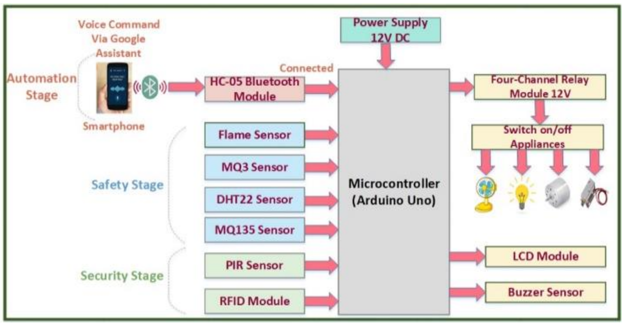


Fig. 1. The proposed smart system framework for the university's chemical laboratory.

A. Security Stage

It is the first stage of the proposed system. The following is an explanation of the security stage's hardware and software:

1) Hardware description

The Arduino Uno, the PIR sensor, the RFID module, the buzzer sensor, the LCD module, the relay module, an electric door lock, a breadboard, and jumper wires are the hardware components used for creating the security stage. The description of these components is presented below.

The **Arduino Uno** is a microcontroller board based on the ATmega328p. It contains 14 digital I/O pins (six of which are PWM outputs), 6 analogue inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It includes everything required to support the microcontroller [28]. In this paper, the Arduino Uno is powered with a 12V DC power supply.

The **PIR sensor** is essentially a human sensing device that is commonly used in PIR-based motion detectors. PIR sensors sense general movement but do not know who or what moved [29, 30].

The **RFID module** is an auto-identification system that employs two basic types of devices: a reader, which serves as the Master of Communication, and tags or cards, which have an associated electronic code they use to be uniquely identified [31].

The **buzzer**, also referred to as a beeper, is a type of audio signaling device that can be mechanical, electromechanical, or piezoelectric (piezo for short). Alarm devices, timers, and confirmation of human input such as a mouse click, or keystroke are common uses for buzzers [32].

The 16×2 **LCD** is a fundamental module that is widely used in a variety of devices and circuits. Because it consumes extremely little electricity, LCD is frequently used in battery-powered electronic appliances. It is used to display the sensors' real-time data [33, 34].

The **four-channel relay module** can control four distinct types of loads (appliances) simultaneously without conflicting with each other. It includes all of the required components and connections to make it happen, such as a flyback diode, a base current limiting resistor, and header and LED indicators for connecting it to other devices [35]. The one used in this paper is a 4-channel 12-volt relay module.

The **DC 12V solenoid electric door lock** can control precisely how the door opens and closes after all the cables are connected and electricity is powered. The plunger resets the latch and relocks the door once the power supply to the solenoid is unplugged. It is an outstanding selection for a locking system that offers extreme security [36].

A **breadboard** is a plastic board with several tiny holes used to build and test circuits. A **jumper wire** is an electrical wire, or a collection of wires in a cable, with a connector or pin at either end. It is usually used to connect the components of a breadboard or other prototype or test circuit [37]. Fig. 2 shows the hardware components for the proposed chemical lab security stage.

Fig. 2. The hardware components for the proposed chemical lab security stage.

2) Software description

The security stage makes use of three different software: the Arduino IDE, Proteus software, and Fritzing software. Below is a detailed explanation of each software.

The **Arduino IDE** is an open-source software used for code editing, compilation, error correction, and code burning on the Arduino board [38]. The version 2.1.0 is the used one in this paper.

Proteus software is a simulation tool that enables the virtual design of the circuit and shows how it performs. Its library contains an extensive number of components that may be used with multiple applications. The simulation of the circuit before hardware implementation is crucial and efficient. If it shows an error in the module, that error may be fixed in the hardware part [39]. This paper uses version 8.10 of Proteus software.

Fritzing is an open-source software for creating electronic wiring diagrams. It is the prototyping step before moving on to the permanent circuit. The Fritzing platform is a wonderful tool for building circuits since it can connect a schematic to a real layout [40]. The version used in this paper is 0.9.8.

3) Principles of working for the security stage

This stage attempts to maintain the security of the lab inside and out. The RFID module is used to provide security from the outside to prevent any unauthorized person from entering the lab. The RFID reader is positioned at the lab entrance next to the door. The RFID cards with unique Identification (ID) numbers are given to the supervisor of the chemical lab. The security on the inside is provided by the use of the PIR sensor, which prevents anyone from staying in the lab after his in-lab study schedule has ended. This sensor is linked to the lab study schedule, and once the schedule is finished, the sensor is activated. In the event of the presence of any person, the lab supervisor is alerted. The proposed algorithm for the chemical lab security stage is detailed in Algorithm 1. The flowchart for one cycle of the proposed chemical lab security stage is displayed in Fig. 3.

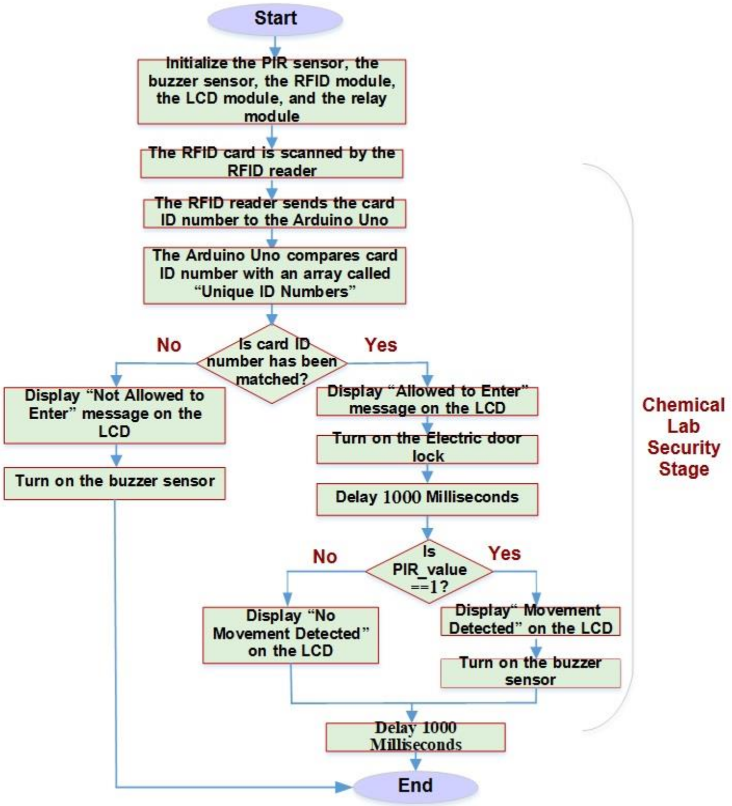


Fig. 3. The flowchart for one cycle of the proposed chemical lab security stage.

B. *Automation Stage*

Lab automation system makes the use of electric appliances easier. In the proposed system, this is the second stage. The following is an illustration of the hardware and software for the automation stage:

1) Hardware description

The hardware components that will be used to develop the automation stage are a smartphone with "Google Assistant", the HC-05 Bluetooth module, lab appliances, and some of the components that were mentioned earlier, namely the Arduino Uno, the LCD module, the four-channel relay module, the breadboard, and the jumper wires. Below is a description of these components.

Smartphone use has revolutionized the way that millions of people across the world work, communicate, and access information. Currently most of the smartphone market is leading in Android which comes with Google Assistant technology. Google Assistant is a technology that grows quickly. It allows the users to control the all apps in their device by using voice commanding mode [41, 42].

