Development of Oyster Mushroom Cultivation Monitoring and Control System using ANFIS

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Abstract - When growing oyster mushroom the right environment must be provided for abundant harvest. But it is a tedious process because growing of oyster mushroom need its ideal environment parameters, (Temperature 22-29 °C, Humidity 80%-90%, Light Intensity 500-1000 lux, and Carbon Dioxide concentration of 400-600 ppm) where here in the Philippines taking care of oyster mushrooms are done in a conventional manner. With this problem, the proponents created a solution that is able to monitor and control automatically the environment of the oyster mushroom house. Inputs of the system are dependent on the sensor readings from DHT22 (temperature and humidity sensor), MQ135 (carbon dioxide sensor) and TSL2561 (lux sensor). To automate the system, two data processing algorithms were developed and implemented. Programming Fuzzy Logic Control (FLC) using linguistic values. ANFIS trains FLC data for output prediction. The outcomes demonstrate that the technology stabilized mushroom farm parameters. ANFIS stabilized the parameters more quickly than fuzzy logic control and the uncontrolled method. Thus, it is a better alternative option.

Keywords—Oyster Mushroom, Pleurotus ostreatus, Fuzzy Logic Control, ANFIS, ANOVA

I. Introduction

The agriculture is a substantial sector of the economy in the Philippines, as well as a considerable contributor to the country's overall economy. Researchers have been examining a new approach for agricultural development using innovative research techniques, such as oyster mushroom production. Other tropical countries grow oyster mushrooms in forests. In the Philippines, oyster mushrooms are grown on farms or in greenhouses for consumption. According to the Philippine Statistical Authority, mushroom output in the Philippines only increased by 7.18 percent between 2019 and 2020, from 671.10MT to 721.16MT. According to Department of Agriculture researcher Troza, most of the imported mushrooms consumed by Filipinos come from Southeast Asia. According to the Food and Nutrition Research Institute, just 0.5% of Filipinos consume veggies and mushrooms, hence only 10% of the total mushrooms consumed are locally grown (FNRI). Due to a scarcity of fresh mushrooms in local markets, Filipinos do not consume mushrooms, causing farmers to be dissatisfied and incur a low return on investments, hence influencing the market's supply and demand. The lowest production volume for the Philippines was 463 metric tons [1]. The primary environmental elements that influence mushroom stalk height, stalk diameter, and cap size are environmental factors. In mushroom cultivation, adjusting temperature, humidity, light, and carbon dioxide in order to maintain a healthy and sufficient development may result in optimal circumstances and growth rate. If not regulated, excess and deficiency of these characteristics may cause mushrooms to distort and rot. In addition, these parameters are interdependent and must be maintained within the ideal range for optimal mushroom growth.

Over the past few years, different new ways of farming have been tried out and tested. One of these is the precise method of farming that aims to make farming more automated and stop crop loss caused by changes in the environment, soil diseases, and pests. Several studies have shown that specific farming methods can solve farming problems. One of the most important parts of precise agriculture is an artificial plant cultivation system. So, the right amount of food can be given, and plants can be grown in a controlled environment by keeping an eye on things like temperature, carbon dioxide (CO2), humidity, light intensity, airflow, and nutrients. [2]

II. RELATED STUDIES

A. *Precision agriculture: On the accuracy of multilevel and clustered ANFIS models for sugarcane yield categorization*

In India, sugar cane is one of the cash crops that the country is known for producing. Sugar cane also plays an essential part in the country's culture because it is an element of the economy that helps create jobs. Therefore, Jayashree et al. (2016) considered detecting early problems in growing sugarcane as their driving force to work on multilevel ANFIS based on hybrid learning 38 to have precise agriculture on sugarcane yield classification. The researchers did this to improve sugarcane yield classification. Clustering ANFIS parameters based on various optimization methodologies such as Particle Swarm Optimization (PSO), Imperialist Competitive Algorithm (ICA), and Genetic Algorithm (GA) was another primary focus of the research. With these optimization approaches, the system's accuracy will be improved, which will assist the entities responsible for making decisions regarding the import and export of crop products [3]

