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Control of Air Cooling System Based on Fuzzy Logic

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Abstract

A comfortable activity in of a room is depended on environment. Temperature and humidity is considered that greatly affect the air condition performance. This study aimed to design and built a prototype air cooling controller, namely the fan, so it can control the speed of the fan according to conditions of temperature and humidity. This research uses arduino uno R3 microcontroller and the of DHT 22 sensor to detect temperature and humidity of room and PIR sensor to detect human presence in the room. Sugeno fuzzy logic method is used to take the decision which is processed by microcontroller. That an test is done by manual calculation, matlab simulation and prototype testing. The results shows the averaged accuracy of temperature testing is 3.89%, while range is 1.99% and average humidity accuracy 3.21%, range is 2.49%. the system is able to control the fan of cooling fan autamatically accordances to the desired rules based on fuzzy logic. Therefore, a proposed prototype model is able works performed.

Keywords: *PIR, DHT 22, Fuzzy, Smart Control Room*

1. Introduction

In line with the rapid development of technology and science, level of human activity hare also increased, however less attention an efficiency of utilization of the equipment used. Has become limitations dayly in activities, a person needs a comfortable conditions order to work with optimal. The existing air conditioning system works in accordance with the manual settings, while the condition of the room can be changed so as not in accordance with the situations needs. Thus, it is necessary to control the air conditioner which is adaptable to desired conditions.

Some of the air conditioner controllers have been made by several researchers including the air conditioner controller developed by Sadi S. and Budiawan T. [1]. The system is designed and built using the fuzzy logic method to determine the decisions to be processed by microcontroller, LM 35 sensor to detect room temperature and PIR sensor to detect human movement. This study did not detected moisturzed while humidity also affected the condition of the room.

Saputra H. [2] has developed an energy-efficient fan based on is used temperature, humidity and motion using fuzzy algorithm method. In this study, PIR sensors to detect human motions and DHT 11 sensors has read the existing temperature as input to be processed in arduino microcontroller and using the Fuzzy method is used to provide quick decisions for this situations. Accuray level of temperature and humidity is the limitation due to only and DHT 11 sensors are use.

To improve accuracy, Izzatul Islam H. [3] used DHT 22 Sensor and PIR Sensor to build Temperature Control and Air Humidity Monitoring System based on Arduino Uno. This study used Arduino Uno to control a DHT sensor input and PIR Sensor, if the temperature reads more than 28 ^{0}C and detected human movement by PIR sensor the relay is in active condition or fan life for 30 seconds. However, if the temperature is less than 28 ^{0}C the relay is off and the fan is off. An improvement of air conditiony controller could be increased by using more than 2 DHT 22 sensors. This works is aimed to improvement the accuray of temperature and humidity based on fuzzy logic.

The accuracy of room air conditioner controllers can still be improved by increasing the number of temperature and humidity sensors. In this study used 4 DHT 22 Sensor with the aim to increase the level of accuracy in detecting temperature and humidity due to uneven room temperature in order to control the controller air conditioner room.

2. Research Method

The air conditioning controller system is built using Arduino R3 control, 4 PIR sensors placed on each side aim to detect humans located in different places, 4 DHT 22 sensors are placed on each side in order to detect the temperature and humidity inside the room is uneven. The system is analyzed based on Fuzzy algorithm where temperature and humidity as input and fan blades are output. Then the system is simulated with MATLAB. The prototype model tested validate which is the results moreover of system and simulation analysis.

2.1. System Architecture

The hardware architecture is illustrated in Figure 1, while the software architecture in Figure 2.

