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Design of Gas Leakage System and Automatic Fan Using Tsukamoto Fuzzy Logic Based on Arduino in Welding Shop Surabaya Aviation Polytechnic

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Abstract

The risk of hazards in the work environment is very high, especially in the welding process. Gas leaks in welding workshops are very risky to the safety and health of workers. This causes the need for a reliable and responsive gas leak detection system. This final project designs and builds a gas leak detection system and automatic fan using Tsukamoto fuzzy logic to be applied in the Surabaya Aviation Polytechnic Welding Workshop. In its design, this system uses two MQ6 gas sensors as CO, CH4, H2, and LPG gas detectors. Then the data obtained from the sensor will be processed by Arduino using Tsukamoto fuzzy logic as a method to determine environmental conditions in three hazardous states: Based on the results of data processing, arduino as a system will control the LCD display, buzzer and fan as a warning so that workers can immediately take appropriate action, the test results show that this system is able to detect gas leaks reliably with high accuracy and is able to provide a rapid response as a reduction in the risk of fire, explosion and health in the long term. With this system, it is expected to improve work safety and maintain the health of workers in the Surabaya Aviation Polytechnic Welding Workshop.

1 INTRODUCTION

Occupational diseases are strongly influenced by the work environment where many workers underestimate work risks and do not use personal protective equipment even though it is available. Industrial activities such as welding have high health risks. Long-term exposure to harmful gases in the welding process is often underestimated. One of the gases produced is Carbon Monoxide (CO) which is colourless and odourless, so it can pose a hazard if inhaled in large quantities. Exposure to CO gas can cause increased levels of Carboxyhemoglobin (COHb) in the blood, headaches, dizziness, shortness of breath, watery eyes, and high blood pressure.

Based on the above background, the author aims to detect gases produced during the welding process in the welding workshop with excessive concentrations that can endanger users who are in the room, especially in the long term. Therefore, the author made a design entitled ‘Designing a Gas Leakage System and Automatic Fan Using Arduino-Based Tsukamoto

Fuzzy Logic in the Welding Shop of Aviation Polytechnic Surabaya.' Thus, the purpose of this research is to design and develop a prototype Gas Leakage System and Automatic Fan Using Arduino-Based Tsukamoto Fuzzy Logic at the Welding Shop of the Surabaya Aviation Polytechnic as a solution that will be applied to the welding workshop at the Surabaya Aviation Polytechnic.

2 METHODOLOGY

Research Design

This research on the Design of Gas Leakage System and Automatic Fan Using Arduino-based Tsukamoto Fuzzy Logic in Welding Shop of Aviation Polytechnic Surabaya uses quantitative development method. This research also uses the Research and Development method with the following flow:

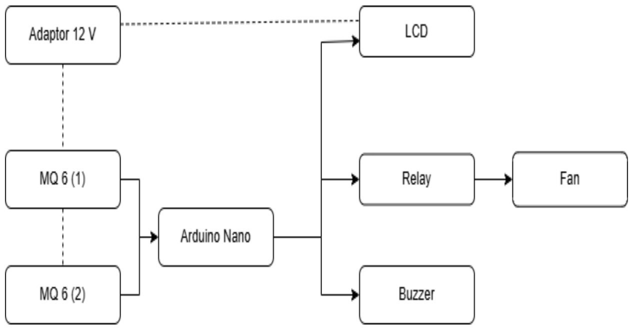

Figure 1. Research Design

Tool Design

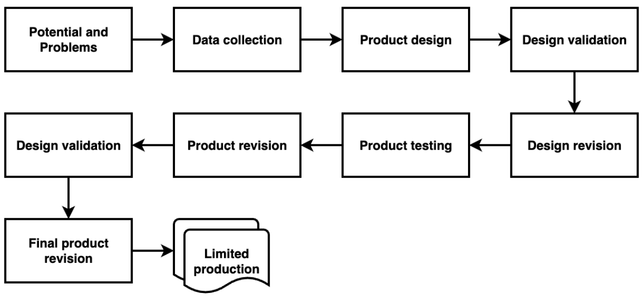

Figure 2 Tool Design

Based on the block diagram above, it can be explained that there are several stages so that this tool can process properly. The adapter will provide the voltage needed to activate the components of the device. Then, the MQ6 1 sensor and MQ6 2 sensor will detect the presence of gas, which functions as an input variable with gas concentration as its respective output. If gas is detected with a concentration that exceeds the limit, the buzzer will automatically sound and the LCD will display the measurement results.

