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Energy Saving of Air Condition using Fuzzy Control System over Zigbee Temperature Sensor

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***Abstract*—In the use of air conditioning system, way to reach a more comfortable and energy-saving effect is the goal pursued constantly by people in the 21th century. In this paper, we will build an experimental environment, and stored the temperature and humidity coefficient, which are measured through each sensor in the surrounding environment, in the database. Apart from traditional single-point temperature sensitivity, we build multi-point of Zigbee sensing to measure the data of temperature and humidity in the surrounding environment, and to increase comfort and to decrease unnecessary energy waste. In recent years, fuzzy theory has been widely used in auto control, image recognition, decision making analysis, timing sequence signal processing; especially in controller design, fuzzy theory gradually become the best way to design the controller. Thus, use fuzzy theory to control air conditioning system is helpful for achieving more comfortable environment. Using fuzzy rule to calculate the membership grade, and control air conditioning system according to the most suitable operation speed of the environment. Thus, in this research, using multi-point sensing network and fuzzy theory and to control air conditioning system effectively achieve a more comfort environment and a energy-saving effect.**

Keywords-Zigbee Sensor,Fuzzy theory, Energy saving

I. INTRODUCTION

Fuzzy theory expresses the uncertainty in human recognition in a mathematical theory. Fuzzy theory extend the traditional binary logic math, which only has right and wrong, to an gray area with continuous multi-value logic. Use the value of membership function to describe the characteristics of a concept. That is to use the value between 0 or 1 to express the degree of an element belong to a concept, and this value of the element is defined as the membership grade to the set. Thus, the value 0 or 1 represents the meaning right or wrong respectively in traditional mathematics. However, as the value is located between 0 and 1 represents the grey area between right and wrong.

Fuzzy theory has been widely used in many kinds of fields. Of course it is used on controlling temperature and humidity. Apart from traditional air conditioning controlling system, which only active after the data returned to the user is much higher than user setting, fuzzy controlling system will sense the environment temperature and humidity status and active right away as the temperature and humidity begin to increase. Moreover, when getting close to the temperature sets by the user, in accordance with temperature and humidity ratio of air conditioning system to increase the operation speed, and fuzzy system decrease the operation speed as the temperature is higher than user's setting. Because fuzzy control system will make the most appropriate control to the experiment environment according to the temperature and humidity parameter returned by the sensor, this action will this will reduce the fluctuation range of the ambient temperature. Thus, fuzzy system will substantially increase the comfort when using air conditioning system.

II. RELATED WORK

This research will use multi-point sensing to sense temperature and humidity in each sensing point. Traditional air conditioning system often use single sensor to sense the temperature and humidity in the environment. However, the position of the sensor fixed, the data returned back will only be limited to the area around the sensor. Furthermore, many sensors are even located inside the air conditioner, and this will severely decrease the accuracy of data sensed by the sensor. Moreover, received an inaccuracy data will not only increase the energy-wasted but decrease the comfort. According to the difference of the experiment environment size, shape and uses, multi-point sensing can set different sensors in different positions. Thus, we can sense the temperature and humidity in the environment precisely. As there are big differences between the data returned by each sensor, we can use fuzzy theory to activate the fans and make

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temperature and humidity much uniform. To sum up, we can infer that multi-point sensing can decrease unnecessary energy waste and improve comfort.

To sum up, we can easily discover that it would be very desirable to combine fuzzy theory and multi-point sensing. We can provide the users not only decrease energy waste but increase comfort by using fuzzy control to transform all environmental factor into appropriate instructions, after returning back and storing the temperature and humidity coefficient sensed by multi-point sensing, to control the operation speed of the fans and the air conditioning system.

