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GPLDABot: Raspberry-Pi based Gas Pipe Leakage Detection and Alerting using Internet of Things

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Abstract
Energy resources such as gas often transported through pipes which play a significant role in cities, industries. Gas leakage in pipes prompts misfortune just as a danger since they can likewise prompt flame mishaps. The main objective of this work is to structure an independent robot for gas pipeline investigation, which is named as GPLDABot. This system includes a robot structure, which uses theDC motors to accomplish the drive required. Here, MQ4, and MQ6 gas sensors are used for identifying the leakage of gases such as methane, butane, LPG, iso-butane, propane, and LNG etc.In addition, Internet of Things (IoT) module is interfaced with the proposed GPLDABot to move the robot in desired direction, which also givea real-time analysis on the cloud platform, and it will movein different directions to detect the defects in gas supplied pipes and thereby preventsthe mishaps in industries.
Keywords: Gas pipe leakage detection, Internet of Things, Raspberry-Pi, LPG sensor, methane gas sensor.

1. Introduction

The source of economy for most countries in the world are gas, oil, and water [1]. Their natural resources are transported from there storage place to the countries through the pipelines. In some of the countries, pipelines are used for supplying gas. These pipelines are the major source between the producers and consumers and at the same time maintaining their pipelines is very costly [2]. For human being it's hard to find the exact position of leakage on pipe area These locations locate by Robot with help of altitude and latitude concept send that data to user or operator and finds the exact location [3]. Thus, user will off the switch and can avoid a future accident. These are essential to political stability, sustain economic growth and safety [4]. The emergence of new high-speed technology and growing computer capacity provides realistic opportunity for new robot controls and realized the new methods of control theory. This technical improvement in the robots created faster, accurate and more intelligent robots using new robots control devices, new drivers and advanced control algorithms. This paper draws a new economical solution of robot control systems. The introduced robot control system can be used for different sophisticated robotic applications.

Figure 1: Distribution of gas through pipeline system.

Generally, themain distribution method for gas is taken place through the pipeline as shown in Figure 1. However, there are several problems related to the use of wireless sensors in pipeline monitoring system. One of the problems is to detect the gas leakage in the pipeline as early as possible. If the detection of the gas leakage in the pipeline fails it could cause some serious issues in the environment and it also effects the human population near the area. Due to the structural defects, corrosion occurs in the gas pipeline. Several factors have been identified that lead to the event of buried pipeline corrosion and cracks such as pipe coatings, soil type, temperature changing, stresses, pressure of the pipe and cyclic loading effects LPG consists of a mixture of gases like propane and butane. The success of designing the LPG gas leakage detector will help to efficiently detect the leakage of LPG gas and avoid risk of fire and pollution, saving life and property. In oil and gas industry, a gas leak is hazardous to personnel and industrial operation. A quick detection and alert would minimize the dangers of gas leak. Nowadays, wireless technologies are used in many areas, and it was used in many applications and several technologies are implemented for monitoring the pipelines. Further, many systems are used in locating the place where leakages occur. Some of the technologies allow some remote system to identified leakage or detect and to report the positions of any leakage to the operator.There are several works in the literature for detecting the gas leakage from pipeline. Subramanian et al. [5] proposed a research implementation that carry out the survey on IoT-based gas detection techniques for ensuring the safety of people and surroundings. In addition, they have presented a simple yet reliable system for gas leakage detection using the sensor named MQ5. Further, the Arduino uno controller also incorporated with a cloud storage for data collection and employed for storing and analysing the data. The leaked gas then converted from parts per million (PPM) to volts via the IDE of Arduino and alerts the user when it crossedthe threshold limit. This system also utilized an application for alerting user with a quick notification through the internet and a buzzer/LED for physical notification.