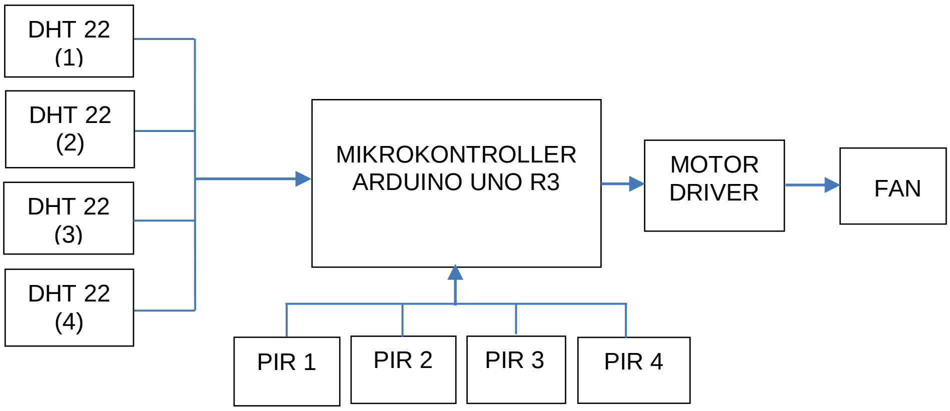

Figure 1. A Proposed System Model

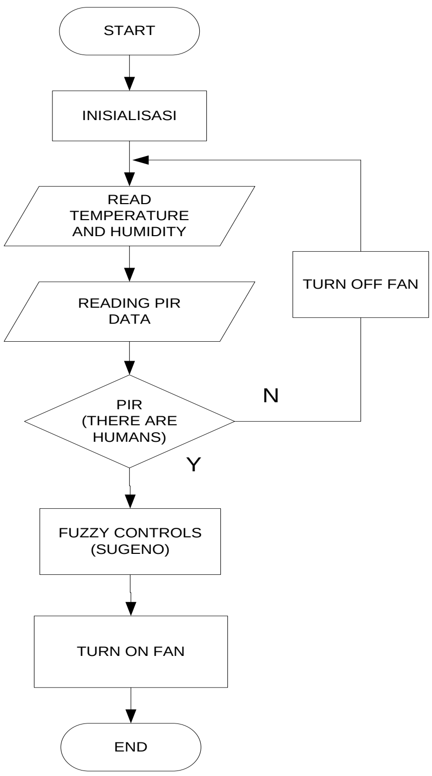

Figure 2. A Flowchart Proposed System

Figure 1 show, 4 (four) DHT 22 are used moreover, to conduct the present of human, 4 PIR sensor are use. Microcontroller is used provided signal processing which is works paralel with fuzzy logic algorithm. Motor driver is used to conduct result form the DHT 22 and microcontroller which able generate fan.

Figure 2 shows microcontroller reads from DHT 22 signal temperature and humidity. The measures value is averaged. Furthermore microcontroller also reads PIR sensors for present of humans. While PIR detected the presence, therefore averaging value and human presence are uses as fuzzy logic input. The fan automatically shut offf, if human presence is undetecable. The prototype awaitiy till PIR sensor has detect the presence of human.

2.2. Fuzzy Controls

Sugeno is used for a four stages is required by output in Sugeno method : fuzzy inference system which is applied in used air conditioner controller. In Sugeno method to get the output required four stages are :
1. Fuzzification
2. Rules and inference
3. Rules Composition
4. Defuzzification

1. Fuzzification

Temperature, humidity and human presence are uses to conduct fan speeds. However, instability of temperature and humidity is not steadey. Therefore, fuzzification is proposed. A membership of this fuzzy is showed table 1 and 2.

Table 1. Temperature Level Data

cold	0 ^{0}C - 24 ^{0}C
medium	20 ^{0}C - 32 ^{0}C
heat	28 ^{0}C - 40 ^{0}C
Very hot	36 ^{0}C - 50 ^{0}C

Table 2. Data Humidity Level

Low humidity	0 % - 50 %
Medium humidity	35 % - 80%
High humidity	70% - 100%

Based on temperature and humidity levels could be on table 1 and 2, performanced on to membeship curves.

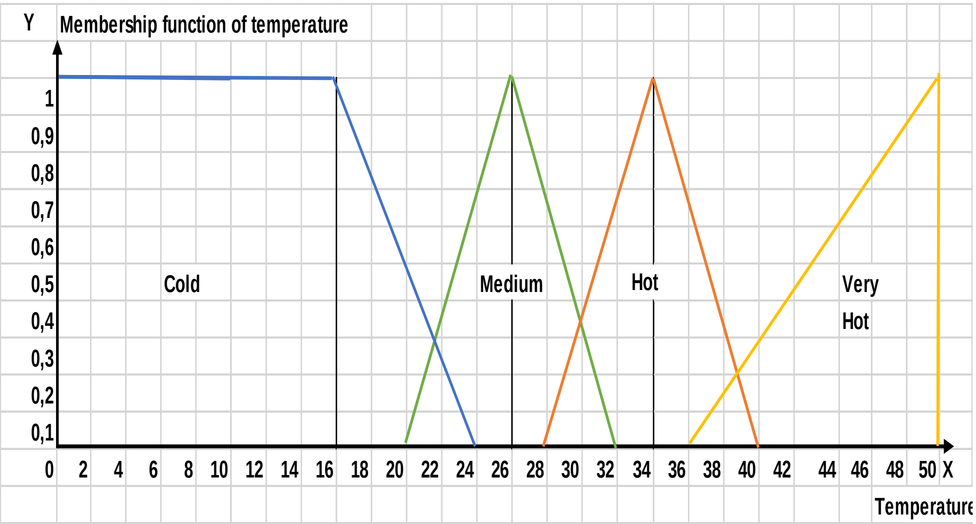

Figure 3. Temperature Membership Curve

a. Membership Function of Cold Temperature : [4]

