A Fuzzy Control System for Temperature and Humidity Warehouse Control

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ABSTRACT
A control system is designed to control certain parameters in the system. The desired state maintained is called a steady state. Control actions however may perform something that makes the system experiences a state of overshoot before reaching the steady state. A fuzzy control system can be used to control the system to reach the steady state without overshoot. In this paper, a model of Mamdani's fuzzy inference process is proposed as the basis for this control. MIN operator is used for inference process if there is only one active rule, while MAX operator is used for composition of inferences if there are more than one active rule. A prototype of the fuzzy controller for temperature and humidity achieves an accuracy of 83.33% for temperature controller and an accuracy of 63.33% for humidity controller.

Keyword: fuzzy controller, Mamdani inference, temperature controller, humidity controller, intelligent control.

1. Introduction

Intelligent control system is a control technique that uses artificial intelligence-based approaches such as artificial neural networks and fuzzy logics [1]. For instance, [2] uses artificial neural networks and genetic algorithms to control a robotic application.

Fuzzy logic control is a methodology to represent, manipulate, and apply human knowledge about how to control systems [3], [4]. In fuzzy systems there are processes that characterize that the system is fuzzy, namely fuzzification, inference and defuzzification mechanisms.

Temperature and humidity are very important to maintain the quality of goods stored in the warehouses, especially for goods produced in the agro-industry. Maintaining the temperature and humidity in accordance with the ideal state storage is an important process in the temperature and humidity control system of the warehouse.

Control system using fuzzy logic has been used [5] to control air conditioning because it is not required to create a complicated mathematical model of the system, but instead fuzzy rules can be compiled based on actual situation. To facilitate the control of temperature and humidity, the control system uses intelligent control based on fuzzy logics embedded in the microcontroller as the central control of temperature and humidity.

2. Research Method

Fuzzy control system based on microcontroller is aimed to control the temperature and humidity of the warehouse based on the goods stored in the warehouse. To determine the type of goods stored in the warehouse, each item is tagged with RFID Mifare Classic 1K ISO / IEC 14443 type A that contains information about the type of goods, expiration date, and the ideal temperature and humidity of the item. When goods enter the warehouse, RFID reader CR013 is connected to the AVR microcontroller ATmega32 [6] to read information in the tags of goods. Temperature and humidity set points of the goods are used as fuzzy control system. To find out if the temperature and humidity of the warehouse in accordance with the type of goods or not, SHT11 [7] is used which is connected to the microcontroller as shown in Figure 1. Comparison output SHT11 with a set point and the rate of change of the difference is used as an input fuzzy control system for controlling the temperature and humidity of the warehouse to conform to the ideal state of storage of goods coming into the warehouse. To manipulate the temperature and humidity of the warehouse three Peltiers are used to lower the temperature, a Peltier to raise the temperature, and a fan for inputting and removing moisture to humidify the warehouse.

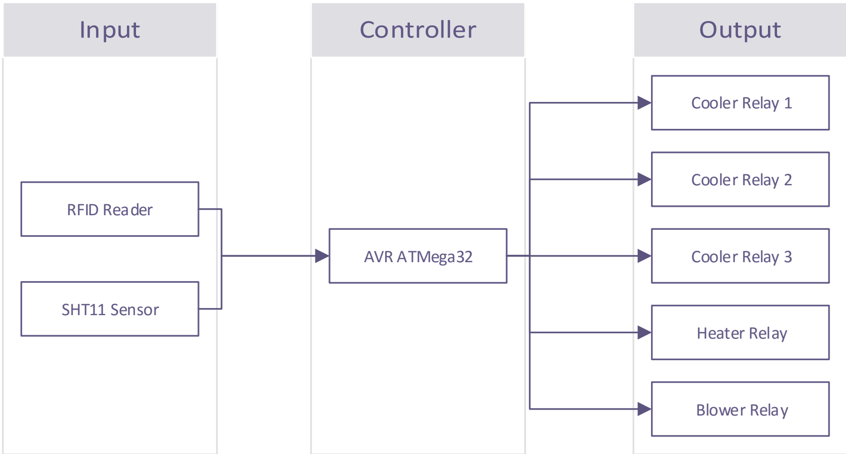

Figure 1. The diagram block of the design of fuzzy control system

Figure 2 shows a flow diagram of fuzzy control system to control the temperature and humidity of the warehouse. The system starts to work when there are goods in the warehouse. RFID Reader will read the data on the RFID tag in the form of ideal temperature and humidity of storage of goods. The reading results of the RFID tag are then compared with the temperature and humidity of the warehouse that are read by the sensors for temperature and humidity. The gap between the readings serves as the basis for determining what actions to do. The system will stop the action of control if the goods are removed from the warehouse. The control action used are modelled using fuzzy control inference Mamdani.

