Internet of Things (*IoT*) Based Multi-server Room Temperature and Humidity Monitoring and Automatic Controlling by Using Fuzzy Logic Controller

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Abstract. The data center is a significant space that serves as a place to store equipment related to the server. Important data must also be safeguarded inside the server room itself, thus security standards are required to safeguard the space, starting with air temperature, humidity, fire disaster prevention, etc. In this paper, the authors propose an Internet of Things (IoT)-based system that uses MPX5100dp sensor for measuring room pressure, the DHT11 sensor, to detect humidity and temperature, with Node-MCU ESP8266 as the transmitter and microcontroller, and the Blynk application as the MQTT bridge to display the measurements and actuator reactions on mobile phones with Android as the platform. The mechanism on this device can track the temperature of the data center's room in real time and could run as expected. This has been proven by testing.

Keywords: DHT11 sensor · MPX5100dp sensor · Node-MCU ESP8266 sensor · Internet of Things

1 Introduction

For data service providers, servers are critical for client computers. The impact of temperature outside tolerance, which results in data center hardware damage due to a room temperature that is too hot, can be caused by room cooling that is not performing properly or has difficulties that the data center operational team is unaware of [1]. For this reason, the server room temperature needs to be monitored regularly, so that if a temperature deviation occurs outside the tolerance limit, it could be immediately identified and followed up so that there is no damage to the server [2].

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In fact, due to several factors that influence it, such as the human actor himself and his position, monitoring and measuring temperature and humidity in multiple separate rooms simultaneously and in real time is not easy to perform directly and accurately in all conditions [3]. These constraints to receiving temperature and humidity information can be reduced with the introduction of Internet of Things (IoT) technologies [4].

In this paper, the author proposes a system that can monitor temperature and humidity on multi-room servers in real time based on IoT using ESP8266, DHT11 humidity temperature sensor and MPX5100dp sensor. The design of this temperature and humidity monitoring system aims to automate the measurement and monitoring of temperature and humidity by using the android platform. Moreover, it could monitor the state of the temperature and humidity of each room in the data center and it also as a reference if it is detected that the server room temperature exceeds the specified standard [5]. Furthermore, by utilizing a controller on the damper opening drive motor that uses fuzzy logic as a decision maker, this system could handle fluctuations in temperature and humidity in each room. This is a contribution of the paper. Sensors and actuators are instruments that facilitate physical environment interaction. The data collected by the sensors must be stored and intelligently processed in order to derive useful conclusions [6].

The organization of this paper is as follows. Section 1 provide the reasons and objectives why this automatic monitoring and control system is proposed and its contribution. Section 2 gives related works about integrated system which is proposed. Section 3 discusses methods which is used to develop this system and test the system. Section 4 explains the proposed technique and describes the systems application and discuss the simulation results and compares them to manually measuring techniques statistically. Section 5 Conclusion of this paper.

2 Related Works

After several decades of development, Internet of things (IoT) became one of an important part in information technology. Instead of analyzing IoT's core technologies, a collection of lightweight smart buildings for organization computer rooms [7]. The system uses sensors to collect environmental data, and through the Raspberry Pi process, controllers will make adaptive responses, such as turning on the air conditioner and alerting users. Experiments demonstrate that the system can be an effective remedy for the inefficiency of current room management, particularly in college computer rooms, and provide a new application for the Internet of Things [8].

Five smaller scale sensors of natural parameters (air temperature, humidity, carbon monoxide, carbon dioxide, and luminosity) were employed. To detect specific types of contamination, various sensors can be included. The results demonstrate that the system is able to provide a viable indoor air quality evaluation in order to anticipate technical interventions for improving indoor air quality. Indeed, indoor air quality can be distinctly compared to the norm for a quality living environment [9]. The combination of IoT with new-age information and communication technologies promises reliable solutions for enhanced environmental health and well-being [10].

