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Implementation of fuzzy inference system algorithm in brooding system simulator with the concept of IoT and wireless nodes

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Abstract. This paper aims to implement the Fuzzy Inference System algorithm as a controller in an IoT-based observation system in a brooding system simulator. The system consists of sensor and actuator nodes that are connected to the internet using a microcontroller. The two nodes are connected wirelessly. Sensor nodes as devices that collect input data variables that are temperature and humidity. The value of the sensor readings is sent to Antares cloud storage by a microcontroller which functions as data storage so that it can be accessed by the user as well as an input controller. The Mamdani Fuzzy Inference System algorithm is implemented on the actuator node. The actuator node takes fuzzy input values from Antares and then outputs in the form of a PWM crisp value that aims to regulate blower speed and heating level. The experiments performed were comparing the calculation of the algorithm using MATLAB and the brooding system simulator. The results showed identical outputs with practical results with an average error of 0.11% for the PWM value of the blower and 0.22% for the PWM value of the heater. The scheme is expected to be an alternative solution for implementing the control algorithm on an IoT-based system.

1. Introduction

Broilers less than 2 weeks old still need a brooding system with a temperature range of 24° C - 32° C and a humidity range of 55% - 70%, so to meet these needs requires a brooding system [1]. The brooding period is the age period of broiler chickens that require more intensive attention so that their needs can be met properly [2]. Several alternative solutions were developed including the implementation of an observation system with the concept of the Internet of Things (IoT) as a medium for gathering the latest condition information [3,4]. The information was obtained from various observations using some sensors. The diversity of sensor types that are easily applied to the IoT concept provides other alternatives in its application, including the concept of sensors and wireless actuators. Wireless sensors and actuators can be diverse devices that can be placed at various points as needed, so that the process of computing, control, and communication become an important part in carrying out a particular process [5-7].

In the brooding system, several sensors and actuators can be implemented which are temperature and humidity sensors along with heater and blower actuators. Sensors and actuators are stored at a point in the enclosure area separately without cables so they can be part of the wireless node. The use of the IoT concept can facilitate the collection and use of data from each node so that the collectivity of sensor and

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actuator data can be maximally utilized as needed and can be easily accessed. The results of the sensor readings that are connected wirelessly and placed in an area that has been determined around the chicken coop can provide information in real-time so that it can be used as input for decision making for the actuator. One of the media that can be used to collect data is cloud storage platform Antares [8,9].

Temperature and humidity information obtained from sensors can be collected in cloud storage, then can be observed and accessed as input for decision-making algorithms. The actuator node as the final control element can operate to process information and make decisions based on sensor data from cloud storage. Many algorithms can be implemented based on the characteristics of the controller device used. In this study, the controller used on the sensor node uses the NodeMCU ESP8266 board while the actuator node uses the Arduino Nano and ESP8266 boards. The algorithm that can be implemented for decision making and can be stored on a microcontroller is the fuzzy logic algorithm [10-14]. The use of a fuzzy logic algorithm on wireless nodes can be used as a determinant of inference conditions [15].

The advantages of this research can be developed in a study that combines the concepts of IoT, wireless nodes and Fuzzy Inference System (FIS) algorithms as an alternative process of monitoring and controlling the brooding system. Mamdani's FIS algorithm is implemented on the actuator node. The actuator node takes fuzzy input values from cloud storage and outputs from the FIS in the form of a PWM firm value that aims to regulate blower speed and heating levels. The experiments performed were comparing the calculation of the FIS algorithm using the MATLAB software and the brooding system simulator. The latest condition data can be sent to cloud storage and displayed graphically via Antares.

2. Method

The research process is carried out by making several stages of design, discussing system architecture, flowchart of sensors node and flowchart of actuators node, and FIS algorithm.



2.1. System architecture

Figure 1. System architecture.

Based on figure 1, the process of taking data from the temperature and humidity sensors (BME280) around the sensor is a sensor node. The data will be taken by the controller and then sent to Antares cloud storage and can be displayed. The actuator node will take data from cloud storage as input to the FIS algorithm. The type of fuzzy logic used is the Mamdani type with the centroid defuzzification method. The fuzzy logic process in the control system will produce an output in the form of a Pulse Width Modulation (PWM) signal, then the signal will be processed by the motor driver to regulate the blow speed and heat level.

2.2. Flowchart of sensor and actuator nodes

The flowchart is divided into a sensor node and actuator node. The sensor node sent temperatur and humidity value to Antares cloud storage as shown in Figure 2. Whereas the actuator node get temperatur and humidity value for Antares cloud storage and will be processed by FIS algorithm.



2.3. Design of fuzzy inference system algorithm

2.3.1. Fuzzification. The fuzzification process is a step of the system to change crisp inputs to the fuzzy set domain. These inputs will be formed as fuzzy input in the form of linguistic variable which are determined based on the membership function used. In this research, a fuzzy inference system algorithm is used with two inputs and two outputs. The fuzzy set for FIS input is shown in Figure 5 and then the fuzzy set for FIS output is shown in figure 6.