III. SYSTEM ARCHITECTURE

Instrument and methods:

Temperature and humidity are barely possible to be absolutely uniform everywhere, moreover; moreover, to improve user's comfort, it is important to precisely and correctly return back the data: the temperature and the humidity data of the experiment environment. In this research, we use Centigrade(℃) as the temperature unit, and Percentage(%) as the humidity unit of the input. We use Percentage(%) as the unit of the operation speed of air conditioning systems and fans. Furthermore, in three different places, we will build three sensors, which are combination of the temperature and humidity sensors. Data of temperature and humidity will send back through wireless sensor, and as the receiver will store the data into the database through personal computer after receiving the data. Fuzzy controlling system will read the data in the database and compare the parameter of temperature and humidity that is set by the user and calculate the membership grade. Then we use fuzzy theory to calculate the operation speed of the air conditioning systems and the fans. In figure 1, we transmit the signal to the IR emitter, and then use IR signal to send the instruction to the fans and the air conditioning system at last.

Fuzzy theory and multi-point sensing make the air conditioning system to control the temperature and humidity under the value set by the users by receiving each parameter from sensors.

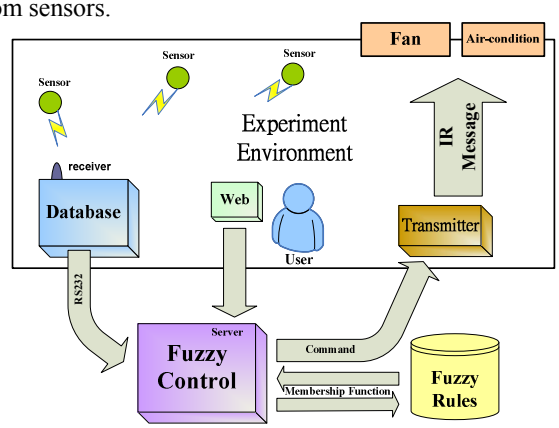

Figure 1 Structure of fuzzy theory and multi-point sensing controlling system

In table 1, fuzzy controlling system defines the input temperature and humidity and output operation speed of the fans and the air conditioning system with three linguistic variables, which are high, medium, and low respectively.

Temperature range returned back by the sensor is from 10℃ to 55℃, and the range of the humidity is from 0% to 100%. The output operation speed of the air conditioning system is from 0% to 100%, and the operation speed of the fans is from 0% to 100%.

Table 1 The linguistic variables of input and output transformed to fuzzy theory

Parameters	Type	Linguistic expressions
Temperature	input	Low,Medium,High
Humidity	input	Low,Medium,High
Speed of air condition	output	Low,Medium,High
Speed of fan motor	output	Low,Medium,High

In this system, we are going to assess the environment temperature and humidity data, and use the most power-saving and comfort way to adjust the operation speed of the air conditioning system and the fans. Thus, we can provide better use effect by cooperation in harmony.

In many applications of fuzzy theory to control the system, the mathematical formulae of membership function are mostly use geometric pattern of triangles, and we will also use the geometric pattern of triangles to define the membership function of temperature, humidity, and operation speed of air conditioning systems and fans in fuzzy theory. We will take the temperature formula of membership function of as an example as follows.

The following statement contains the linguistic variables of temperature and the membership function of fuzzy theory. (Linguistic variables of temperature= A, temperature parameter= a)

$$\mu_{Low}(A)=\begin{cases}1 & ; \quad 0 \le a < 22 \\ \dfrac{25-a}{3} & ; \quad 22 \le a < 25 \\ 0 & ; \quad 25 \le a < 28\end{cases} \tag{1}$$

$$\mu_{Medium}(A)=\begin{cases}0 & ; \quad 0 \le a < 22 \\ \dfrac{a-22}{3} & ; \quad 22 \le a < 25 \\ \dfrac{25-a}{3} & ; \quad 25 \le a < 28 \\ 0 & ; \quad 28 \le a \le 32\end{cases} \tag{2}$$

$$\mu_{High}(A)=\begin{cases}0 & ; \quad 0 \le a < 25 \\ \dfrac{a-25}{3} & ; \quad 25 \le a < 28 \\ 1 & ; \quad 28 \le a < 32\end{cases} \tag{3}$$

Temperature settings in fuzzy theory

$$\begin{aligned}\mu_{Low}(A)&=\{1/19+1/20+1/21+1/22+0.67/23+0.33/24+0/25\}\\ \mu_{Medium}(A)&=\{0/22+0.33/23+0.67/24+1/25+0.67/26+0.33/27+0/28\}\\ \mu_{High}(A)&=\{0/25+0.33/26+0.67/27+1/28+...+1/32\}\end{aligned} \tag{4}$$

The rest input and output parameter of fuzzy theory are as Fig.2 and Fig.3.