The air's temperature and relative humidity are crucial for maximizing productivity in the room. One of the causes of the server becoming hot is unsuitable temperature or humidity in the server room. There are a number of factors that make server air less conducive, such as the influence of temperature; if the temperature is too high, it can damage the hardware, and if it is too low, it can waste a great deal of electricity [11–13].

The prototype from [14] contains various types of sensors that measure all measurable temperature and humidity parameters. This system can be utilized to monitor the temperature and humidity of a specific room or location. The proposed system continuously transmits data to the cloud for remote data monitoring. For direct monitoring and regulation, the system is equipped with dynamic Telegram application-based user notification capabilities. The creation of an autonomous wireless sensor monitoring system for civil engineering constructions is discussed by Barroca [15]. The goal is to offer a method for measuring both humidity and temperature inside a concrete construction. The early age and healing phase era have been the focus of the investigation. There have been four solutions discussed.

Due to the fact that Internet-of-Things (IoT) is a developing technology, it offers a number of services to collect and analyze environmental changes utilizing web APIs from companies like IBM Watson, OpenHAB, SimpleSoft, ThingSpeak, etc. Here, we suggest a Raspberry-Pi-based system for monitoring a room's temperature that makes use of ThingSpeak as an online API. The gathered data is evaluated online, and users all over the world are given graphical output [16, 17].

3 Methods

The steps to conducting this research could be explained as follows:

- Designing the hardware of the system
- Developing the software system
- Testing the performance of the system.

3.1 Designing the Hardware of the System

The hardware design of the system can be described in the schematic depicted in Fig. 1.

The DHT 11 sensor and MPX5100dp sensor are the core component of the Temperature, Humidity and Pressure Measurement System in the Data Center Room. It measures pressure in addition to temperature and humidity. The result of sensors' reading will then be processed by the Arduino UNO Microcontroller and Node-MCU ESP8266 as input, and its output will be a servo motor that controls the damper. The data will then be presented on the Android and LCD screens after being received.

3.2 Developing the Software System

We define the temperature and humidity data from sensor DHT 11 and MPX5100dp sensor which serves to read the state of the pressure as measurement variables for the fuzzy logic input as an intelligent control algorithm. Then the input from each DHT 11 sensor and MPX5100dp sensor will be processed on the microcontroller on the Arduino

UNO and Node-MCU ESP8266 and the results of the processing will be displayed and sent to the LCD screen and Android.

We use fuzzy logic algorithm to controlling response of servo motor as actuator. The temperature measurement variable from the DHT 11 sensor is convert to language variable as follows:

- Cold [0, 20]
- Normal [15, 25]
- Hot [20, 30]
- Next, Measurement Variable (Pressure) from the MPX5100dp Sensor is as follows:
- Low [0, 50]
- Normal [45, 55]
- Height [50, 60]

By using the triangle and trapezium membership functions, we could make the fuzzification process to convert the membership degree μ of crisp values. They could be depicted in Figs. 2 and 3.

Furthermore, the result of both sensors reading is directly (crisp values) converted to membership degree of the group of language variable. After the sensors reading have been converted to membership degree of the group of language variable.

Moreover, by using the Sugeno's rule base, the response of servo motor could be explained in Table 1.

Description of rule value.

- Slightly Open: 20%
- Normally Open: 40%
- Open Wide: 60%
- Open very wide: 80%
- Fully open: 100%

