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Research Article

Artificial House for Swiftlets (COLLOCALIA FUCIPHAGA) Based on MAMDANI FIS (Fuzzy Inference System)

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Abstract

Indonesia is an archipelagic country crossed by the equator, surrounded by the ocean, and traversed by many rivers, with a high level of rainfall. One of its islands is West Kalimantan, which has the longest river in Indonesia, the Kapuas River. In addition to the Kapuas River, there are also several tributaries scattered across this island, ensuring a constant water supply in the region. A natural condition surrounded by water, creates an environment with temperature and humidity that is ideal for the habitat of the swiftlets (COLLOCALIA FUCIPHAGA). The swiftlets initially inhabit caves with humidity levels around 80-95% and temperatures between 25-27 ℃. The nests of these swiftlets contain valuable substances, especially for health and cosmetics purposes, making them highly valuable in the market. Due to their high economic value, many farmers construct artificial houses for swiftlets of various sizes. The main challenge in a swiftlet house is to maintain humidity and temperature conditions close to the ideal habitat. This research aims to create a prototype control and monitoring system based on Mamdani FIS to maintain humidity and temperature inside the swiftlets house close to the ideal conditions, achieved by implementing an effective timing mechanism for humidifier machines and fans. Experiments results of the prototype show that the average humidity produced is 87.06%, and the temperature is 25.19 ℃. The placement of this prototype within an Artificial house for swiftlets should be movable within certain rooms and positioned according to the swiftlets' needs to ensure that the location is favored by the birds. This prototype can be operated manually and automatically, thus providing flexibility for Swiftlet farmers to control and monitor the Swiftlet’s house condition. This automatic control can be done globally via smartphone devices, so it is also able to provide great convenience for Swiftlets farmers to change and monitor the temperature and humidity.

Keywords

Swiftlet, Nests, Artificial Houses, Mamdani FIS, Humidity, Temperature

1. Introduction

Swiftlets (COLLOCALIA FUCIPHAGA) can only thrive and grow in regions with a tropical climate and high rainfall, making them commonly found in Southeast Asia. Swiftlets nests have many special properties, especially in the field of health and cosmetics. For instance, they contain glycoproteins [1] for immune system regulation, contain Sialic acid for fetal brain development, contain Epidermal Growth Factor (EGF) [2] that can stimulate high collagen production to fade facial spots and wrinkles, and other beneficial compounds. Due to the abundance of Swiftlets farmers in Indonesia, Swiftlets nests have become an Indonesian export commodity to various countries in Asia, Europe, Australia,

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and the USA. Furthermore, data indicates that in 2020, Indonesia's swallow nests dominated 48.16% of the global market ("source: Ministry of Trade, November 2020"). White-nest swiftlets prefer temperatures ranging from 24-26 ℃ and humidity between 80-95% [3], conditions typically found in caves, which are their natural habitats. Currently, these caves have been replaced with an Artificial house for swiftlets (swiftlets house) with heights of up to 15 meters, serving as both residence and nest-producing sites for the swiftlets. To attract and retain swiftlets in these houses, several treatments must be carried out, namely: building architecture designed to facilitate swiftlet movement, maintaining suitable temperature and humidity, increasing food availability around the swiftlet building, creating unique scents to attract swiftlets, and generating sound sources to entice them into the building. These efforts have been made by Swiftlets farmers, but they are still using traditional (manual) methods and have not incorporated technological elements. The most challenging aspect for a farmer is how to maintain the building temperature and humidity to match its natural habitat. What the farmers often do is create water ponds on the ground floor or place water buckets throughout the building. However, these methods have many drawbacks and limitations, leading to unstable temperature and humidity conditions. Consequently, the farmers cannot easily control and monitor the environment within the Swiftlets house since it is usually far from their residence. Up to this point, farmers still use traditional methods, relying on human intervention to regulate the surrounding parameters in a Swiftlets house, making it difficult to produce the desired quality and quantity of Swiftlets nests.

Farmers in Indonesia are generally categorized as traditional farmers who require relatively large labor, are highly dependent on seasons, do not involve intelligent technology, and face high economic costs. Such practices can be quite burdensome for a farmer. By implementing the concept of Smart Farming based on IoT (Internet of Things), a farmer can use a mobile application to control and monitor the conditions around their Swiftlets house area. To control the switching time (switching control) according to variable settings, this can be done using the Fuzzy method with the assistance of several sensors as the main aspects of the system [4].

Predicting microclimate changes in a greenhouse is crucial because plants are highly vulnerable to potential losses due to dramatic microclimate changes in the greenhouse [5]. A smart greenhouse incorporates schemes and objectives that allow for optimal plant growth through temperature control, soil moisture, and humidity [6]. Ensuring automatic climate control is fundamental. This is primarily used to maintain a protected environment despite fluctuations in the outdoor climate, committing to energy conservation and improved plant productivity. Therefore, before constructing a greenhouse, modeling is required, which will be the key to subsequent success. However, building a complete and perfect model is also very challenging as it involves multiple inter-related variables and constraints, both in physical and plant physiological phenomena [7].

