Jurnal Arus Elektro Indonesia (JAEI) Vol. 11, No. 1, Mei 2025
ISSN. 2502-3608; e-ISSN. 2443-2318, Terakreditasi Sinta 5
DOI: 10.19184/jaei.v11i1.53108

Internet of Things-Based LoRa Air Quality Monitoring System in the University of Jember

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Abstract
In current environmental conditions, air quality is often underestimated even though it is crucial for the survival of living organisms. Good air quality that contains sufficient oxygen for breathing and photosynthesis, as well as stable carbon dioxide levels, is essential for humans, animals, and plants. Pollution factors such as motor vehicle exhaust, factory emissions, and waste burning can reduce air quality and thus have an indirect impact on the health of living beings. This research focuses on air pollution caused by carbon monoxide and carbon dioxide, using the Mamdani fuzzy method to determine uncertainty and vagueness values. An IoT system with two LoRa devices is used to monitor air quality, with data from sensors represented via MATLAB using fuzzy logic for more accurate results. LoRa device integration with Arduino and ESP32 can be used for accurate sensor reading and communication, ensuring proper data transmission between nodes and gateways for real-time monitoring and comparison of gas parameters at different locations. The reading results from the sensors and the monitoring results on the Blynk platform show identical values with 0% error from monitoring. For the percentage of ISPU values from simulation results in MATLAB compared to manual calculations, there is a difference of 1.12% when compared with the reading values from the sensors.

***Keywords* — Air Quality, fuzzy logic, Internet of Things, LoRa.**

I. INTRODUCTION

In current environmental conditions, air quality is often overlooked, even though this aspect is very important to monitor because air has a significant impact on the survival of various creatures. Air consists of various gases including oxygen, carbon dioxide, carbon monoxide, water vapor, and others. Good quality air contains enough oxygen for plant respiration and photosynthesis and has balanced carbon dioxide levels. Therefore, the presence of healthy air is indispensable in daily life for humans, animals, and plants. Many elements can damage air quality, such as smoke pollution from motor vehicles, factory fumes, garbage burning, and similar sources. If this problem is left unchecked, it will affect the health of all living things (Fariza D., 2018). Air is considered good if it contains 78% Nitrogen, 20% oxygen, 0.93% Argon, 0.03% Carbon Dioxide, 0.12% carbon monoxide, 0.04% Ammonia, and 0.0615% other gases [1].

In this research, the focus is on air pollution caused by carbon monoxide and carbon dioxide gases. Carbon monoxide is a compound consisting of one carbon atom and one oxygen atom, represented by the chemical formula CO. It is colorless, odorless, and toxic. Carbon monoxide is usually produced from combustion processes such as factory smoke, motor vehicle emissions, and similar sources (Setya Widhoyono, 2020). The fuzzy Mamdani method is a logic system used to determine the value of uncertainty and ambiguity of existing values. This logic system uses linguistic rules similar to traditional logic and is expressed in the form of "if-then" statements, with the membership function applied to input variables [2].

Similar research has been conducted by previous researchers. In their research, various types of sensors were used to detect several gases in the air. However, the weakness of this research was that the processing of data read by the sensors was difficult to interpret properly. The difference between the author's research and previous researchers lies in the use of sensors. The sensors used by the author focus on detecting two gas parameters: carbon monoxide and carbon dioxide, making integration and interpretation in data processing easier [3].

A. LoRa SX1276

LoRa SX1276 is one type of LoRa (Long Range) wireless communication technology used to transmit output data during node detection in monitoring system areas. This LoRa module uses the SX1276 radio chip developed by Semtech Corporation. LoRa SX1276 is easy to use, compact in size, and has low power consumption, which are advantages that make it very suitable for IoT devices requiring long-distance wireless connections. LoRa SX1276 can transmit data at a speed of 32 kbps with a frequency around 915 MHz.

B. Arduino Nano

Arduino Nano is an open-source microcontroller module and single board based on Microchip ATmega328 technology. Arduino Nano provides the same connectivity and

ISSN. 2502-3608; e-ISSN. 2443-2318, Terakreditasi Sinta 5
DOI: 10.19184/jaei.v11i1.53108

specifications as the Arduino Uno board in a smaller form factor (Wikipedia). Arduino Nano 3.x uses the ATmega328 microcontroller, while Arduino Nano 2.x uses ATmega168. Arduino Nano is not equipped with a power supply socket but can use power from a mini USB port.