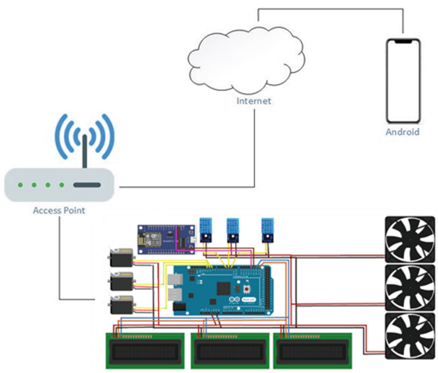

Fig. 1. System's architecture

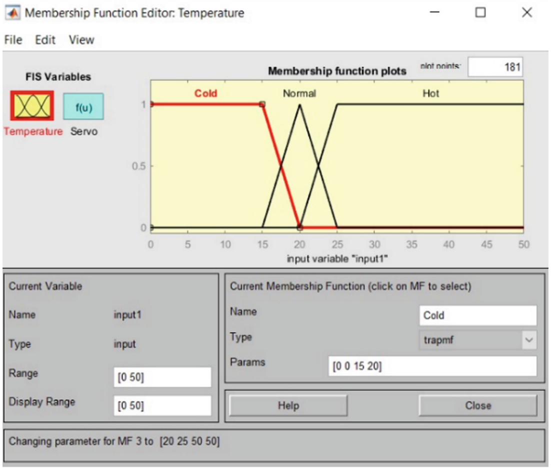

Fig. 2. Membership function of temperature.

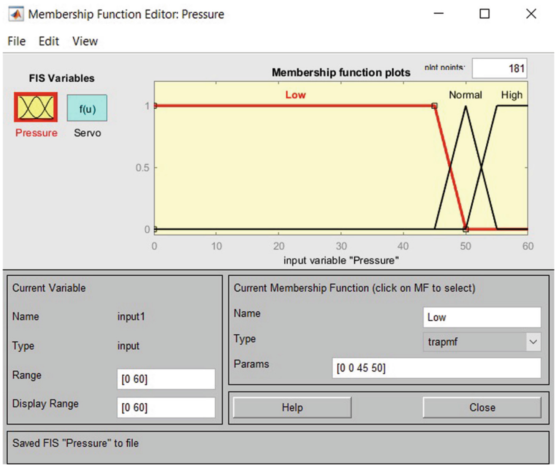

Fig. 3. Result and Discussions Membership function of pressure.

Table 1. Servo motor rules

Temp. Press.	Cold	Normal	Hot
Low	Slightly Open	Normally Open	Open Wide
Normal	Normally Open	Open Wide	Open very wide
High	Open Wide	Open very wide	Fully open

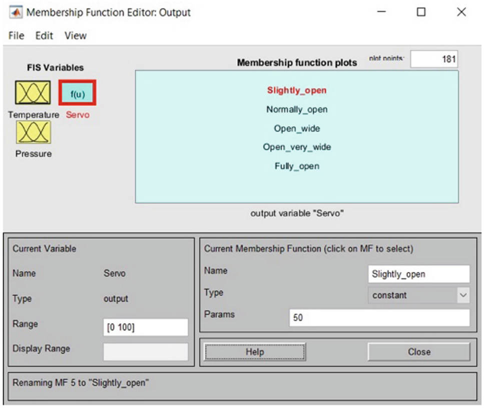

Fig. 4. Servo Motor Rule Value.

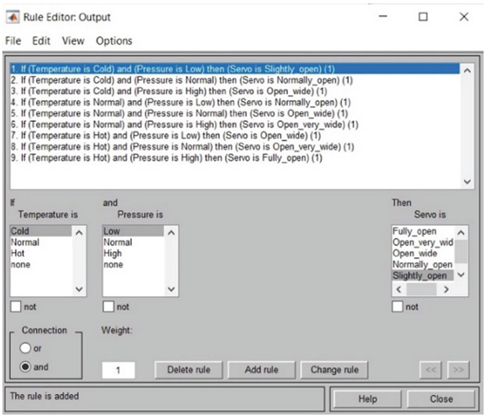

Fig. 5. Rule base of servo motor action.

The crisp value of the servo-motor response could be gotten by defuzzification process of servo-motor rules by using Eq. (1).

$$Z = \frac{\alpha_{pred_1} \times z_1 + \alpha_{pred_2} \times z_2 + \ldots + \alpha pred_n \times z_n}{\alpha_{pred_1} + \alpha_{pred_2} + \ldots + \alpha pred_n} \tag{1}$$

By using Eq. (1), then the action of servo-motor response as output variable could be determined. In the Fig. 4 describes the membership of output variable.

In addition, by using the rule base, as follows (Fig. 5).

