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Original Research Paper

Implementation of Sugeno Fuzzy Logic Method as an Automatic Humidity and Moisture Control System in Terrarium

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Abstract: A terrarium is a mini ecosystem that requires precise humidity control to ensure plant growth and the survival of animals within it. However, manual humidity control is difficult to implement consistently, especially if the external environment changes. This problem can be overcome by implementing an automatic system based on Sugeno fuzzy logic. This research aims to design and implement an automatic system that is able to control terrarium humidity dynamically using a fuzzy logic approach. This system is designed using humidity sensor data as input which is then processed through Sugeno fuzzy logic to determine appropriate control actions. The method used involves modeling input humidity and temperature sensors, determining fuzzy rules, and defuzzification using the Sugeno method to regulate the automatic irrigation system in the terrarium. Tests were conducted under several different environmental conditions to measure the system's response to changes in humidity and temperature. The research results show that the system is able to maintain terrarium humidity within optimal limits with a low error rate. The system is able to adjust control actions in real-time, produce consistent calculations, and provide humidity stability despite external changes.

Keywords: Automatic System, Fuzzy Logic, Humidity, Sugeno Fuzzy Logic, Terrarium.

1. Introduction

Automatic control systems are very important for the progress of a country. Due to its practical nature, every aspect of daily life helps the system operate better. Automatic control systems can also reduce losses caused by humans themselves [1], for example, controlled traffic lights, money counting machines, automatic toll payments, and automatic watering in the crop sector and many more. Automatic control systems in the crop sector and cultivated land enable cultivators to carry out their work effectively. In the plant and cultivation sector there is the terrarium method, the terrarium method is one method planting that combines transparent containers and ornamental plants. Terrarium is growing rapidly during the COVID-19 pandemic, where people are required to work from home [2]. Maintaining a constant humidity level for terrarium, however, can be a challenge, especially if there are environmental fluctuations or measurement irregularities. Uncertain measurements can cause plant growth in the terrarium to become unstable, therefore fuzzy logic was created as a way to overcome the problem of uncertain measurements.

In general, Fuzzy logic is an improvement on Boolean logic which introduces the concept of partial truth [3]. By applying fuzzy logic as an automatic humidity control system in terrariums, it is possible to contribute to the development of innovative solutions in designing environmental control systems for tropical plants in terrarium conditions, with the aim of improving plant health and growth effectively. In the context of automatic control systems, there is a Fuzzy Inference System (FIS) with 2 different methods, namely Mamdani and Sugeno. The use of the Sugeno fuzzy logic method is able to calculate vague data to become less vague [4].

2. Literature Review

2.1. Terrarium

Terrarium is a model or way of growing ornamental plants in a transparent container and arranged so that it looks like a garden [5] and the interior climate conditions are adjusted to the needs [6] of the plants inside. Discovered by Nathaniel B. Ward (1791-1868) and continuing to develop today, terrariums are in demand by plant hobbyists as decoration for their rooms.

2.2. Fuzzy Logic Sugeno

Fuzzy logic is a control system that utilizes fuzzy logic [7] which has a theory for dealing with uncertainty [8]. Fuzzy logic was developed by Prof. Lotfi Zadeh in 1965 to solve problems that conventional logic could not solve. In contrast to Artificial Neural Networks which continue to learn existing class data [9], fuzzy logic involves several main elements that form the basis of the system. Following are the key elements in fuzzy logic.

The Sugeno fuzzy logic method, named after Japanese researchers Professor Takagi and Sugeno, is one of the methods in fuzzy logic known as "Sugeno-style" rules or "Takagi-Sugeno fuzzy systems". FIS Sugeno improves the weaknesses of pure fuzzy systems to add simple mathematical calculations as part of THEN [10].

2.3. ESP32

ESP32 is a microcontroller introduced by Espressif Systems, which is the successor to the ESP8266 microcontroller [11]. Built on a dual-core Xtensa LX6 processor with speeds up to 240 MHz, the ESP32 has strong performance and is flexible for various IoT (Internet of Things) applications. In addition, this microcontroller is equipped with GPIO (General Purpose Input Output), ADC (Analog to Digital Converter), DAC (Digital to Analog Converter), and interfaces for communication devices such as SPI, I2C, and UART. Its features allow the ESP32 to be used in projects requiring wireless communications, sensor control, and home automation, as well as other smart devices.