The **HC-05 Bluetooth module** allows Arduino Uno and an Android smartphone to connect wirelessly. The HC-05 is a slave device that operates on 3.6 to 6 volts. It has six pins: state, RXD, TXD, GND, VCC, and EN. It offers a coverage area of 10-100 meters [43, 44].

Algorithm 1. The Proposed Algorithm for the Security Stage

Step No.	Step Description
Step 1	Initialize the PIR sensor, the RFID module, the buzzer sensor, the LCD module, and the relay module.
Step 2	The RFID card is scanned by the RFID reader.
Step 3	The RFID reader sends the RFID card's unique ID number to the Arduino Uno.
Step 4	The Arduino Uno compares the ID number with numbers stored in an array called "Unique ID Numbers".

Step 5	**If** (Matching == True)
	Display ("**Allowed to Enter**") message on the LCD.
	Turn on the electric door lock.
	Else
	Display ("**Not Allowed to Enter**") message on the LCD.
	Turn on the buzzer sensor to alert the lab supervisor.
	Break;
	End If

Step 6	**If** (PIR_value ==1)
	Display ("**Movement Detected**") message on the LCD.
	Turn on the buzzer sensor to alert the lab supervisor.
	Else
	Display ("**No Movement Detected**") message on the LCD.
	End If

Lab appliances employed in this paper include lights, fans, water motor and electric door lock. Fig. 4 shows the hardware components for the proposed chemical lab automation stage.

Fig. 4. The hardware components for the proposed chemical lab automation stage.

2) Software description

The automation stage also makes use of the three software packages that are used in the security stage in addition to the MIT App Inventor 2. It is an open-source web application that enables the creation of fully working smartphone applications. It is divided into two parts [45, 46]. The first is the Designer part, in which the application's Graphical User Interface (GUI)is designed with various components such as textboxes, labels, buttons, speech recognizers, etc. (as shown in Fig. 5). The second part is the Blocks Editor, which is used to program the components from the Designer part to specify the Android app's behavior (as shown in Fig. 6). In the proposed system, "Chemical_laboratory.apk" application is created by using the MIT App Invertor 2 to control (on and off) all appliances in the chemical lab using a mobile phone as a remote control.

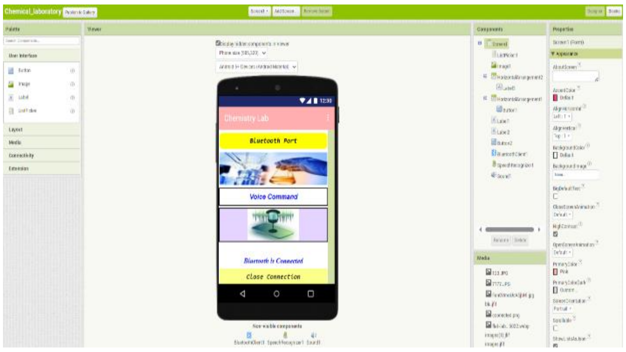


Fig. 5. The MIT app inventor 2 designer part-layout voice commands.

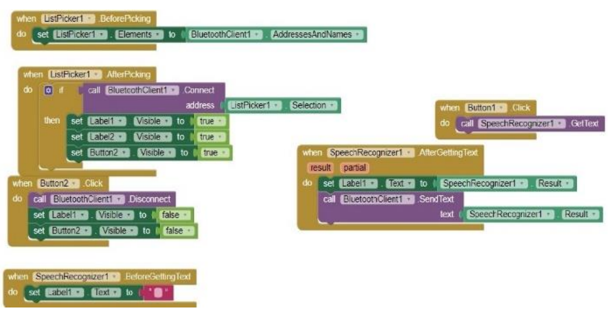


Fig. 6. The MIT app inventor 2 blocks editor-bluetooth connection and voice commands recognition.

3) Principles of working for the automation stage

This stage seeks to remotely control all lab electrical appliances via voice commands to conserve electricity, human efforts, etc. The Bluetooth and relay modules are connected to the Arduino Uno. The "Chemical_laboratory" application is installed on the lab supervisor's smartphone, which is supported by Google Assistant. The set of the voice commands used in the proposed system is shown in Table II. The proposed algorithm for the chemical lab automation stage is detailed in Algorithm 2. The flowchart for the proposed chemical lab automation stage is shown in Fig. 7.

TABLE II. THE SET OF THE VOICE COMMANDS USED IN THE PROPOSED SYSTEM

Command No.	Voice Commands (Input)	Actions (Output)
1	Turn on light	Light is on
2	Turn off light	Light is off
3	Turn on fan	Fan is on
4	Turn off fan	Fan is off
5	Turn on electric door lock	The door is open
6	Turn off electric door lock	The door is close
7	Turn on water motor	Water motor is on
8	Turn off water motor	Water motor is off
9	Turn on all appliances	All appliances are on
10	Turn off all appliances	All appliances are off

Algorithm 2.	**The Proposed Algorithm for the Automation Stage**
Step No.	**Step Description**
Step 1	Initialize the HC-05 Bluetooth module, the LCD module, and the relay module.
Step 2	Open application "Chemical_laboratory" on any android smartphone.
Step 3	Scan the discoverable Bluetooth devices and select (HC-05) Bluetooth module.

Step 4	**If** (connected==true)
	Pair the HC-05 Bluetooth module with the Arduino Uno board.
	Else
	Display an error message " Disconnected" in mobile application.
	Go to **Step 3**
	End If

Step 5	Use the "Google Assistant" package to give a voice command to switch appliances (on / off) and then convert it to text.
Step 6	The Bluetooth module transfers the text to the Arduino Uno.
Step 7	The Arduino Uno compares the text to the code written in the Arduino (IDE).

Step 8	**If** (Matching ==true)
	Display the text of the voice command on the LCD.
	The Arduino Uno sends a signal to the relay module to turn on/off the desired appliance.
	Else
	Display an error message "Appliance not found".
	Go to **Step 5**
	End If

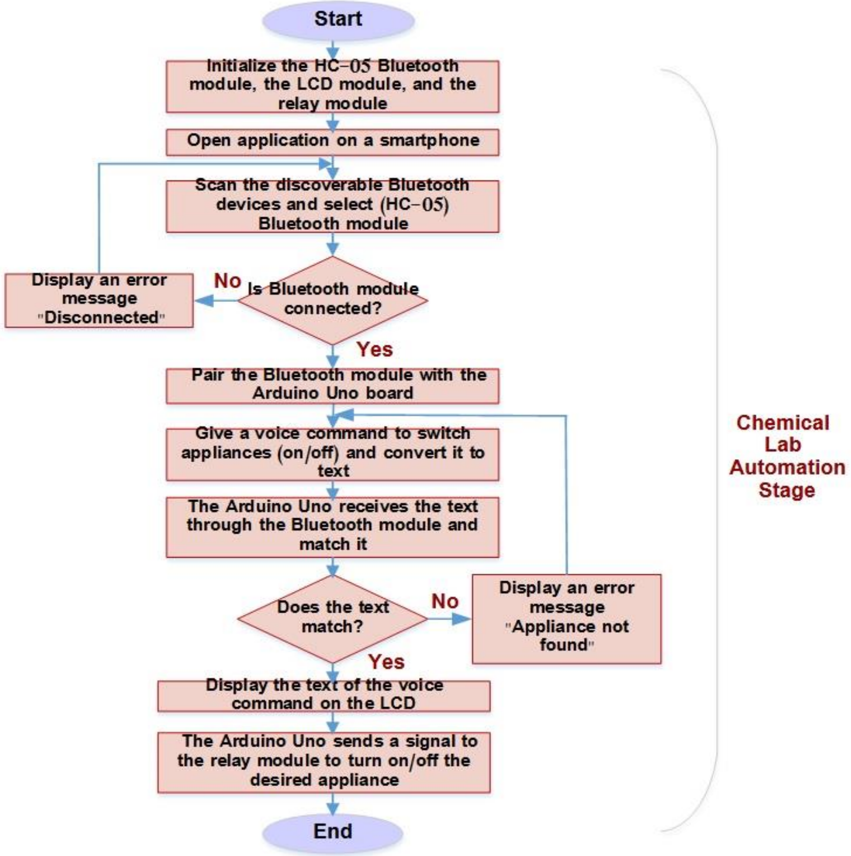


Fig. 7. The flowchart for the proposed chemical lab automation stage.