To achieve temperature and humidity stability, modern agriculture, such as in a greenhouse, often utilizes the Internet of Things (IoT) through wireless sensor networks (WSN) and Fuzzy controllers. These systems using wireless sensor networks (WSN) can implement a comfortable microclimate within a greenhouse [8]. This method can create an ideal climate for precise plant growth with effective telemonitoring. The implementation of the Mamdani-type fuzzy inference system, optimized using a hybrid method combining genetic algorithms and interior point methods, allows for predicting relative humidity in a greenhouse with high interpretability and precision, achieving an effectiveness percentage of 90.97% and a mean square error (MSE) of 8.2e-3 [9].

A greenhouse agriculture is an environment designed to ensure intensive agricultural production. Favorable climatic conditions (temperature, lighting, humidity, etc.) for agricultural production must be artificially replicated by controlling several actuators (air heaters/coolers, ventilation, and humidifiers/dehumidifiers) [10]. By implementing the concept of smart farming based on Internet of Things (IoT) technology, farmers can use mobile applications to observe and monitor air humidity, air temperature, and soil humidity. A greenhouse agriculture is a complex Multi-Input Multi-Output (MIMO) system with internal parameters that create a favorable microclimate for agricultural production. Internal temperature and humidity are two parameters that have a significant impact on greenhouse yields. Fuzzy controllers have been developed for intelligent control of indoor temperature and humidity, which raise indoor air temperature at night by up to 15 ℃ and lower daytime temperatures by up to 24 ℃, maintaining a constant relative humidity value of 70% during the day and 80% at night [11]. In a tomato cultivation area in a greenhouse in Southern China, high-temperature and high-humidity conditions [HTHH] affect tomato growth, with high temperature playing a more significant role than high relative humidity (RH) values [12].

In India, agriculture plays a crucial role today. The economic growth of India is also significantly influenced by agriculture, as approximately 61.5% of the total population directly or indirectly relies on agriculture-related activities. To aid in improving yields and efficiency, Fuzzy methods have been used to generate effective irrigation scheduling and optimize water usage [13]. Fuzzy methods have also been employed by other researchers for irrigation system purposes, such as accurately predicting water consumption in different climates while saving water consumption by about 70% [14]. The Mamdani technique of fuzzy logic controllers, using Lyapunov functions, is used for designing smart greenhouses. This approach imitates human thought processes in control systems by establishing logical rules that guide greenhouse functions [15]. The Mamdani method is also used to provide sufficient water for rose plants in the

Mexico, with control over humidity (RH) and temperature (T) [16]. Other researchers have utilized genetic algorithms to maintain temperature and humidity levels in a greenhouse with highly satisfying results [17]. The integration of fuzzy logic with sensors, actuators, and microcontrollers through the Internet of Things has been applied in a mushroom greenhouse to control fans and sprayers, resulting in ideal temperature and humidity conditions. Research findings indicate increased productivity, with average yields reaching 3.3 kg compared to the previous 1.4 kg [18].

To achieve the desired conditions for swiftlets house, especially concerning temperature and humidity stability, an Intelligent mechanism can be employed to ensure control and monitoring, as is often done in modern agricultural management. In a greenhouse, an Intelligent mechanism frequently used is the application of a Fuzzy Logic Controller (FLC) to maintain temperature and humidity variables. The use of FLC in modern agriculture has been widely adopted to assist farmers in enhancing their crop productivity by maintaining the ideal conditions required by their crops.

This applied research design will utilize an approach similar to what has been applied in a modern greenhouse, as discussed in previous studies. It will use the Mamdani Fuzzy Inference System (FIS) to maintain temperature and humidity variables within a Swiftlet's house in order to improve the quality and quantity of swiftlets nests. This improvement aims to increase the income of swiftlet farmers, particularly in the West Kalimantan Province of Indonesia. In this research, the following components will be used: a humidifier machine, temperature and humidity sensors, current sensors (CT sensors), a router, and an IP camera. Control and monitoring will be carried out through a Web interface, with the main controller being a microcontroller connected to the internet. The research paper will consist of several sections, including: A review of Swiftlets house, Hardware development, Simulation and experiment result, and Conclusion.

2. Method

Due to the economic value of the swiftlet nest, the famers construct an artificial house for swiftlets. In general, it comes in different sizes: small, medium, and large, depending on the availability of land and the financial capabilities of farmers. For maintaining the temperature and humidity, a fuzzy-based control and monitoring prototype is needed so that the Swiftlet house conditions approach the ideal state. The prototype is designed to be placed in an artificial house for swiftlets with a medium size of 8x12x13 m as shown in Figure 1.