Mahalingam et al. [6] introduced design and implementation of economically suitable gas leakage detection system, which ensured a continuous monitoring and checking the gas level and detection. However, this system is applicable only for restricted area where the leakage is found or occurs. Raju and Rani describedthe robot technology, where the mini robot is designed to find the leakage in

insecure places [7]. In addition, they have also developed android mobile applicationfor receiving information from robot directly using Bluetooth. However, thissystem has a disadvantage that, before practically used in industrial area more setting, and development is needed in detection and indication on mini robot simulation. In [8], Mahajanet al. expressed the system which detects the gas leakage and can be monitor on IoT. Shahewaz and Rajendra Prasad [9]proposed a gas leakage detection system with the help of gas sensors which detects the various types of gases and sends the signal to Arduino microcontroller. This system uses buzzer and GSM as altering components.However, the Arduino controller is memory inefficient. Alshammari and M. T. Chughtai [10] implemented Arduino-based gas leakage detector and warning generator using the concept of IoT. However, they have not used IoT module for controlling the leakage detection system. Recently Bhavithra et al. proposed the system of gas leakage detection and alerting using PIC microcontroller [11]. This system is having protection circuitry consist of exhaust fan and LPG safe solenoid valve. MQ6 gas sensor is used to detect LPG gas leakage. The disadvantage of the system is that it can only detect the leakage of LPG and propane gas. However, none of the literature works utilized raspberry pi interfacing with IoT module for operating the GPLD robot with both MQ4, and MQ6 sensor modules. Therefore, this article proposes an innovate GPLDABot prototype model for detecting the gas pipe leakage and alertingusing IoT module. In addition, it also developed an open platform HTML page for operating the proposed robot model.

2. Proposed GPLDABot system

Theblock diagram of proposed GPLDABot system is illustrated in Figure 2, where it consists of a microprocessor called raspberry pi for controlling the whole circuit, power supply to drive the raspberry pi processor, a prototype design of a robot, where the overall circuit is constructed to design GPLDABotsystem. It has two gas sensor modules such as MQ4, and MQ6, where the MQ4 is used to detect the methane gas concentration in the air and produces its reading as an analog voltage while the MQ6 is utilized to detect the gas leakage in consumer and industry applications, this sensor is opted for detecting LPG, propane, iso-butane, and LNG. The output module called LCD is used for displaying the functional operation of proposed GPLDABot system and buzzer is interfaced as an alerting system whenever the leakage detects in pipeline. As shown in Figure 2, proposed GPLDABot system is interfaced to IoT module, which is used for operating the overall hardware kit by instructing the commands such as front, left, right, back, and stop. This system also created an HTML page for continuous monitoring of gas leakage by checking the status of both MQ4, and MQ6 sensor outputs.

2.1 Working

Here, an innovative robot is implemented which moves on to the outer surface of the gas pipe and moves with the pipe to check forleakages of gas. The robot starts moving by giving the commands using the interface buttons given on HTML page. As the robot keeps moving along the pipe it keeps monitoring for any gas leakage, on detection it uses an interface of IoT module and updates the status of sensors on designed HTML page with ON, and OFF states. For this purpose, an open source IoT development platform is adopted to receive and display the gas leakage alert over IoT. Further, it also displays the status of operation on LCD and alerts by ringing the buzzer once the gas is

detected.In this way, a fully automated insect like robot is developed which moves with the gas pipe and detects gas leakages instantly at a low budget.