2.4. OLED Display

OLED is often used in electronic technology, such as in display screen or sensor applications. The primary production procedure of OLED display consists of four phases such as thin-film transistor (TFT), evaporation and encapsulation (EVEN), cell, and module lines [12]. Unlike LCD screens, OLED does not require a backlight, because each pixel is capable of emitting its own light. This results in sharper contrast, deeper blacks, and more efficient power consumption, especially when displaying content with a lot of dark colors.

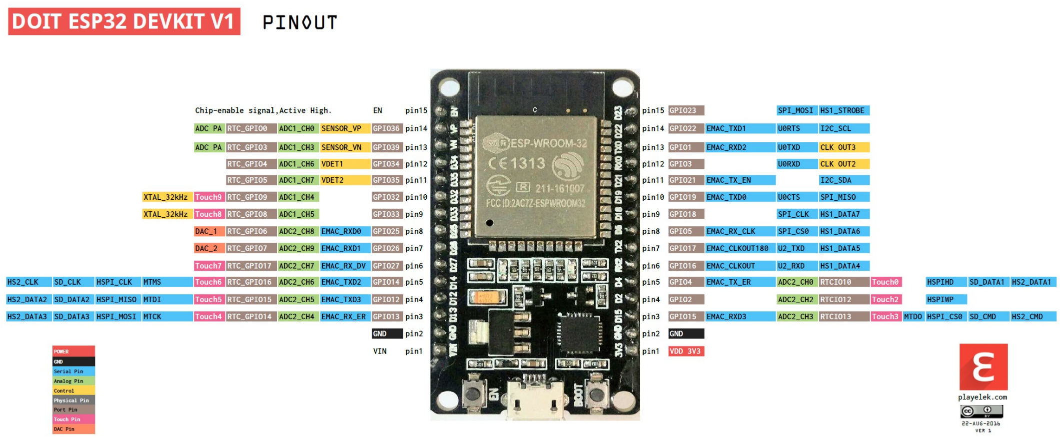


Figure 1. ESP32

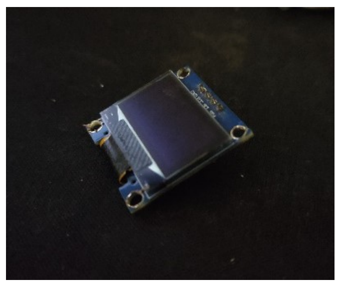


Figure 2. OLED Display

2.5. DHT22 Sensor

The DHT22 sensor is commonly used to measure room and environmental temperatures [13]. From the data sheet provided [14] compared to the DHT11, the DHT22 is superior in terms of measurement range, precision accuracy and reading speed. In this way, applying fuzzy logic to the data produced by the DHT22 sensor can provide certain advantages in managing and controlling environmental conditions, especially in automatic control systems, such as automatic humidity control systems in terrariums.

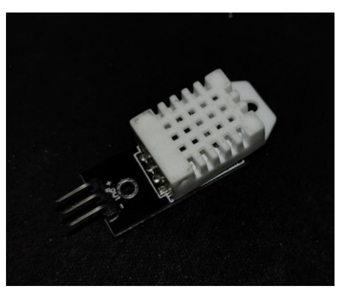


Figure 3. DHT22

2.6. YL-69 Sensor

The YL-69 soil moisture sensor is a sensor that is capable of detecting water content in the soil [15]. The use of the YL-69 sensor is used so that watering is carried out efficiently and effectively. The existence of YL-69 allows modeling of fuzzy logic in a more natural linguistic form. For example is "Dry", "Normal" and "Wet". The YL69 sensor provides numerical data, and fuzzy logic helps translate this data into linguistic conditions that can be interpreted by humans.

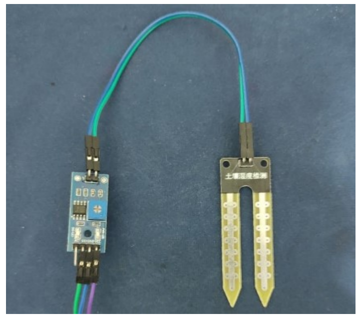


Figure 4. Charger Controller

2.7. Water Level Sensor

Water Level Sensor is a tool that measures the height of liquid in a fixed container [16]. In a terrarium where water is always flowing to control humidity, drainage is required so that the water does not settle in the terrarium. The function of the water level sensor is to run the water pump to remove water from the terrarium.