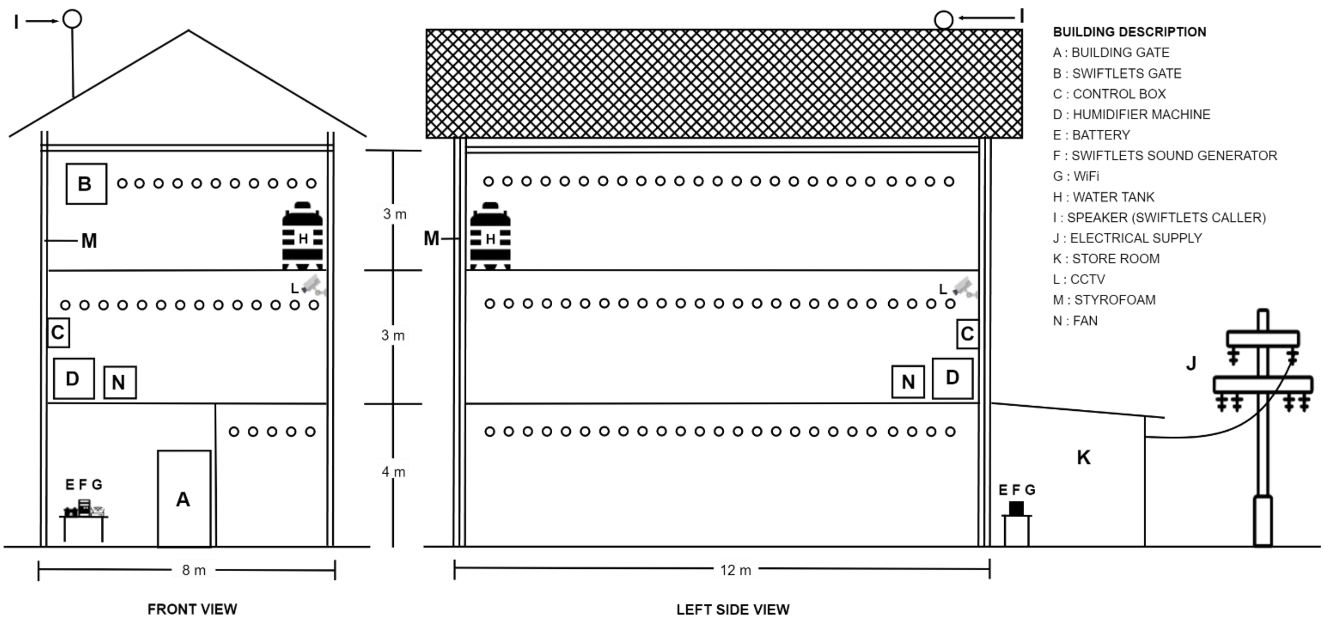


Figure 1. *The Artificial house for Swiftlet.*

The design and development of control and monitoring for an Artificial house for swiftlets based on the Mamdani Fuzzy Inference System (FIS) is focused on hardware development, fuzzy inference system, programming procedures, and performance analysis. The proposed prototype design has several elements, namely a 1-phase MCB, a multifunctional PZEM004 sensor, a 5V power supply, a 5V relay, a DHT22 sensor, a Humidifier machine, a fan, LCD display, and an ESP32 Microcontroller. The schematic diagram of the hardware design is shown in Figure 2.