The gas concentration status will be calculated using fuzzy logic by first defining fuzzy variables. Next, membership functions will be defined for the gas concentration measurements of each sensor, and then fuzzy rules will be created. Next, apply the membership function to the fuzzy rule and perform defuzzification to get the result in the form of a decision. The decision obtained will be displayed as the status of the room condition. The output will also control the buzzer, relay, and fan according to the detected status.

Fuzzy Logic Tsukamoto

Tsukamoto fuzzy logic is extended monotone reasoning. The consequence of an IF-THEN rule must be represented by a fuzzy set with a monotonous membership function. The result of this method is a conclusion drawn from each rule based on α-predictors and obtained through a weighted average to find the z value.

$$Z = \frac{\propto pred1 * z1 + \propto pred2 * z2 + \propto pred3 * z3 + \cdots}{\propto pred1 + \propto pred2 + \propto pred3 + \cdots} \quad (1)$$

Tool Components

1. Hardware
   a. Arduino
   The type of Arduino used in the design of this device is the LGT8F328P LQFP32 MiniEVB Type-C, which serves as a replacement for the Arduino Nano. This component was chosen because it offers modern connectivity using USB Type-C at a more affordable price. Below are the pins available on this component for easy installation. Adaptor 12V DC
   b. 12V DC adaptor

In the planning of this project, a 12 V DC adapter was used as it is compatible with many electronic components and safe for prototyping.

c. MQ6 Sensor

The MQ6 sensor was chosen for its ability to detect gases relevant to the welding environment, especially carbon monoxide (CO), which is harmful in the long term, but colourless and odourless, making it more difficult for humans to detect.

d. I2C LCD

The selection of I2C LCD is done because this LCD offers many advantages, one of which is an easy-to-use code, making it simpler to implement in this project. This LCD is used to display sensor data and data processed by Arduino.

e. Relay

By using relays in the design of this project, the device can operate more reliably and safely by ensuring that the fan works according to the requirements. The relay plays an important role in switching the fan on or off.

f. Buzzer

The 5V buzzer is chosen so that the alert provided can be easily integrated with the microcontroller while remaining efficient in power consumption and cost-effective.

g. Fan

The fan used in the design of this device is a 12V 0.30A DC fan with the KLOP 8025HS model. This fan was chosen because it fits the prototype design in terms of size and compatibility.

2. Software

In the design of this device, the Arduino IDE software is used to create code that will be applied to the Arduino. In this device, the Arduino is set to receive data from the MQ6 sensor and then process it based on the Tsukamoto Fuzzy Logic method. There are several stages in designing the code for the software:

a. Hardware Initialisation

This stage involves initialising the hardware that will be synchronised with the system, namely the MQ6 sensor, LCD, Relay, buzzer, and fan.

b. Data Readout

The gas sensor data reading is in the main loop for processing. In addition, at this stage, the data is also updated, and the fan is continuously controlled.

c. Data Update Function

At this stage, the sensor value will be read periodically to determine the current gas condition based on Tsukamoto Fuzzy Logic.

d. Actuator Control Function

At this stage, there is an actuator function that is controlled based on the fuzzy value obtained from the sensor reading.

e. Programme Upload

Connect the device used for programming to Arduino nano using USB Type-C. Before uploading the code to Arduino, make sure to select the appropriate board first. Next is to compile the code that has been made until the message ‘Done Compiling’ appears. This indicates that the programme made does not contain errors and is ready to be uploaded to Arduino.