C. *Safety Stage*0

This is the third stage of the proposed system. Below is a detailed explanation of the hardware and software of the safety stage.

1) *Hardware description*

The hardware components that will be used to develop the safety stage are the flame sensor, the MQ3 smoke sensor, the MQ135 air quality sensor, and the DHT22 temperature and humidity sensor. In addition to using some of the previous hardware, which are the Arduino Uno, the relay module, the buzzer sensor, the LCD module, the lab appliances, the breadboard, and the jumper wires. Below is a description of these components.

The **flame sensor** detects and responds to the presence of a flame. It can also detect ordinary light sources with wavelengths ranging from 760 nm to 1100 nm. The detection range can extend up to 100 cm [47].

The **MQ3 sensor** detects alcohol, benzine, methane (CH4), hexane, Liquefied Petroleum Gas (LPG), ethanol, and smoke. It can operate in temperatures ranging from 10°C to 50°C. It is highly sensitive and has a fast response time [48].

The **MQ135 sensor** is used for monitoring air quality or pollution. It can detect various chemical contents in the air and give an appropriate voltage variation at the output pin based on the chemical concentration in the air. It can detect alcohol, benzene, smoke, NH_3, butane, propane, and other chemicals [49]. Air quality measurements are taken based on the Parts per Million (PPM) metric.

The **DHT22** is a simple, affordable digital temperature and humidity sensor that measures the surrounding air using a capacitive humidity sensor and a thermistor. The temperature range is −40 °C to 125 °C, with an accuracy of ±0.5 °C. The humidity range is 0 to 100% with a ±2–5% accuracy [50]. Fig. 8 shows the hardware components for the proposed chemical lab safety stage.

Fig. 8. The hardware components for the proposed chemical lab safety stage.

2) *Software description*

The safety stage also makes use of the three software packages used in the previous two stages namely: the Arduino IDE, Proteus software, and Fritzing software. The proposed system circuit diagram using Fritzing software is shown in Fig. 9. The circuit simulation for the proposed system in Proteus is illustrated in Fig. 10. A sample of the programming code for the proposed system in the Arduino IDE is shown in Fig. 11.

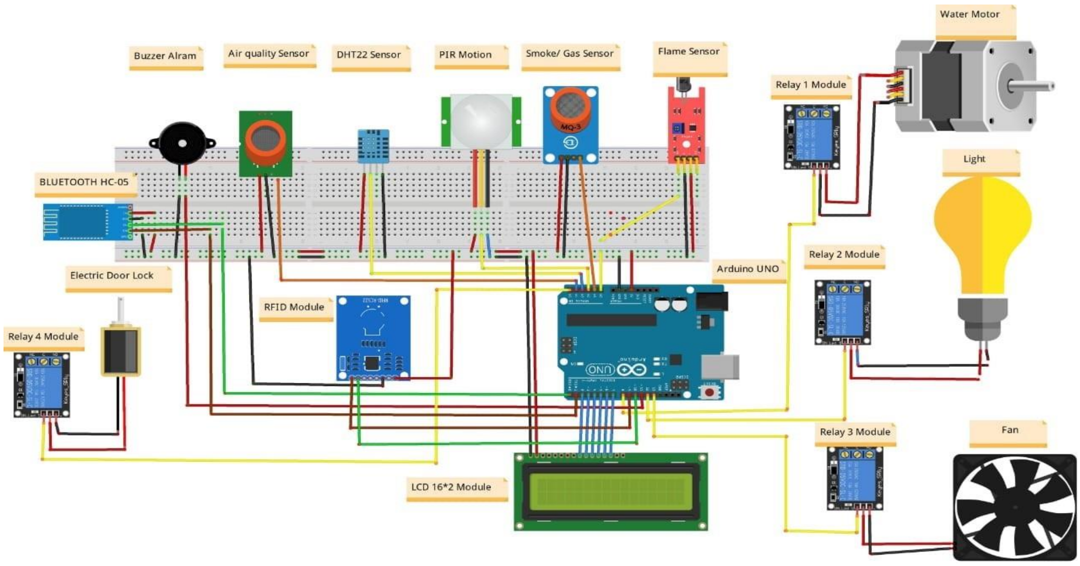


Fig. 9. The circuit diagram of the proposed system using Fritzing software.

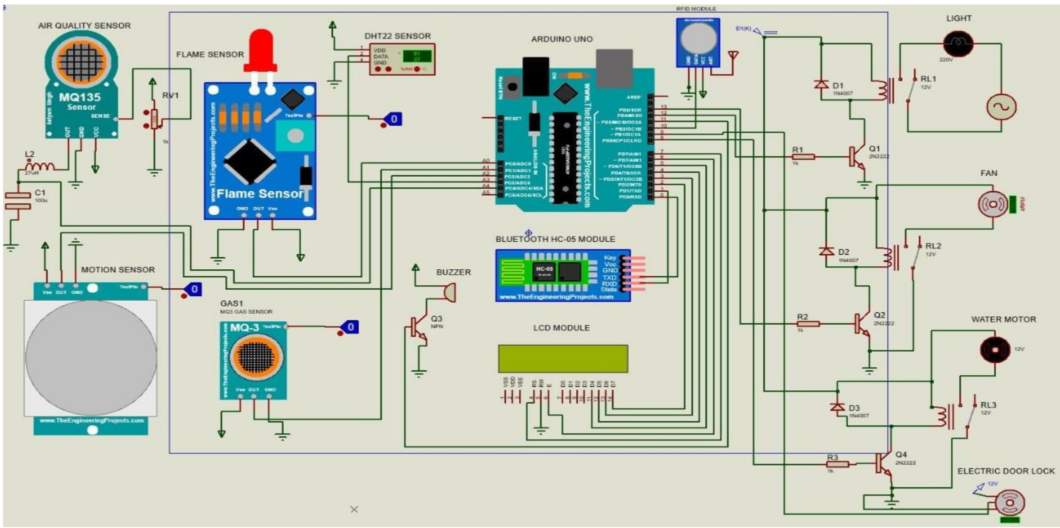


Fig. 10. The simulation of the proposed system in Proteus.

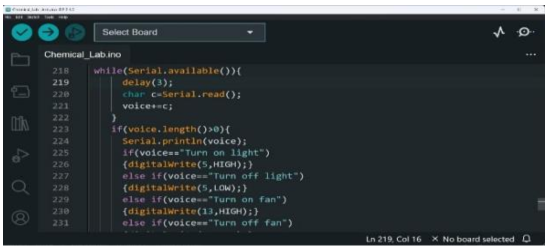


Fig. 11. Sample of the programming code for the proposed system in the Arduino IDE.