Formulae of each temperature membership transform to the operation speed of the air conditioning system:

$$\frac{0\%\times\mu_{Low}+50\%\times\mu_{Medium}+100\%\times\mu_{High}}{\mu_{Low}+\mu_{Medium}+\mu_{High}} = \text{Speed of air condition motor(\%)} \tag{5}$$

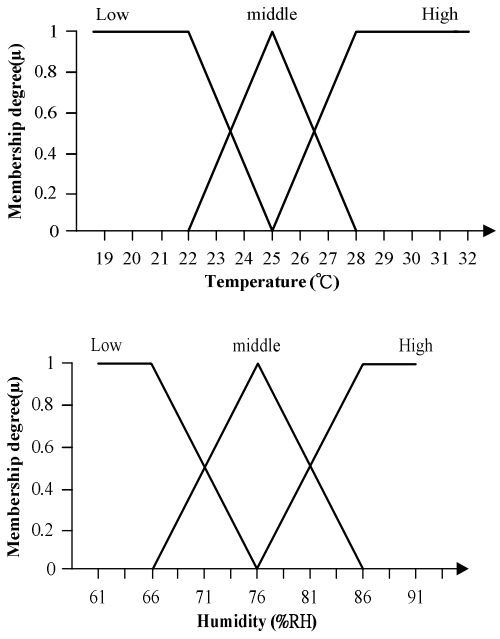

Figure 2 The membership function of the input parameter

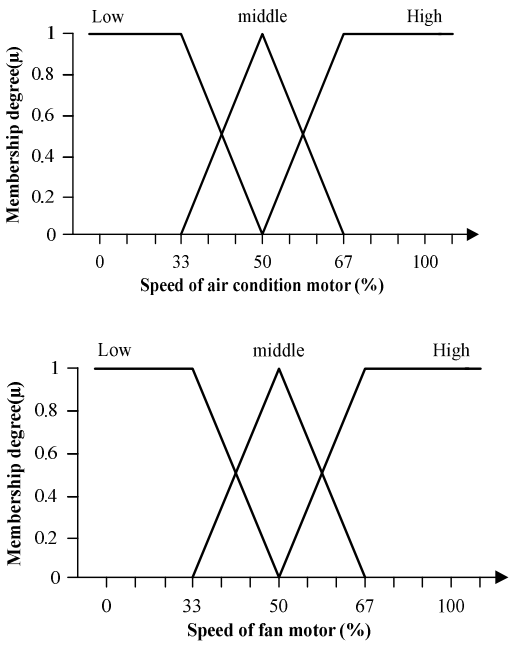

Figure 3 The membership function of the output parameter

IV. SIMULATION AND RESULT

In fuzzy theory, there is a fuzzy rule base that is being used to calculate the operation mode of air conditioning system of each parameters of membership function represent. There will be 6 parameters in three sensors, and each parameter has 3 linguistic variables. Thus, as shown in fig.2, we will have 729 fuzzy rules.

The linker SQL of this system is coding by BCB(Borland C++ Builder 6.0) and store the data acquired by the sensor in the database (MySQL 5.0). This program is set to read temperature and humidity data from database and analyze them once every 10 minutes. Calculating the membership grade from the fuzzy mechanism, then using fuzzy rule base to return back the most proper operation speed of the environment. Transfer the actual controlling instruction to the air conditioning system through IR after defuzzfy.

Through multi-point sensing in hardware design and fuzzy theory in software coding, we can achieve better result. Actual parameter results are shown in table 3.

Table 3 Partial value of input and output

Fig.4, fig.5, and table 4 are the comparison of the power consumption of our system with traditional controlling system.