Figure 4. Fuzzification of inputs.

Figure 5. Fuzzification of outputs.

2.3.2. Inference. The inference process is needed. Based on FIS rules that are built based on inputs and outputs discussed in tables 1 and tables 2. FIS Fix all the rules that are made the basis of knowledge. The method used in the inference process used is the if-then rule with the Mamdani type. The rules constructed to consist of rules for moving blowers and heaters with each rule consisting of 25 pieces. Table 3 shown rules for blower and heater.

2.3.3. *Defuzzification*. The defuzzification process used to map the values of fuzzy sets into crisp values is the Centroid method. In the Centroid method, a resolute solution is obtained by taking the central point of the fuzzy area.

In1\ In2	Very cold	Cold	Warm	Hot	Very hot	
Very dry	B: Normal	B: Slow	B: Very slow	B: Very slow	B: Very slow	
	H: Fast	H: Mid	H: Slow	H: Very slow	H: Very slow	
Dry	B: Fast	B: Normal	B: Slow	B: Very slow	B: Very slow	
	H: Fast	H: Mid	H: Mid	H: Slow	H: Very slow	
Moist	B: Very fast	B: Fast	B: Normal	B: Slow	B: Very slow	
	H: Fast	H: Fast	H: Mid	H: Slow	H: Very slow	
Wet	B: Very fast	B: Very fast	B: Fast	B: Normal	B: Slow	
	H: Very fast	H: Very fast	H: Mid	H: Mid	H: Slow	
Very wet	B: Very fast	B: Very fast	B: Very fast	B: Fast	B: Normal	
	H: Very fast	H: Very fast	H: Fast	H: Mid	H: Slow	

Table 1. If-then rules for blower (B) and heater (H) output.

3. Result and discussion

In the simulator brooding system with dimensions $42 \ge 30 \ge 27$ cm, there is an overall system implementation, the sensor nodes are placed inside the simulator while the actuator nodes are placed at the top with the heater and blower positions leading to the simulator. As shown in the figure 6.



		AGUS ROHN		
ome / Widgets				
Scarch Widgets	Q + Add W			
Grafik Suhu	Grafik Kelembaban			
Data Source: temperature (MonitoringSistem/BME280Sensor)	Data Source: hum/dity (MonitoringSistem/BME280Sensor)			
4D temperature	100 burnio	iity		
20	50			
0 7.41 pm 7.46 pm	0 7:41.pm	7:46 pm		

Figure 6. Brooding system simulator with sensor node and actuator node.

Figure 7. Graphics display on the Antares platform.

Data that is read by the sensor node will be sent periodically to the Antares platform, then Antares will start recording temperature and humidity data. The images resulting from recording data in Antares can be seen in figure 7. The actuator node will pull the last data on the Antares platform. For the communication process between ESP01 and Arduino Nano, any data pulled from Antares will be displayed on the LCD. At this actuator node, the fuzzy inference system algorithm is implemented.

Algorithm testing is done by changing the input values and observing changes in output values and comparing them with calculations simulated using Fuzzy Logic Toolbox MATLAB software. The following results of the comparison between the simulation and the implementation are shown in Table 5. Enter the system in the form of a temperature and humidity value with an output in the form of blower and heater PWM. Based on table 2, ten experiments have been carried out with different input values to produce a different output. The difference that can be observed from these experiments is the number behind the comma. The FIS results based on simulation and implementation have identical values and there are no significantly different values.

No -	Input		Actuator node		Fuzzy Logic Toolbox		Error	
	Temp (°C)	Humidity (%)	Blower (PWM)	Heater (PWM)	Blower (PWM)	Heater (PWM)	Blower (PWM)	Heater (PWM)
1	25.00	68.00	203.0	181.0	203	181	0	0
2	29.98	57.47	155.9	137.5	157	138	1.4	0.5
3	29.90	49.28	135.0	128.9	135	129	0	0.1
4	33.25	75.81	178.1	137.5	177	138	1.1	0.5
5	27.94	44.78	111.7	87.5	111	87.5	0.7	0
6	28.18	48.41	132.1	120.6	132	121	0.1	0.4
7	30.28	47.29	126.6	109.0	127	106	0.4	3
8	31.04	41.75	113.2	57.8	113	57.7	0.2	0.1
9	30.71	39.15	112.7	67.2	112	66.6	0.7	1.4
10	28.59	49.03	134.2	126.5	134	127	0.2	0.5

Table 2. Comparison result of the FIS algorithm.

4. Conclussion

Implantation scheme for control and monitoring system in the Brooding system can be realized using an integrated system consisting of sensor nodes and actuator nodes. The decision-making process using a fuzzy inference algorithm with Mamdani type can produce PWM output values that are relatively the same as the results of practice, PWM blower error simulation is 0.11% and PWM heater is 0.22%. Fuzzy

inference system programming can be integrated with microcontrollers and IoT platforms by sending control signals in the form of PWM outputs that vary according to the input of temperature and humidity sensors.

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