How the Tool Work

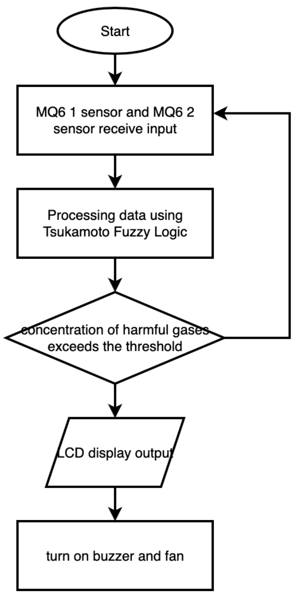

Figure 3 Tools Flowchart

Based on the flowchart above, the following can be explained:

1. The adapter provides the voltage needed to activate the components of all the devices.
2. MQ6 sensor 1 and MQ6 sensor 2 detect the presence of gas, which becomes the input variable with gas concentration as the output.
3. If gas is detected with a concentration exceeding the limit, the buzzer will sound automatically, and the LCD will display the measurement results from each sensor.
4. The gas concentration status will be calculated using the fuzzy logic method by first defining fuzzy variables.
5. Then, membership functions will be defined for the gas concentration measurement results from each sensor, and fuzzy rules will be created.
6. Next, apply the membership function to the fuzzy rule for further defuzzification to obtain the decision result.
7. The decision obtained will be displayed as the room condition status. This output will also control the activation of buzzers, relays, and fans according to the detected status.

RESULTS AND DISCUSSION

Component Testing Results

To find out whether the performance of the device made works well or not, it is necessary to test and collect data according to the device made. In this project, the MQ6 sensor will be used to detect the presence of CO, CH4, H2 and LPG gas in an area. So, testing needs to be done to ensure that these components can work according to specifications by spraying 3 types of gas into the project tool.

1. Testing the MQ6 sensor for CO sensitivity

Figure 4 CO testing

Table 1 CO Testing Results

Test	Results	LCD	Fan
1	154	LOW	OFF
2	143	LOW	OFF
3	566	MID	ON

2. Testing the MQ6 sensor for CH_4 and LPG sensitivity

Figure 5 CH4 dan LPG testing

Tabel 1 CH_4 dan LPG CO Testing Results

Test	Result	LCD	Fan
1	734	MID	ON
2	234	LOW	OFF
3	1885	HIGH	ON

a. Testing MQ6 sensor for H_2 sensitivity

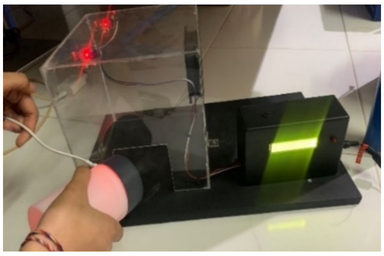

Figure 6 H_2 Testing

Table 2 H_2 CO Testing Results

Test	Results	LCD	Fan
1	734	MID	ON
2	234	LOW	OFF
3	1885	HIGH	ON

Analysis results:
Based on the tests that have been carried out, the MQ6 sensor shows a good response to the presence of CO, CH4, H2 and LPG gases. The analogue value displayed on the LCD also increases as the gas concentration increases. This shows that the sensor can function properly, can send data well can be seen through the display of detection data on the LCD. The MQ6 sensor is declared suitable for use.

System Testing Results
After doing some tests to find out whether the designed tool has worked well and according to purpose. Then it is proven by several tests on the system.

a. Effectiveness of MQ6 Sensor

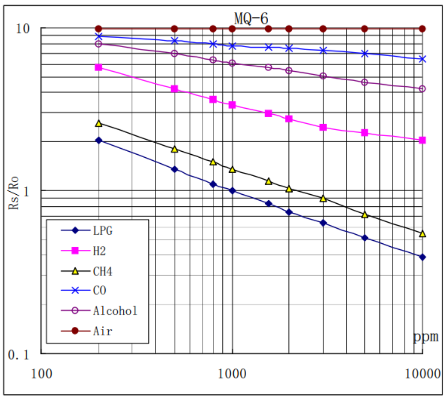

Figure 7 Sensor MQ6 Datasheet

Based on the curve above, the MQ-6 sensor has sensitivity to several gases, namely LPG (Liquefied Petroleum Gas), H2 (Hydrogen), CH4 (Methane), CO (Carbon Monoxide), Alcohol and Water. This sensitivity allows this sensor to be useful in various security applications, especially for detecting dangerous gas leaks that cause explosions or fires.