3. Hardware description

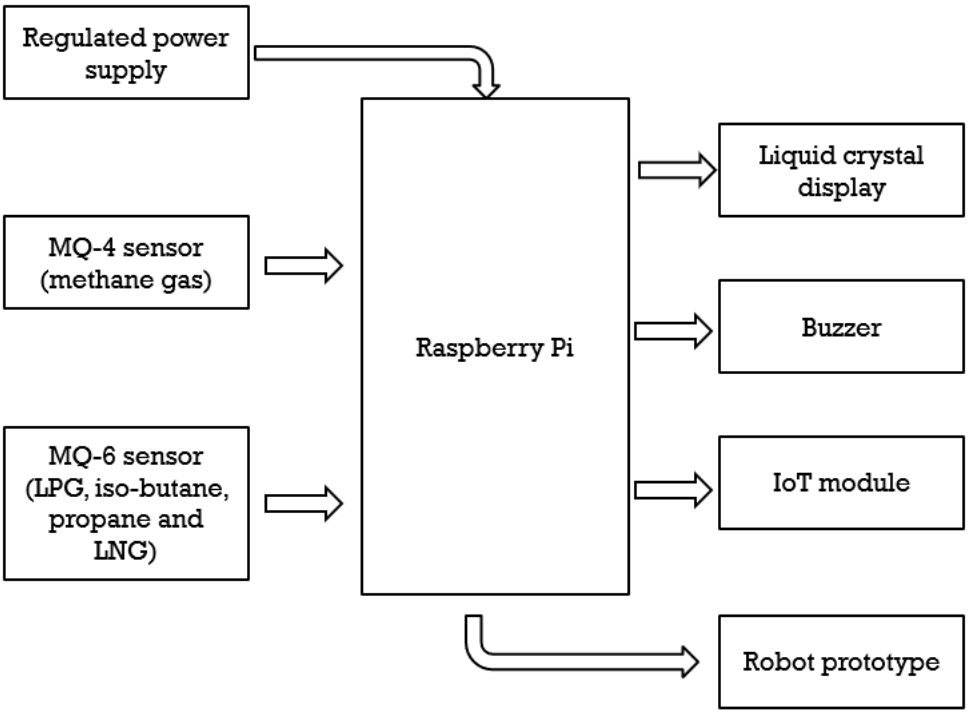


Figure 2: Proposed block diagram of GPLDABot system.

3.1 Raspberry Pi

It is an ultra-cheap minicomputer with 5.5 cm width and 9 cm length. It consists of a component named System on Chip (SoC) which comprises of single core CPU with a supportive processor for computing floating points, GPU, and RAM with 512 MB size (SD-RAM). Moreover, it consumes less power, which is just around 5-7 watts. The architecture of raspberry pi is given in Figure 3. It has couple of cache memory levels, where first level is of 32KB size, and the latter is of 128KB size. These are utilized to store recent programs and ALU is utilized to execute instructions.

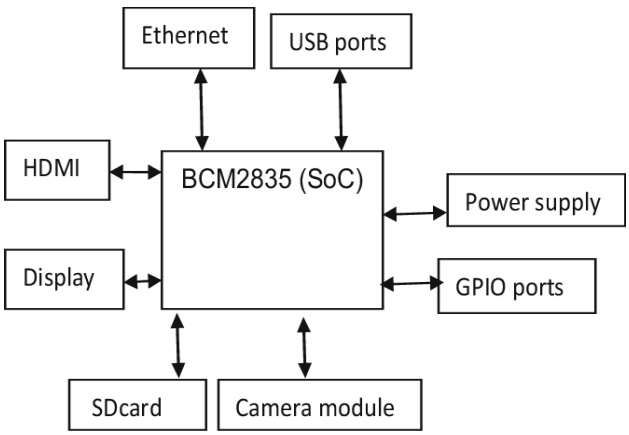


Figure 3. System architecture of Raspberry pi.

It is a very small device and can incorporate other devices also. It consists of both the hardware and software. It requires an SD card and a power supply to related mouse and keyboard. Additionally, a display also exists for functioning OS such as Windows and Linux. Table 1 listed the specifications of raspberry pi like chip type, core architecture, size of CPU, and RAM, type of OS, required power supply, and the dimensions etc. Figure 4 illustrate the raspberry pi module with the location of its connectors and ICs.

Table 1. Specifications of Raspberry pi.