C. ESP32

The ESP32 is a full-featured, high-performance microcontroller designed by the Expressive System company. This type of ESP uses a dual core processor running on Xtensa LX16 instructions. The microcontroller is equipped with WiFi and Bluetooth, allowing developers to create applications that connect to the Internet and communicate wirelessly with other devices. In addition, the ESP32 has quite powerful processing capabilities and supports many different communication protocols such as SPI, I2C, and UART, making it suitable for various IoT applications. It also provides processing for analogue signals, sensor read support, and digital input/output (I/O) device support.

D. MQ-7

The MQ-7 sensor is a type of gas sensor used to detect carbon monoxide (CO) concentrations in the air. MQ-7 uses a sensing material consisting of tin dioxide (SnO_2) which has lower conductivity in clean air. The MQ-7 sensor operates using a 5V voltage that heats the carbon monoxide gas adsorbed at low temperatures, after which high temperatures are used to clean other gases adsorbed at low temperatures. Changes in conductivity can be converted into an output that corresponds to the concentration of carbon monoxide gas at the 90-second point. The MQ-7 sensor has standard operating conditions, including input voltage, heater voltage, and load resistance, which must be adjusted to achieve the correct output.

E. MQ-135

The MQ-135 sensor is a gas sensor that can detect carbon dioxide, carbon monoxide, ammonia, and other gases. The MQ-135 sensor works on the principle of changing resistance values when exposed to gas. The result of air quality detection is a change in the analog resistor value on the output pin. This output pin can be connected to the ADC pin of the Arduino analog input microcontroller by adding one resistor. The MQ-135 sensor has high sensitivity and can detect concentrations from 10 to 10,000 ppm. It also has a low loop voltage (Vc), making it ideal for use in air quality measurement systems. This sensor has good durability for use as a pollution indicator.

F. Router Antenna

A router antenna is an antenna that functions to transmit and receive wireless signals between devices and other wireless devices such as PCs or IoT (Internet of Things) devices. The speed of the router antenna depends on the type and quality of the antenna used. A router antenna can have a maximum data rate of about 300 Mbps to 10 Gbps. The antenna speed also depends on the type of module used.

G. Blynk

Blynk is a platform for iOS and Android devices to control IoT devices such as Arduino, NodeMCU, Raspberry Pi, and similar applications over the Internet. Blynk has two versions: website and application. This platform can be used for hardware control, displaying sensor data, storing data, visualization, and more. The Blynk platform has three main components: applications, servers, and libraries. Widgets available on Blynk include Button, Value visualization, Historical Graph, Twitter, and Email.

H. MATLAB

MATLAB is a numerical computing and programming platform used by many professionals to analyze data, create algorithms, and build models and applications. MATLAB is a matrix programming language that uses multiple paradigms, including functional, imperative, procedural, object-oriented, and array programming. MATLAB provides various features such as matrix manipulation, function and data graphing, algorithm implementation, user interface creation, and communication with programs written in various languages. The system also has a toolbox that uses the MuPAD symbolic engine, providing access to symbolic computing capabilities.

II. RESEARCH METHODOLOGY

Based on figure 1, when the system starts, node initialization is performed so that the sensor can read the desired parameters. The sensor reads the surrounding environment with reference to certain gas level, the sensitivity of the sensor here greatly affects the reading results. The sensor reading data obtained is sent displayed on the blynk platform in real-time. The reference value displayed on blynk as sensor reading data is processed in matlab software using fuzzy logic methods that will get more accurate data or data with a smaller percent error value. Matlab output in the form of data with values that have been processed using the fuzzy Mamdani method is data that is not much different from the actual environment.

In Figure 2, there are three parts that represent the system of the tool to be made. In the first section, namely the input section consisting of 2 different sensors, namely MQ7 and MQ135, the two sensors can detect various gases such as carbon monoxide, carbon dioxide, ammonia, and so on. The data collection area or sensor coverage used is in the dimensions of 5 m x 5 m at each research location. The sensor is initialized on a node consisting of an arduino nano microcontroller and LoRa sx1276. Data from the node is then sent to the gateway, for the gateway itself consists of esp32 and LoRa sx1276. The connection between the node and the gateway will run when both parts are connected to the same network. After passing through the gateway, the data is sent using the internet of things and will be displayed on the PC/smartphone receiving device using the iot blynk platform which has a requirement to be connected to the same network, the connection between blynk and the microcontroller uses a token that will only be connected if both are on the same network access.