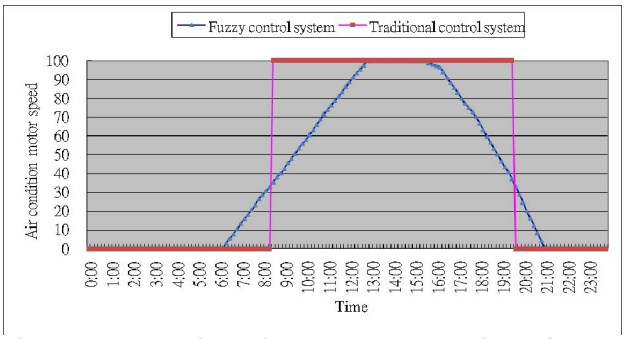

Figure 4 Comparison the power consumption of our system with traditional controlling system in controlling air conditioning system.

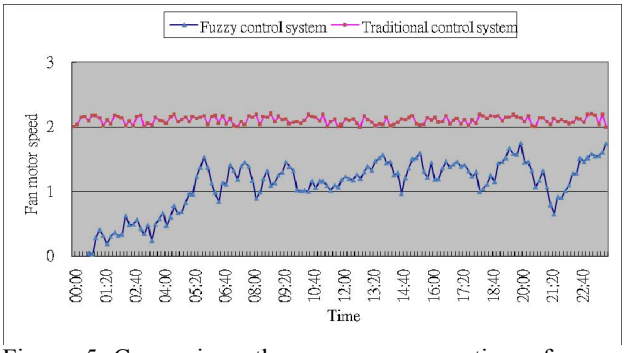

Figure 5 Comparison the power consumption of our system with traditional controlling system in controlling fans.

Table 4 Ratio of the energy-saving of our system to traditional controlling system

Total operating volume of air conditioning system in our controlling system	Total operating volume of air conditioning system in traditional controlling system	energy-saving ratio (%)
5516	6600	16.425
Total operating volume of fan in our controlling system	Total operating volume of fan in traditional controlling system	energy-saving ratio (%)
225	288	21.931

V. CONCLUSIONS

Results and future development: The followings are some advantages through comparing our controlling system to the traditional system:

(1) Decide the operation speed through the temperature and humidity parameter collected from each sensing point.
(2) Measure the environment temperature and humidity through multi-point sensing precisely.
(3) Let the fans and air conditioning system operation as planned.
(4) Able to change fuzzy rule according to different environmental needs.
(5) Sense environment parameter in a short term to improve the comfort.
(6) Saving energy by using the most proper operation speed to the environment.

In this paper, we can discover that using fuzzy theory and multi-point sensing controlling system can not only increase the comfort but decrease the power consumption when using.

Apart from traditional controlling system, we provide precise control instructions to control air conditioning system. Thus, system use our controlling system will be much more successfully in controlling

ACKNOWLEDGEMENT

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Table 2 Fuzzy rule base

Sensor		1				2				3						
Rukes		Temperature		Humidity		Temperature		Humidity		Temperature		Humidity		Air condition motor speed		Fan motor speed
1	if	Low	and	Low	and	Low	and	Low	and	Low	and	Low	Then	Low	and	Low
2	if	Low	and	Low	and	Low	and	Low	and	Low	and	Medium	Then	Low	and	Low
3	if	Low	and	Low	and	Low	and	Medium	and	Low	and	Low	Then	Low	and	Low
4	if	Low	and	Medium	and	Low	and	Low	and	Low	and	Low	Then	Low	and	Low
5	if	Low	and	Low	and	Low	and	Medium	and	Low	and	Medium	Then	Low	and	Midium
6	if	Low	and	Medium	and	Low	and	Low	and	Low	and	Medium	Then	Low	and	Midium
7	if	Low	and	Medium	and	Low	and	Medium	and	Low	and	Low	Then	Low	and	Midium
8	if	Low	and	Medium	and	Low	and	Medium	and	Low	and	Medium	Then	Medium	and	Low
9	if	Low	and	Low	and	Low	and	Low	and	Medium	and	Low	Then	Medium	and	Midium
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
720	if	Medium	and	High	and	Medium	and	Medium	and	Medium	and	High	Then	High	and	Midium
721	if	Medium	and	High	and	Medium	and	High	and	Medium	and	Medium	Then	High	and	Midium
722	if	Medium	and	High	and	Medium	and	High	and	Medium	and	High	Then	High	and	Midium
723	if	Medium	and	High	and	Medium	and	High	and	High	and	High	Then	High	and	High
724	if	Medium	and	High	and	High	and	High	and	Medium	and	High	Then	High	and	High
725	if	High	and	High	and	Medium	and	High	and	Medium	and	High	Then	High	and	High
726	if	Medium	and	High	and	High	and	High	and	High	and	High	Then	High	and	High
727	if	High	and	High	and	Medium	and	High	and	High	and	High	Then	High	and	High
728	if	High	and	High	and	High	and	High	and	Medium	and	High	Then	High	and	High
729	if	High	and	High	and	High	and	High	and	High	and	High	Then	High	and	High