$$\mu\ cold\ [x] = \begin{cases} 1; & x \le 16 \\ \frac{(24-x)}{(24-16)}; & 16 \le x \le 24 \\ 0; & x \ge 24 \end{cases} \qquad \text{...} \qquad (1)$$

b. Membership Function Medium Temperature:

$$\mu\ medium\ [x] = \begin{cases} 0; & x \le 20\ atau\ x \ge 32 \\ \frac{(x-20)}{(26-20)}; & 20 \le x \le 26 \\ \frac{(32-x)}{(32-26)}; & 26 \le x \le 32 \end{cases} \qquad \text{...} \qquad (2)$$

c. Membership Function Heat Temperature:

$$\mu\ heat\ [x] = \begin{cases} 0; & x \le 28\ atau\ x \ge 40 \\ \frac{(x-28)}{(34-28)}; & 28 \le x \le 34 \\ \frac{(40-x)}{(40-34)}; & 34 \le x \le 40 \end{cases} \qquad \text{...} \qquad (3)$$

d. Membership Function Very Hot Temperature :

$$\mu\ very\ hot\ [x] = \begin{cases} 0; & x \le 36 \\ \frac{(x-36)}{(50-36)}; & 36 \le x \le 50 \\ 1; & x \ge 50 \end{cases} \qquad \text{...} \qquad (4)$$

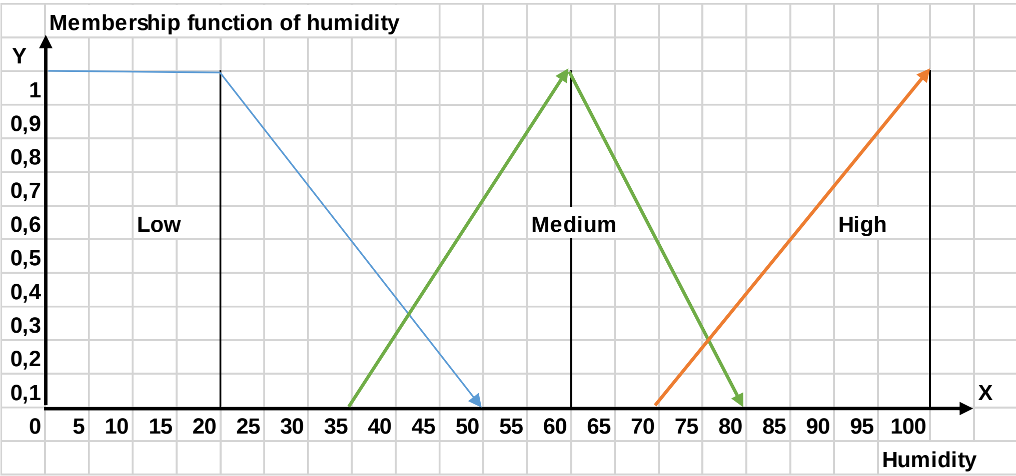

Figure 4. Humidity Membership Curve

a. Membership Function Humidity Low :

$$\mu\ low\ [x] = \begin{cases} 1; & x \le 20 \\ \frac{(50-x)}{(50-20)}; & 20 \le x \le 50 \\ 0; & x \ge 50 \end{cases} \qquad \text{...} \qquad (5)$$

b. Membership Function Humidity medium :

$$\mu\ medium\ [x] = \begin{cases} 0; & x \le 35\ atau\ x \ge 80 \\ \frac{(x-35)}{(60-35)}; & 35 \le x \le 60 \\ \frac{(80-x)}{(80-60)}; & 60 \le x \le 80 \end{cases} \qquad \text{...} \qquad (6)$$

c. Membership Function Humidity high :

$$\mu \text{ high } [x] = \begin{cases} 0; & x \leq 70 \\ \frac{(x-70)}{(100-70)}; & 70 \leq x \leq 100 \\ 1; & x \geq 100 \end{cases} \quad \text{...} \quad (7)$$