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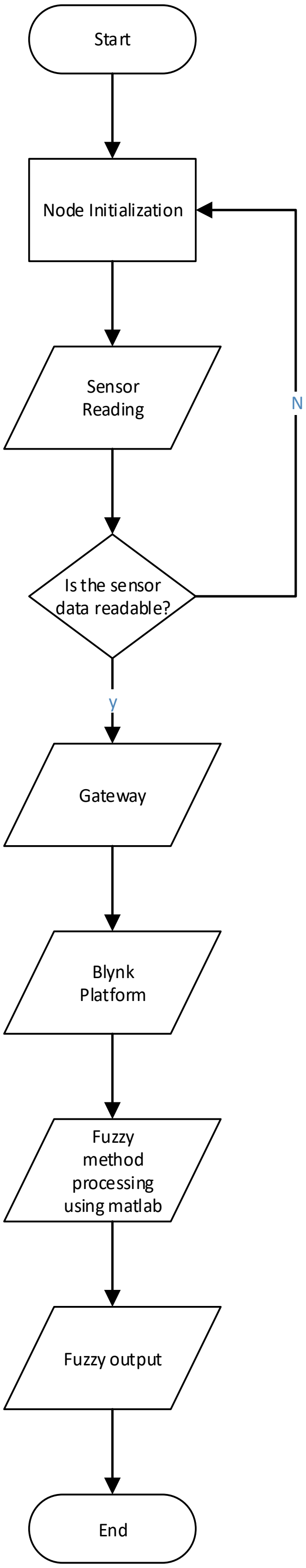

Fig. 1 Flowchart systems

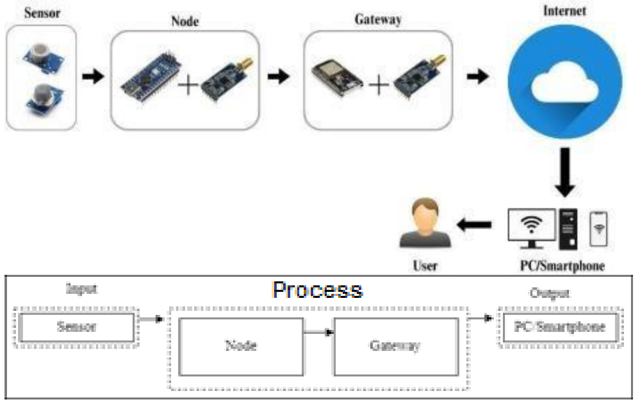

Fig. 2 Part of all the systems

Data Processing Using Fuzzy Logic Method

A. Fuzzification

TABLE 1. FUZZIFICATION FUNCTION PROCESS

No.	Name	Description	Function
1.	NK	Carbon monoxide values	Input Variable
2.	NC	Carbon dioxide value	Input Variable
3.	ISPU	Air Quality	Output

TABLE 2. FUZZIFICATION VARIABLES

Function	Variables	Notation	Talking Universe (ppm)
Input	NK	a	0 - 50
	NC	b	0 - 2000
Output	ISPU	z	0 - 300

B. Inference

In the fuzzification stage, a representation of the membership function value is carried out based on the fuzzy set of each input variable, which can be presented in a triangular curve. The membership function of each input variable is low, medium, and high. high. In this stage there is also the formation of rules that use input from the fuzzification output.