B. An Automated Temperature Control System: A Fuzzy Logic Approach

In 2018, The De Lasalle University of Manila had developed a study using a fuzzy logic approach to monitor and control the temperature inside a Bamboo-style greenhouse for growing lettuce crops. Five digital humidity and temperature sensors were installed inside the chamber to monitor and control the inside air temperature. The readings from five sensors were calibrated and compared to commercially available room temperature. Based on the calibration results, temperature sensors have a 3.75% mean difference only. [4]

C. IoT Based Mushroom Monitoring System & IOT for smart farms

In 2018, The Malaysian Institute of Microelectronic Systems has developed a Shiitake Mushroom Smart System (SSSM) that controls the mushrooms' temperature, humidity, and Carbon Dioxide using Wireless Sensor Network (WSN) inside the greenhouse. The system contains control devices which are triggered by predefined threshold values (Pravinthraja, 2018). Similarly, Chieochan et al. (2017) of Maejo University in Thailand have developed a system for smart agriculture using IOT, consisting of sensors for measuring the field moisture and humidity. The study also used NETPIE, which automatically monitors the sprinklers and fog pumping. It sends notifications through the use of the LINE app, which can be installed on mobile devices. [5][6]

D. Fuzzy Logic-based Controlled Environment for the Production of Oyster Mushroom

In 2019, Amen et al. of MAPUA University developed a study on a controlled environment for mushrooms using a Fuzzy Logic Based system. This study created a controlled environment with a temperature sensor and humidity sensor utilizing the Arduino-Uno Microcontroller, using a Fuzzy Logic algorithm and integrating sound with WSN to determine the productivity of the oyster mushroom. The researcher used analysis of variance (ANOVA) to determine the productivity of the three treatments. Findings revealed that the desired temperature for growing oyster mushrooms in a controlled environment is 22ºC to 29ºC, and humidity is 70% and above. The automatic control system and human control were compared. The automated control system possessed more efficiency in controlling humidity than the latter.[7]

III. METHODOLOGY

A. Design System

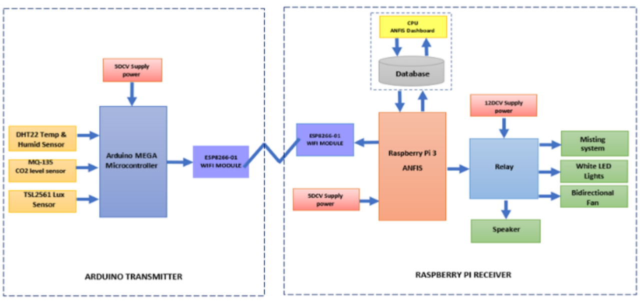

Figure 1. Block Diagram of the System

Figure 1 shows the research prototype block diagram. It includes two systems. The first system is responsible for monitoring the mushroom house's environment and sending data to the second system. The second system adjusts the mushroom house's environmental conditions shown on table 1, such as temperature, humidity, carbon dioxide, and luminosity, depending on sensor and Arduino data averages. The Arduino microcontroller operates as the transmitter, while the Raspberry Pi + CPU serves as the receiver, with an ESP8266 Wi-Fi module serving as the communication channel. Four sensor sets (DHT22, MQ-135, and TSL2561) are directly linked to the Arduino Mega 2560, which is supplied with 5V DC power. The Raspberry Pi Receiver and the ANFIS system process the received information. The CPU will consist of a database, a Web application for monitoring the status of the entire mushroom house setup, and the Adaptive Neuro-Fuzzy Inference Algorithm will be integrated to process the data received from the sensors and send commands back to the raspberry pi to manage the environmental parameters of the mushroom house by activating the misting system, white LED strips, and bidirectional exhaust fan. Under specific conditions shown on Table 2, a sound system will activate when a trigger value reaches a predetermined threshold.