Whereas fan output membership are :

Table 3. Fan Output Data

Off fan (z1)	10
slow fan (z2)	30
Medium fan (z3)	60
Fast fan (z4)	80
Very fast fan (z5)	100

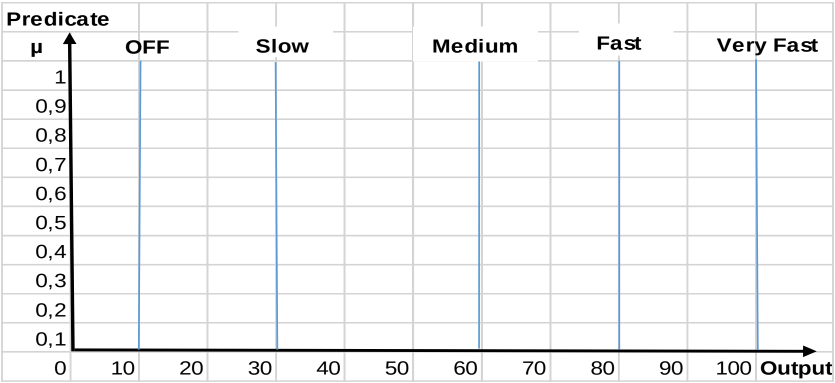

Figure 5. Output Membership Curve

2. Rules

Inference rules of AC controller could be setting according to Table 4.

Table 4. Fuzzy Rules For Controll Systems

		HUMIDITY		
		low	medium	High
TEMPERATURE	cold	slow	slow	Off
	medium	medium	slow	Off
	hot	fast	medium	medium
	Very hot	Very fast	Very fast	fast

3. Inference

A fuzzy from fuzzification has become input for a rules that has been setup for fuzzy output [4].

There are three points that have to do, i.e : applied of fuzzy operator, rules, whole output compostions. Max-Min methode is uses in this works.

Fuzzy Operator Aplication

There are 12 rule that have been establish based on data achieved which is useful in fuzzy application. Since the system consists of several rules, then reasoning (inference) is derived from the collection and correlation between rules. The method to be used in performing Fuzzy operator application process is MIN method.

The existing rules, the data has been entered as input data on the composition of the assessment in the previous stage after the application process Fuzzy operators included into some parts of the rules. The process is called aggregation process [4].

α Predikat R1 = min (μ temperature [x], μ humudity [x]) .... (8)

Composition of All Rules

To process the composition of all Fuzzy output is done by using MAX method. If all propositions have been evaluated, the output will contain a fuzzy set that reflects the contribution of each proposition. In general can be written :

$$\mu sf\ [Xi] \leftarrow \max(\mu sf\ [Xi], \mu kf[Xi]) \quad \text{..} \quad (9)$$

with :

μsf [Xi] = membership value fuzzy solution rule i th
μkf [Xi] = consequential membership value fuzzy rule i th

4. Defuzzification

Defuzzification on the Sugeno method is done by finding the averages value. [5]

$$Z = \frac{\sum_{i=1}^{n} \alpha i\ Zi}{\sum_{i=1}^{n} \alpha i} \quad \text{..} \quad (10)$$

with αi is α the i-predicate, and Z_i is the output of the i th rule antecedent.

3. Testing and Data Analysis

The testing is experiences to investigate the performance metrics of proposed systems.

1. To do processing the whole output fuzzy composition, Max method is deployed is the whole proposition has evaluated.
2. Testing PIR sensor type KC HCSR 501
   In testing the PIR sensor under inactive conditions and testing the PIR sensor under active conditions is performed by moving the hand object within the area of the PIR sensor range. From the test the PIR sensor can be active after detecting human movement.
3. Testing Temperature and Humidity of DHT Sensor 22
   Testing is done by comparing with different temperature. The comparator temperature sensor used is a temperature sensor type DS 1820. The test is performed on 4 DHT 22 sensors used on the prototype. Accuracy value is obtained by relative error calculation, in the percentage formulated : [6]

According accuray performance metrics, Table 5 has shows the performance based on formula :

$$X = \frac{|Xi - Xp|}{Xp} \times 100\ \% \quad \text{..} \quad (11)$$

Information :

X = relative error (accuracy value)
Xi = DHT sensor temperature value 22
Xp = sensor temperature value DS 1820