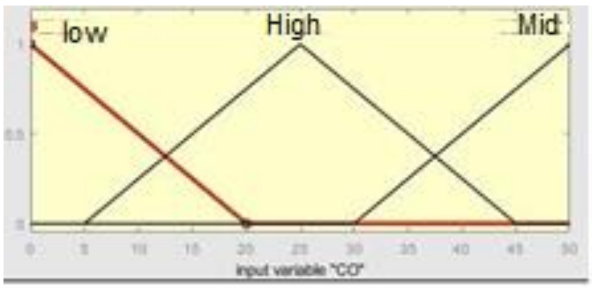

Fig. 3 Input Variable CO

ISSN. 2502-3608; e-ISSN. 2443-2318, Terakreditasi Sinta 5
DOI: 10.19184/jaei.v11i1.53108

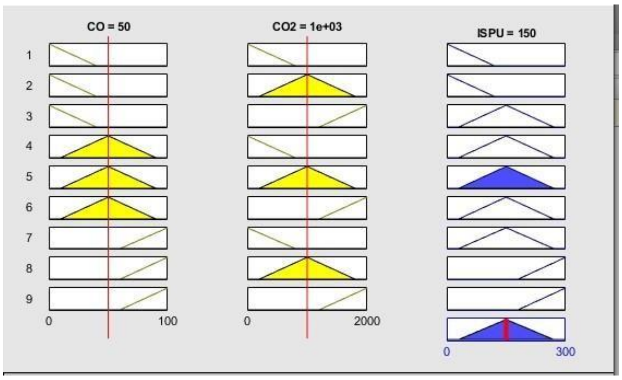

Fig. 4 Inference process

TABLE 3. INFERENCE COMPARATION

Rule	IF		ISPU
	CO_2	CO	
R1	Low	Low	Healthy
R2	Low	Mid	Healthy
R3	Low	High	Mid
R4	Mid	Low	Mid
R5	Mid	Mid	Mid
R6	Mid	High	Mid
R7	High	Low	Mid
R8	High	Mid	Unhealthy
R9	High	High	Unhealthy

C. Defuzzification

The defuzzification stage is the last stage in the Mamdani fuzzy method, at this stage using the output of inference in the form of membership functions in the rules which are then represented in the form of crisp values.

III. RESULT

In making the air quality monitoring system, two LoRa are used to communicate with each other to send and receive information, the first LoRa is integrated with Arduino Nano into a node, with two sensors, namely MQ7 and MQ135. The node here functions to read gas levels in the environment around the research. Then the reading results from the sensor are sent to the second LoRa which has been integrated with esp32 into a gateway. Both LoRa devices are installed with a 433MHz antenna with a gain of 12dbi so that information exchange becomes more possible between the two LoRa devices.

Results of sensor reading data at the research location.

TABLE 4. LOCATION SENSOR READ VALUE 1

Data	Time	Parameter Value	
		CO	CO_2
1	2024-07-28 10:25:13	6.84 ppm	528.44 ppm
2	2024-07-28 10:25:14	0.94 ppm	527.62 ppm
3	2024-07-28 10:25:15	0.94 ppm	538.44 ppm
4	2024-07-28 10:25:17	5.85 ppm	527.62 ppm
5	2024-07-28 10:27:06	0.95 ppm	506.48 ppm
6	2024-07-28 10:27:07	0.95 ppm	516.97 ppm
7	2024-07-28 10:27:08	0.94 ppm	538.44 ppm

TABLE 5. LOCATION SENSOR READ VALUE 2

Data	Time	Parameter Value	
		CO	CO_2
1	2024-07-28 10:51:19	9.81 ppm	560.58 ppm
2	2024-07-28 10:51:20	0.92 ppm	560.58 ppm
3	2024-07-28 10:51:22	0.92 ppm	549.42 ppm
4	2024-07-28 10:51:23	0.94 ppm	560.58 ppm
5	2024-07-28 10:51:24	6.82 ppm	560.58 ppm
6	2024-07-28 10:51:25	0.91 ppm	560.58 ppm
7	2024-07-28 10:51:30	0.92 ppm	549.42 ppm

Fig. 5 System Flow


Fig. 6 LoRa Node (left) and LoRa Gateway (right)