Chip	Broadcom BCM2835 SoC
Core architecture	ARM 11
CPU	700 MHz Low power ARM1176JZFS
RAM	512 MB (SD-RAM)
OS	Linux
Dimensions	$85.6 \times 53.98 \times 17\ mm$
Power	Micro USB socket, 5 V, 1.2 A

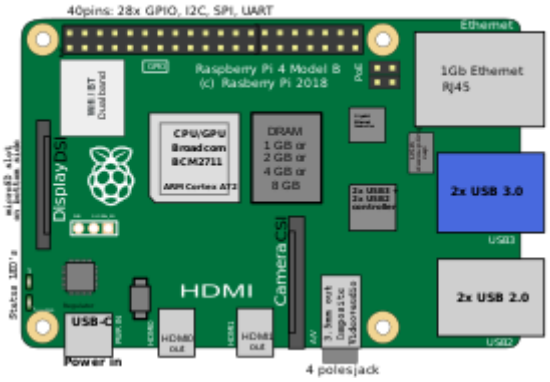


Figure 4: Raspberry pi module.

3.2 Buzzer

A buzzer or beeper audio signalling device, which may be mechanical, electromechanical, or piezoelectric. Typical uses of buzzers and beepers include alarm devices, timers, and beepers include alarm devices, timers, and confirmation of user input such as a mouse click or keystroke. Figure 5 shows the pin configuration of buzzer.

Figure 5: Buzzer pin configuration.

Table 2. Specifications of buzzer.

Color	Black
Frequency range	3,300 Hz
Operating temperature	-20℃ to +60℃
Operating voltage	3V to 24V DC
Sound pressure level	85dBA or 10cm
Supply current	15mA

It includes two pins namely positive and negative. The positive terminal of this is represented with the '+' symbol or a longer terminal. This terminal is powered through 6V whereas the negative terminal is represented with the '-' symbol or short terminal, and it is connected to the GND terminal.

3.2.3 Liquid crystal display

Figure 6 demonstrate the pin description of LCD module. It is a liquid crystal display technology works by blocking light. Specifically, it is made of two pieces of polarized glass that contain a liquid crystal material between them. A backlight creates light that passes through the first substrate. It is used for display purpose.

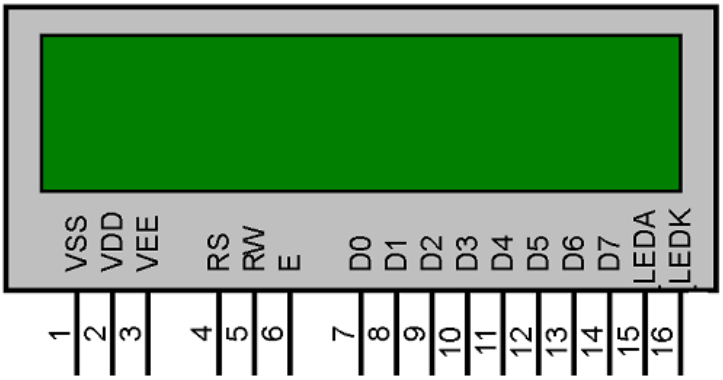


Figure 6: Pin description of LCD module.

3.2.4 MQ-4 gas sensor

MQ-4 methane gas sensor detects the concentration of methane gas in the air and outputs its reading as an analog voltage. The concentration sensing range of 300 ppm to 10,000 ppm is suitable for leak detection. For example, the sensor could detect if someone left a gas stove on but not lit. The sensor can operate at temperatures from -10 to 50°C and consumes less than 150 mA at 5 V.Connecting five volts across the heating (H) pins keeps the sensor hot enough to function correctly. Connecting five volts at either the A or B pins causes the sensor to emit an analog voltage on the other pins. A resistive load between the output pins and ground sets the sensitivity of the detector.Figure 8 demonstrate the structure and Table 3, and Table 4 illustrate the pin names with their descriptions for MQ-4 sensor module and MQ-4 sensor, respectively.