Table 5. Testing Temperature

No	Termometer Digital	DHT 22				Accuracy			
	DS 1802	1	2	3	4	1	2	3	4
1	22,4	23,9	23,8	23,6	23,7	6,70	6,25	5,36	5,80
2	22,8	24,2	23,3	23,9	23,9	6,14	2,19	4,82	4,82
3	24,8	24,3	24,5	24,1	24,1	2,06	1,21	2,82	2,82

4	24,9	25,0	24,8	24,9	24,9	0,40	0,40	0,00	0,00
5	25,2	26,3	26,5	26,1	26,1	4,37	5,16	3,57	3,57
6	26,2	27,6	27,8	26,3	27,3	5,34	6,11	0,38	4,20
7	27,1	28,3	28,7	27,8	27,9	4,43	5,90	2,58	2,95
8	27,3	28,7	28,9	28,2	28,3	5,13	5,86	3,30	3,66
9	28,3	29,2	29,1	28,6	28,8	3,18	2,83	1,06	1,77
10	29,3	30,5	31,2	30	30,4	4,10	6,48	2,39	3,75
11	29,6	31,8	31,6	30,0	31,9	7,43	6,76	1,35	7,77
12	30,3	32	31,8	31,3	32	5,61	4,95	3,30	5,61
Average	26,52	27,89	27,67	26,80	27,44	4,57	4,51	2,58	3,89

It is shows that average of the accuray values is performed. Which is could be used for 1 testing accuracy and ranges of 1.99%. Therefore the accuracy of the DHT 22 sensor is good, it can be used for testing. Temperature comparative testing of DS and DHT 22 is showed on figure 7.

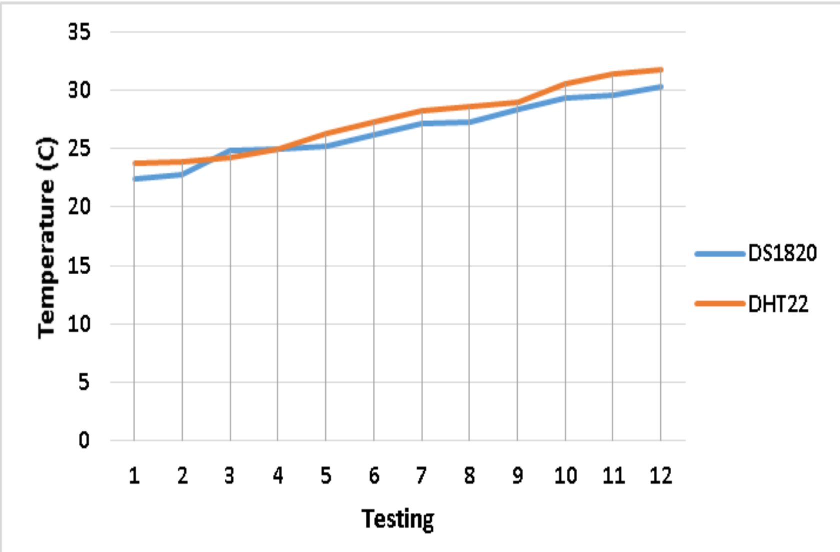

Figure 6. DS 1802 and DHT 22 Temperature Comparison Curves

The humidity test on DHT 22 was performed by the same method as in the temperature with the comparator is hygrometer. From the results of the measurements in table 4 below, it can be shown that average accuracy averaged is 3.21% and the ranges 2.49%, moreover the accuracy of DHT 22 sensor is perform well and could be used for testing.

Table 6. Humidity Testing

No	**Hygrometer**	**DHT 22 (%)**				**Accuracy**			
	(%)	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
1	57	59,6	54,9	57,9	58	4,56	3,83	1,58	1,75
2	57	60,1	55,4	58,4	58,5	5,44	2,89	2,46	2,63
3	57	59,6	55,4	58,3	57,7	4,56	2,89	2,28	1,23
4	56	59,2	55,3	58,1	57,5	5,71	1,27	3,75	2,68

5	63	62,8	57	62	60,7	0,32	10,53	1,61	3,79
6	62	62,6	57,2	61,9	60,4	0,97	8,39	0,16	2,65
7	61	62,1	57,9	61,3	59,8	1,80	5,35	0,49	2,01
8	60	61,3	56,4	60,6	59,3	2,17	6,38	1,00	1,18
9	65	67,1	61,4	65,8	65,2	3,23	5,86	1,23	0,31
10	66	67,5	62	66	66,6	2,27	6,45	0,00	0,91
11	77	81,5	76,3	81	79,6	5,84	0,92	5,19	3,38
12	77	83,1	76,1	81,8	80,8	7,92	1,18	6,23	4,94
Average	63,17	65,54	60,44	64,43	63,68	3,73	4,66	2,17	2,29

Humidity comparative of DHT 22 and hygrometer is showed on figure 8.