TABLE 1. THRESHOLD VALUES FOR THE ENVIRONMENTAL GROWTH PARAMETERS OF OYSTER MUSHROOM

Parameter	**Setpoint Value**
Temperature	22-29 C°
Humidity	80% - 90%
Light Intensity	500-1000 lux
CO_2 Level	400 - 600 ppm

TABLE 2. TRIGGERING CONDITIONS FOR THE SOUND OF A THUNDERSTORM

Condition	**Result**
IF Humidity is >80% AND temperature drops from original value into its 60-80% value, speaker will turn on.	Thunder sound will trigger.
Stop IF humidity drops <80% AND if temperature stabilizes to its 60-80% value.	Sound will stop.
Else	Speaker will turn off.

Figure 2 shows the flowchart of the system used for fuzzy logic control; to begin, it initializes the Arduino and then establishes a link with the Raspberry pi across the same network. After the connection has been made, the Arduino will send the readings from the sensors, including temperature, humidity, and lux, for Fuzzification, in which the actions are to be determined based on the membership values, and will then proceed with the Defuzzification process, in which the Actuators will either activate or not activate. As soon as the criteria are satisfied, the data will be promptly stored on the FLC server. In any other case, it will save the data in the database and continue to do so until it exceeds the threshold value

Figure 3 shows the flowchart of ANFIS, following the training of datasets from fuzzy logic control data, a new microcontroller and computer will be integrated for use with the ANFIS algorithm. The command to activate the actuators will be sent from the output of the predicted values from the ANFIS system. When the predetermined threshold values are reached, it will save the readings as well as the actions taken by the actuators in the database. In any other case, even if the threshold values are not reached, it will continue to record data in the database and keep the actuator action until the threshold values are reached.