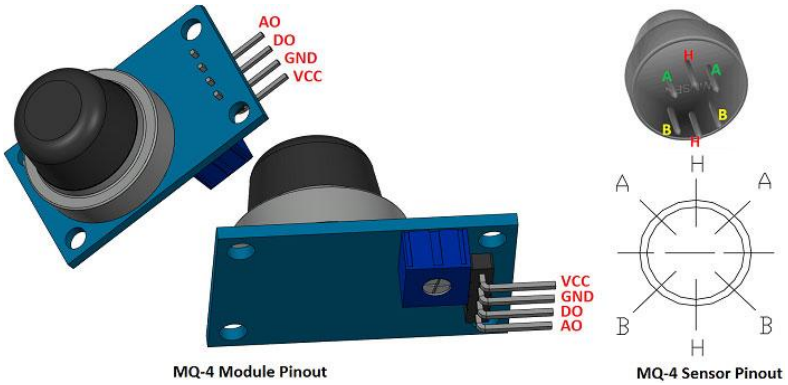
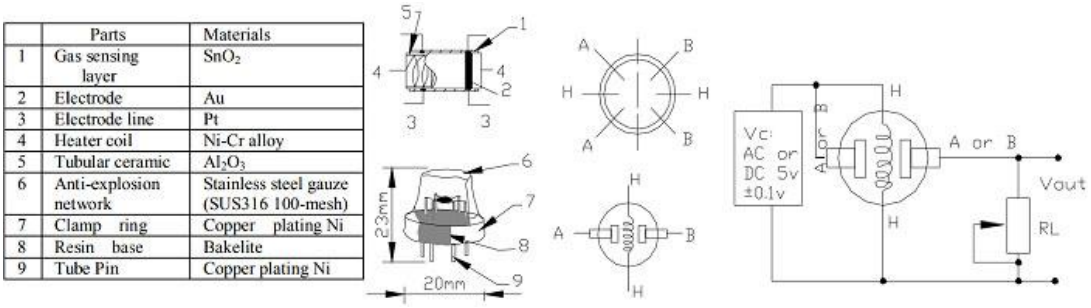


Figure 7: Module and sensor pinout of MQ-4 gas sensor.



	Parts	Materials
1	Gas sensing layer	SnO_2
2	Electrode	Au
3	Electrode line	Pt
4	Heater coil	Ni-Cr alloy
5	Tubular ceramic	Al_2O_3
6	Anti-explosion network	Stainless steel gauze (SUS316 100-mesh)
7	Clamp ring	Copper plating Ni
8	Resin base	Bakelite
9	Tube Pin	Copper plating Ni

Figure 8: Structure and configuration of MQ-4 gas sensor.

Features

- Good sensitivity to Combustible gas in wide range**.**
- High sensitivity to CH4, Natural gas.
- Small sensitivity to alcohol, smoke.
- Fast response Stable and long life**.**
- Simple drive circuit

Table 3. Pin description of MQ-4 sensor module.

Pin Name	Description
VCC	This pin powers the module, typically the operating voltage is +5V
GND	Used to connect the module to system ground
Digital Out(DO)	You can also use this sensor to get digital output from this pin, by setting a threshold value using the potentiometer
Analog Out(AO)	This pin outputs 0-5V analog voltage based on the intensity of the gas

Table 4. Pin name and its description of MQ-4 sensor.

PinNo.	Pin name	Description
1	H-Pins	Out of the two H pins, one pin is connected to supply and the other to ground
2	A-Pins	The A pins and B pins are interchangeable. These pins will be tied to

		Supply voltage.
3	B-Pins	A pins and B pins are interchangeable. One pin will act as output while the other will be pulled to ground.

3.2.5 MQ-6 gas sensor

The MQ-6 module is used in gas leakage detecting equipment in family and industry, this module has high sensitivity to LPG, iso-butane, propane, and LNG. It can also be used to detect the presence of alcohol, cooking fumes, and cigarette smoke.The module gives out the concentration of the gases as an analog voltage equivalent to the concentration of the gases. The module also has an onboard comparator for comparing against an adjustable pre-set value and giving out a digital high or low. It can be easily interfaced with raspberry pi.