3) *Principles of working for the safety stage*

This stage aims to create an alert system to ensure lab safety. In the event of smoke, fire, increased humidity or temperature, or poor air quality, the buzzer sensor launches an alert sound, and an alert message displays on the LCD. Also, safety actions are carried out until the lab supervisor arrives. The proposed algorithm for the chemical lab safety stage is detailed in Algorithm 3. The flowchart for one cycle of the proposed chemical lab safety stage is shown in Fig. 12.

Algorithm 3.	**The Proposed Algorithm for the Safety Stage**
Step No.	**Step Description**
Step 1	Initialize the flame sensor, the MQ3 sensor, the MQ135 sensor, the DHT22 sensor, the buzzer sensor, the LCD module, and the relay module.

Step 2	**If** (MQ3_value == 1)
	Display ("**Smoke Detected**") message on the LCD.
	Turn on the buzzer sensor to alert the lab supervisor.
	Turn on fan.
	Else
	Display a message ("**No Smoke Detected**") on the LCD.
	End If

Step 3	**If** (Flame_value ==1) Display ("**Fire Detected**") message on the LCD. Turn on the buzzer sensor to alert the lab supervisor. Turn off all appliances except water motor to put out the fire.

Else
Display (“**No Fire Detected**”) message on the LCD.
End If

Step 4 **If** (DHT22_temp >= **32** ° C)
Display temperature value and (“Level: High”) on the LCD.
Turn on the buzzer sensor to alert the lab supervisor.
Turn off all appliances except the fan.
Else
Display temperature value and (“Level: Low”) on the LCD.
End If
If (DHT22_hum >= **70**%)
Display humidity value and (“Level: High”) on the LCD.
Turn on the buzzer sensor to alert the lab supervisor.
Turn off all appliances except the fan.
Else
Display humidity value and (“Level: Low”) on the LCD.
End If

Step 5 **If** (MQ135_value <= **1000** PPM)
Display air quality value and (“Fresh Air”) on the LCD.
Else If (MQ135_value>**1000** && MQ135_value <**2000**)
Display air quality value and (“Poor Air”) on the LCD.
Turn on the buzzer sensor to alert the lab supervisor.
Else
Display air quality value and (“Danger Air”) on the LCD.
Turn on the buzzer sensor to alert the lab supervisor.
End If

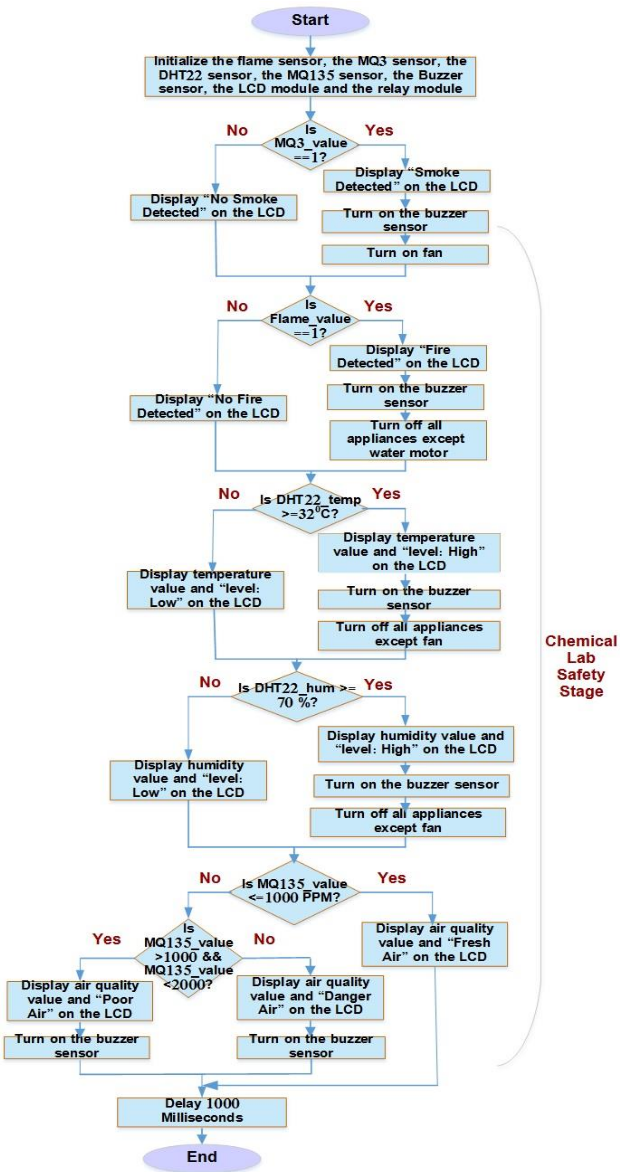
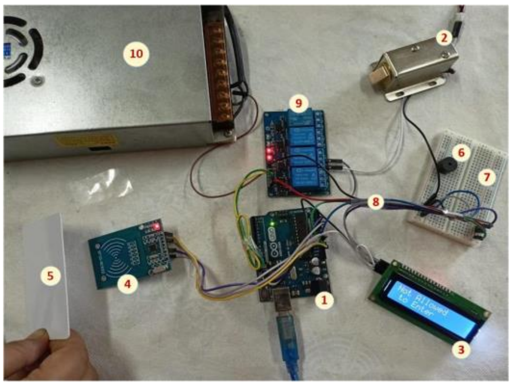
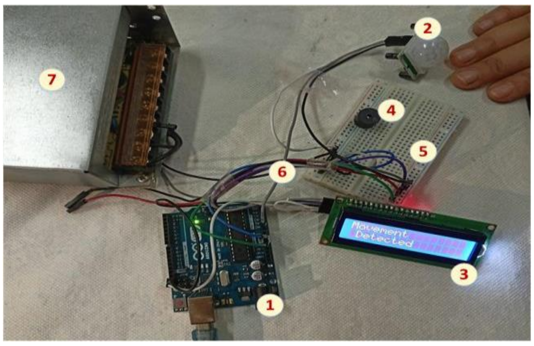
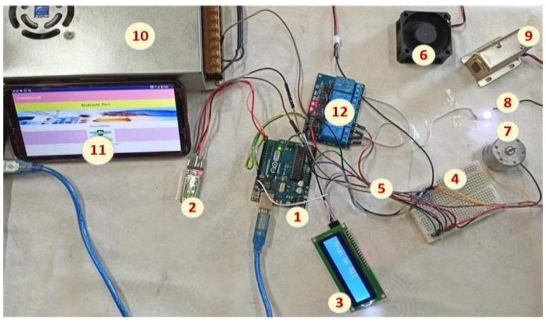