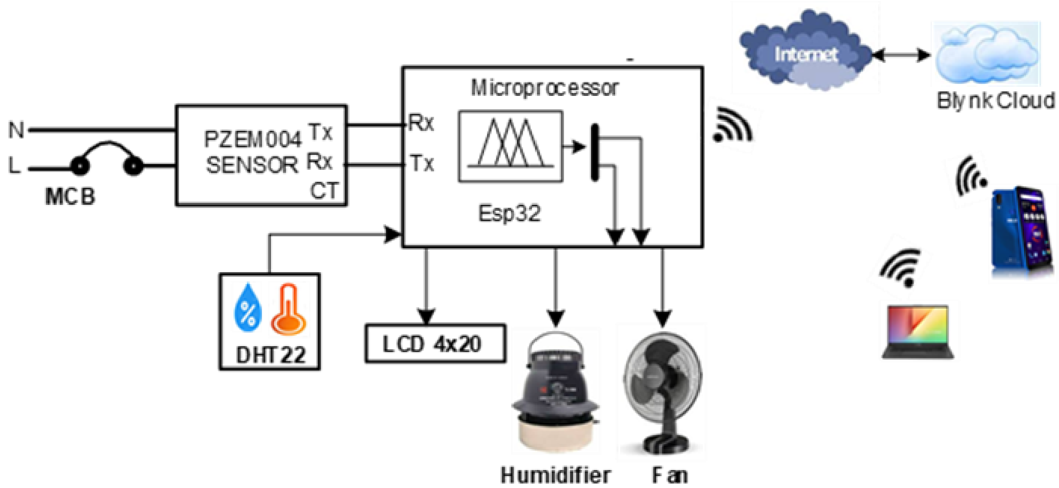
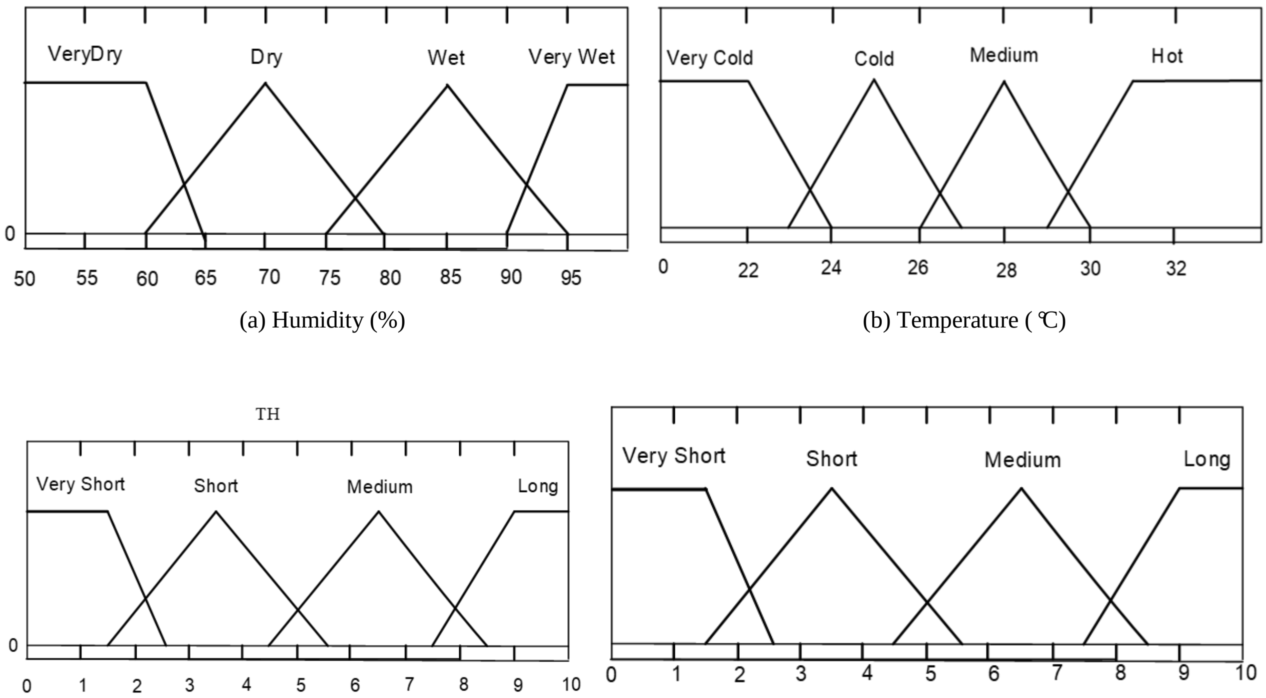


Figure 2. Schematic Diagram of prototype.

The PZEM sensor is connected to the 1-phase power source and to the CT terminal to detect voltage (V), current (I), and power (P) parameters. These electrical parameters are highly beneficial for a farmer to perform necessary repairs in case of electrical disturbances that may occur. The DHT22 sensor functions to detect humidity (H) and temperature (T) parameters, which serve as input data for the prototype. This input data represents the environmental conditions in a part of the swiftlet house area and becomes fuzzy input that will be processed by the ESP32 microprocessor into a time value in minutes to operate the Humidifier and Fan.



(a) Humidity (%) (b) Temperature (℃)

(c) TH (minutes) (d) TF (minutes)

Figure 3. Membership Functions for Two Inputs and Two Outputs.

FIS (Fuzzy Inference System) is a method used to map fuzzy inputs into fuzzy outputs using fuzzy rules. In this proposed system, the method employs the Mamdani FIS, with the fuzzy inputs being humidity and temperature parameters in an Swiftlets house. Meanwhile, the outputs are the time values TH and TF in minutes. Membership functions for both input and output variables use a combination of trapezoidal and triangular shapes, as shown in Figure 3.

The establishment of fuzzy rules for the FIS method consists of 16 rules, as shown in Table 1.

