Development of Liquefied Petroleum Gas (LPG) leakage detection wheeled robot on horizontal pipes based on Arduino Uno

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Abstract. LPG utilization need more attention to safety aspects of human, environmental and equipment. This research aims to develop a wheeled robot which is capable of detecting LPG leaks in horizontal pipes by data acquisition via wireless internet, so that it is useful to facilitate human work in determining LPG leak points on horizontal pipes. The controller of this robot is Arduino UNO and equipped with sensors. The sensor measurement data is acquisitioned using the Node MCU module to the Blynk application as an interface application. This robot has an emergency stop feature on the Blynk application. The final results of this research are LPG leak detection robots on horizontal pipes which can provide information on leak points based on gas sensor measurement data and rotary encoder installed on robots with acquisition via wireless internet and data storage on MicroSD. The robot is equipped with buzzer indicator that will sound when a leak is indicated with a gas concentration of more than 30% on one of the gas sensors. Based on the results of final test of the robot, the average value of the leakage point distance obtained is +8.7 cm.

1. Introduction
Liquefied Petroleum Gas (LPG) is gas produced from oil and gas refineries or natural gas separation, with the main components are liquefied propane (C₃H₈) and butane (C₄H₁₀) gas. LPG consists of elements of carbon and hydrogen which are hydrocarbon compounds with the main components C₃ and C₄ [1]. Industries that use LPG as a component of production require appropriate technology to realize efficient production processes and pay attention to safety aspects. The state of the gas pipeline tends to have a long dimension and makes it difficult for the user if leak detection is done manually on the gas pipe so that it is needed a tool in the form of a wheeled robot that capable to detecting leakage of LPG pipes. To answer the demands of the industrial and commercial world, the application of microcontrollers to robots can be a solution. One example of a microcontroller is the Arduino UNO module. Arduino is an open source platform for making interactive objects standalone or collaborating with software on a computer [2]. Based on these reasons, we need a wheeled robot tool with a special gas sensor to detect LPG. Data is acquired through wireless internet because it has a relatively fast data transfer speed. Through this research, LPG leak detection robots can be produced on horizontal pipes and provide leak point information based on measurement data acquired via wireless internet.
Determination of the LPG leak point has the effect of facilitating the NDT testing/inspection division to determine the follow-up of testing techniques that must be implemented.

2. Literature Review

Dani Martinez, et al [3] made the procedure of determining the location of an object using a static Light Detection and Ranging (LIDAR) sensor for mobile robots and determine the location of error. This robot implements the SLAM (Simultaneous Localization And Mapping Procedure) procedure. Jamaludin Marzuqi and Muhammad Taufiqurrohman (2014) [4] made a car robot to scan an LPG pipe. By using the HS-133 sensor as a gas sensor. The microcontroller will process the data that generated by the sensor then the acquisition will be displayed on the LCD. Mifza Ferdian Putra, et al (2017) [5] produced a monitoring tool that works in a condition where the pipe is leaking so the sensor will send an order to turn on the buzzer output warning that there has been a gas leak and the fan will turn on to release the leaking gas in a room. Ahmad Nurhadi (2017) [6] has a working system that is the robot will be active based on a predetermined time and the robot will walk along the black line along the gas pipeline. If the MQ-2 gas sensor detects a leak in the gas pipeline, the robot will stop and will give a warning signal in the form of a flashing LED and the buzzer will sound. Gophicand G, et al (2017) [7] built a pipe scanning robot using Radio Frequency (RF), the robot will move according to the commands given by the RF remote. The RFID module is used to identify locations using cards to be interface to the robot. Based on previous studies, this study has a correlation to the gas leak detector. The research that was explained before has a gap in a few points, so the contribution of researchers in this study is that a robot designed to be able to detect LPG leaks when there are obstacles in the form of a pipe connection. The robot is equipped with three sensors that are placed on different sides of the pipe holder. This robot starts to move at the user's command remotely using the Blynk application and is accompanied by an emergency stop button when there is a discrepancy in terms of robot movement.