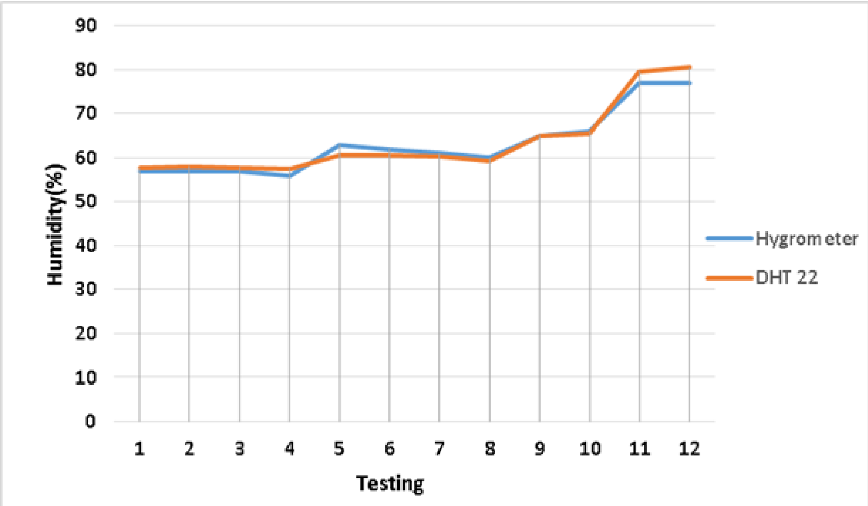

Figure 7. Comparison Curves of Hygrometer and DHT 22

3.1. Motor Testing

In this test the motor used 12 Volt DC fan motor. Testing is done by varying the value of pulse width modulation (PWM). Where the design system of this prototype used 4 different PWM values.

Table 7. Motor Test Results

NO	RESULT PWM	FAN
1	70	Slow
2	150	Medium
3	200	Fast
4	225	Very Fast

3.2. Software Testing (Fuzzy System)

Fuzzy logic testing is performed to understand the fuzzy system process as automatic controlling of fan speed. This test is done by comparing the output value obtained through the calculation method, Matlab FIS Editor application, and arduino fuzzy program. Testing following method testing as follows :

1. Testing Fuzzu System with manual calculation.

If the data input of the temperature is 20 ^{0}C and humidity is 90%

Temperature = 20 ℃

MF cold $= \frac{(24-20)}{(24-16)} = \mathbf{0,5}$

MF medium = 0

MF hot = 0

MF very hot = 0

Humidity = 90 %

MF low = 0

MF medium = 0

MF high $= \frac{(90-70)}{(100-70)} = \mathbf{0,7}$

Fuzzy Rule Implications (MIN Method) :

Tabel 8. Rule Of Implication Fuzzy

LEMBAB→ SUHU ↓	RENDAH	SEDANG	TINGGI
DINGIN	Aturan 1. 0	Aturan 2. 0	Aturan 3. 0,5
SEDANG	Aturan 4. 0	Aturan 5. 0	Aturan 6. 0
PANAS	Aturan 7. 0	Aturan 8. 0	Aturan 9. 0
SANGAT PANAS	Aturan 10. 0	Aturan 11. 0	Aturan 12. 0

Fuzzy Rule Composition (MAX Method) :

- Fan Speed output :

1. Max Off Fan = MAX (rule 3; rule 6)
   = MAX (0,5; 0)
   = 0,5
2. Max Slow Fan = MAX (rule 1; rule 2; rule 5)
   = MAX (0; 0; 0)
   = 0
3. Max Medium Fan = MAX (rule 4; rule 8; rule 9)
   = MAX (0; 0; 0)
   = 0
4. Max Fast Fan = MAX (rule 7; rule 12)
   = MAX (0; 0)
   = 0
5. Max Very Fast Fan = MAX (rule 10; rule 11)
   = MAX (0; 0)
   = 0