Table 1. *Fuzzy Rules in the System.*

No.	Humidity	Temperature	Humidifier	Fan
1	Very Dry	Very Cold	Long spray	Very short
2	Very Dry	Cold	Long spray	Very short
3	Very Dry	Medium	Long spray	Long
4	Very Dry	Hot	Long spray	Long
5.	Dry	Very Cold	Medium	Very short
6	Dry	Cold	medium	Very short
7	Dry	Medium	Medium	Medium
8	Dry	Hot	Medium	Long
9	Wet	Very Cold	Short Spray	Very short
10	Wet	Cold	Short Spray	Short
11	Wet	Medium	Short Spray	Short
12	wet	Hot	Short Spray	Medium
13	Very wet	Very Cold	Very short	Very short
14	Very wet	Cold	Very short	short
15	Very Wet	Medium	Very short	Medium
16	Very wet	Hot	Very short	Medium

After passing the functional testing of all control components and system integration, the program code (sketch) is written using the Arduino IDE (Integrated Development Environment) version 1.8.19. The sketch writing consists of three parts: Initialization, Setup, and Looping.

The initialization process consists of several parts, namely: Defining BLYNK TEMPLATE ID, Template name, and AUTH Token, Including the required library files and defining all the variables used, Defining membership functions (MF) for fuzzy input and output. The Setup process includes several configurations, namely: Setting the terminal (port) function and serial communication speed on the Microcontroller, Defining the Fuzzy rules used, Connecting Blynk IoT variables to the microcontroller. The Looping process includes several activities, namely: Executing all program subroutines, Displaying all microcontroller output parameters on the dashboard view on Web BLYNK cloud or on a smartphone display.

Before system integration is performed, a performance test is conducted on sensor components to ensure accurate measurements of temperature (T), humidity (H), voltage (V), current (I), and power (P). The next step is a prolonged performance test after integrating all components into the system, which typically lasts around 8 weeks. This ensures that the hardware prototype can be used in real conditions without a significant decrease in performance over an extended period. Following these performance tests, an analysis is conducted based on FIS (Fuzzy Inference System) simulations and experimental results.

3. Result and Discussion

After the fuzzification process and the formation of fuzzy rules, implementation is carried out using MATLAB software to determine the system's output in response to changes in temperature and humidity. Figure 4 shows the results of simulation 1 in the Rule Viewer. Column 1 represents changes in humidity, column 2 represents changes in temperature, column 3 is the Time Humidifier On (TH), and column 4 is the Time Fan On (TF). If the humidity is 80%, and the temperature is 28℃, then the humidifier and fan will run for 9.1 minutes.

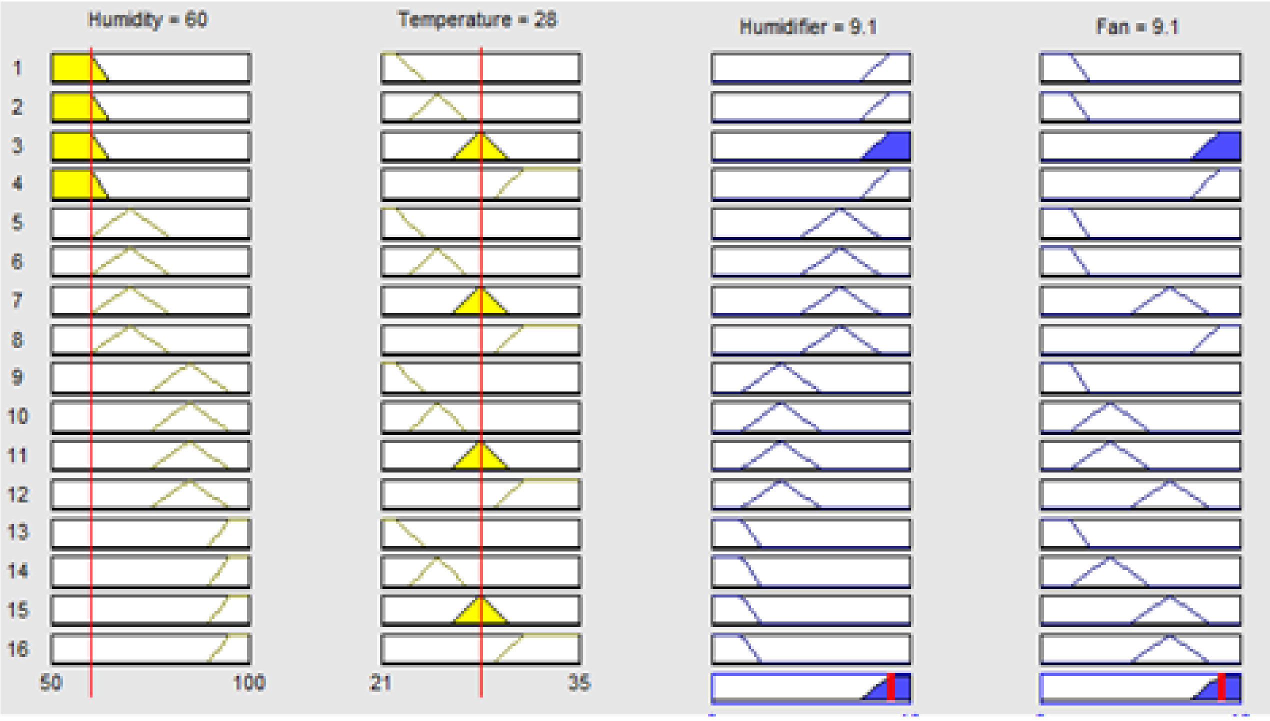


Figure 4. *Simulation 1 with input: H=60% T=28 ℃, Output: TH and TF = 9.1 minutes.*