In order to understand how fuzzy logic algorithm works in the system, the following is an example of calculation simulation with two inputs i.e., the DHT11 and MPX5100dp sensor and one output the servo-motor.

How much will the servo motor move if the average temperature is 19 °C and the average pressure is 52 kPa?

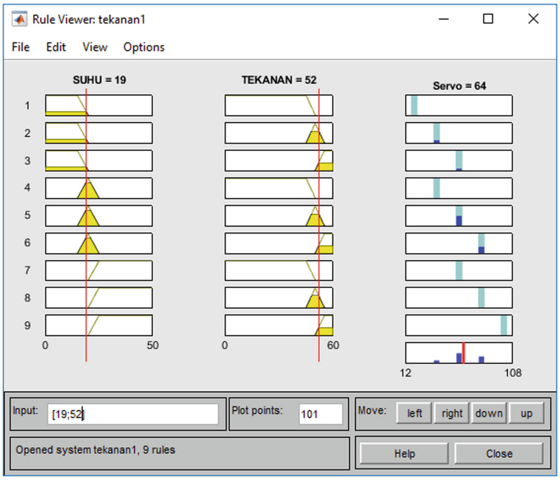

Fig. 6. The simulation result by using MATLAB.

Step 1: Conducting fuzzification process to determine the α_{pred} or membership degree μ base on the membership function. For examples, in a case the temperature 19 °C has $\alpha_{temp,normal}$ or membership degree μ of normal group is 0.8 and $\alpha_{temp,cold}$ or membership degree μ of cold group is 0.2. Next, the pressure 52 kPa has $\alpha_{press,normal}$ or membership degree μ of normal group is 0.6 and $\alpha_{press,high}$ or membership degree μ of high group is 0.4.

Step 2: By using the Sugeno rule base, it will be gotten as follows.

$$\alpha_{temp,normal} \cap \alpha_{press,normal} = 0.6$$
$$\alpha_{temp,normal} \cap \alpha_{press,high} = 0.4$$
$$\alpha_{temp,cold} \cap \alpha_{press,normal} = 0.2$$
$$\alpha_{temp,cold} \cap \alpha_{press,high} = 0.2$$

Step 3: By using the rule base of servo motor action, we find

$$\alpha_{temp,normal} \cap \alpha_{press,normal} = 0.6 \Rightarrow \text{output variable} = 60\%$$
$$\alpha_{temp,normal} \cap \alpha_{press,high} = 0.4 \Rightarrow \text{output variable} = 80\%$$
$$\alpha_{temp,cold} \cap \alpha_{press,normal} = 0.2 \Rightarrow \text{output variable} = 40\%$$
$$\alpha_{temp,cold} \cap \alpha_{press,high} = 0.2 \Rightarrow \text{output variable} = 60\%$$

Step 4: Conducting defuzzification by using Eq. (1), we can find the crisp value of servo-motor as follows.

$$Z = \frac{0.6 \times 60 + 0.4 \times 80 + 0.2 \times 40 + 0.2 \times 60}{0.6 + 0.4 + 0.2 + 0.2} = 62.5\%$$

While, it is carried out by MATLAB simulating, we can the result depicted in Fig. 6.

Manual computations produced the following results 62.5. While, the MATLAB calculations produced the following outcomes 64. Therefore, it may be stated that there is a 1.5 inaccuracy in the results of the manual and MATLAB calculations. Next, this fuzzy algorithm is embedded in the Arduino UNO Microcontroller for controlling the servo-motor response.

4 Result and Discussions

The implementation of the system is developed by the hardware parts must be related to each other and integrated according to the needs and the manufacture of room temperature control tools for a data center. The hardware specifications used in building this tool are as follows.