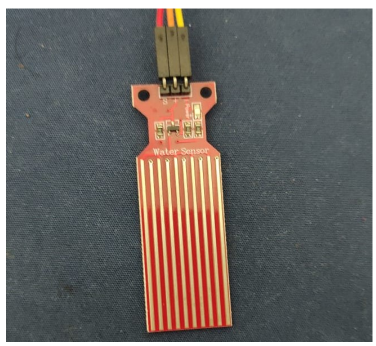
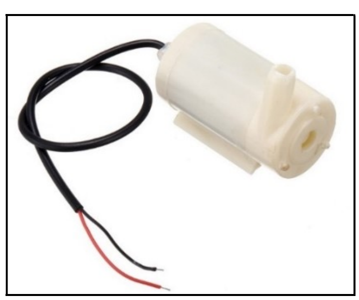


Figure 5. Water Level Sensor

2.8. Water Pump

Water pump is a device that functions to circulate water. It takes 2 water pumps to flush and remove water from the terrarium. The water pump used to water the plants in the terrarium has a voltage of 12 volts which aims to maintain the plants' humidity needs. The second water pump has a voltage of 5 volts which functions as drainage so that the water does not sit in the terrarium for too long.



Gambar 6. Water Pump DC

2.9. Fan DC

DC Fan is a device that can channel wind. The wind produced by the fan functions to maintain humidity in the terrarium. For this reason, 2 fans are needed to circulate air in and air out.

Figure 7. DC Fan

3. Methodology

This research focuses on improving the development of existing system performance in fuzzy logic calculations implemented in terrarium. The main goal is to develop an effective and efficient control system based on research and development of fuzzy logic technology.

3.1. Planning

Planning is a systematic process of determining goals and the steps required to achieve them. The research planning process is carried out in several stages, namely the preparation, design, testing, and implementation stages [17]. Using literature studies for data collection was carried out to find out which devices were suitable for use in this research so that there were no errors in the system.

3.2. Tool Design

To complete the research on the implementation of Sugeno fuzzy logic on an automatic humidity control system in terrariums, tools are needed in the form of hardware and software.

Table 1. Testing Fuzzy System

No	Device	Needs
1	ESP32	1 unit
2	YL-69	1 unit
3	DHT-22	1 unit
4	Water Level Sensor	1 unit
5	DC Fan	2 unit
6	Water Pump 5V	1 unit
7	Water Pump 12V	1 unit
8	Adaptor 12V	2 unit
9	Nozzle Spray	1 unit
10	Jumper Cable	Plenty
11	Hose 4mm	20 cm
12	Relay 4 Channel	1 unit
13	Modul Stepdown	2 unit

Table 2. Testing Fuzzy System

No	Software
1	Arduino IDE
2	WokWi

The design is carried out so that the prepared tool functions well when testing the tool. The design was made using an electronic device simulation application to make it easier before carrying out the actual assembly.

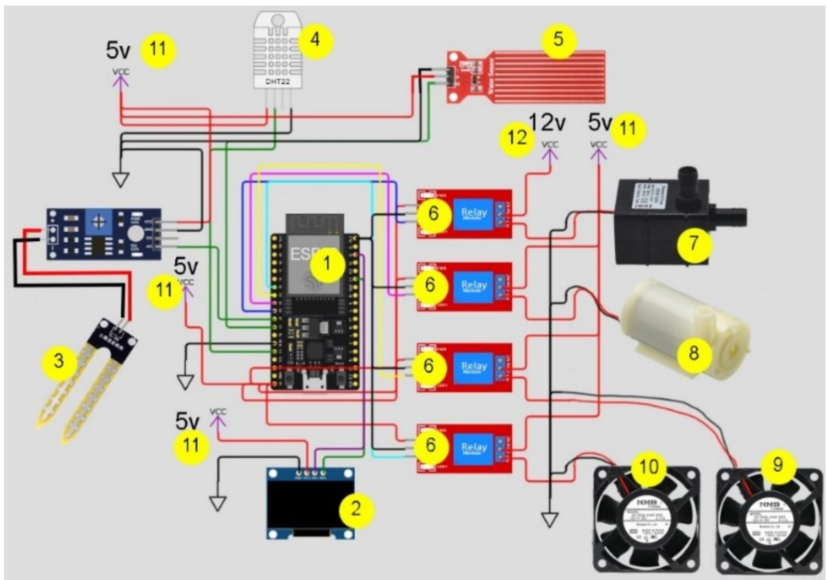


Figure 8. System Design

From Figure 8, we can observe an overview of each device of the automatic humidity control system in the terrarium. Following is an explanation of each automatic humidity control system in the terrarium device:

1) ESP32 as the brain for processing the Sugeno fuzzy logic system.
2) OLED Display to determine the value of the sensor connected to the ESP32.
3) YL-69 sensor for reading soil moisture in terrariums.
4) DHT22 sensor to read temperature and humidity in the terrarium.
5) Water level sensor to read the height of water pooling at the bottom of the terrarium.
6) Relay 4 Channel for controlling actuator.
7) Water Pump DC 12 Volt for watering plants in terrariums.
8) Water Pump DC 5 Volt for as drainage for water that settles at the bottom of the terrarium.
9) Fan DC 5 Volt as a carrier for incoming air to add humidity.
10) Second Fan DC 5 Volt to remove excess air humidity in the terrarium.
11) Is the required power supply voltage.
12) Is the power supply voltage required specifically for a 12 Volt water pump.

3.3. Flowchart

It is important to create a flowchart so that it is structured and there are no errors when programming is carried out for this automatic humidity control system.

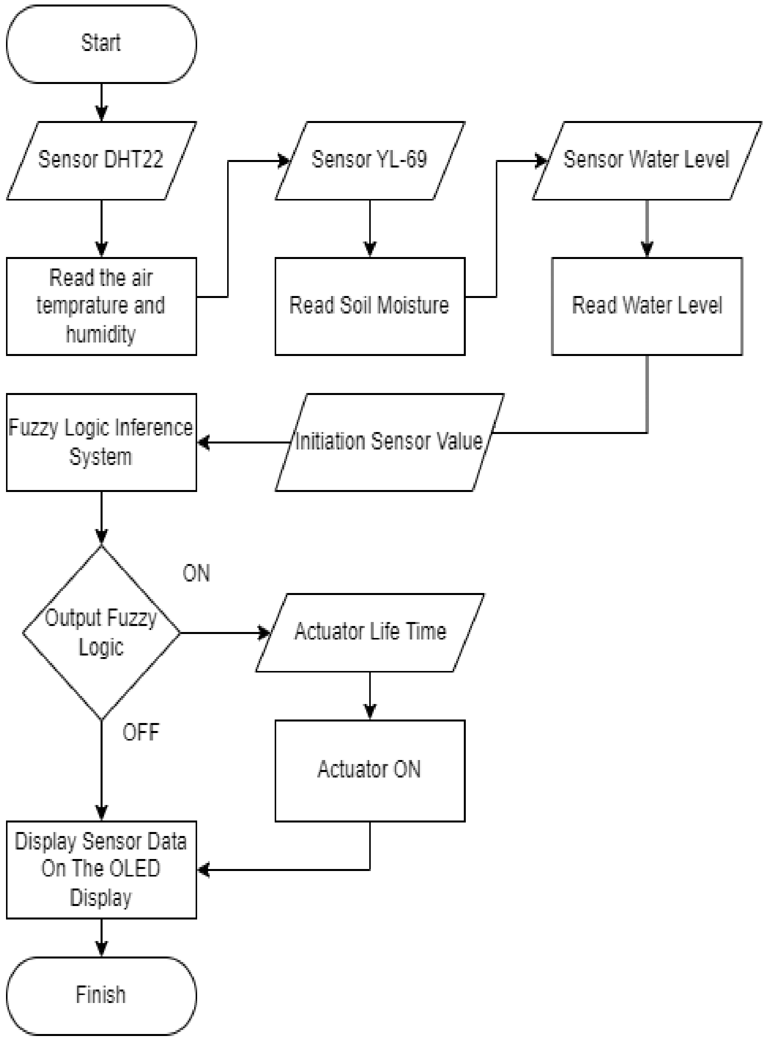


Figure 9. Flowchart System

3.4. Data Representation

This part describes the various techniques used to convey data, including fuzzification, fuzzy rules composition, and defuzzification.