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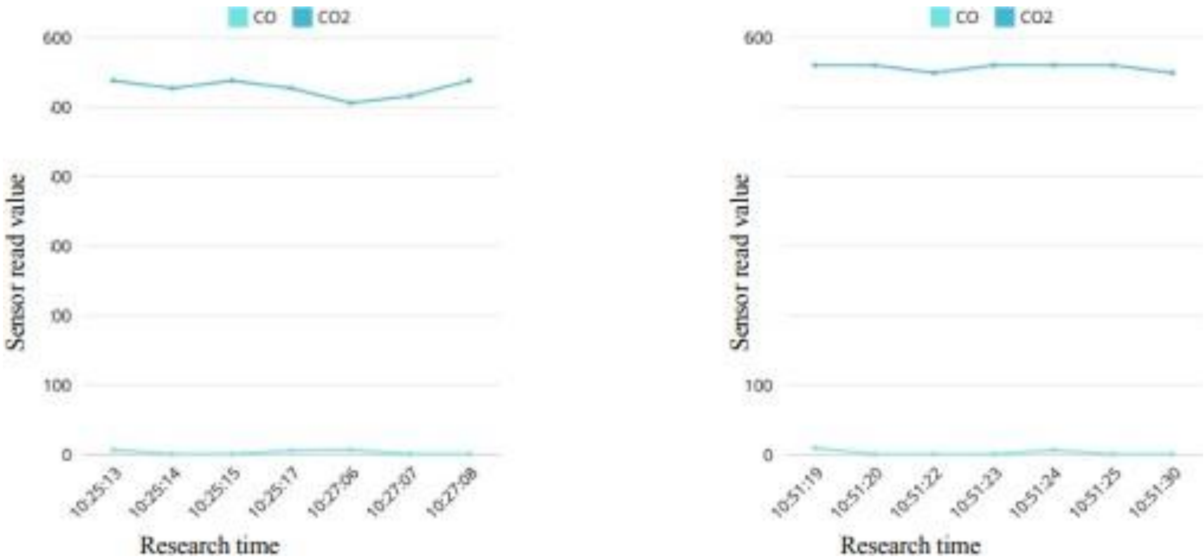

Fig. 7 Sensor Read Data in Graphical Form on the Platform Blynk

Based on the sample values obtained from sensor readings at the two research locations, it can be said that the value of the carbon monoxide gas parameter has a not too significant change displayed at every second, for the value of the carbon dioxide gas parameter there is some data whose value has increased and decreased significantly, but the value of the two gas parameters tends not to be significant. This is due to several factors including stable environmental conditions and interference from other gases.

Fuzzy Methode

A. Fuzzification

TABLE 6. FUZZY INPUT AND OUTPUT SET

Variables		Fuzzy Set		Domain
Name	Notation	Name	Notation	
		Low	R	[0-16.67]
NK	A	Medium	S	[16.68-34.33]
		High	T	[34.34-50]
		Low	R	[0-666.67]
NC	B	Medium	S	[666.67-1333.34]
		High	T	[1333.34-2000]
		Healthy	S'	[0-100]
ISPU	Z	Medium	S	[101-200]
		Unhealthy	TS	[201-300]
		Strongly no healthy	STS	[≥301]

To determine the value of gas parameter levels is as follows (sample data used in the calculation is data number 1):

1. Variable carbon monoxide value
   Low: (16.67 ppm-6.84 ppm)/16.67 ppm=0.5896
   Medium: (6.84 ppm-8.33 ppm)/8.33 ppm=-0.178=0
   High: (6.84 ppm -16.67 ppm)/16.67 ppm=-5896=0
2. Variable carbon dioxide value
   Low: (666.67 ppm-538.44 ppm)/666.67 ppm=0.1923
   Medium:(538.44ppm-333.33ppm)/333.33ppm=0.6153
   High: : (538.44 ppm-666.67 ppm)/666.67 ppm=- 0.1923=0

B. Fuzzy Inference

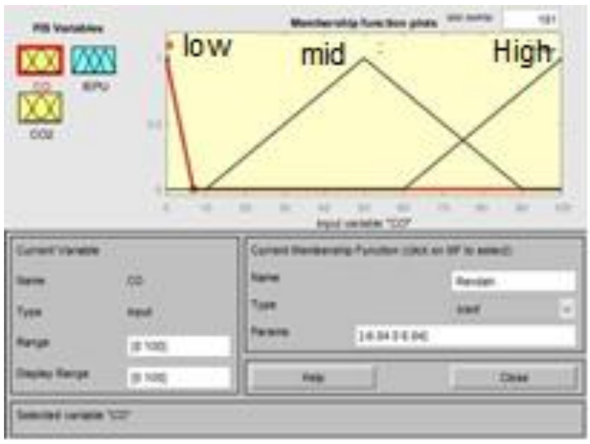

Fig. 8 Gas Parameter Result Data is Entered into FIS

At the next stage, the MIN function is applied to determine the predicate alpha data in the inference process, for the results of the MIN function can be seen in bottom figure.