The Arduino UNO, Motor servo, MCU ESP8266 Node, DHT 11 (three units), 3 LCD units, Expansion Board for Node-MCU ESP8266, Laptops, Wireless Router, and Cable Jumper. The hardware for reading the DHT11 sensor value and MPX5100dp sensor value, which are processed by the Arduino UNO microcontroller and NodeMCU8266, the value will be displayed on the LCD monitor screen and the Android platform, and for the output it will drive the servo motor. The data-logger will be stored on the SD-card. The DHT11 sensor and MPX5100dp sensor will read the temperature and humidity around the data center room, which is then read and processed by the Arduino UNO and NodeMCU8266. Then the Node-MCU ESP8266 will upload temperature and humidity data to the database via the internet from the access point.

When data is read and stored in the database and updated in real time. Then the user will download the data through the Android smartphone or tablet system. The data will be displayed and updated regularly on the Android smartphone or tablet application in real time (Fig. 7).

Testing the DHT11 sensor requires the Arduino IDE and installing the DHT11 library. Testing the DHT11 sensor is done by connecting the sensor pin to the Arduino UNO board pin. If the DHT11 sensor has no errors, the Serial Monitor display will contain the data sent by the Arduino UNO, which will appear as below.

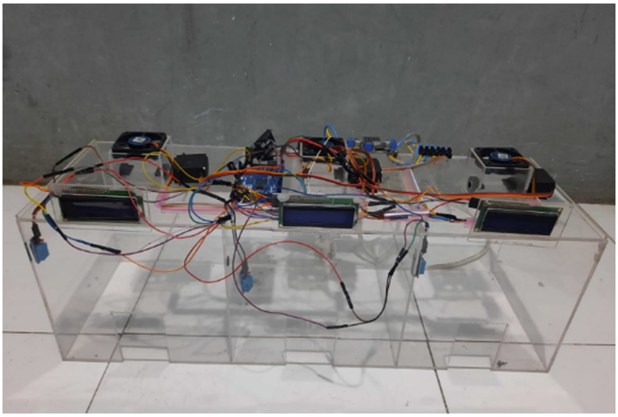

Fig. 7. The hardware circuits.

Fig. 8. Sensor test normal condition.

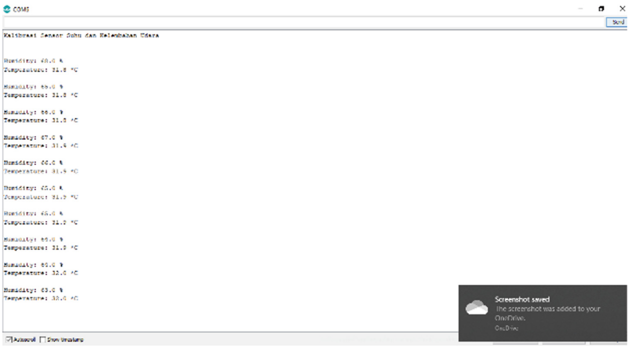

Fig. 9. Sensor test results normal condition.

Figures 8 and 9 depict the result of tests of the temperature and humidity in normal conditions. On the LCD display, it shows that the temperature and humidity in room 3 are 31 °C and 67%, respectively. While on the mobile phone screen, the readings of temperature and humidity are 31.30 °C and 67%, respectively. As a result, the servo motor responds by servo-motor 115 degrees of rotation.

Next, in pictures 10 and 11, it can be seen that the temperature and humidity under cold conditions are 27 °C and 75%, respectively. Consequently, the servo motor rotates 58 degrees in response (Figs. 10 and 11).

Figures 12 and 13 show that in hot conditions, the temperature and humidity are 36 °C and 51%, respectively. The servo motor subsequently rotates 154 degrees as a result.

From the above test, it appears that the sensor readings for monitoring and controlling the response of the servo motor based on changes in temperature, humidity and pressure in the room are in accordance with the conditions desired by the authors. The response given by the actuator, in this case, the rotation of the servo motor based on the input temperature, humidity, and air pressure in the room, could be illustrated in Fig. 14.

The performance of servo-motor response, could be explained in Table 2.

Fig. 10. Sensor test cold condition.