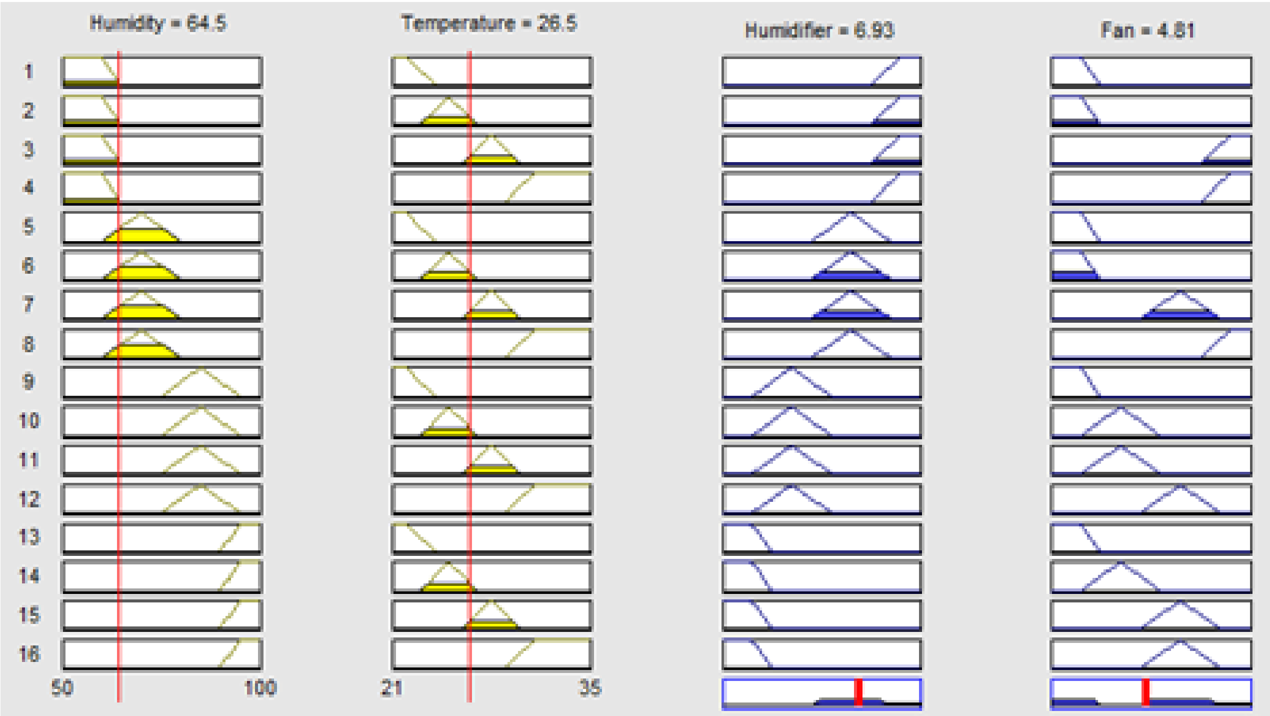
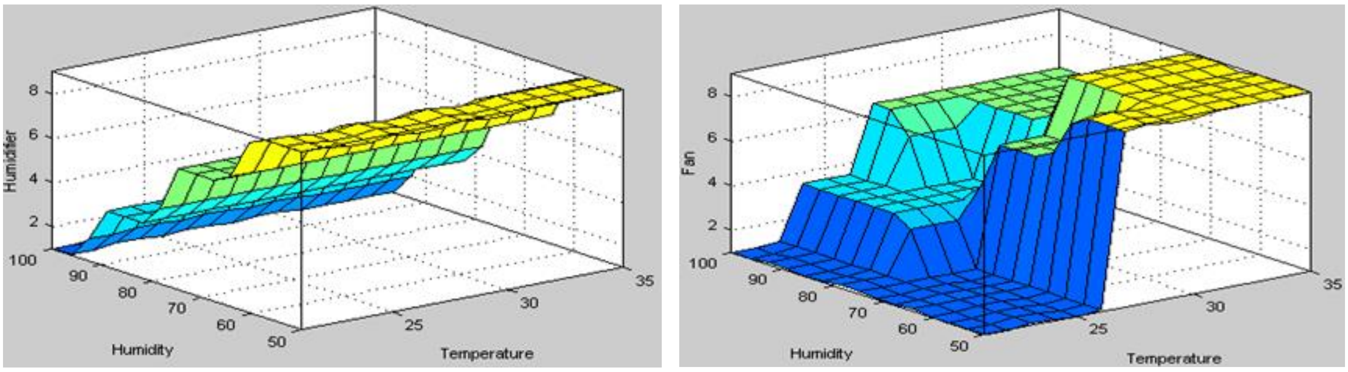