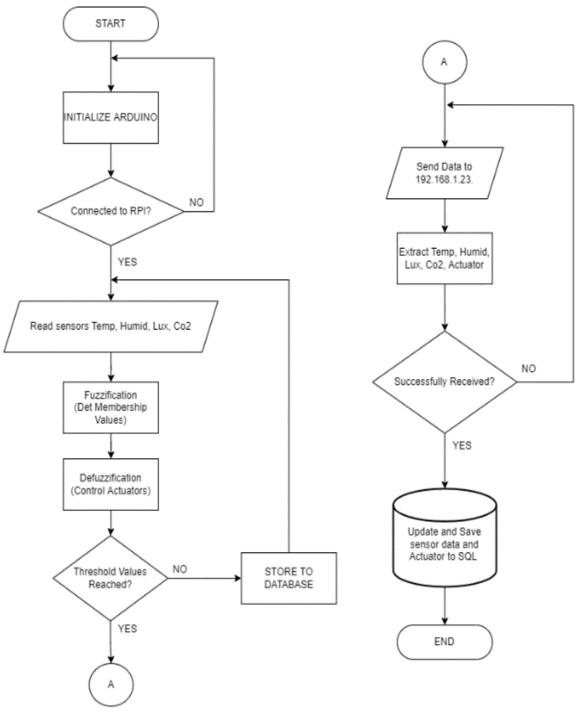

Figure 2. Fuzzy Logic Control System Flowchart Monitoring and Control

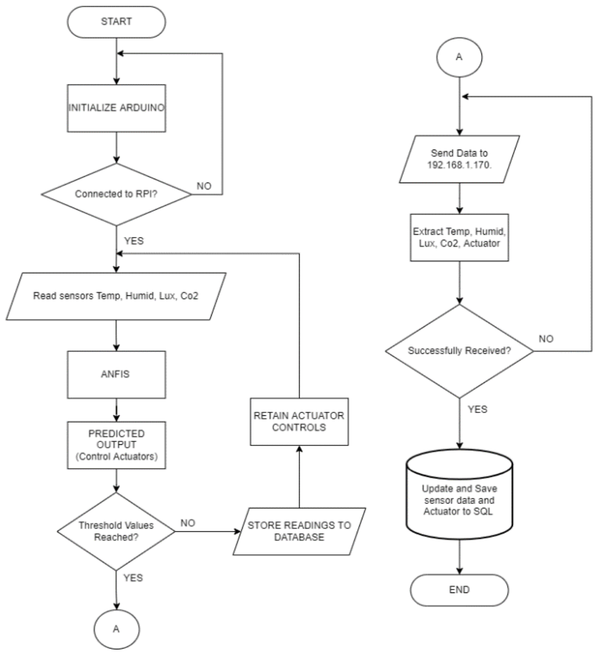

Figure 3. Flowchart of Adaptive Neuro-Fuzzy Inference System

B. Implementation of the ANFIS Algorithm

The house has a cloth wall and also is surrounded on all sides by a misting system. The placement of sensors and actuators is proportionally arranged to obtain a good response and accurate results as shown in Figure 3, the microcontrollers are attached to the frame in each room by means of a wooden frame measuring 2.5 meters by 2 meters. As can be seen in Figure 4.4, each of the four sets of sensors is attached to each of the four corners of the wooden frame. As shown in figure 6, The mushroom house includes the installation of a sound system and a bidirectional fan. All actuators are linked to a 12VDC relay module and a 12VDC power source as shown in Figure 5.

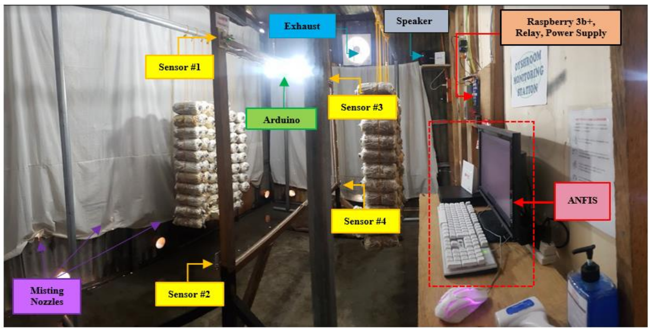

Figure 3. Actual Oyster Mushroom House with Label ANFIS side

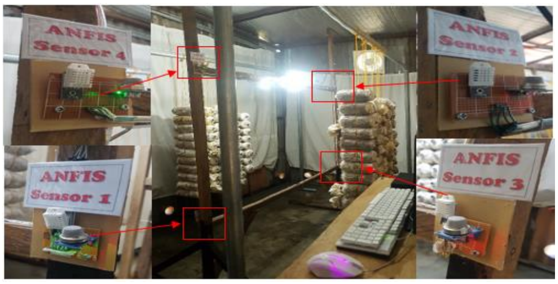

Figure 4. Sensor Placement (ANFIS)

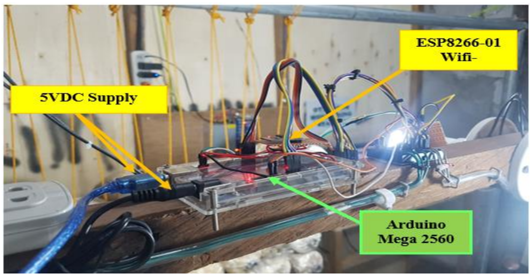

Figure 4. Placement of Arduino Mega as a transmitter at the top of the wooden frame