3. Theory

Wheeled robot is easier to build, controlled and are used in flat fields [8]. There are several components support wheeled robot movements, among others are: line sensor, motor driver, motor, servo motor, rotary encoder, ultrasonic sensor, relay, LPG, Arduino Uno, gas sensor, node mcu, UBEC, SD Card, Blynk applications, and gear.

3.1. Line sensor

The digital IR sensor consists of an IR transmitter, IR receiver, and an Op-Amp. Once powered, IR LED continuously keeps emitting IR light. Hence, the IR LED acts as transmitter and therefore, the photodiode acts as receiver. As soon as the IR radiation is reflected by a surface, it is absorbed by the receiver (photodiode) [9].

3.2. Motor driver

The motor driver is a dual H-bridge IC based driver. This motor driver functions to manage the direction or speed of a DC motor. Robot need this motor driver circuit is because generally DC motors will work by requiring more than 250 mA of current [10].

3.3. DC Motor

The DC motor works on Lorentz’s power principle that claims “any conductor that get in it electrical current and it’s located in a magnetic field, a force will act on that, and therefore the direction of that force will be vertical on the both (the direction of magnetic field and electric field) according to Fleming’s left-hand rule”. Because of presence of the magnetic field between the two poles, it is enough to stimulate a new field by using Faraday urging to create the rotating part to starts its work. [11].
3.4. **Servo motor**
Servo is a small direct current (DC) motor which runs on electricity from a battery and spins at high RPM (rotations per minute) with very low torque. An appointment of gears takes the high-speed of the motor and slows it down while at the identical time increasing the torque depending upon basic law work = force x distance [12].

3.5. **Rotary encoder**
Rotary encoder generally use an optical sensor to generate a pulse signal which might be interpreted into position. LED is placed on one side of the disk so that the light will go through to the holes of the disk. If the light from LED can reach the phototransistor through the present holes, then the phototransistor will experience saturation and will produce a square wave pulse [13].

3.6. **Ultrasonic sensor**
The Ultrasonic wave propagation velocity is subject to temperature of the medium, within the air it’s approximately 340 m/s at 15 °C of air or atmospheric temperature, the identical as sonic velocity. The velocity (V) may be computed as a function of temperature as shown in Equation (1).

\[
V = 340 + 0.6(T - 15) \text{ m/s}
\]  

Where T= temperature (°C). Because of the travel distance is extremely short, the travel time is not affected by temperature to a greater extend. [14].

3.7. **Relay**
Relay is applied to equipment like remote control, monitor displays, audio equipment, etc. The working principle of a relay is that when the coil gets electrical energy, an electromagnetic force will emerge which will attract a resilient armature and also the contact will close [15].

3.8. **Liquefied petroleum gas (LPG)**
Liquefied Petroleum Gas (LPG) is gas produced from oil and gas refineries or natural gas separation, with the main components being liquefied propane (C₃H₈) and butane (C₄H₁₀). LPG consists of elements of hydrocarbon compounds with the main components C₃ and C₄ [1].

3.9. **Arduino UNO**
Arduino is an open source computing platform that’s used for constructing and programming electronic devices. It is also capable of acting as a mini computer similar to other microcontrollers by taking inputs and controlling the outputs for a variety of electronics devices [2].

3.10. **MQ-6 Gas sensor**
MQ-6 Gas sensor has a fast response to LPG (Liquefied Petroleum Gas), is stable, durable and can be used in a simple drive circuit. The gas sensor commonly used in equipment detects gas leaks in household and industrial activities, which are suitable for detecting LPG, isobutane and propane [16].

3.11. **Node MCU**
Node MCU includes firmware which runs on the ESP8266 Wi-Fi SOC from Express if systems, and hardware which relies on the ESP-12 module. The term Node MCU by default refers to the firmware rather than the development kits. The firmware uses the LUA scripting language [17].

3.12. **UBEC (universal battery elimination circuit)**
BEC stands for battery eliminator circuit, and all it does is eliminate the requirement for a separate battery to power the electronics. The advantage of using a power module is that it gives the ability to measure battery voltage and capacity [18].