C. Defuzzification

In matlab, the read value from the sensor is entered into the defuzzification input FIS to display the sensor value representation for each rule, the sensor value representation

Jurnal Arus Elektro Indonesia (JAEI) Vol. xx, No. xx, Maret 2023
ISSN. 2502-3608; e-ISSN. 2443-2318, Terakreditasi Sinta 5
DOI: 10.19184/jaei.v11i1.53108

obtained can be seen in the figure below as a representation of defuzzification.

Defuzzification is a stage of the fuzzy mamdani method which is carried out in the process of calculating the weight average value for each rule.

Z1: Z Healthy=50-0.41*(50)=29.5
Z2: Z_Sealthy=100-0*(100- 51)=100
Z3:Z-Medium=100-0*(100-51)=100
Z4: Z- Medium=100-0*(100-51)=100
Z5: Z_Sedang=100-0*(100-51)=100
Z6: Z_Sedang=100-0*(100-51)=100
Z7: Z_Sedang=100-0*(100-51)=100
Z8:Z_Not Healthy=200-0*(200-101)=200
Z9: Z_Tidak Sehat=200-0*(200-101)=200

Then look for the weight average value, which can be calculated in the following way:

WA=(0.41*29.5)/(0.41)=29.5

The value of the weight average is calculated for each reading result value that has been obtained for each rule, so that the weight average value will be the reference value for the defuzzification value by manual calculation, the weight average value can be seen in table 7.

Based on the value that has been obtained from the sensor reading results and the representation value of the fuzzy mamdani method, the air quality category value can be determined as seen in table 8.

TABLE 7. WEIGHT AVERAGE RESULTS OF ALL SAMPLES

Z	Sample Data Weight Average						
	1	2	3	4	5	6	7
Z1	29.5	25.1	9.97	23.59	12.45	10.22	9.76
Z2	100	100	100	200	100	14.64	11.10
Z3	100	100	200	100	100	100	200
Z4	100	100	12.65	16.98	200	200	100
Z5	100	100	100	100	200	200	100
Z6	200	100	100	15.8	100	200	16.71
Z7	100	100	100	100	13.42	13.56	12.17
Z8	200	200	200	100	11.48	12.87	100
Z9	200	200	200	200	100	100	100
WA	29.5	25.1	19.56	28.98	21.43	20.22	18.54

TABLE 8. RESULTS AIR QUALITY VALUES AND CATEGORIES

Data	Time	Parameter Value		ISPU	Category
		CO (ppm)	CO_2 (ppm)		
1	2024-07-28 10:25:13	6.84	538.44	29.5	Healthy
2	2024-07-28 10:25:14	0.94	527.62	25.1	Healthy
3	2024-07-28 10:25:15	0.94	538.44	19.56	Healthy
4	2024-07-28 10:25:17	5.85	527.62	28.98	Healthy
5	2024-07-28 10:27:06	0.95	506.48	21.43	Healthy
6	2024-07-28 10:27:07	0.95	516.97	20.22	Healthy
7	2024-07-28 10:27:08	0.94	538.44	18.54	Healthy