The developed fuzzy control system, both hardware and software, is a prototype of an adaptive warehouse system [8]. The hardware includes a prototype implementation of the warehouse and implementation of electronic circuits, while the implementation of the software includes the manufacture of fuzzy control program which will be embedded in the microcontroller.

The fuzzy control system uses 25 rules for temperature control as shown in Table 1 and 25 rules to control humidity as shown in Table 2.

Table 1. The temperature rule set

	DT				
ET	**NB**	**NS**	**AZ**	**PS**	**PB**
NB	NG(T1)	NG(T2)	NG(T3)	NG(T4)	NG(T5)
NS	NG(T6)	NG(T7)	NG(T8)	NG(T9)	AZ(T10)
AZ	AZ(T11)	AZ(T12)	AZ(T13)	AZ(T14)	AZ(T15)
PS	PM(T16)	PM(T17)	PM(T18)	PS(T19)	PS(T20)
PB	PB(T21)	PB(T22)	PB(T23)	PM(T24)	PB(T25)

Table 2. The humidity rule set

	DH				
EH	**NB**	**NS**	**AZ**	**PS**	**PB**
NB	NB(H1)	NB(H2)	NB(H3)	NB(H4)	NB(H5)
NS	NS(H6)	NS(H7)	NS(H8)	NS(H9)	NS(H10)
AZ	ZO(H11)	ZO(H12)	ZO(H13)	ZO(H14)	ZO(H15)
PS	ZO(H16)	ZO(H17)	ZO(H18)	ZO(H19)	ZO(H20)
PB	ZO(H21)	ZO(H22)	ZO(H23)	ZO(H24)	ZO(H25)

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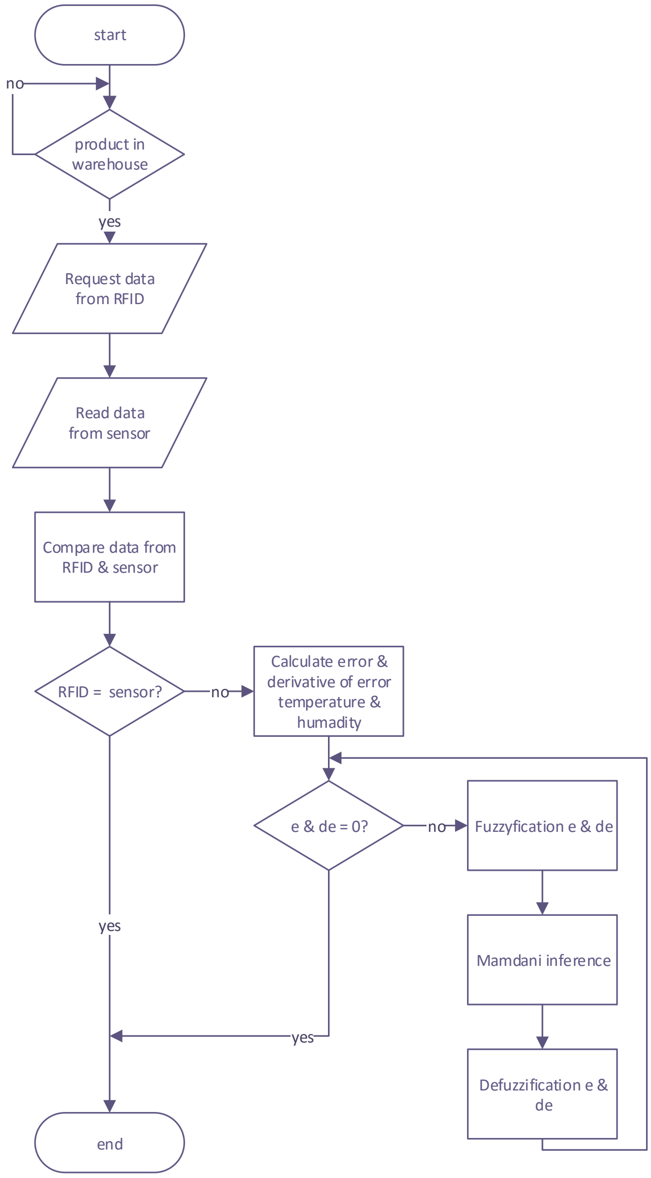

Figure 2. The flowchart of the fuzzy controller

3. Result and Analysis

The fuzzy inference used in this control system uses Mamdani inference. The process of fuzzification, inference, and defuzzification follows variables, equations, and fuzzy rules as in [9].