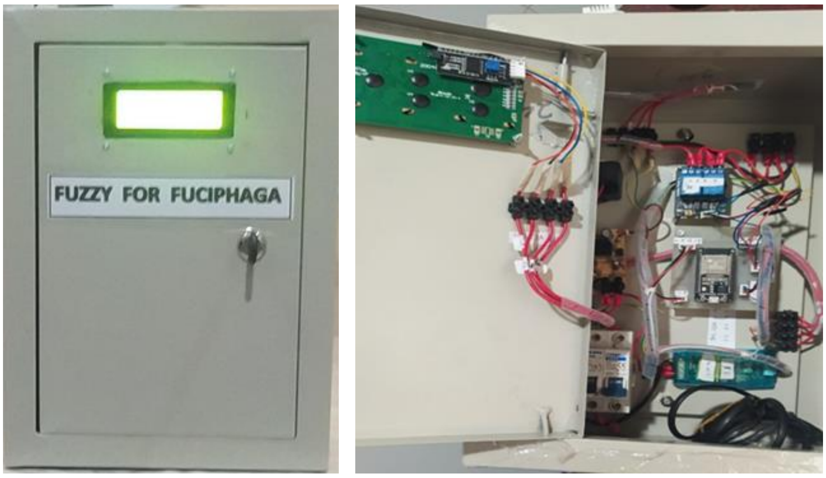
Figure 5. *Simulation 2 with input: H=64.5% T=28.5 ℃, Output: TH=6.93 minutes and TF = 4.81 minutes.*

Figure 5 is the result of simulation 2 in the Rule Viewer. If Humidity = 64.5% and Temperature = 28.5 ℃, then the values of TH and TF are 6.93 minutes and 4.81 minutes, respectively. The relationship between the input variables T and H and the output variables TH and TF in a 3-dimensional form through the Surface Viewer is shown in Figure 6. The X-axis represents the Temperature value, the Y-axis represents the Humidity value, and the Z-axis represents the values of TH and TF outputs.



(a) Humidity and temperature on the duration of TH (b) Humidity and temperature on the duration of TF

Figure 6. *MATLAB Surface Viewer.*



(a) (b)

Figure 7. *Prototype System Display (a) Front View (b) Interior View.*

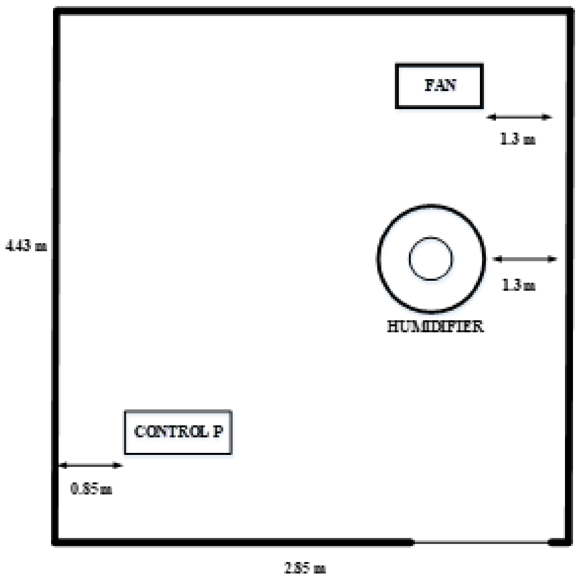


Figure 8. *The Placement of the Prototype Inside the Experimental room.*

The prototype of the control and monitoring system for the Swiftlets house is placed on a panel made of iron plate measuring 35 x 25 x 15 cm, which has been equipped with overload protection and a 4x20 LCD to display parameters such as humidity, temperature, and other electrical parameters, as shown in Figure 7.

The experiment for the design and construction of the prototype system was conducted in a small room size of 2.85 x 3.4 x 4.43 m, with the placement of the control panel, a humidifier, and a fan as shown in Figure 8.

Based on the experiments conducted on the prototype, it is evident that the final conditions of humidity and temperature parameters will have different values depending on the initial humidity and temperature conditions, as shown in Table 2. The temperature and humidity data were taken from morning to midday, because during this time the temperature and humidity parameters experienced significant changes. Morning time is a transition from slightly cold to hot temperatures, and slightly wet to very dry humidity.