Table 3 Partial value of input and output

Sensor	1		2		3		Output	
Time	Temperature(℃)	Humidity(%)	Temperature(℃)	Humidity(%)	Temperature(℃)	Humidity(%)	Air conditioner	Fan
10:00	25.28	60.34	25.26	60.32	25.70	60.06	57	1
10:10	25.43	60.16	25.41	60.14	25.82	59.96	59	1
10:20	25.59	60.05	25.55	60.00	25.95	59.77	62	1
10:30	25.76	59.86	25.70	59.85	26.14	59.61	64	1
10:40	25.92	59.75	25.88	59.66	26.31	59.47	67	1
10:50	26.10	59.58	26.03	59.49	26.42	59.31	70	1
11:00	26.25	59.46	26.13	59.36	26.54	59.19	72	1
11:10	26.41	59.31	26.27	59.22	26.73	59.01	74	1
11:20	26.59	59.15	26.37	59.03	26.91	58.81	77	2

11:30	26.78	59.02	26.52	58.85	27.06	58.65	80	2
11:40	26.98	58.86	26.70	58.68	27.25	58.51	83	2
11:50	27.13	58.68	26.87	58.57	27.40	58.35	86	2
12:00	27.26	58.49	26.98	58.43	27.51	58.16	88	2
12:10	27.39	58.36	27.09	58.32	27.70	58.05	90	2
12:20	27.50	58.19	27.27	58.12	27.82	57.86	92	2
12:30	27.68	57.99	27.38	57.99	27.99	57.72	95	2
12:40	27.79	57.88	27.49	57.86	28.14	57.59	97	2
12:50	27.93	57.77	27.64	57.71	28.25	57.44	99	2
13:00	28.12	57.62	27.78	57.53	28.36	57.25	100	2
13:10	28.31	57.43	27.97	57.38	28.48	57.09	100	2
13:20	28.51	57.24	28.08	57.27	28.60	56.98	100	2
13:30	28.69	57.09	28.27	57.08	28.76	56.87	100	1
13:40	28.63	56.98	28.19	56.96	28.71	56.69	100	2
13:50	28.53	56.85	28.17	56.80	28.66	56.59	100	1
14:00	28.46	56.73	28.15	56.62	28.64	56.47	100	1
14:10	28.39	56.60	28.12	56.47	28.64	56.31	100	2
14:20	28.35	56.49	28.07	56.29	28.59	56.16	100	2
14:30	28.31	56.35	27.98	56.15	28.56	56.00	100	2
14:40	28.25	56.21	27.89	55.98	28.51	55.82	100	2
14:50	28.17	56.06	27.84	55.82	28.46	55.66	100	2
15:00	28.17	55.93	27.80	55.65	28.42	55.48	100	2
15:10	28.13	55.75	27.79	55.51	28.40	55.37	100	2
15:20	28.05	55.59	27.72	55.36	28.40	55.24	100	2
15:30	27.97	55.43	27.63	55.23	28.36	55.10	100	2
15:40	27.91	55.29	27.54	55.06	28.35	54.96	99	3
15:50	27.87	55.13	27.49	54.90	28.29	54.81	98	3
16:00	27.86	54.94	27.42	54.77	28.27	54.62	97	3