After conducting several tests, it can be concluded that the Gas Leakage System designed has been able to detect several types of dangerous gases such as CO, CH4, H2 and LPG with sufficient accuracy. This can be proven by the following figure:

Figure 8 Gas Leakage System Results

The picture above is an LCD display that shows the detection results of the MQ6 sensor (1) of 54 ppm, the MQ6 sensor (2) of 5130 ppm with the status of the 'MID' hazard condition. This proves that the sensor can work effectively in detecting harmful gases. By applying Fuzzy Logic Tsukamoto in Arduino, this system has the ability to process sensor data properly.

b. Effectiveness of Tsukamoto Fuzzy Logic Method

Manual calculations were carried out for several test cases using the Tsukamoto Fuzzy Logic method and obtained the following results:

Table 3 Manual Calculation of Tsukamoto Fuzzy Logic

No	MQ6 (1)	MQ6 (2)	Output	LCD	FAN
1	9	279	171	MID	ON
2	36	513	200	MID	ON
3	81	72	76,7	LOW	OFF
4	691	526	323	HIGH	ON
5	107	902	201	MID	ON
6	54	90	76,7	LOW	OFF
7	54	5130	200	MID	ON
8	9	117	80	LOW	OFF
9	99	360	200	MID	ON
10	90	369	200	MID	OFF
11	54	306	200	MID	ON
12	198	432	321	HIGH	ON
13	36	90	76,7	LOW	OFF
14	36	270	160	MID	ON
15	99	648	200	MID	ON
16	36	36	76,7	LOW	OFF
17	45	99	76,7	LOW	OFF
18	99	108	78,3	LOW	OFF
19	108	108	87,1	LOW	ON
20	117	99	80	LOW	OFF
…	…	…	…	…	…
50	108	108	LOW	LOW	OFF

In addition to manual calculations, system testing was also carried out with the following results:

Table 4 System Testing Results

No	MQ6 (1)	MQ 6 (2)	LCD	FAN
1	9	279	MID	ON
2	36	513	MID	ON
3	81	72	LOW	OFF
4	691	526	HIGH	ON
5	107	902	MID	ON
6	54	90	LOW	OFF
7	54	5130	MID	ON
8	9	117	LOW	ON
9	99	360	MID	ON
10	90	369	LOW	OFF
11	54	306	LOW	OFF
12	198	432	HIGH	ON
13	36	90	LOW	OFF
14	36	270	LOW	OFF
15	99	648	MID	ON
16	36	36	LOW	OFF
17	45	99	LOW	OFF
18	99	108	LOW	OFF
19	108	108	MID	ON
20	117	99	LOW	OFF
…	…	…	…	…
50	108	108	LOW	OFF

The output comparison between data processing using formulas and data processing using the system is carried out with the following results.

Table 5 Comparison of Manual Calculation Output with System

Test	MQ6 (1)	MQ 6 (2)	Output with Formula	Output with System	Compatibility
1	9	279	MID	MID	Yes
2	36	513	MID	MID	Yes
3	81	72	LOW	LOW	Yes
4	691	526	HIGH	HIGH	Yes
5	107	902	MID	MID	Yes
6	54	90	LOW	LOW	Yes
7	54	5130	MID	MID	Yes
8	9	117	LOW	LOW	Yes

9	99	360	MID	MID	Yes
10	90	369	MID	LOW	No
11	54	306	MID	LOW	No
12	198	432	HIGH	HIGH	Yes
13	36	90	LOW	LOW	Yes
14	36	270	MID	LOW	No
15	99	648	MID	MID	Yes
16	36	36	LOW	LOW	Yes
17	45	99	LOW	LOW	Yes
18	99	108	LOW	LOW	Yes
19	108	108	LOW	MID	No
20	117	99	LOW	LOW	Yes
…	…	…	…	…	…
50	108	108	LOW	LOW	Yes