3.13. **SD card module**
The secure digital (SD) card is an ultra-small flash memory card designed to provide high capacity memory in small sizes. SD card modules can be used in the electronic world for data storage. SD card module commonly uses the standard format namely FAT 32 [19].

3.14. **Blynk application**

Blynk is an open source android app which is designed and developed to control the hardware via internet of things (IOT). This digitally displays sensor data, it can accumulate and visualize the information. It can also do other parameters such as Blynk App, Blynk Server, and Blynk Library [20].

3.15. **Arduino IDE**

Arduino IDE on the computer to create, open, and change sketches (Arduino calls programs “sketches”). Sketches define what the board will do. Parts of the IDE are Compile, Stop, Create new sketch, Save Sketch, Tab Button, Sketch Editor, Text Console, and Line Number [21].

3.16. **Gear**

The gear is used to change the rotation speed and torque to regulate the motor to its load conditions. The gear also functions to transmit motor power from one shaft to another [22].

3.17. **Statistics of measurement deviations**

The Z discrepancy between two values of the identical physical quantity \((\bar{x} \pm \Delta x)\) and \((\bar{y} \pm \Delta y)\), where \(Y\) is the standard or reference value and \(X\) as the measurement result value. The calculation of the discrepancy value is shown in Equation (2).

\[
Z = \frac{\bar{x} - \bar{y}}{Y} \times 100\%
\]  

If the measurement of discrepancy value is extremely small, it can be concluded that the measurement results are very well [23].

4. **Research methods**

4.1. **Hardware development**

The tool that been produced in this study is a robot that has the main function to detect LPG leakage in a horizontal pipe and send sensor measurement data to users via wireless internet.

4.2. **Software development**

Software development covers Arduino IDE and Blynk programming, then continued by accuracy and scenario tests. Arduino IDE Programming consist Making tools and implementing software to hardware,

4.3. **Accuracy test**

Accuracy test aims to determine how well the measurements by the robots to standard measurements. Therefore, data collection is needed to obtain several parameters.

4.4. **Scenario test**

Scenario testing is done with the aim to find out some possibilities that will occur when the robot detects LPG leakage. The several scenario tests include scenario I, II, and III.

4.4.1. **Scenario I**

The robot detects LPG leaks with varying test path lengths. Furthermore, interference is given in the form of wind at the point of leakage.
4.4.2. Scenario II.
The robot detects LPG leakage with the location of the pipe in an open space with position variations of the leak point and the flange on the test pipe.

4.4.3. Scenario III.
The robot detects LPG leaks on the pipes with varied trajectories.

5. Results and Discussion

5.1. Subsystem test result

5.1.1. The result of a wheeled robot
Robot installation includes robot assembly, gear preparation, component assembly, and the final result of the tool. After designing the shape of the robot, the robot is carried out by the assembly process that shown in Figure 1. The arrangement of the gear on the robot is used to move the pipe holder as shown in Figure 2 and the results of the robot and holder hardware are shown in Figure 3.

![Figure 1. Assembly of wheeled robots](image1.png)

![Figure 2. Holder gear drive arrangement](image2.png)

![Figure 3. Robot and holder hardware](image3.png)

The components installation process is shown in Figure 4. After the tool is arranged in accordance with the design planning, the results are in the form of a wheeled robot detecting LPG leakage on a horizontal pipe with a front-view robotic display as shown in Figure 5.

![Figure 4. Installation of robot components](image4.png)
5.1.2. The results of the Blynk interface application.
The Blynk application is used as interface application of sensor readings on wheeled robots. The interface application created consists of one graph sensor that displays output of three LPG sensors and one rotary encoder. Additionally, there is a button for activation/remote emergency as shown in Figure 6.