(1) Fuzzification

There are two membership functions used in this research, namely the sensor input membership function and the output membership function. The sensor input membership function consists of four inputs, namely temperature value, air humidity value, soil moisture value and water level, where:

- temperature consists of three fuzzy sets, namely cold, normal and hot.
- air humidity consists of three fuzzy sets, namely dry, humid and very damp.
- soil moisture consists of 3 fuzzy sets, namely dry, damp and wet.
- water level consists of 3 fuzzy sets, namely shallow, quite deep and deep.

The output membership function of water pumps and fans consists of 2 fuzzy sets, namely off and on, except for water pumps which have 3 fuzzy sets, namely off, fast and long.

The fuzzy membership function consists of 8 variables because each sensor input value uses a trapezoidal curve shape.

Table 3. Membership Function

Function	Variabel	Fuzzy Set	Domain
Input	Temperature	Cold	[0 - 20]
		Normal	[18 - 32]
		Hot	[30 - 40]
	Humidity	Dry	[0 - 45]
		Humid	[40 - 90]
		Very Humid	[85 - 100]
	Soil Moisture	Dry	[0 - 40]
		Moist	[35 - 80]
		Wet	[75 - 100]
	Water Level	Shallow	[0 - 260]
		Quite Deep	[200 - 500]
		Deep	[480 - 820]
Output	Watering Water Pump	Off	[0]
		Fast	[0, 10]
		Long	[10, 20]
	Drainage Water Pump	Off	[0]
		On	[0, 10]
	Fan In	Off	[0]
		On	[0, 10]
	Fan Out	Off	[0]
		On	[0, 10]