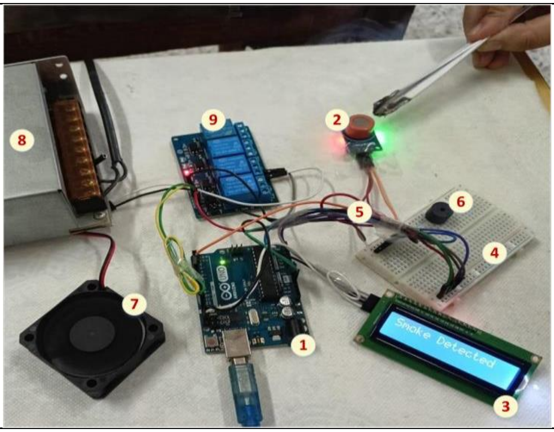
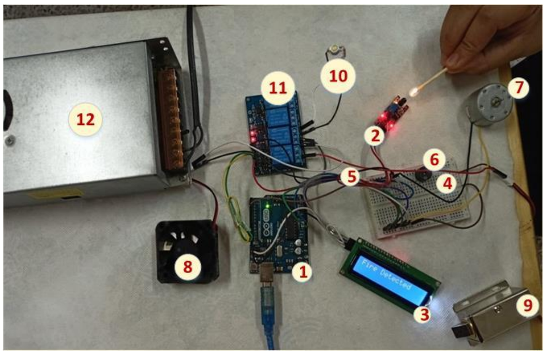
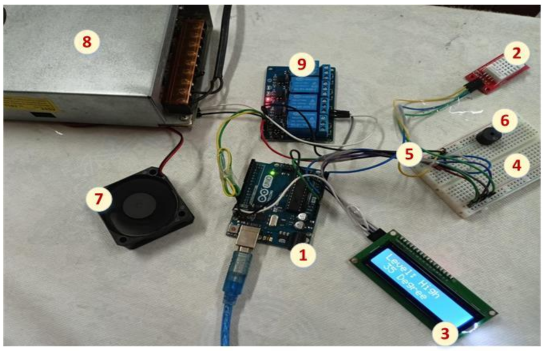
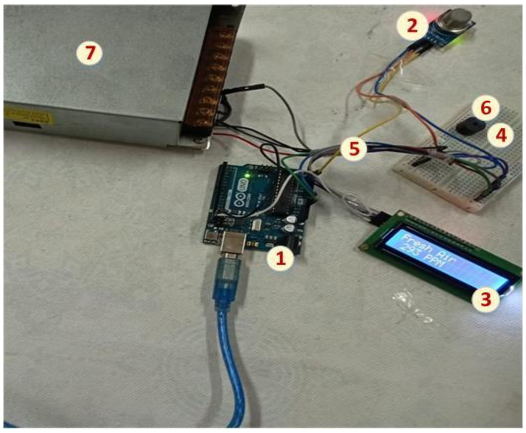
Fig. 12. The flowchart for one cycle of the proposed chemical lab safety stage.

IV. System Implementation and Results

To implement the proposed system, it is implemented on a prototype. All of the components (RFID module, PIR sensor, flame sensor, MQ3 sensor, MQ135 sensor, DHT22 sensor, LCD module, 4-channel relay module, HC-05 Bluetooth module and buzzer sensor) are connected to the Arduino board. The jumper cables and breadboard are used for connecting the components to the Arduino Uno. The "Chemical_laboratory" Android-based application is installed on the smartphone of the chemical lab supervisor. The lab supervisor will direct the Arduino Uno to turn on or off appliances by giving voice commands through the application. After transferring the voice commands text to the Arduino Uno through the Bluetooth module, the Arduino Uno sends a signal to the relay module to turn on or off the desired appliances. The proposed system's step-by-step implementation is shown in Table III. Fig. 13 shows the installation of all components in the proposed system.

TABLE III. Implementing the Proposed System Step By Step

No.	Stage Name	Images for Implementation	Description
1	**Security Stage**		**Image Components:** **1:** Arduino Uno **2:** Electric door lock **3:** LCD **4:** RFID reader **5:** RFID card **6:** Buzzer sensor **7:** Breadboard **8:** Jumper wires **9:** Four channel relay module **10:** Power supply **Image Description:** The RFID card is not validated in this case. As a result, the message "Not allowed to Enter" displays on the LCD screen, the electric lock is turned off, and the buzzer sensor will be triggered to alert the lab supervisor.
2	**Security Stage**		**Image Components:** **1:** Arduino Uno **2:** PIR sensor **3:** LCD **4:** Buzzer sensor **5:** Breadboard **6:** Jumper wires **7:** Power supply **Image Description:** Movement is detected in this case. So, the message "Movement Detected" displays on the LCD, and the buzzer sensor will be triggered to alert the lab supervisor.
3	**Automation Stage**		**Image Components:** **1:** Arduino Uno **2:** Bluetooth module **3:** LCD **4:** Breadboard **5:** Jumper wires **6:** Fan **7:** Water motor **8:** Light. **9:** Electric door lock **10:** Power supply. **11:** Smartphone with the application. **12:** Four channel relay module **Image Description:** A voice command is given to turn on all lab appliances in this case. So, the message "Turn on All" displays on the LCD, and all appliances are on.

4	**Safety Stage**		**<u>Image Components:</u>** **1:** Arduino Uno **2:** MQ3 smoke sensor **3:** LCD **4:** Breadboard **5:** Jumper wires **6:** Buzzer sensor **7:** Fan **8:** Power supply **9:** Four channel relay module **<u>Image Description:</u>** Smoke is detected in this case. So, the message "Smoke Detected" displays on the LCD screen, the fan is on, and the buzzer sensor is on to alert the lab supervisor.
5	**Safety Stage**		**<u>Image Components:</u>** **1:** Arduino Uno. **2:** Flame sensor. **3:** LCD **4:** Breadboard **5:** Jumper wires **6:** Buzzer sensor. **7:** Water motor. **8:** Fan. **9:** Electric door lock. **10:** Light **11:** Four channel relay module **12:** Power supply. **<u>Image Description:</u>** Flame is detected in this case. So, the message "Fire Detected" appears on the LCD, all appliances are off except the water motor, and the buzzer sensor is on to alert the lab supervisor.
6	**Safety Stage**		**<u>Image Components:</u>** **1:** Arduino Uno. **2:** DHT22 sensor. **3:** LCD **4:** Breadboard **5:** Jumper wires **6:** Buzzer sensor. **7:** Fan. **8:** Power supply. **9:** Four channel relay module **<u>Image Description:</u>** The temperature is more than 32°C in this case. Therefore, the message "Level: High" and the temperature value display on the LCD screen, all appliances are turned off except the fan, and the buzzer sensor will be triggered to alert the lab supervisor.
7	**Safety Stage**		**<u>Image Components:</u>** **1:** Arduino Uno **2:** MQ135 sensor **3:** LCD **4:** Breadboard **5:** Jumper wires **6:** Buzzer sensor **7:** Power supply **<u>Image Description:</u>** The air quality is less than 1000 PPM in this case. So, the message "Fresh Air" and the air quality value appear on the LCD screen.

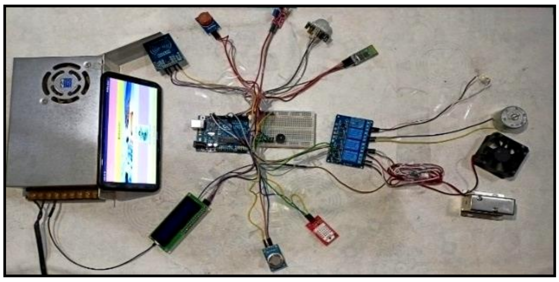


Fig. 13. The installation of all components in the proposed system.

The proposed system was tested to verify its performance and confirm that all requirements were fulfilled. Accordingly, four experiments were conducted. The first experiment was carried out to check the chemical lab's security. Meanwhile, the second experiment was conducted to ensure the remote control of chemical lab appliances. The third experiment was done to guarantee the safety of the chemical lab. Finally, the fourth experiment was carried out to determine the overall accuracy of the proposed system. The detailed analysis of these experiments is as follows.

A. Testing of the Chemical Lab Security Stage

This test was conducted to check that the PIR sensor and the RFID module are correctly performing their respective functions in providing security to the chemical lab. The findings of this test are explained below.