Of the 50 trials, there were 8 times that the output did not match between the output of the manual calculation and the output of the same system calculation using the Tsukamoto Fuzzy Logic method. If the discrepancy occurs 8 times in 50 trials then:

$$\text{Discrepancy Presentation} = \left(\frac{8}{50}\right) \times 100\% = 16\%$$

So, the possibility of a mismatch between system calculations and fuzzy calculations on this tool amounts to 16%.

Benefits for Welding Shop Poltekbang Surabaya

The implementation of the results of this research will make a significant contribution to improving worker safety in welding shops. The system provides early gas detection with sufficient accuracy and rapid automatic response. This can help prevent workplace accidents or the risk of worker health problems due to long-term exposure to hazardous gases.

Based on the test results, it was found that this system is sufficient and able to function properly to be implemented in a welding shop environment to provide more protection for workers. Of course, many adjustments are needed in its implementation such as:

1. Adjustment of components that must be adjusted to the needs if applied to a room with a certain area.
2. Real fuzzy logic calculation by recalculating the room area and exposure limit according to working time.
3. Calibrate the sensor regularly because there will be environmental variations such as temperature and humidity that will affect the sensor's work.

Determination of the Best Research Variables

In this Gas Leakage System design research, determining the best variables is very important to ensure the system can detect leaks effectively and accurately. The steps in determining the best variables for this research are:

1. Data collection

Data collection is carried out on the detection results of the two sensors in ppm units and the resulting hazard status and activation of fans and buzzers.

Table 6 Correlation Analysis of Variables

MQ-6 (1)	MQ-6 (2)	Hazard Status	Fan and Buzzer Activation
90 ppm	63 ppm	LOW	OFF
36 ppm	145 ppm	LOW	OFF
2007 ppm	405 ppm	HIGH	ON
1089 ppm	117 ppm	HIGH	ON
2151 ppm	0 ppm	MID	ON
117 ppm	5778 ppm	HIGH	ON
90 ppm	5571 ppm	MID	ON

The resulting data shows that the gas concentration detected on the MQ-6 (1) and MQ-6 (2) sensors greatly affects the hazard status displayed on the LCD. The following are some statements about the table above:

- If the MQ-6 (1) sensor gets a low input of ≤ 100 ppm and the MQ-6 (2) sensor gets a low input of ≤ 100 ppm. MQ-6 (2) sensor gets a low input of ≤ 100 ppm as well, the level of danger that is concluded is LOW.
- If the MQ-6 sensor (1) gets a low input ≤100 and the MQ-6 sensor (2) gets a medium input with a scope of 200 ≤ x ≤ 300 ppm then the inferred hazard level is MID.
- If the MQ-6 sensor (1) gets a medium input with a coverage of 200 ≤ x ≤ 300 ppm and the MQ-6 sensor (2) gets a high input with a coverage of ≥300 ppm, the inferred hazard level is HIGH.
- If the MQ-6 sensor (1) receives a high input with a coverage of ≥300 ppm and the MQ-6 sensor (2) receives a low input of ≤100, the inferred hazard level is MID.
- If the MQ-6 sensor (1) receives a high input with a coverage of ≥300 ppm and the MQ-6 sensor (2) receives a medium input with a coverage of 200 ≤ x ≤ 300 ppm, the inferred hazard level is HIGH.
- If the MQ-6 sensor (1) receives a high input with a coverage of ≥300 ppm and the MQ-6 sensor (2) receives a medium input with a coverage of ≥300 ppm, the inferred hazard level is HIGH.MQ-6 (2) mendapatkan input sedang dengan cakupan ≥300 ppm maka tingkatan bahaya yang disimpulkan adalah HIGH.