Defuzzification :

$$Z = \frac{(apred1 * Z1) + (apred2 * Z2) + (apred3 * Z3) + (apred4 * Z4) + (apred5 * Z5)}{apred1 + apred2 + apred3 + apred4 + apred5}$$

$$Z = \frac{(Max\ off * 10) + (Max\ slow * 30) + (Max\ medium * 60) + (Max\ fast * 80) + (Max\ very\ fast * 100)}{Max\ off + Max\ slow + Max\ medium + Max\ fast + Max\ very\ fast}$$

$$z = \frac{(0,5\times10)+(0\times30)+(0\times60)+(0\times80)+(0\times100)}{(0,5+0+0+0+0)}$$

= 10

2. Testing the fuzzy system with Matlab FIS editor

   If the data input of the temperature is 38 ^{0}C and humidity is 40%

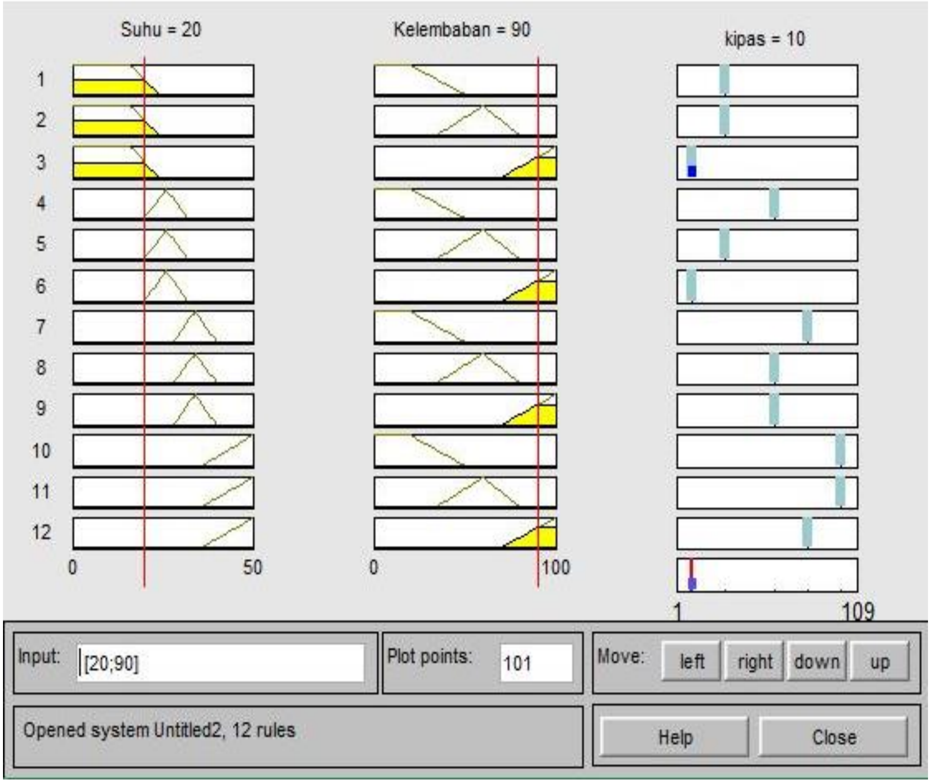

Figure 8. Testing the fuzzy system with Matlab FIS editor

3. Testing fuzzy system using arduino software that is displayed through serial monitor. If the input data temperature = 20 ^{0}C and humidity = 90%