1) The PIR sensor detection range test

The PIR sensor accuracy was measured at various distances from the sensor in order to detect any movement from anyone. Table IV shows the results of the PIR sensor detection range.

TABLE IV. RESULTS OF THE PIR SENSOR DETECTION RANGE

No.	Distance of Anyone from the PIR Sensor (cm)	Detection
1	0	Yes
2	50	Yes
3	100	Yes
4	150	Yes
5	200	Yes
6	250	Yes
7	300	Yes
8	350	No
9	400	No

According to the previous results, the sensor identifies anyone at a distance of 0 cm to 300 cm. However, if a person is more than 300 cm away from the sensor, the sensor will not detect his presence.

2) The RFID module detection range test

The RFID module accuracy was measured at different distances from the reader to RFID cards. Table V shows the results of the RFID module detection range.

TABLE V. RESULTS OF THE RFID MODULE DETECTION RANGE

Cards	Distance from RFID Reader to RFID Cards (cm)					
	0 cm	1 cm	2 cm	3 cm	4cm	5 cm
Card 1	✓	✓	✓	✓	✓	x
Card 2	✓	✓	✓	✓	✓	x
Card 3	✓	✓	✓	✓	✓	x
Card 4	✓	✓	✓	✓	✓	x

Table V shows that the allowed detection range is up to 4 cm. More than 4 cm, the RFID reader cannot detect the card data.

B. Testing of the Chemical Lab Automation Stage

This test was done to ensure that the proposed Android application worked properly in remotely managing the chemical lab appliances (on and off). As shown in Tables VI and VII, each voice command via Google Assistant was tested ten times in both normal and noisy environments.

TABLE VI. TEST THE VOICE COMMANDS IN NORMAL ENVIRONMENT

No.	Voice Commands	Total Number of Trials	No. of Good Trials	Accuracy (%)
1	Turn on light	10	10	100
2	Turn off light	10	10	100
3	Turn on fan	10	10	100
4	Turn off fan	10	10	100
5	Turn on electric door lock	10	9	90
6	Turn off electric door lock	10	10	100
7	Turn on water motor	10	10	100
8	Turn off water motor	10	10	100
9	Turn on all appliances	10	10	100
10	Turn off all appliances	10	10	100
Average				**99**

TABLE VII. TEST THE VOICE COMMANDS IN NOISY ENVIRONMENT

No.	Voice Commands	Total Number of Trials	No. of Good Trials	Accuracy (%)
1	Turn on light	10	10	100
2	Turn off light	10	10	100
3	Turn on fan	10	10	100
4	Turn off fan	10	10	100
5	Turn on electric door lock	10	9	90
6	Turn off electric door lock	10	10	100
7	Turn on water motor	10	10	100
8	Turn off water motor	10	9	90
9	Turn on all appliances	10	9	90
10	Turn off all appliances	10	10	100
Average				**97**

Tables VI and VII indicate that voice commands are performed efficiently in both normal and noisy environments.

C. Testing of the Chemical Lab Safety Stage

This test was conducted to check that the flame, the MQ3, the MQ135, and the DHT22 sensors work effectively in providing safety to the chemical lab. The findings of this test are explained below.

1) The flame sensor detection range test

The accuracy of the flame sensor was measured at various distances from the fire source. This test case was executed to determine the optimal sensor detection distance range. The findings of the flame sensor detection range are shown in Table VIII.

According to the results above, the sensor detects fire at a distance of 0 cm to 20 cm. The sensor will not detect any flame when the source is more than 20 cm distant from the sensor.

TABLE VIII. RESULTS OF THE FLAME SENSOR DETECTION RANGE

No.	Distance of Fire Source from the Flame Sensor (cm)	Detection
1	0	Yes
2	5	Yes
3	10	Yes
4	15	Yes
5	20	Yes
6	25	No
7	30	No

2) The MQ3 smoke sensor detection range test

The accuracy of the MQ3 sensor was measured at various distances from the smoke source. This test case was performed to determine the best sensor detection distance range. Table IX shows the results of the MQ3 sensor detection range.

TABLE IX. RESULTS OF THE MQ3 SENSOR DETECTION RANGE

No.	Distance of Smoke Source From the MQ3 Sensor (cm)	Detection
1	0	Yes
2	5	Yes
3	10	Yes
4	15	Yes
5	20	No

According to the above results, the sensor detects smoke from a distance of 0 cm to 15 cm. If the smoke source is more than 15 cm away from the sensor, it will not detect its presence.

3) The MQ135 air quality sensor test

The Arduino IDE component "Arduino serial plotter" was used to analyze the performance of the MQ135 sensor. It was employed in the proposed system to build a real-time graph of the MQ135 air quality sensor's serial data. Fig. 14 shows the graph of the MQ135 sensor data using the serial plotter in the Arduino IDE.

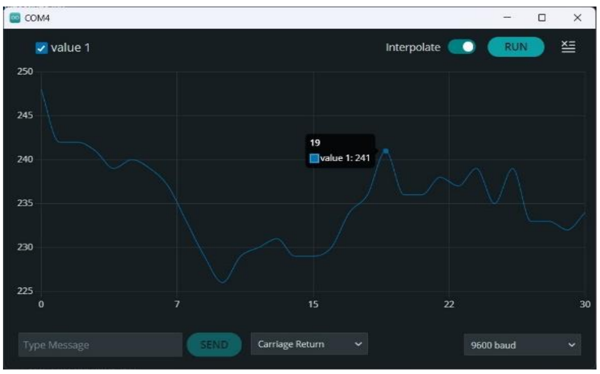


Fig. 14. The graph of the MQ135 sensor data using the serial plotter in the Arduino IDE.

According to the previous graph, the MQ135 sensor performs its role very well and consistently. This demonstrates its efficacy in the proposed system.

4) Testing of the DHT22 sensor response

The results of the DHT22 sensor were compared with the Thermo-Hygrometer digital measuring device. This was done to test the accuracy of the DHT22 sensor in measuring temperature and humidity. Tables X and XI show the results of the DHT22 sensor response testing.

TABLE X. RESULTS OF THE DHT22 SENSOR FOR TEMPERATURE

No.	DHT22 (Temperature) (°C)	Thermometer (°C)	Error (°C)
1	24.1	24.2	0.1
2	24.3	24.7	0.4
3	24.6	24.9	0.3
4	24.7	25.3	0.6
5	25.2	24.9	0.3
6	25.2	25.3	0.1
7	25.4	25.7	0.3
8	25.6	26.1	0.5
9	26.2	25.8	0.4
10	25.9	26.5	0.6
	Average		**0.36**

TABLE XI. RESULTS OF THE DHT22 SENSOR FOR HUMIDITY

No.	DHT22 (Humidity) (%)	Hygrometer (%)	Error (%)
1	61	62	1
2	62	64	2
3	64	64	0
4	65	68	3
5	67	69	2
6	70	68	2
7	69	72	3
8	73	70	3
9	71	73	2
10	73	75	2
	Average		**2**

As shown in the tables above, the findings with the DHT22 sensor are not significantly different from the results with the Thermo-Hygrometer digital measurement device. The test results showed that the DHT22 sensor is operating well, with an average temperature and humidity error value of 0.36 °C and 2%, respectively.

D. Testing the Overall Accuracy of the Proposed System

This is the last test, and its purpose is to assess the overall accuracy of the proposed system. As indicated in Table XII, the accuracy of each key component in the proposed system was assessed after 20 trials. The average accuracy for all key components was then calculated, expressing the total accuracy of the proposed system.