***Table 2**. The Prototype experiment Results.*

No.	Initial Condition		Time		Final Condition	
	H (%)	T (°C)	TH (minute)	TF (minute)	Humidity (%)	Temp.(°C)
1	64.20	27.20	6.95	6.95	84.60	26.30
2	83.60	27.20	3.50	3.50	88.10	26.20
3	87.30	26.20	3.50	3.50	91.00	26.10
4	68.20	27.80	6.50	6.50	84.50	25.60
5	63.00	26.70	7.49	6.36	87.40	24.50
6	73.60	25.50	6,50	1.10	90.10	24.50
7	79.60	26.00	3.79	3.37	89.50	26.20
8	72.20	25.90	6.50	1.12	88.90	24.40
9	75.70	25.80	6.03	1.64	86.40	24.60
10	74.40	24.40	4.67	2.88	85.60	23.70
11	74.40	24.70	6.50	1.12	86.00	24.40
12	77.10	24.90	5.22	2.43	82.40	26.40
13	75.50	25.50	6.15	1.50	86.20	24.10
14	66.10	26.10	6.50	1.13	85.50	24.10
15	63.80	26.80	7.17	6.40	85.00	24.20
16	71.00	28.40	6.50	6.50	91.70	26.50
17	91.80	26.60	2.55	5.00	87.20	26.50
				Average	87.06	25.19

Based on Table 2, the average humidity value is 86.06%, and the temperature is 25.19 ℃. These average values are still within the ideal range for humidity and temperature in their natural habitat, which is 85-95% humidity and 25-27 ℃ temperature. However, the placement of the prototype in the actual Swiftlets house should be done in a movable manner, especially in places where swiftlets are likely to settle. After successfully attracting swiftlets to one location, the prototype can be moved to another location so that all areas have the opportunity for swiftlets to settle. This relocation is done to ensure that all floors of the Swiftlets house can experience ideal conditions, thus improving both the quantity and quality of swiftlets nests over time.

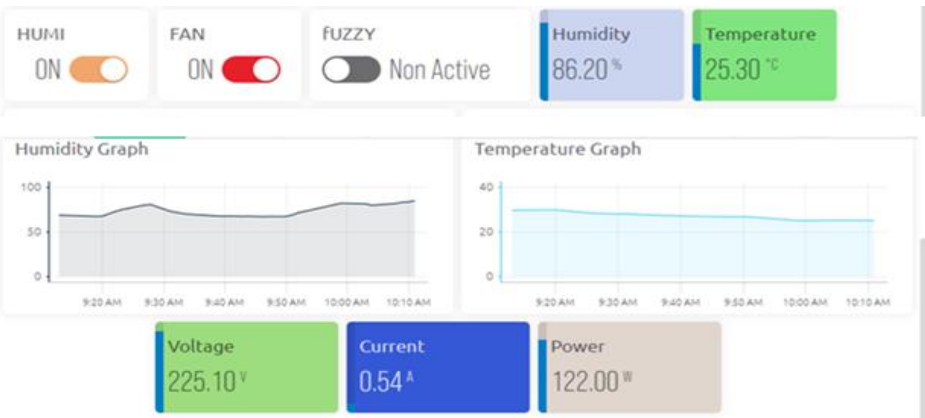


***Figure 9**. Display of parameters on the web.*

Another feature of the prototype is that a swiftlets farmer can monitor all parameters globally through communication devices such as smartphones, laptops, or similar devices, as shown in Figure 9. These parameters include Humidity, Temperature, Voltage (V), Current (I), and Power (P). Therefore, a swiftlets farmer can monitor the conditions of their Swiftlets house and quickly detect any technical disturbances that may occur in the prototype.

4. Conclusion

The purpose of this research is to design and construct a prototype system that can be used to control and monitor a Swiftlets house in order to produce better quality and quantity of swiftlet nests, thereby increasing the selling price. The experimental results indicate that the Fuzzy-based Mamdani FIS output in this prototype has averages of humidity 87.06% and a room temperature of 25.19 ℃. These output values align well with the original habitat conditions of swiftlets, which typically have humidity ranging from 85-95% and a temperature of around 25-27 ℃. The existence of this prototype will greatly assist swiftlet farmers in paying closer attention to the swiftlets house conditions, enabling easier control and monitoring through widely-used smartphone devices. However, to produce an ideal condition evenly in all parts of the building, the placement of this prototype within a Swiftlets house should be movable within certain rooms and positioned according to the swiftlets' needs to ensure that the location is favored by the swiftlets.

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Author Contributions

Achmad Marzuki: Conceptualization, Formal Analysis, Software, Writing Original draft, Methodology, Supervision, Writing - review & editing**.**

Wawan Heryawan: Data collection, Formal Analysis, Validation, Resources, Project Administration.

Irman Dulhan: Design implementation, Project Administration, Formal Analysis, Resources, Validation, Data curation.

Conflicts of Interest

The authors declare no conflicts of interest.

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