5.2. Final robot test

5.2.1. Scenario I test results.
The results of scenario I test as shown in Table 1.

| Test | Distance of measured leak point (cm) |
|------|-------------------------------------|
|      | TK-A<sup>a</sup> | TK-B<sup>b</sup> | TK-C<sup>c</sup> | TK-D<sup>d</sup> | TK-E<sup>e</sup> | TK-F<sup>f</sup> |
| 1    | 35       | 65       | 97       | 78       | 110      | 137      |
| 2    | 37       | 66       | 96       | 76       | 112      | 140      |
| 3    | 38       | 67       | 96       | 75       | 108      | 140      |
| 4    | 40       | 67       | 93       | 74       | 112      | 145      |
| 5    | 37       | 68       | 96       | 77       | 115      | 133      |
| 6    | 37       | 66       | 97       | 76       | 108      | 140      |
| 7    | 39       | 63       | 99       | 82       | 116      | 143      |
| 8    | 38       | 68       | 94       | 80       | 111      | 142      |
| 9    | 35       | 66       | 98       | 73       | 109      | 139      |
| 10   | 40       | 68       | 97       | 79       | 113      | 142      |

<sup>a</sup> Leak point A with an actual distance of 30 cm on a 100 cm pipe
<sup>b</sup> Leak point B with an actual distance of 60 cm on a 100 cm pipe
<sup>c</sup> Leak point C with an actual distance of 90 cm on a 100 cm pipe
<sup>d</sup> Leak point D with an actual distance of 70 cm on a 200 cm pipe
<sup>e</sup> Leak point E with an actual distance of 100 cm on a 200 cm pipe
<sup>f</sup> Leak point F with an actual distance of 130 cm on a 200 cm pipe

In this scenario, researchers also test the buzzer indicator. If concentrations of LPG around the sensor is more than 30% so that the buzzer in the robot will give the sirene indicator.

5.2.2. Scenario II test results.
The results of scenario II test as shown in Table 2.
5.2.3. **Scenario III test results.**
Scenario III testing was carried out in accordance with procedures designed in the research method, but there are obstacles when the robot is run. Constraints that occur are robotic holders caught when there is a change in the shape of the pipe with an angle of 90°. Based on the test, to change the position of 90°, the robot must move slowly towards the 45° angle first until finally 90°, in other words the robot cannot turn 90° directly so that the movement of the robot on pipe L becomes imperfect. Another thing that causes these obstacles is the open holder is not wide enough to anticipate a collision with an L-shaped pipe so that the holder is stuck and the movement of the robot cannot be continued.

5.3. **Accuracy test**

5.3.1. **Test the accuracy of scenario I.**
The results of the calculation of the discrepancy value of each leak point in scenario I presented in Table 3.

### Table 3. Scenario I data testing discrepancy

| Test | Discrepancy value (%) |
|------|-----------------------|
|      | TK-A\(^a\) | TK-B\(^b\) | TK-C\(^c\) | TK-D\(^d\) | TK-E\(^e\) | TK-F\(^f\) |
| 1    | 16,67    | 8,33     | 7,78     | 11,43    | 20,00    | 5,38     |
| 2    | 23,33    | 10,00    | 6,67     | 8,57     | 23,00    | 7,69     |
| 3    | 26,67    | 11,67    | 6,67     | 7,14     | 8,00     | 7,69     |
| 4    | 33,33    | 11,67    | 3,33     | 5,71     | 12,00    | 10,00    |
| 5    | 23,33    | 13,33    | 6,67     | 10,00    | 15,00    | 2,31     |
| 6    | 23,33    | 10,00    | 7,78     | 8,57     | 8,00     | 7,69     |
| 7    | 30,00    | 5,00     | 10,00    | 17,14    | 16,00    | 10,00    |
| 8    | 26,67    | 13,33    | 4,44     | 14,29    | 11,00    | 9,23     |
| 9    | 16,67    | 10,00    | 8,89     | 4,29     | 9,00     | 6,92     |
| 10   | 33,33    | 13,33    | 7,78     | 12,86    | 13,00    | 9,23     |

\(^a\) Leak point A with an actual distance of 30 cm on a 100 cm pipe  
\(^b\) Leak point B with an actual distance of 60 cm on a 100 cm pipe  
\(^c\) Leak point C with an actual distance of 90 cm on a 100 cm pipe  
\(^d\) Leak point D with an actual distance of 70 cm on a 200 cm pipe  
\(^e\) Leak point E with an actual distance of 100 cm on a 200 cm pipe  
\(^f\) Leak point F with an actual distance of 130 cm on a 200 cm pipe
5.3.2. Test the accuracy of scenario II.