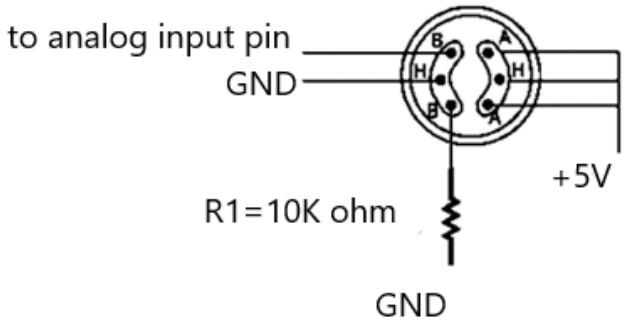


Figure 9: Schematic diagram of MQ-6 gas sensor.

This is a simple-to-usesensor module, and suitable for sensing LPG (composed of mostly propane and butane) concentrations in the air. The MQ-6 can detect gas concentrations anywhere from 200 to 10000ppm.This sensor has a high sensitivity and fast response time. The sensor's output is an analog resistance. The drive circuit is very simple, all we need to do is power the heater coil with 5V, add a load resistance, and connect the output to an ADC.

Sensitive material of MQ-6 gas sensor is SnO2, which with lower conductivity in clean air. When the target combustible gas exists, the sensor's conductivity is higher along with the gas concentration rising. Ithas high sensitised to propane, butane, and LPG, also response to natural gas. The sensor could be used to detect different combustible gas, especially methane, it is with low cost and suitable for different application.

3.2.6 DC motor

A DC motor is any of a class of rotary electrical machines that converts direct current electrical energy into mechanical energy. The most common types rely on the forces produced by magnetic fields. Nearly all types of DC motors have some internal mechanism, either electromechanical or electronic, to periodically change the direction of current flow in part of the motor.DC motors were the first form of motor widely used, as they could be powered from existing direct-current lighting power distribution systems. A DC motor's speed can be controlled over a wide range, using either a variable supply voltage or by changing the strength of current in its field windings. Small DC motors are used in tools, toys, and appliances. The universal motor can operate on direct current but is a lightweight brushed motor used for portable power tools and appliances. Larger DC motors are

currently used in propulsion of electric vehicles, elevator and hoists, and in drives for steel rolling mills. The advent of power electronics has made replacement of DC motors with Ac motors possible in many applications.

3.2.7 L293D motor drive module

L293D is a basic motor driver IC that enables us to drive a DC motor in either direction andalsocontrol the speed of the motor. The L293D is a 16-pin IC, with 8-pins on each side, allowing us to control the motor. It means that a single L293D can be utilized to run up to two DC motors. L293D consist of two H-bridge circuits, which is the simplest circuit for changing polarity across the load connected to it.There are 2 OUTPUT pins, 2 INPUT pins, and 1 ENABLE pin for driving each motor. It is designed to drive inductive loads such as solenoids, relays, DC motors, and bipolar stepper motors, as well as other high-current/high-voltage loads.