TABLE XII. TESTING THE OVERALL ACCURACY OF THE PROPOSED SYSTEM

No.	Key components	Total Number of Trials	No. of Good Trials	Accuracy (%)
1	RFID module	20	19	95
2	PIR sensor	20	20	100
3	MQ3 sensor	20	20	100
4	Flame sensor	20	20	100
5	MQ135 sensor	20	20	100
6	DHT22 for temperature	20	19	95
7	DHT22 for humidity	20	19	95
8	Buzzer sensor	20	20	100
9	LCD module	20	20	100
10	Lab appliances	20	19	95
		Average		**98**

The accuracy value is calculated as follows:

$$\text{Accuracy} = \frac{\text{number of good trials}}{\text{total number of trials}} \times 100 \tag{1}$$

From Table XII, the proposed system obtained an accuracy of 98% on all key components. This showed that the proposed system works correctly and efficiently. It also includes some features such as security, user-friendly, dependability, adaptability, and low costs. These features are described more below:

Security: The proposed system properly achieves the security feature. It's equipped with a security system to secure the lab from both inside and outside. If there is any unauthorized person outside the laboratory or any person inside the laboratory after the end of the study schedule, the lab supervisor will be immediately notified.

User-friendly: The proposed system fully delivers the user-friendly interface feature. The proposed mobile application "Chemical_laboratory" has an easy-to-use user interface that the laboratory supervisor can easily make use of.

Dependability: The proposed system fully supports the dependability feature. This was carried out following several tests on it, the outcomes of which were quite satisfying.

Adaptability: The proposed system has full adaptability. The system adapts to conditions such as the presence of smoke, fire, excessive temperature, or humidity, etc., and takes the right steps in the case of an emergency.

Low-costs: The proposed system maximizes the benefit of low-cost. This is because it is less costly than any other IoT-based system.

V. Conclusion

Safety should be prioritized in a chemical lab, as it is vital for teaching staff, supervisors, students, building occupants, and the surrounding environment. In addition, security is critical, which means access to this facility must be restricted to authorized people only. Meanwhile, a source of electricity must also be tracked and managed effectively, as individuals may leave lights, fans, and other appliances on by accident. As a result, the current paper aims to design and implement an integrated automation, safety, and security system for the university chemical lab using IOT. It can remotely turn on and off lights, fans, and other appliances by giving voice commands through Google Assistant to save energy throughout the day. The system also includes sensors for detecting environmental factors such as flames, smoke, and so on. In the case of an emergency, suitable safety precautions are taken. It additionally consists of an effective security system that makes use of the RFID module and the PIR sensor. RFID is employed to protect the lab from the outside. The buzzer sensor automatically alerts the lab supervisor in the event of an unauthorized user. The PIR sensor is used to secure the lab from within. It is activated at the end of the lab's study schedule to identify the presence of anyone. The results showed that the proposed system is simple, efficient, easy to use, and manages energy efficiently. The use of the proposed system is not limited to laboratories only; it can also be used at home with the blind and visually impaired. It allows them to stay safe and do their activities without needing the help of another person.

Conflict of Interest

The author declares no conflict of interest.

References

[1] A. Lukum and Y. Paramata, "Students' satisfaction toward the services of the chemical laboratory," *International Journal of Evaluation and Research in Education (IJERE)*, vol. 4, no. 1, pp. 22–29, March 2015.
[2] E. Fitriani, Z. Darwis, L. R. Ananda, A. Rahmadianty, and M. Paristiowati, "Assessing the feasibility of chemical laboratory safety videos," *Journal of Physics: Conference Series*, vol. 1869, no. 1, pp. 1–5, 2021.
[3] K. S. Ziara, A. K. Ibraheem, and A. A. Furaiji, "Chemical safety awareness for undergraduate analytical chemistry students: A case study at Baghdad university, republic of Iraq," *Scholars International Journal of Chemistry and Material Sciences*, vol. 4, no. 4, pp. 30–35, 2021.
[4] M. Abbas, A. M. Zakaria, M. A. Balkhyour, and M. Kashif, "Chemical safety in academic laboratories: An exploratory factor analysis of safe work practices and facilities in a university," *Journal of Safety Studies*, vol. 2, no. 1, pp. 1–14, 2016.
[5] D. Yoon, "Operational process for R&D laboratory safety," *SAGE Open*, vol. 11, no. 1, pp. 1–9, 2021.
[6] V. Biradar, V. Borawake, V. Chavan, and L. Aswal, "Intelligent laboratory management system based on internet of things: A study," *International Research Journal of Engineering and Technology (IRJET)*, vol. 6, no. 12, pp. 517–519, Dec. 2019.
[7] Y. He, Z. He, F. Zhang, and Q. Fang, "Safety management strategy of university laboratory," *Open Journal of Business and Management*, vol. 10, no. 3, pp. 1160–1166, May 2022.
[8] S. A. Ahmed and K. H. Mahdi, "Statistical evaluation of safety procedures and chemical security in chemical laboratories, College Ibn Al Haitham," *Journal of Physics: Conference Series*, pp. 1–9, 2019.
[9] P. N. Achaliya and S. B. Mahale, "Computer laboratory automation using internet of things," in *Proc. 6th International Conference on Recent Trends in* Engineering *and Technology*, 2018, pp. 84–92.
[10] S. V. Priya, S. Vignesh, U. S. Chandar, and K. Dinesh, "Laboratory safety system using IOT," *International Journal of Scientific Development and Research*, vol. 5, no. 9, pp. 498–505, September 2020.
[11] Z. K. Mohammed and E. S. Ahmed, "Internet of things applications, challenges and related future technologies," *World Scientific News*, vol. 67, no. 2, pp. 126–148, 2017.
[12] C. Ravali and B. Lakshmi, "A robust implementation design smart digital laboratory based IoT," *Journal of Engineering Sciences*, vol .13, no. 09, pp. 287–294, 2022.
[13] S. Bhowmik, S. Biswas, K. Vishwakarma, S. Chattoraj, and P. Roy, "Home automation system using android application," *International Journal of Scientific and Research Publications*, vol. 6, no. 12, pp. 467–470, December 2016.
[14] S. Chintha and K. R. Prathima, "Google assistant voice activated automatic control of home appliances using IOT and node MCU," *International Journal of Advanced Research in Engineering and Technology (IJARET)*, vol. 12, no. 3, pp. 120-127, March 2021.
[15] T. W. Lai, Z. L. Oo, and M. M. Than, "Bluetooth Based Home Automation System Using Android and Arduino," in *Proc. 2nd Conference on Computer Application and Research (CCAR 2018) University of Computer Studies*, Taunggyi, Myanmar, October 2018, pp. 123–129.
[16] R. Arifin and R. Sarno, "Door automation system based on speech Command and PIN using android smartphone," in *Proc. 2018 International Conference on Information and Communications Technology (ICOIACT)*, March 2018, pp. 1–6.
[17] P. Uike *et al*., "Voice-control home automation system," *TIJER—International Research Journal*, vol. 10, no. 2, pp. 657–660, 2023.
[18] R. Kishore, N. Nishanth, K. Suriya, and B. Dhanush, "IOT based industrial monitoring system using Arduino," *International Research Journal of Engineering and Technology (IRJET)*, vol. 08, no. 08, pp. 4147–4149, Aug 2021.
[19] V. Sharma, V. Singh, V. K. Mahar, S. Naryani, and S. Kumawat, "RFID based access control system using Arduino," *International*