The results of the calculation of the discrepancy value of each leak point in scenario II presented in Table 4.

Table 4. Scenario II test discrepancy data

| Test | Discrepancy value (%) |
|------|------------------------|
|      | TK-G$^g$ | TK-H$^h$ | TK-I$^i$ |
| 1    | 20,00%   | 11,25%   | 10,00%   |
| 2    | 30,00%   | 13,75%   | 7,50%    |
| 3    | 25,00%   | 15,00%   | 8,33%    |
| 4    | 15,00%   | 10,00%   | 8,33%    |
| 5    | 17,50%   | 13,75%   | 9,17%    |
| 6    | 20,00%   | 11,25%   | 10,83%   |
| 7    | 32,50%   | 13,75%   | 5,83%    |
| 8    | 25,00%   | 8,75%    | 6,67%    |
| 9    | 20,00%   | 15,00%   | 9,17%    |
| 10   | 27,50%   | 15,00%   | 5,83%    |

$^g$ Leak point G with an actual distance of 40 cm at the position of the 0° leak point
$^h$ Leak point H with an actual distance of 80 cm at the position of the 120° leak point
$^i$ Leak point H with an actual distance of 80 cm at the position of the 240° leak point

After calculating the discrepancy mean value of each leak point from various scenarios, the calculating results of the average discrepancy presented in Table 5.

Table 5. Distance of the average error overall point of leakage

| Leak point | Leak distance | Average discrepancy | Error distance |
|------------|---------------|---------------------|----------------|
| TK-A$^a$   | 30 cm         | 25,33%              | 7,60 cm        |
| TK-B$^b$   | 60 cm         | 10,67%              | 6,40 cm        |
| TK-C$^c$   | 90 cm         | 7,00%               | 6,30 cm        |
| TK-D$^d$   | 70 cm         | 10,00%              | 7,00 cm        |
| TK-E$^e$   | 100 cm        | 11,40%              | 11,40 cm       |
| TK-F$^f$   | 130 cm        | 7,62%               | 9,90 cm        |
| TK-G$^g$   | 40 cm         | 23,25%              | 9,30 cm        |
| TK-H$^h$   | 80 cm         | 12,75%              | 10,20 cm       |
| TK-I$^i$   | 120 cm        | 8,75%               | 10,50 cm       |

Average error distances of all leak point 8,70 cm

$^a$ Leak point A with an actual distance of 30 cm on a 100 cm pipe
$^b$ Leak point B with an actual distance of 60 cm on a 100 cm pipe
$^c$ Leak point C with an actual distance of 90 cm on a 100 cm pipe
$^d$ Leak point D with an actual distance of 70 cm on a 200 cm pipe
$^e$ Leak point E with an actual distance of 100 cm on a 200 cm pipe
$^f$ Leak point F with an actual distance of 130 cm on a 200 cm pipe
$^g$ Leak point G with an actual distance of 40 cm at the position of the 0° leak point
$^h$ Leak point H with an actual distance of 80 cm at the position of the 120° leak point
$^i$ Leak point H with an actual distance of 80 cm at the position of the 240° leak point

Based on the average distance error value of all leaks points, an average error distance is 8,7 cm. So that we can analyze this error caused by the delay of data acquisition from sensor in robot and the system read the data sequentially so there is a gap in microsecond of every sensor data acquisition. The graph of determining leakage scenario I with a 200 cm pipe length as shown in Figure 7, and Figure 8 shows a graph of determining leakage scenario I with a pipe length of 100 cm.
6. Conclusion
A LPG leak detection wheeled robot on horizontal pipes was developed. It that can provide information on leak points based on sensor measurement data that installed on robots with acquisitions via wireless internet. Sensor measurement data acquired via the internet to the Blynk application and stored on micro-SD as a document. The average error distance value of the leakage point is 8.7 cm.
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