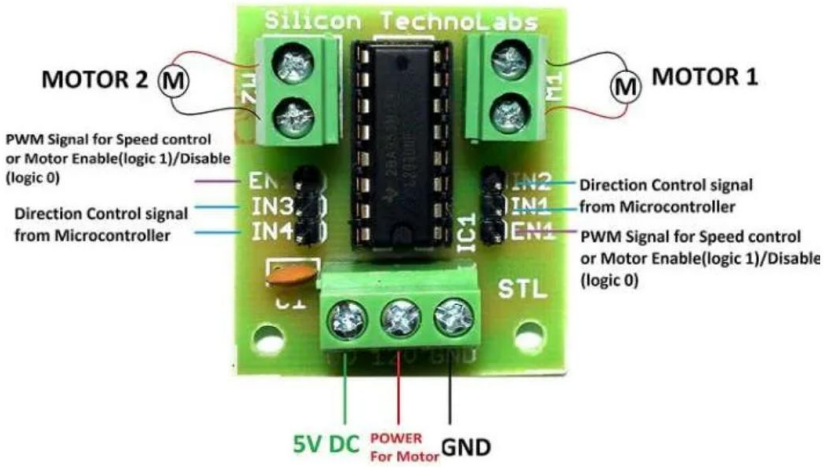


Figure 10: Pinouts of L293D motor driver module.

The functioning of each pin and port is as follows:

IN1, IN2, and IN3, IN4 are input pins used for providing a control signal from the controller to run the motor in different directions.

- If input logic at IN1, IN2 is (1,0) the motor rotates in one direction.
- If input logic at IN1, IN2 is (0,1) the motor rotates in the other direction.

EN1 and EN2 are enable pins. Connect 5v DC to EN1 and EN2 pin to operate the motor at its normal speed

- If speed control is needed, then give PWM output at pin EN1 and En2 from the microcontroller.

Power for the motor. If 12V DC gear motor is used, then apply 12V.

4. Experimental results

This section explains the performed hardware experiments on proposed GPLDABot system. Figure 11 illustrate the hardware implementation, where it has shown the images of kit with different operating modes. When it operates in front direction, the state of both sensors is in OFF condition, which means there is no leakage detection of gas in surrounding environment. Figure 12 disclose the operations of right, left, and back directions, respectively. Figure 13 demonstrate the view of IoT

development platform-based HTML page, which displays the current state of gas leakage and the push buttons for controlling the robot vehicle. The left side image in Figure 13 shows MQ4 is in ON state, and MQ-6 is in OFF state, which means there is a leakage of methane gas in surrounding places of GPLDABot system. Similarly, the right-side image of Figure 13 illustrates that MQ-4 is in OFF state, and MQ-6 is in ON state, that means there is a possible leakage of LPG, iso-butane, propane and LNG etc. In addition, it also has an option of stop button and refresh button for better monitoring of pipe leakage in specific area.

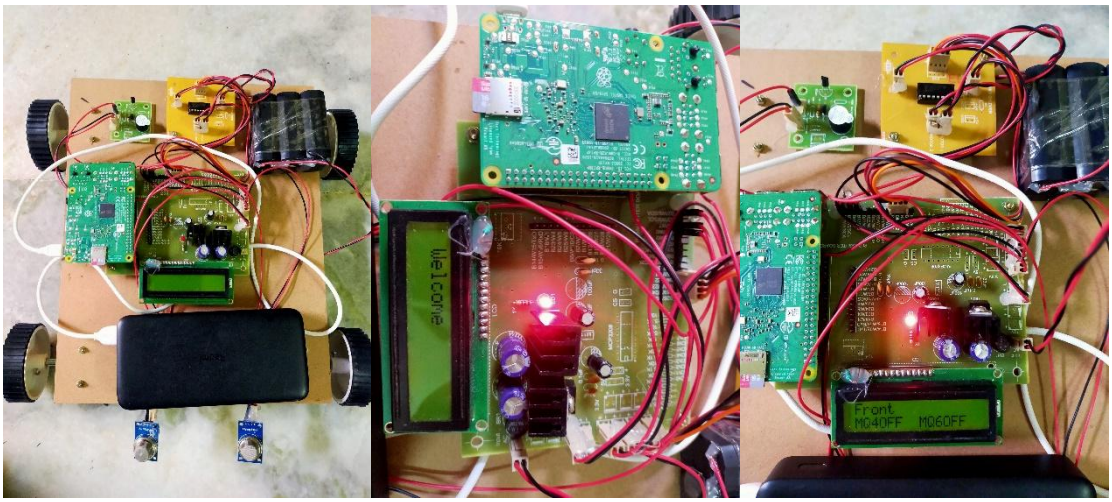


Figure 11: Hardware implementation of proposed GPLDABot prototype. overall hardware kit (left).after ON operation (middle).operating infrontdirection(right).