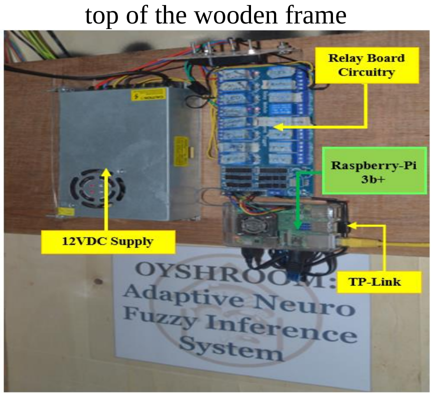

Figure 5. OYSHROOM Adaptive Neuro Fuzzy Inference System Wiring Circuit

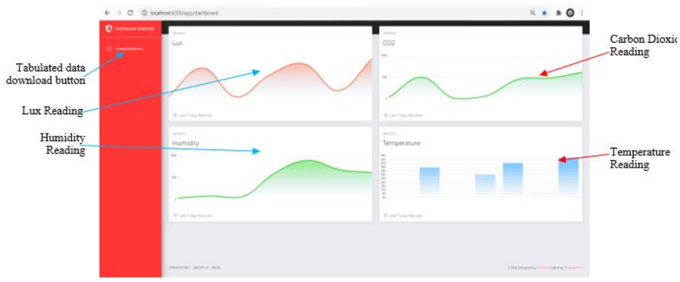

Figure 7. Web Application User Interface

Figure 7. shows the User Interface of the Web Application. It illustrates the real-time status of environmental parameters (Temperature, Carbon Dioxide, Light Intensity, and Humidity) of oyster mushrooms environment and downloads the excel file for the data readings of selected dates. The web application was used to let the user control and see the current state of the the actuators. The raspberry pi has assigned gpio pins to each Actuator. The interface has the Pin status, "turn off pin," and "turn on pin" commands that are sent to the Raspberry Pi to make the actuators work.

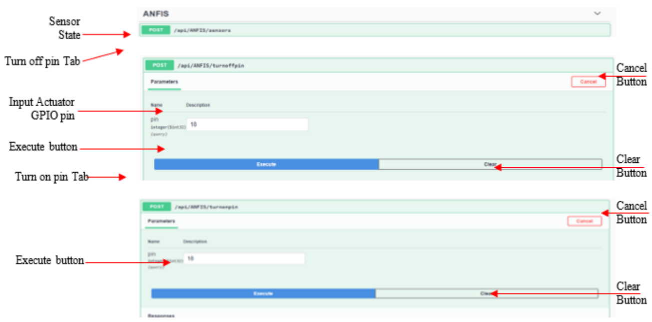

Figure 8. Manual Control and Configuration of Pins on ANFIS

Figure 8. shows the manual control available for the ANFIS side by allowing the user to input the pins of the relay before sending the command to the actuators. The status of the sensors is displayed on the first tab of the dashboard. The second tab is where the pin will be turned once it has been inserted. On the Raspberry Pi, it is used for manual control to turn off actuators based on the GPIO pins that have been assigned. The turn on pin is located under the third tab. When manual control is being used, this tab is responsible for turning on the actuators. The GPIO pin that is assigned to the actuator on the Raspberry Pi serves as the basis for the input pin as well.

C. Calibration Data

The sensors were calibrated using industry-grade sensors. The mushroom house (ANFIS) contains 4 sets of sensors that are automatically averaged by each parameter. The proponents collected data until the actual sensors are calibrated with the industrial grade sensors. The proponents calibrated the sensors for five consecutive days, Table 3 shows the sample calibration data gathered on April 3, 2021 to April 07, 2021 based from the results of the calibration the percentage difference from temperature 1.87%, humidity 0.39%, carbon dioxide 0.68%, and lux with 9.28% only.

TABLE 3. CALIBRATION DATA

Date and Time	Industrial Grade Sensor Readings				Actual Sensor Readings			
	TEMP	HUM	CO_2	LUX	TEMP	HUM	CO_2	LUX
2021-04-03	31.1	60.22	151	305.92	32.33	61.87	158.35	322.25
2021-04-04	33.5	65.72	147	335.35	32.15	64.97	153.62	327.5
2021-04-05	35.3	65.73	148	281.00	34.45	65.33	137.00	284.5
2021-04-06	34.3	60.22	142	252.23	34.00	61.53	140.75	424.25
2021-04-07	31.5	63.22	141	407.86	29.70	62.67	144.32	381.5

To measure the difference between two sensors % difference was calculated based on the equation below.

$$\% \text{ Differnce} = \frac{|\text{Mean of Industrial Grade Sensor} - \text{Mean of Actual Sensor}|}{\left[\frac{\text{Mean of Industrial Grade Sensor} + \text{Mean of Actual Sensor}}{2}\right]} \text{x100}$$

IV. TESTING AND DATA ANALYSIS

A. Readings of Enviromental Parameters

The daily average readings of the environmental parameters that were taken within the mushroom house are depicted in Figures 11 through 14. The temperature varies from 28 to 32 degrees Celsius, which is sufficiently close to the maximum limit of the optimal temperature setting, which is 29 degrees Celsius. The collection of data got under way when it was still the dry season. The world-weather report indicates that the average temperature in Imus, Cavite, during the months of April through August 2021 would range from 30 to 33 degrees Celsius. This information was derived from the historical measurement readings taken there. This continues to demonstrate that the monitoring and control system for oyster mushroom growing is functioning properly and is a feasible option. In terms of humidity, it runs from 90% and higher, as opposed to 75% to 87% over the same time a year ago between April and July 2021. Both the CO_2 level and the lux readings inside of the mushroom house are always kept at ideal conditions. Using different sound meter apps, the range of decibel readings for the thunderstorm sound on the oyster mushroom house is shown to be between 67 and 71 db.