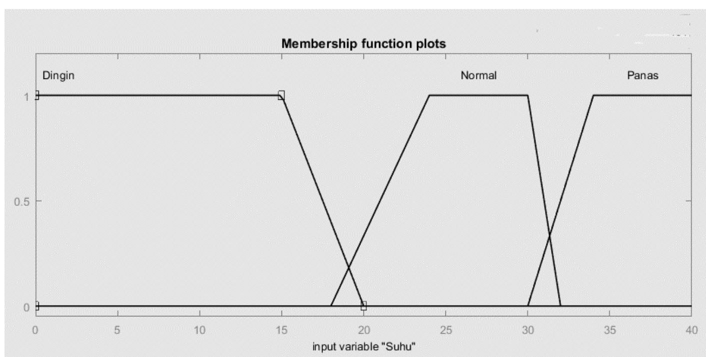


Figure 10. Membership Temperature

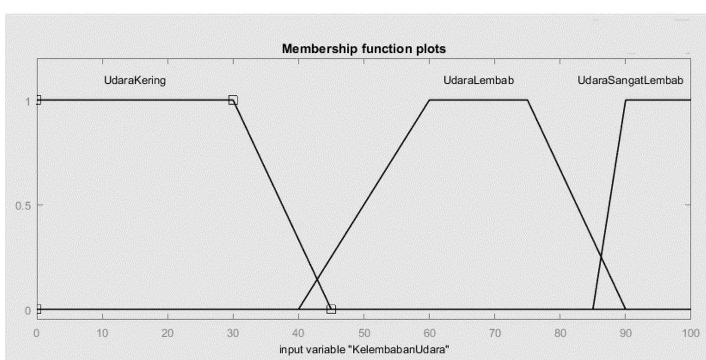


Figure 11. Membership Humidity

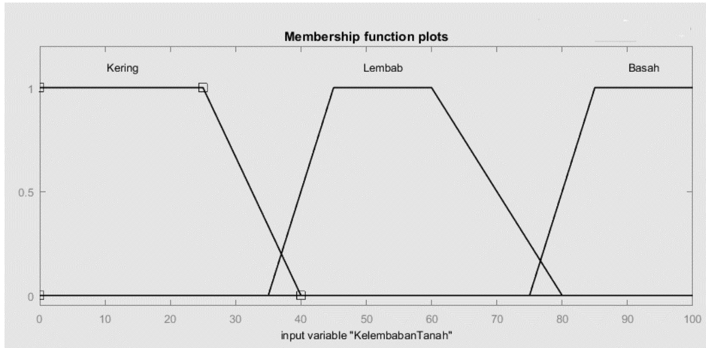


Figure 12. Membership Soil Moisture

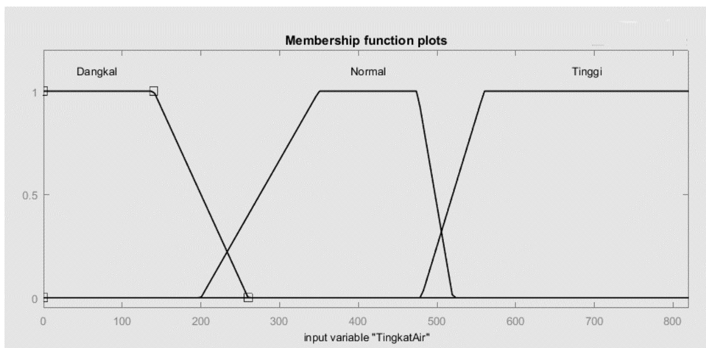


Figure 13. Membership Water Level

(2) Inference

After forming a fuzzy set (fuzzification), then the step of forming fuzzy rules is carried out. Rules are formed as statements of the relationship between input and output. The AND operator is used as a link between two inputs, and the operator to create a correspondence between input and output is IF-THEN [10].

During the composing phase of this study, the MIN's implicit function is used to find the prediction of α- for each rules. Subsequently, nilai predikat α is used to calculate the inferential results in a table form based on the following rules: z1, z2, z3, ...

Table 3. Fuzzy Rules

Rules	If	Then
1	Temperature is Cold Humidity is Dry Soil Moisture is Dry Water Level is Shallow	Watering Water Pump is Long Drainage Water Pump is Off Fan In is On Fan Out is On
2	Temperature is Normal Humidity is Dry Soil Moisture is Dry Water Level is Shallow	Watering Water Pump is Long Drainage Water Pump is Off Fan In is On Fan Out is Off
…	…	…
81	Temperature is Hot Humidity is Very Humid Soil Moisture is Wet Water Level is Deep	Watering Water Pump is Off Drainage Water Pump is On Fan In is On Fan Out is On

(3) Defuzzification

Defuzzification is a process in fuzzy logic that changes fuzzy values into crisp values. So if a fuzzy set is given in a certain range, real values can be taken as output[18]. In Figure 14 and figure 15 below is the membership function of the fuzzy output for the watering water pump, drainage water pump, fan in and fan out in singleton form where the value is to determine the length of output life time.

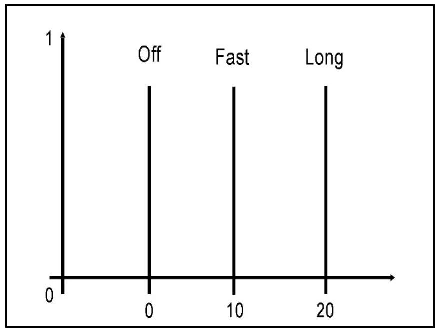


Figure 14. Membership Watering Water Pump

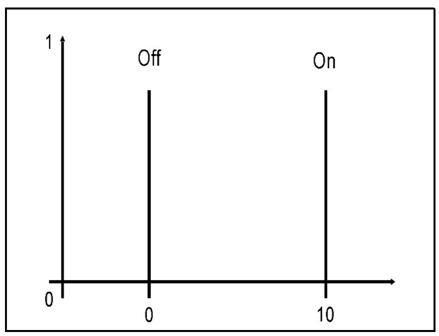


Figure 15. Membership Drainage Water Pump, Fan In “and” Fan Out

In this stage, the Sugeno fuzzy defuzzification process uses the average method. The results of the defuzzification will be completed using the equation (1).

$$\frac{\sum_i^n apred_i * Z_i}{\sum_1^n apred_i} \quad (1)$$

4. Finding and Discussion

4.1. Tool Assembly

The hardware is integrated on the ESP-32 board and other components that have been explained previously, namely using several electronic components such as, ESP-32, temperature sensor, air humidity, soil moisture sensor, air level sensor, water pump, fan, OLED screen and power supply. All input and output data is processed on the ESP-32 board, thus the ESP-32 board functions as the main component of the system. The following image shows a series of system hardware consisting of components that have been combined.

4.2. System Implementation

The working principle of this tool begins with the process of providing a power supply in the form of a 12 Volt adapter. The system works using the four sensors detecting the values of air temperature, air humidity, soil humidity and water level which are tested in the terrarium. The results of the sensor value readings are then displayed on the OLED display.