The prototype system was tested by placing an RFID tag containing data of the ideal temperature and humidity of the goods. The temperature of the warehouse needed to store these goods are 20°C and the ideal storage humidity is 50%. The initial temperature and the initial humidity set by the prototype is 26°C and 80%, respectively.

3.1. Result

Experiments were conducted on the sensor readings SHT11 temperature and process control system based on the difference between the temperature and humidity of the warehouse beginning with ideal temperature and humidity storage of goods, as well as the rate of change of the value difference. The results of the temperature control based on the error value and derivative of error of temperature are shown in Table 3. The results of humidity control base on its error value and derivative of error for humidity are shown in Table 4. The effect of control actions carried out against changes of error is shown in Figure 3.

3.3. Temperature Control Analysis

Table 3 shows that the fuzzy control action was done by enabling or disabling the cooling or heating. The accuracy of the temperature control is 83.33% based on the acts performed by fuzzy rules, which are made directly with the actions taken by the prototype.

This can be caused by the selection of temperature actuator, which can respond fast enough when an inference is generated. When the actuator works, measuring the temperature inside the warehouse has resulted in different temperature error. Temperature's actuator used in this prototype can only be controlled with on-off models. The work of the temperature actuator was not optimal if done at a voltage or frequency manipulation. We can only manipulate the number of peltiers used.

Fuzzy controllers used for controlling the temperature can eliminate overshoot that are usually found in conventional control. In Figure 3, the purple line shows the changes of temperature's error after fuzzy control action. The value of temperature needed was 0, which is called steady state. All controlling system's purpose is to always be in the steady state. Figure 3 also shows how the changes of temperature error always lead to steady state and then maintain around the steady state.

Fuzzy controller shows that temperature controller can reach a steady state without overshoot and maintain the state always in steady state. When the value has not reached the steady state, the temperature controller tries to decrease its value by activating cooler actuator and if the allowed value of temperature error steady state will pass. If there is a tendency of the temperature error value continues to fall, then the fuzzy controller will reduce the speed error temperature reached steady state by reducing the amount of active cooling. This is done so that the error value does not fall below the steady state value. If the value drops below the temperature error of the steady state value, the prototype will raise the temperature by turning on the heater.

Table 3. The results of temperature control

NO	TEMPERATURE (°C)	ERROR	DERIVATIVE OF ERROR	ACTIONS OF TEMPERATURE CONTROL
1	26.73	6.73	0.000	ALL COOLER ACTIVATED
2	26.02	6.02	0.012	ALL COOLER ACTIVATED
3	25.83	5.83	0.003	ALL COOLER ACTIVATED
4	25.42	5.42	0.007	ALL COOLER ACTIVATED
5	25.05	5.05	0.006	ALL COOLER ACTIVATED
6	24.72	4.72	0.006	ALL COOLER ACTIVATED
7	24.12	4.12	0.010	ALL COOLER ACTIVATED
8	23.97	3.97	0.003	2 COOLER ACTIVATED
9	23.72	3.72	0.004	ALL COOLER ACTIVATED
10	23.14	3.14	0.010	2 COOLER ACTIVATED
11	22.95	2.95	0.003	2 COOLER ACTIVATED
12	22.56	2.56	0.007	2 COOLER ACTIVATED
13	22.13	2.13	0.007	2 COOLER ACTIVATED
14	21.85	1.85	0.005	2 COOLER ACTIVATED
15	21.53	1.53	0.005	2 COOLER ACTIVATED
16	21.13	1.13	0.007	2 COOLER ACTIVATED
17	20.81	0.81	0.005	2 COOLER ACTIVATED
18	20.51	0.51	0.005	2 COOLER ACTIVATED
19	20.14	0.14	0.006	1 COOLER ACTIVATED
20	19.81	-0.19	0.006	COOLER & HEATER NONACTIVATED
21	19.68	-0.32	0.002	HEATER ACTIVATED
22	20.57	0.57	-0.015	2 COOLER ACTIVATED
23	20.35	0.35	0.004	2 COOLER ACTIVATED
24	20.12	0.12	0.004	1 COOLER ACTIVATED
25	19.91	-0.09	0.004	HEATER ACTIVATED
26	19.71	-0.29	0.003	HEATER ACTIVATED
27	20.91	0.91	-0.020	2 COOLER ACTIVATED
28	20.71	0.71	0.003	2 COOLER ACTIVATED
29	20.52	0.52	0.003	2 COOLER ACTIVATED
30	20.41	0.41	0.002	2 COOLER ACTIVATED

3.4. Humidity Control Analysis

The fuzzy control action for humidity control are given in Table 4. The actions taken are to activate the blower to the variation of speed rotational of the blower to circulate the water vapor into the warehouse. The accuracy of the humidity control is 63.33% based on fuzzy rules that are used to control the humidity in comparison to the actions of the prototype system.