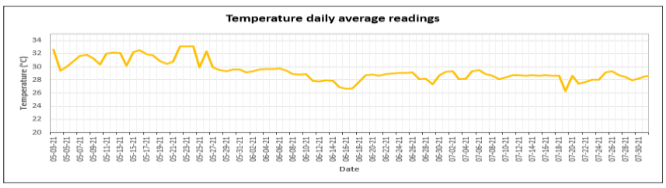

Figure 11. Temperature Daily Average Reading using ANFIS

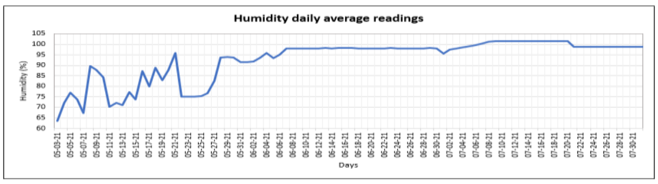

Figure 12. Humidity Daily Average Reading using ANFIS

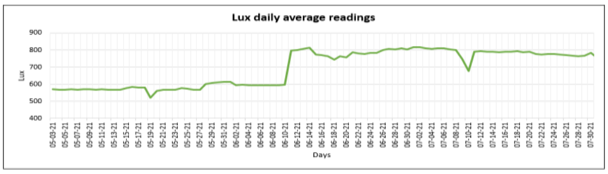

Figure 13. Lux Daily Average Reading using ANFIS

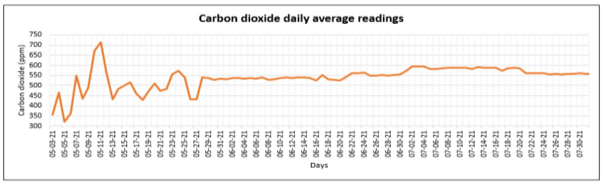

Figure 14. Carbon Dioxide Daily Average Reading using ANFIS

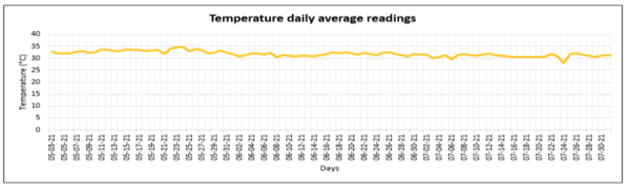

Figure 15. Temperature Daily Average Readings using Conventional Method

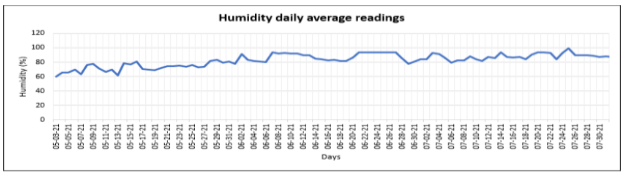

Figure 16. Humidity Daily Average Readings using Conventional Method

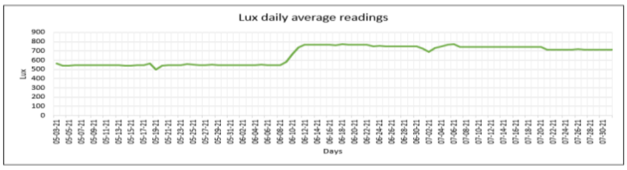

Figure 17. Lux Daily Average Reading using Conventional Method

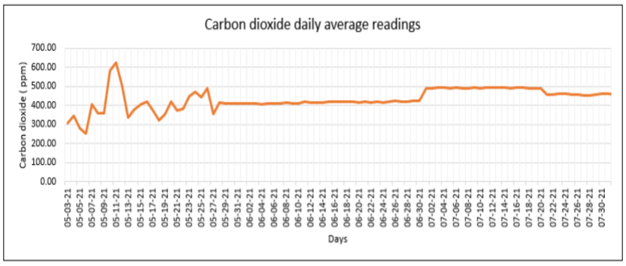

Figure 18. Carbon Dioxide Daily Average Reading using Conventional Method

B. *Statistical Analysis*

The Analysis of Variance ANOVA is used to statistically treat the gathered data parameters to identify whether there is a significant difference between the three techniques of cultivating oyster mushrooms. Tables 4 to 7 summarize the results for temperature, humidity, lux, and carbon dioxide at an alpha level of 0.05. Temperature has an F-statistical value of 136.9919, humidity has a value of 42.6641, lux has an F-statistical value of 8.35189, and carbon dioxide has a value of 145.014. Because of the exceedingly unusual sample correlation, the null hypothesis for Temperatures, Humidity, Lux, and Carbon dioxides of each method is rejected, and the Alternative hypothesis is accepted.

TABLE 4. SUMMARY OF ANALYSIS USING ANOVA FOR TEMPERATURE

ANOVA for TEMPERATURE			
	FLC	ANFIS	CONVENTIONAL
No. of Data	119	119	119
Mean	30.831	29.287	31.869
Variance	1.431	1.907	1.063
F-statistic bet. Groups	136.9918662		
F-Critical bet. Groups	3.021227351		
P-value bet. Groups	8.64E-45		
Decision	Reject Ho		
Interpretation	There is a significant difference		

TABLE 5. SUMMARY OF ANALYSIS USING ANOVA FOR HUMIDITY

ANOVA for HUMIDITY			
	FLC	ANFIS	CONVENTIONAL
No. of Data	119	119	119
Mean	92.049	94.082	83.967
Variance	89.720	81.650	68.147
F-statistic bet. Groups	42.66406502		