Figure 16. System Prototype

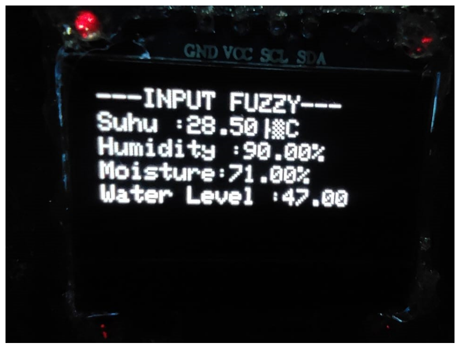


Figure 17. Input Display on OLED Display

After the input is initialized, the output value will come out as a result of the Sugeno fuzzy logic calculation to turn on the actuator with the time that has been generated by the Sugeno fuzzy logic.

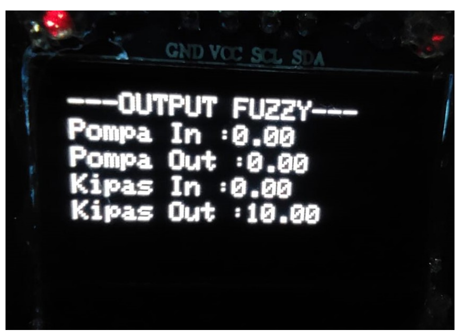


Figure 18. Input Display on OLED Display

Information from Figure 1 indicates that the exhaust fan is on for 10 seconds to reduce the humidity in the terrarium. and this also indicates that the Sugeno fuzzy logic system in the terrarium has been applied well.

4.3. Testing

Then testing was carried out on the fuzzy inference system program. This test was carried out to obtain information on whether the implementation of the Sugeno fuzzy method on the system was able to obtain output results that were in accordance with the previous design. The results of this test are shown in table 4. From the sensor readings, the system will start calculating and obtain the length of time for each output to be active through the implementation of the fuzzy Sugeno method

Table 4. Testing: Fuzzy System

No	**Input**				**Output**	**Output Respons e**
	Temperature	**Humidity**	**Soil Moisture**	**Water Level**		
1	28ºC	90%	71%	47	Watering Water Pump Drainage Water Pump Fan In Fan Out	OFF OFF OFF ON (10s)
2	29ºC	84%	81%	89	Watering Water Pump Drainage Water Pump Fan In Fan Out	OFF OFF OFF OFF

Figure 18. Output is On

5. Conclusions

Based on the results of testing in an automatic humidity control system with Sugeno fuzzy logic on a terrarium which was tested for 2 days at 17:00, the soil moisture value was 90% on the first day and 81% on the second day. In this way, researchers can draw the conclusion that research regarding the implementation of the Sugeno fuzzy logic method as an automatic humidity control system in terrariums can run normally.

To enhance the effectiveness and utility of this research in the future, several suggestions are proposed. First, using a larger terrarium container is recommended to mitigate the issue of the DHT22 sensor providing overly rapid humidity readings due to its proximity to the fan. Additionally, it would be beneficial to replace the current sensors with outdoor-compatible models to improve their resilience to water exposure. Lastly, maintaining cleanliness of the fans is crucial to prevent dust from contaminating the terrarium environment. These adjustments could contribute to more accurate and reliable control of humidity and moisture levels.

References

[1] I. W. Yoga Widiana, I. G. A. P. Raka Agung, and P. Rahardjo, "Rancang bangun kendali otomatis lampu dan pendingin ruangan pada ruang perkuliahan berbasis mikrokontroler Arduino Nano," *J. SPEKTRUM*, vol. 6, no. 2, p. 112, 2019.

[2] M. Kadir, Junaedi, A. Hambali, S. Thamrin, and Nildayanti, "Pembuatan terrarium mini untuk meningkatkan aktivitas dan kreativitas kelompok PKK Desa Mandalle Kabupaten Pangkep di

masa pandemi COVID-19," *J-ABDI J. Pengabdi. Kpd. Masy.*, vol. 1, no. 7, pp. 1607–1614, 2021.

[3] I. Sutrisno, E. P. Hidayat, B. W. Raebawa, M. Sya'iin, and others, "Penerapan kontroler logika fuzzy sebagai sarana pendidikan untuk mengawasi kesehatan air di tambak," *J. Pendidik.*, vol. 7, pp. 4014–4018, 2023. [Online]. Available: https://www.jptam.org/index.php/jptam/article/view/5885 [Accessed: January 2024].