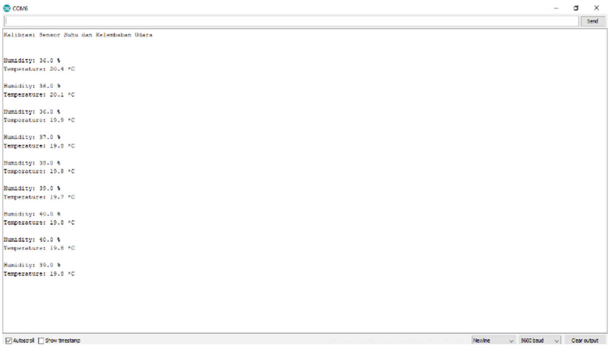

Fig. 11. Sensor test results cold condition.

Fig. 12. Sensor test results hot condition 1.

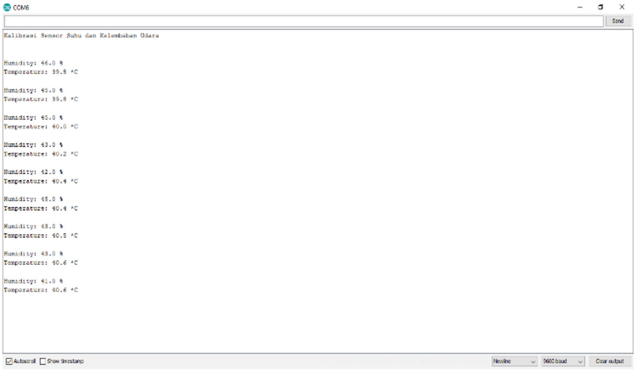

Fig. 13. Sensor test results hot condition 2.

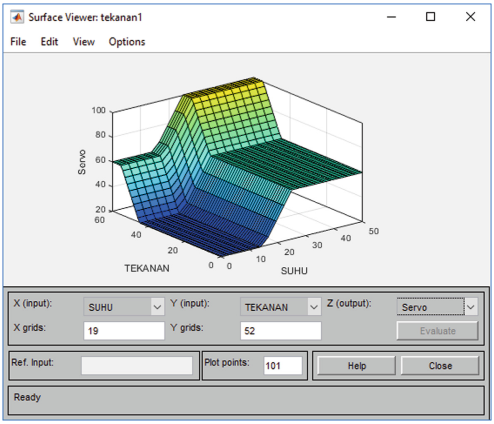

Fig. 14. The surface viewer.

Table 2. The Performance Characteristic of the Servo-motor.

The performance characteristics	Value
Rise time *tr*	50.6 s
Settling time *ts*	74.68 s
Settling Min.	150
Settling Max.	160
Overshoot	0
Undershoot	0
Peak	160
Peak Time	75 s

The performance characteristics of a control system are characterized by transient responses to inputs. The transient response of a control system practically always exhibits damped oscillations before reaching a steady state. Rise time tr is the time it takes for the response to increase from 10% to 100%, 5–90%, 5–95%, or 0–100% of the final value used. Peak time tp is the time it takes for the response to reach its maximum first overshoot and settling time ts is the time required for the response to the unit ladder to enter the 2% or 5% of the final value criteria area.

5 Conclusion

Analysis and testing of the temperature, RH (humidity), and air pressure measurement systems has been carried out in several server rooms of the data center by using Fuzzy Logic. The DHT11 and MPX5100dp sensors are suitable for the design of temperature, RH (humidity), and air pressure measurement systems in rooms. By using Fuzzy Logic, the DHT11 sensor can read temperature and humidity, and the MPX5100dp sensor can read the pressure of a room. Monitoring can be seen directly from the LCD screen and the data logger can be stored on the memory card. The reading function from the sensor is used as input for the controller that uses the Fuzzy Logic algorithm to control the response of the actuator, which in this system uses a servo motor that is connected to the air duct damper open and close system that circulates cold air generated by the central cooling system. The servo motor automatically moves according to the crisp value obtained from the value of the defuzzification result. The measurement results can be directly seen from the mobile phone screen and LCD display when the room lacks or excess air pressure, which results in a decrease or increase in room temperature by opening and closing the air duct damper.

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