These experiments proved that the highest correlation was found between the gas concentration detection results and the hazard status and activation of the fan and buzzer. This shows that gas concentration is a key variable in determining the hazard level which then affects the activation of the fan and buzzer. key variable in determining the hazard level which then affects the activation of the fan and buzzer.

Calculate Statistical Values

a. ∑X = Sum all MQ-6 sensor values (1)
b. ∑Y = Sum all MQ-6 sensor values (2)
c. ∑XY = Multiply each pair of X and Y then sum the results
d. ∑X2 = Square each X value, then sum the results
e. ∑Y2 = Square each Y value, then sum the results
f. n = Number of data pairs

The rule is applied to the following research data: ∑X = 5580

a. ∑Y = 12.079
b. ∑XY = 2.128.554
c. ∑X2 = 31.136.400
d. ∑Y2 = 145.902.241
e. n = 7

Enter into the Pearson formula

$$r = \frac{n(\sum XY) - (\sum X)(\sum Y)}{\sqrt{[n\sum X2 - (\sum X)2][n\sum Y2 - (\sum Y)2]}} \quad (4.1)$$

$$r = \frac{7(2.128.554) - (5580)(12.079)}{\sqrt{[7\,x\,31.136.400 - (5580)2][7\,x\,145.902.241 - (12.079)2]}}$$

$$r = \frac{14.899.878 - 67.400{,}82}{\sqrt{[7\,x\,31.136.400 - (5580)2][7\,x\,145.902.241 - (12.079)2]}}$$

$$r = \frac{14.832.478}{(\sqrt{217.954.800 - 31.136.400)\,(1.021.315.687 - 145.902.241}}$$

$$r = \frac{14.832.478}{\sqrt{(186.818.400)(875.413.446)}}$$

$$r = \frac{14.832.478}{404.404.920}$$

$r = 0{,}0366771936$

r is close to 0, then there is no strong linear relationship between the two sensors. Based on the results of the research that has been done, it can be concluded that the gas concentration is the key variable in determining the level of danger which then affects the activation of the fan and buzzer. In addition, the calculation results of r obtained close to 0 indicate that there is no strong linear relationship between the two sensors.

Advantages and Disadvantage of Tools

After several tests of components and systems that have been designed in such a way. Overall, the results of the discussion can be concluded through an explanation of the advantages and disadvantages of the tool, namely:

1. Tool Advantages
   a. It can support safety and security in a way that was rarely prioritised before.
   b. The time needed to process data is also fairly fast.
   c. Can manually monitor the condition of the room through the LCD.
   d. With the buzzer indicator and automatic fan, workers in the room can immediately take appropriate action as soon as possible.
2. Tool Disadvantage
   a. It cannot be guaranteed that the fan can completely remove harmful gases in the room quickly.
   b. The limits of hazardous gas and smoke levels are still often different and need to be adjusted further.
   c. Still has a presentation of discrepancies between manual calculations and system calculations of 16%.

3 CONCLUSIONS AND SUGGESTIONS

Conclusion

After passing through various stages of research, several conclusions can be drawn, namely:

1. The gas leakage system designed can be made in accordance with the initial objectives, namely being able to detect hazardous gases in the welding process with a sufficient level of accuracy. The system also successfully determines the status of environmental hazards into three categories namely LOW, MID and HIGH through the LCD display according to predetermined parameters. The automatic fan control system can also work in accordance with the output, namely the fan will turn on in MID and HIGH conditions.
2. The application of the Tsukamoto Fuzzy Logic method can be proven effective in processing sensor data so as to produce reliable outputs. The use of this method is able to provide a fast and precise response in the process of identifying the level

of gas hazard detected in an environment. Of the 50 trials, there was a mismatch between the output of the manual fuzzy calculation and the output of the system calculation 8 times. This is still within acceptable limits so that this system can be reliable for use in a welding shop environment.

3. The existence of this system makes a significant contribution in improving work safety and early detection of gas leaks with a fast response. So that it can prevent work accidents and health problems due to long-term exposure to hazardous gases.