[4] E. Setyawan, U. Chotijah, and H. D. Bhakti, "Implementasi pemadam kebakaran otomatis pada ruangan menggunakan pendeteksi asap suhu ruangan dan sensor api berbasis ESP32 dengan metode fuzzy Sugeno dan Internet of Things (IoT)," *Indexia*, vol. 3, no. 1, p. 1, 2021.

[5] R. Gondo and J. E. Mbaiwa, "Agriculture," *The Palgrave Handbook of Urban Development Planning in Africa*, pp. 75–103, 2022.

[6] T. Hollandt, M. Baur, and A.-C. Wöhr, "Animal-appropriate housing of ball pythons (Python regius)—Behavior-based evaluation of two types of housing systems," *PLoS One*, vol. 16, no. 5, pp. 1–20, 2021.

[7] E. A. Nugroho, "Sistem pengendali lampu lalulintas berbasis logika fuzzy," *J. SIMETRIS*, vol. 8, no. 1, pp. 75–84, 2017.

[8] U. Athiyah, A. P. Handayani, M. Y. Aldean, N. P. Putra, and R. Ramadhani, "Sistem inferensi fuzzy: Pengertian, penerapan, dan manfaatnya," *J. Dinda Data Sci. Inf. Technol. Data Anal.*, vol. 1, no. 2, pp. 73–76, 2021.

[9] A. M. I. Komang Nurjaya and Estananto, "Pemodelan sistem kendali suhu otomatis pada smart poultry farm menggunakan metode jaringan saraf tiruan," *e-Proceeding Eng.*, vol. 9, no. 2, pp. 136–144, 2022.

[10] R. Bakri, A. N. Rahma, I. Suryani, and Y. Sari, "Penerapan logika fuzzy dalam menentukan jumlah peserta BPJS Kesehatan menggunakan fuzzy inference system Sugeno," *J. Lebesgue J. Ilm. Pendidik. Mat. Mat. dan Stat.*, vol. 1, no. 3, pp. 182–192, 2020.

[11] C. E. Savitri and N. Paramytha, "Sistem monitoring parkir mobil berbasis mikrokontroller ESP32," *J. Ampere*, vol. 7, no. 2, p. 135, 2022.

[12] D. Lee, D. Lee, and K. Kim, "Self-growth learning-based machine scheduler to minimize setup time and tardiness in OLED display semiconductor manufacturing," *Appl. Soft Comput.*, vol. 145, p. 110600, 2023.

[13] C. F. Hadi, R. M. Yasi, and A. Prasetyo, "Model decision tree forecasting berbasis DHT22 pada smart hydroponic microgreen," *J. Telecommun. Electron. Control Eng.*, vol. 6, no. 1, pp. 29–38, 2024.

[14] T. Liu, "Aosong Electronics Co., Ltd," *Digit. Relat. humidity Temp. sensor/module (DHT22)*, vol. 22, pp. 1–10, 2013.

[15] M. Lamsani, R. A. Pangestika, M. Cahyanti, and E. R. Swedia, "Sistem identifikasi warna tanah Munsell menggunakan sensor warna TCS3200 dan kelembaban YL-69," *Sebatik*, vol. 27, no. 1, pp. 379–389, 2023.

[16] M. Abdul Azis, I. Lammada, M. Ferdyansyah Perdana Putra, and M. Ihsan Fadhilah, "Spend (Sistem peringatan dini banjir menggunakan water level sensor dengan Arduino Uno)," *J. Mhs. Tek. Inform.*, vol. 8, no. 4, pp. 4457–4464, 2024.

[17] S. B. Fauzia, "Bahan ajar: Pengantar perencanaan," *Bahan Ajar Pengantar Perenc.*, pp. 1–158, 2021. [Online]. Available: https://repository.unkris.ac.id/260/1/Bahan%20Ajar%20Pengantar%20Perencanaan%20_%20Fauziya.pdf. [Accessed: January 2024].

[18] D. Vinsensia, "Analisis kinerja pelayanan kesehatan dengan pendekatan logika fuzzy Sugeno," *J. Media Inform.*, vol. 2, no. 2, pp. 62–73, 2021.