F-Critical bet. Groups	3.021227351		
P-value bet. Groups	2.51E-17		
Decision	Reject Ho		
Interpretation	There is a significant difference		

TABLE 6. SUMMARY OF ANALYSIS USING ANOVA FOR CO2

ANOVA for CARBON DIOXIDE			
	FLC	ANFIS	CONVENTIONAL
No. of Data	119	119	119
Mean	533.50	549.17	442.28
Variance	2580.0	2831.6	2792.3
F-statistic bet. Groups	145.0135925		
F-Critical bet. Groups	3.021227351		
P-value bet. Groups	9.94338E-47		
Decision	Reject Ho		
Interpretation	There is a significant difference		

TABLE 7. SUMMARY OF ANALYSIS USING ANOVA FOR LUX

ANOVA for LUX			
	FLC	ANFIS	CONVETIONAL
No. of Data	119	119	119
Mean	664.34	710.62	674.72
Variance	8218.41	8923.20	8070.44
F-statistic bet. Groups	8.351887177		
F-Critical bet. Groups	3.021227351		
P-value bet. Groups	0.000285626		
Decision	Reject Ho		
Interpretation	There is a significant difference		

Figure 17. Decibel Readings of the Thunderstorm Sound

V. Conclusion and Recommendations

The proponents were able to construct an environmental growth chamber using temperature, humidity, lux, and CO2 sensors, as well as actuators such as exhaust fans, misting systems, LED lighting, and speakers. They were interconnected by the microcontrollers Arduino and wirelessly communicating with raspberry pi and the Wi-Fi module. This system is integrated using Arduino and C# programming, where the program created can monitor, control, and regulate the specific threshold parameters for mushroom development. Based on the graphs of the regulated system's daily average temperature, humidity, CO, and lux of the controlled system, it is evident that the mushroom oyster house is indeed controlling and maintaining the set parameters into its threshold values compared to the uncontrolled system.

For the monitoring system it is recommended to have cloud data storage, appropriate cooling systems to mitigate the effects of extreme temperatures during summer, have a self-sustaining mushroom house with power management, and develop a mobile application that can modify the enduser to access the monitoring display analysis.

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