Research Journal of Modernization in Engineering Technology and Science, vol. 4, no. 6, pp. 654–659, June 2022.
[20] E. Darmawan and R. Taufan, "Space security system using motion sensor and notification of short message service with Arduino-based fuzzy logic algorithm," *Journal of Physics Conference Series*, vol. 1179, no. 1, pp. 1–7, 2019.
[21] S. Bhandari, K. Patil, G. Singh, and Y. Ajgar, "IOT based smart laboratory," *International Journal of Research and Analytical Reviews*, vol. 6, no. 2, pp. 159–162, 2019.
[22] S. Basheer, A. S. Al-Luhaidan, and R. M. Mathew, "A secured smart automation system for computer labs in engineering colleges using the internet of things," *Computer Applications in Engineering Education*, vol. 29, pp. 339–349, 2020.
[23] E. Simanungkalit, M. Husna, and J. S. Tarigan, "Design Arduino-based smart laboratory," *Jurnal Mantik*, vol. 5, no. 2, pp. 894-897, 2021.
[24] M. Khairnar, N. Tarle, S. Bhandare, and D. Kadam, "IOT based lab automation using android application," *International Research Journal of Modernization in Engineering Technology and Science*, vol. 3, pp. 463–467, 2021.
[25] S. Narhari, R. Shinde, R. Gaikwad, A. Talathi, and A. R. Kamble, "Smart lab automated control system using IOT," *International Journal of Scientific Research and Engineering Trends*, vol. 4, no. 2, pp. 389–391, 2018.
[26] M. Awaludin, A. Y. Rangan, and A. Yusnita, "Internet of things (IoT) based temperature and humidity monitoring system in the chemical laboratory of the Samarinda industry standardization and research center," *TEPIAN*, vol. 2, no. 3, pp. 85–93, 2021.
[27] M. O. Kama *et al*., "Automated temperature control system for chemistry laboratory using MQTT IoT," *International Journal of* Mechatronics, *Electrical and Computer Technology (IJMEC)*, vol. 12, no. 44, pp. 5195–5201, 2022.
[28] N. Prameela, N. Tulasichitra, and R. Karthik, "Design and implementation of smart automation system," *International Journal of Mechanical Engineering and Technology (IJMET)*, vol. 8, no. 5, pp. 674–680, May 2017.
[29] R. Ranjan, R. Mistri, S. Saurav, S. Kujur, and V. Tiwary, "Home automation using PIR and voice recognition sensors," *International Journal for Research in Applied Science and Engineering Technology (IJRASET)*, vol. 6, pp. 1471–1474, May 2018.
[30] R. Ranjithkumar, S. Rathish, K. Ram, and M. Manikandan, "IoT based home automation using PIR motion sensor and node MCU," *International Journal of Engineering and Advanced Technology (IJEAT*), vol. 9, no. 4, pp. 881–884, 2020.
[31] H. Landaluce *et al*., "A review of IoT sensing applications and challenges using RFID and wireless sensor networks," *Sensors*, vol. 20, no. 9, pp. 2–18, 2020.
[32] K. Dhumal, T. Meshram, A.Padol, and G. Yeole, "Electrical rain detector using Arduino uno with LCD and buzzer," *International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)*, vol. 2, no. 1, pp. 444–447, March 2022.
[33] R. Suganthi, P. G. Devi, G. S. Razaq, D. R. Kishore, and U. K. Rajan, "Home automation and security using IOT," *International Research Journal of Engineering and Technology (IRJET)*, vol. 08, no. 04, pp. 396–398, Apr. 2021.
[34] M. Sameer, M. Anshid, R. Dubey, M. V. Rohith, and B. K. Venkatesha, "IOT based smart home automation," *Journal of Emerging Technologies and Innovative Research (JETIR)*, vol. 8, no. 7, pp. 57–60, 2021.
[35] A. Singh, G. Baheti, S. K. Pramukh, and S. Pawar, "Arduino based home automation using Bluetooth android smartphone," *International Journal of Research in Engineering and Technology*, vol. 9, no. 6, pp. 19–28, June 2021.
[36] S. Mishra, O. Mohite, and S. Kharat, "Smart door lock system using Arduino," *International Research Journal of Modernization in Engineering Technology and Science*, vol. 4, no. 4, pp. 1503–1507, 2022.
[37] F. B. Ahmed, "Home automation using Arduino," Bachelor thesis, Czech Technical University, Faculty of Mechanical Engineering, 2021.
[38] S. B. Mandhre, R. Kutwal, and P. Naykodi, "Bluetooth based home automation using android and Arduino—Review paper," *International Research Journal of Modernization in Engineering Technology and Science*, vol. 4, no. 5, pp. 1790–1795, 2022.
[39] P. Saranya, Y. Bhavya, U. Bhavya, and C. Sai, "IOT automatic water conservation system," in *Proc. IOP Conference Series Materials Science and Engineering*, 2021, vol. 1084, pp. 1–6.
[40] E. Laman *et al*., "Design of an internet of things based electromagnetic robotic arm for pick and place applications," *Malaysian Journal on Composite Science and Manufacturing*, vol. 2, no. 1, pp. 12–20, 2020.
[41] M. S. Srinath, M. N. Kishore, and M. D. Praveena, "Nteractive home automation system with google assistant," *International Journal of Pure and Applied Mathematics*, vol. 119, no. 12, pp. 14083–14086, 2018.
[42] N. Rathod and P. D. Paikrao, "Google assistance based home automation," *International Journal of Communications*, vol. 5, pp. 36–47, 2020.
[43] P. Sharma, V. Agarwal, T. Nayyar, and T. Awasthi, "Bluetooth home automation system," *International journal of Engineering, Business and Management*, vol. 5, no. 5, pp. 8–12, 2021.
[44] M. R. Haque *et al*., "Towards the development of an energy-efficient smart home through IoT," *International Journal of Advanced Technology and Engineering Exploration*, vol. 6, no. 58, pp. 208–216, 2019.
[45] A. Vojić, E. Mujčić, and U. Drakulić, "Remote control and monitoring in smart homes using voice commands," in *Proc. IOP Conference Series Materials Science and Engineering*, vol. 1208, pp. 1–7, 2021.
[46] R. K. Kodali and K. S. Mahesh, "Low cost implementation of smart home automation," in *Proc. 2017 International Conference on Advances in Computing, Communications and Informatics (ICACCI)*, pp. 461–466, 2017.
[47] H. M. Marhoon, M. I. Mahdi, E. D. Hussein, and A. R. Ibrahim, "Designing and implementing applications of smart home appliances," *Modern Applied Science*, vol. 12, no. 12, pp. 8–17, 2018.
[48] P. Sowndarya and N. Saranya, "Sensor based industrial kitchen foodstuffs monitoring system," *International Journal of Computer communication and Informatics*, vol. 3, no. 1, pp. 26–43, 2021.
[49] D. V. Dhanashri, D. R. Kamble, G. V. Bhosale, P. D. Bhosale, and P. P. Kale, "Air pollution detection using IOT," *Journal of Engineering, Computing and Architecture*, vol. 10, no. 4, pp. 442–447, 2020.
[50] G. S. Rao, M. B. Shanmugi, D. Pradeepa, and V. U. Kamali, "Smart home automation system by integrating sensors and raspberry PI," *SSRG International Journal of Computer Science and Engineering (SSRG-IJCSE)*, pp. 30–33, 2019.