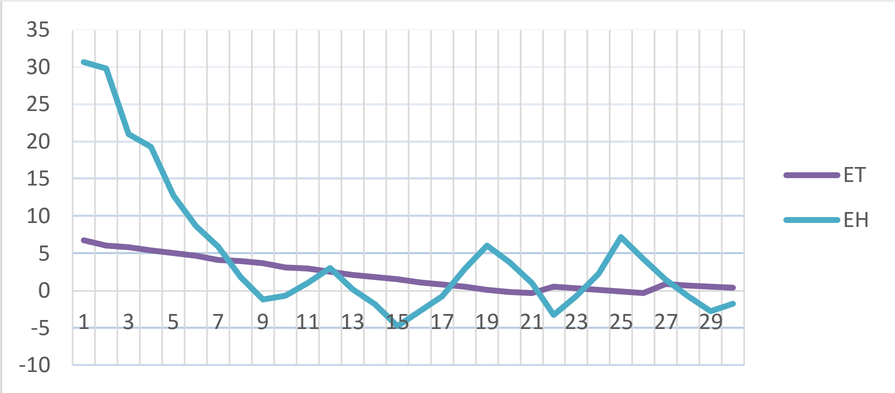

Figure 3. The rate of change in error

Blue line in Figure 3 shows the change in the value of error imposed by the humidity fuzzy control action. The fuzzy control action successfully controls the humidity with no overshoot. But there are oscillations around the humidity steady state value. This is due to the humidity parameter is very sensitive to the action of humidity control. Humidity quickly goes down the humidity error value, but after being charged action to raise the humidity by flowing water vapor into the storehouse warehouse humidity will also rise rapidly.

Table 4. The results of humidity control

NO	HUMIDITY (%)	ERROR	DERIVATIVE OF ERROR	ACTIONS OF HUMIDITY CONTROL
1	80.64	30.64	0.000	BLOWER NONACTIVATED
2	79.81	29.81	0.014	BLOWER NONACTIVATED
3	71.01	21.01	0.147	BLOWER NONACTIVATED
4	69.28	19.28	0.029	BLOWER NONACTIVATED
5	62.79	12.79	0.108	BLOWER NONACTIVATED
6	58.72	8.72	0.068	BLOWER NONACTIVATED
7	55.92	5.92	0.047	BLOWER NONACTIVATED
8	51.83	1.83	0.068	BLOWER NONACTIVATED
9	48.82	-1.18	0.050	BLOWER NONACTIVATED
10	49.29	-0.71	-0.008	BLOWER NONACTIVATED
11	51.01	1.01	-0.029	BLOWER NONACTIVATED
12	53.03	3.03	-0.034	BLOWER NONACTIVATED
13	50.19	0.19	0.047	BLOWER NONACTIVATED
14	48.18	-1.82	0.034	MEDIUM SPEED OF BLOWER
15	45.27	-4.73	0.048	BLOWER NONACTIVATED
16	47.28	-2.72	-0.034	MEDIUM SPEED OF BLOWER
17	49.28	-0.72	-0.033	MEDIUM SPEED OF BLOWER
18	52.92	2.92	-0.061	BLOWER NONACTIVATED
19	56.02	6.02	-0.052	BLOWER NONACTIVATED
20	53.83	3.83	0.037	BLOWER NONACTIVATED
21	51.02	1.02	0.047	BLOWER NONACTIVATED
22	46.72	-3.28	0.072	MEDIUM SPEED OF BLOWER
23	49.26	-0.74	-0.042	MEDIUM SPEED OF BLOWER
24	52.24	2.24	-0.050	BLOWER NONACTIVATED
25	57.23	7.23	-0.083	BLOWER NONACTIVATED
26	54.27	4.27	0.049	BLOWER NONACTIVATED
27	51.48	1.48	0.047	BLOWER NONACTIVATED
28	49.27	-0.73	0.037	MEDIUM SPEED OF BLOWER
29	47.27	-2.73	0.033	MEDIUM SPEED OF BLOWER
30	48.28	-1.72	-0.017	MEDIUM SPEED OF BLOWER

4. Conclusion

Mamdani fuzzy inference models can be used to control the actions of a decision made under the current rules. The rules used in the fuzzy inference are based on the value of the input parameters. MIN operator is used for inference process if only one single rule is active and MAX operator is used for the composition of more than one active rule.

The accuracy of the system to control temperature and humidity in accordance with the rules made in fuzzy systems for temperature is 83.33% and 63.33% for humidity.

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