Suggestions

Based on the research result and testing that have been conducted, there are several suggestions that can be given to achieve further development, namely:

a. System testing in real conditions, in this case the welding shop at Poltekbang Surabaya. This needs to be done to ensure that the system can work well and meet the actual work environment requirements. Periodic calibration is needed to ensure that the level of detection accuracy is sufficient. This will help maintain sensor performance to remain in optimal condition and minimize potential errors.

b. Addition and adjustment of the placement of several components such as sensors are also necessary to increase the system's detection coverage and provide more adequate protection. In addition to adjusting components according to needs, such as power source, fan size, and buzzer, adjustments to the Fuzzy Logic Tsukamoto method calculations are also necessary to be conducted.

c. Furthermore, this system can also be developed with the addition of a monitoring system. Centralized monitoring that can be accessed in real-time is highly recommended to support even faster response times.

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REFERENCE

[1] F. Jalaluddin, Y. Suprapto, L. S. Moonlight and T. I. Suharto, "Microcontroller-Based Door Security System Design Using Fingerprint," *Journal of Nesia Engineering Science (JNESc),* 2022.

[2] B. Dukish, Coding the Arduino, Ohio: Springer Science + Business Media, 2018.

[3] L. Louis, "PRINSIP KERJA ARDUINO DAN PENGGUNAANNYA SEBAGAI ALAT UNTUK STUDI DAN PENELITIAN," *International Journal of Control, Automation, Communication and Systems (IJCACS),* pp. 23-26, 2016.

[4] L. S. Moonlight and A. S. Prabowo, "Forecasting System for Passenger, Airplane, Luggage and Cargo, Using Artificial Intelligence Method-Backpropagation Neural Network at Juanda International Airport," *Warta Ardhia Jurnal Perhubungan Udara,* vol. 45, no. 2, pp. 99-110, 2019. DOI: 10.25104/wa.v45i2.358.99-110.

[5] L. S. Moonlight, L. Rochmawati, Suhanto and M. Rifai, "Sistem Informasi On Time Performance (OTP) Penerbangan di Bandar Udara Internasional Juanda Surabaya," *Warta Penelitian Perhubungan,* vol. 34, no. 2, pp. 93-104, 2022.

[6] L. S. Moonlight, B. R. Trilaksono, B. B. Harianto and F. Faizah, "Implementation of recurrent neural network for the forecasting of USD buy rate against IDR," *International Journal of Electrical and Computer Engineering,* vol. 13, no. 4, pp. 4567-4581, 2023.

[7] S. U. Filla, R. Kurniawan and S. , "PROTOTYPE ALAT PENGATUR TEMPERATUR RUANG KERJA PADA RUMAH MENGGUNAKAN LOGIKA FUZZY," *Journal of Science and Social Research,* 2024.

[8] E. A. Prastyo, "MQ-6 Gas Sensor (LPG and Butane)," 2021. [Online]. Available: https://www.edukasielektronika.com/2020/10/mq-6-gas-sensor-lpg-and-butane.html#:~:text=MQ-6%20Gas%20Sensor%20%28LPG%20and%20Butane%29%20adalah%20sebuah,dimana%20konduktivitasnya%20akan%20rendah%20di%20udara%20yang%20bersih..

[9] R. Noor, "Relay: Pengertian, Simbol, Fungsi, Jenis dan Cara Kerja Relay," 2023. [Online]. Available: https://ilmuelektro.id/relay/#:~:text=Relay%20adalah%20komponen%20elektronika%20yang%20bekerja%20secara%20listrik%2C,menggunakan%20prinsip%20elektromagnetik%20sehingga%20dapat%20menggerakkan%20kontak%20saklar..

[10] semeruintisukses, "Perbedaan Antara Exhaust Fan dan Blower: Fungsi dan Aplikasi yang Berbeda," 2024. [Online]. Available: https://www.semeruintisukses.net/blog/perbedaan-exhaust-fan-dan-blower.

[11] R. I. Sudjoko and Hartono, "Rancang Bangun Sistem Proteksi Generator Sinkron 3 Phasa," *Penelitian,* 2018.