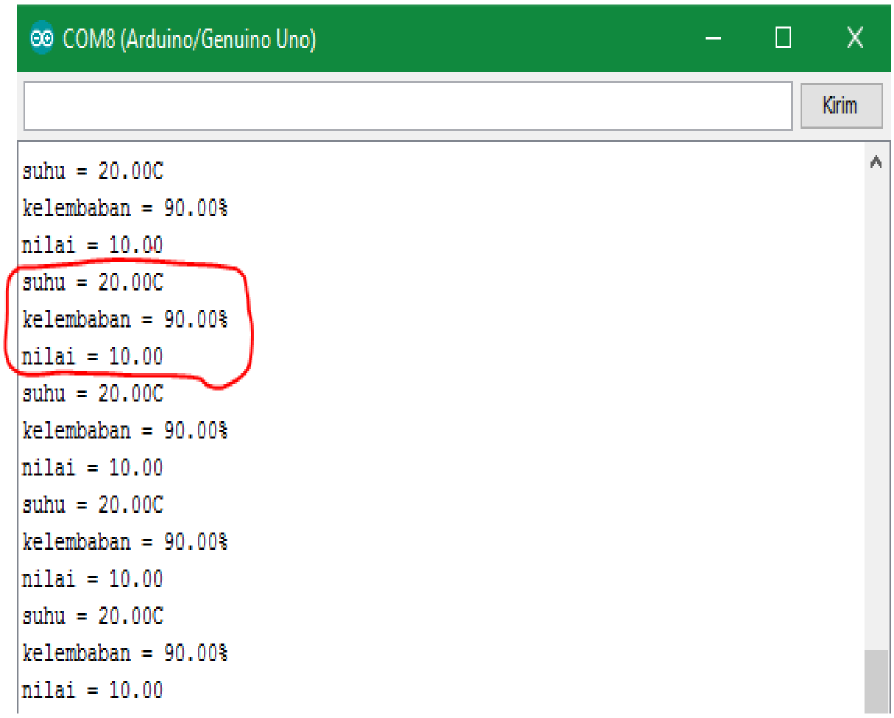

Figure 9. Testing fuzzy system using arduino software

Through testing methods that has been done, moreover output ratio of fuzzy system is obtained and showed on the table 9.

Table 9. Comparison of Fuzzy System Output Value

No	Input Data		Value		
	Temperature (℃)	Humudity (%)	Matlab FIS Editor	Program Arduino	Manual Calculation
1	38	40	80	80	76,67
2	20	90	10	10	10
3	42	50	100	100	100
4	35	80	60	60	60
5	25	60	30	30	30

Shows, it is concluded that the program used on the prototype is in accordance with the desired fuzzy system.

3.3. Prototype Testing

The first test is done by conditioning the PIR sensor in a state of inactivity (without movement), the test results can be seen in Figure 10.

Figure 10. Off Fan Condition

It is can be known the system will not work is, if the PIR sensor is not detected a movement. Further testing of the PIR sensor is conditioned by giving movement to the prototype.

Figure 11. Slow Play Fan

It is shows that the temperature input value is 28.8 ^{0}C and the humidity value is 84.7%, the temperature value shown in the prototype fulfills the function of the fuzzy temperate membership while in the moisture fulfills the function of moderate moisture membership in fuzzy. The defuzzification value is 17.71%, is it meets the rules (If temperatures are medium and humidity is moderate, then the fan goes rotates slowly). In subsequent tests the temperature and humidity are different. Testing can be seen in figure 12.

Figure 12. Medium Play Fan

The value of temperature test the is obtained 35.0 ^{0}C it is fulfilled the function of membership of hot fuzzy function and humidity value is 80.0% Therefore meet the value of moderate fuzzy membership. Moreover the value of temperature and humidity has meet the rules (if the temperature is hot and humidity is moderate then the fan is midle spinning). The next test by giving different input from the previous test, the test results can be seen in Figure 13.

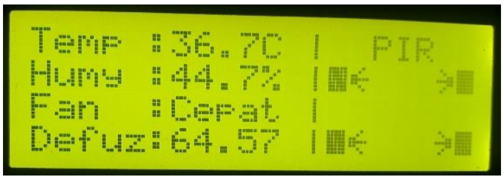

Figure 13. Fast Play Fan

The value of temperature test obtained 36.7 ^{0}C it is fulfill function of membership of hot fuzzy function and humidity value is 44.7% so as to meet the value of low fuzzy membership, moreover the value of temperature and humidity has meet the rules (if the temperature of heat and low humidity then the fan spins fastly). The last test is to give conditions different from the previous test, the test results can be seen in Figure 14.

Figure 14. Very Fast Play Fan

The value of temperature testing obtained 42.2 ^{0}C it is fulfilled function of the membership of the function of very hot fuzzy and humidity value is 50.7% Therefore meet the value of low fuzzy membership. Value of temperature and humidity has meet the rules (if the temperature is very hot and low humidity then the fan spinning very fast).

4. Conclusion

Based on the results of system testing and discussion of the development of fuzzy-based air-cooling system control system design, it can be drawn some conclusions as follows :

a. Fuzzy-based air conditioning control system using PIR and DHT 22 sensors is able to control the fan rotation according desired rules on fuzzy logic based on changes in the environment around the cooling machine.
b. The investigation testing through manual testing, simulation testing and prototype testing show, that a proposed model able works performed.

5. Recommendation

The proposed prototype system model could be deployed in real application.

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