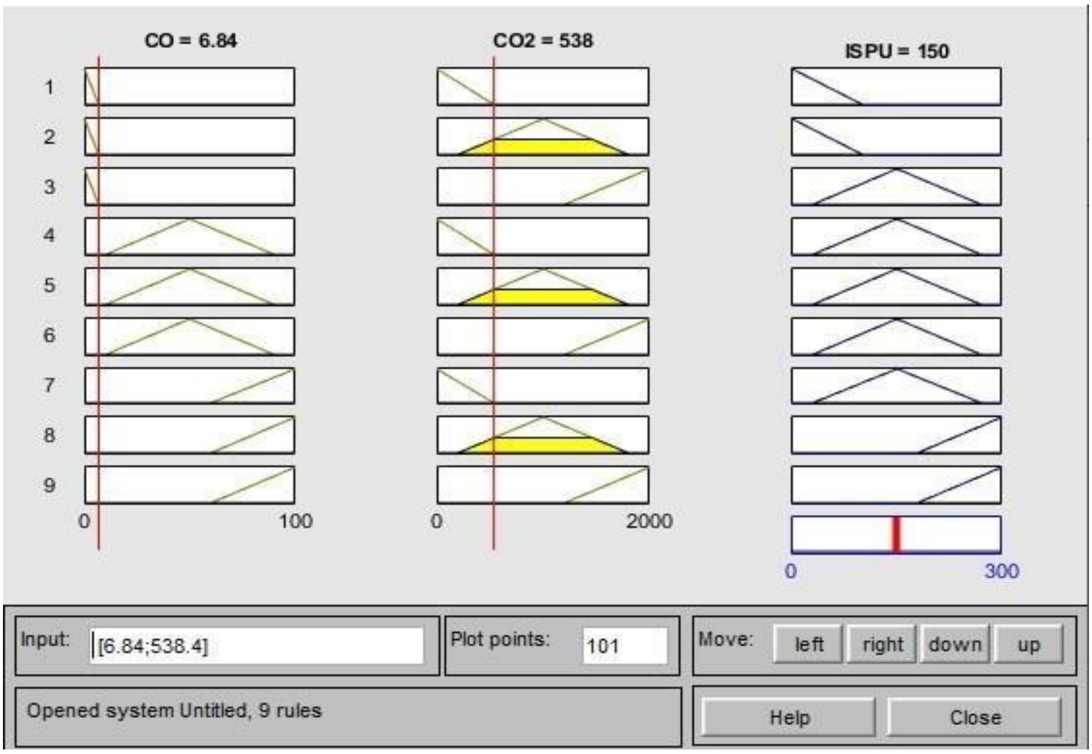

Fig. 9 Representation of Sensor Reading Values

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Monitoring air quality using LoRa SX1276 which then the results are displayed on the blynk platform and represented using the fuzzy mamdani method is an effort made to be able to compare the value between gas parameters at one location with another location. In addition, the information conveyed from one LoRa node to the LoRa gateway using the help of a 433 MHz antenna can facilitate in terms of conveying the value of sensor readings, the antenna used has a power of 12dbi with an omnidirectional radiation pattern. The quality of the delivery of sensor readings to the LoRa gateway is compared using an air detector to test the accuracy of the communication quality between the two LoRa nodes. The value of ISPU obtained shows that the air quality at the time of the research was considered healthy with ISPU values in the range of 0-100, namely 29.5, 25.1, 19.56 and so on, these values are the final output due to the low value of pollutant gases contained in the area. In data 1 and data 4 the value of carbon monoxide read tends to be higher than other data, the difference in data is due to the fact that at the time of data collection there were several vehicles passing by and emitting smoke. The fuzzy mamdani method is used to determine the classification of air quality based on sensor reading values using manual calculations and FIS simulations in MATLAB. The calculation is done using the variable value of each parameter to get the membership degree value, then from the value obtained, the predicate alpha data is calculated to get the weight average value. ISPU value is obtained from the weight average value based on the rules used.

IV. CONCLUSION

Based on the results of the analysis and calculations and simulations that have been carried out, several conclusions can be drawn in this study, namely:

1. The use of LoRa in the air quality monitoring system is considered good, because it can convey information in the form of sensor read values that are the same as the values displayed on the Air Quality Detector. It can be seen in the carbon monoxide gas parameter when there are vehicles passing by producing higher gas levels than when there are no vehicles, the value of carbon monoxide gas read when there are vehicles is 6.84 ppm, 5.85 ppm, 9.81 ppm, and 6.82 ppm.
2. Connecting two LoRa can be done by using an additional 433 MHz antenna device with a transmitting power of 12 dbi, the antenna becomes the sender at the node and the receiver at the gateway so that the sensor reading value is conveyed accurately.
3. Representing the sensor reading value using the Fuzzy Mamdani method can be done by simulation on the FIS Matlab interface and manual calculation. In manual calculations, calculations are carried out on the value of membership degrees, MIN functions to obtain predicate alpha data, and weight averages to obtain ISPU values.

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DOI: 10.19184/jaei.v11i1.53108

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