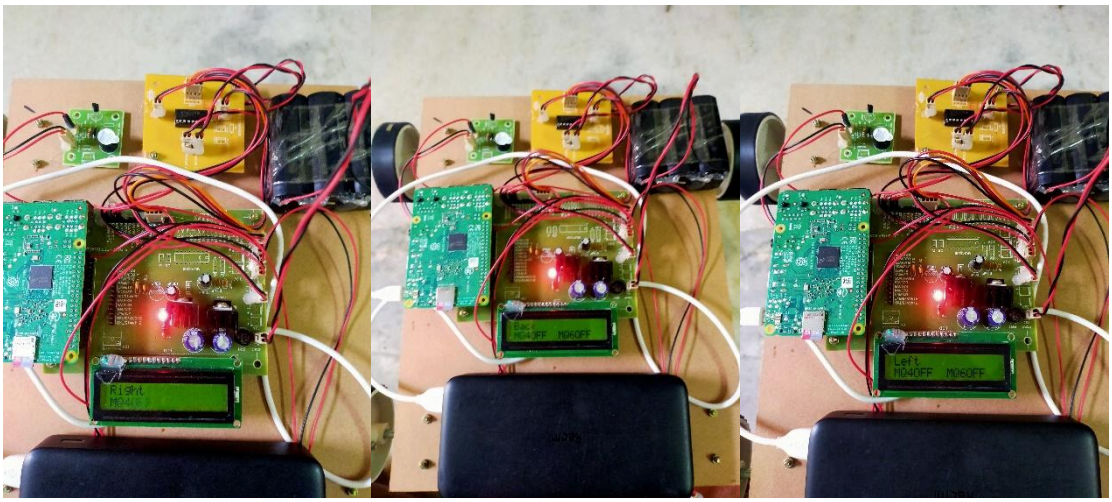


Figure 12: Hardware implementation of proposed GPLDABot prototype. operating in right direction (left). operating in back direction (middle). operating in left direction (right).

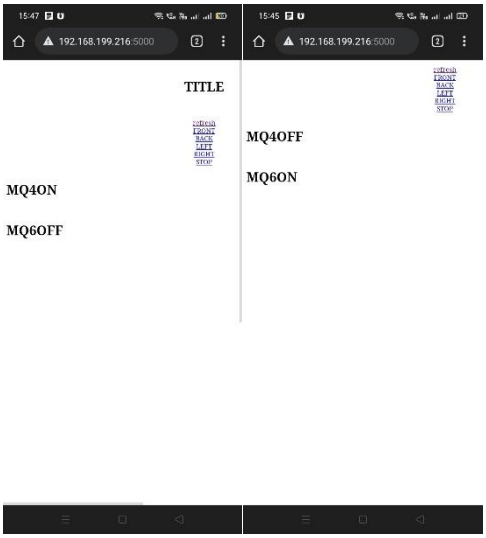


Figure 13: IoT module page for controlling the robot and checking the state of gas leakage.

5. Conclusion

This article designed and implemented an innovate robotic prototype for leakage detection in gas pipes. The proposed system is employed using Raspberry pi and IoT module for enhanced performance with accurate outcome. In addition, it also used two gas sensors named MQ-4, and MQ-6 for detecting different types of humans made and even natural gases whereas the earlier GPLD systems utilized only solitary sensor. Further, the proposed GPLDABot utilized open source IoT development platform for creating the HTML page, where both the controlling and the leakage state of gas can be monitored simultaneously. Furthermore, this work can be extended to implement current advancements in gas pipe leakage systems for enhanced prevention of gas leakage with recent progression in machine learning and artificial intelligence techniques.

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