**PAPER • OPEN ACCESS**

# Modeling the operation of climate control system in premises based on fuzzy controller

To cite this article: L Zh Sansyzbay and B B Orazbayev 2019 *J. Phys.: Conf. Ser.* **1399** 044017

View the article online for updates and enhancements.

# Modeling the operation of climate control system in premises based on fuzzy controller

**L Zh Sansyzbay and B B Orazbayev**

Department of System analysis and Control, Faculty of Information Technologies, L.N. Gumilyov Eurasian National University, 2 Satpaev Street, Nur-Sultan, Kazakhstan


E-mail: sansyzbaylazzat@gmail.com

**Abstract**. Most of the currently existing microclimate control systems operate on the basis of traditional P, PI, PID controllers. But the work of such systems is effective only in a narrow operating range. With significant fluctuations in environment, it is required to reconfigure the parameters of these regulators each time. In such cases, maintaining comfortable conditions in the room is recommended by using intelligent control technologies, so-called fuzzy control systems, operating in terms of fuzzy logic. The aim of the paper is to research the possibility of implementation of intelligent control systems to maintain the comfortable microclimate in the premises and checking the adequacy of the system through simulation. The climate control system is based on fuzzy inference and provides forming the base of fuzzy production rules, fuzzification of input values, aggregation of truth of sub conditions of each rule, activation of conclusions and defuzzification process that generates an output signal to control the smart home functional devices. Procedures of the fuzzy inference and simulation are implemented in the Matlab programming environment using the Fuzzy Logic Toolbox and Simulink packages. The results of the paper showed that the developed intelligent microclimate control system for premises based on fuzzy logic provides a flexible self-tuning of the engineering equipment and maintaining the microclimate parameters at the required level.

## 1.  Introduction

It is required to investigate the processes of microclimate formation in the rooms for the evaluation of microclimate comfort as well as for the determination of the required power of the engineering systems equipment. As a rule, conducting an experiment in nature is accompanied by significant material and energy costs, and it may lead to the accidents in the operation of the engineering equipment.

In this scenario, it is a well-known option to use the process modeling or process reproduction on the basis of certain methods, provided that the reproduction should adequately reflect the conditions of the processes in nature [1].

One of the powerful tools for performing the modeling is using Simulink and Fuzzy Logic Toolbox environments in Matlab application package.

The purpose of the paper is a development of fuzzy microclimate control systems, as well as its validation (checking the adequacy of the system by conducting simulations).

## 2.  Development of Matlab model for fuzzy temperature control system in the room

Implementation of fuzzy controllers is widely practiced in numerous fields: industry [2-3], transport [4], construction [5].

Apart from that, fuzzy controllers are used in the field of microclimate parameters maintenance in both industrial and residential buildings [6-14]. In these studies, the following microclimate parameters are maintained at the required level using a fuzzy controller: temperature, humidity, carbon dioxide composition, dust concentration.

Temperature control is one of the major factors influencing microclimate in both industrial and residential buildings. Therefore, the modeling of the control system based on the fuzzy controller is tested on the basis of the room temperature control loop.

This control loop consists of the following blocks (figure 1):

1.Block "Set temperature" establishes the desired temperature in the room.

2.Block "Fuzzy controller" represents a model of the fuzzy controller, which is formed using Fuzzy Logic Toolbox package, designed specifically for constructing the fuzzy expert and / or control systems.

3.Using "Room model" block, heat losses through constructions enclosing room are considered.

4.Block "Conditioner Model". In buildings, the conditioner is installed, which can operate in two modes: a heating or cooling.

The system operates in the following way: the difference between the set and the current room temperature is provided to the input of the controller. Based on the generated base of rules, the controller provides an output signal to the conditioner, which includes the heating or the cooling mode with the appropriate productivity based on the error value.
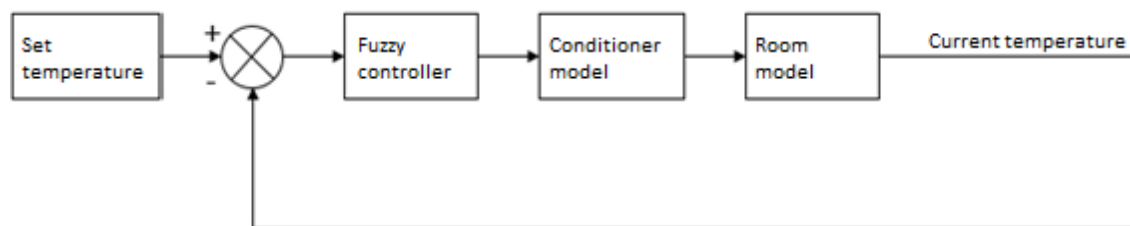


**Figure 1.** Temperature control loop block diagram.

## 3. Determination of heat loss through the enclosing surfaces

Serviced rooms are the primary elements of the climate system. Flows of heat, moisture and impurities are coming to the rooms through the outer enclosing surfaces (outer walls, windows, roof), as well as through the inner enclosure (interior walls, ceiling, floor) and internal sources. These flows by interacting with the volume of rooms are converted and transformed, thereby they cause changes in corresponding parameters of microclimate.

Heat losses occur in the room through the walls, windows, ceiling and floor.

The following is the general formula for the calculation of heat loss (1):

$$Q_{heatloss} = Q_{walls} + Q_{windows} + Q_{ceiling} + Q_{floor} \qquad (1)$$

where, $Q_{walls}, Q_{windows}, Q_{ceiling}, Q_{floor}$ - heat loss through exterior walls, windows, ceiling and floor, respectively.

Heat losses through the wall are determined according to the expression (2):

$$Q_{walls} = k_{walls} \cdot S_{walls} \cdot (t_{in} - t_{out}) \qquad (2)$$

where, $Q_{walls}$ - heat loss through exterior walls, kcal/h; $k_{walls}$ - heat transfer coefficient of the wall, kcal/m²·hour·°C; $S_{walls}$ - an area of the wall, m²; $t_{in}$ - internal temperature of the room, °C; $t_{out}$ - outside temperature, °C.

Heat transfer coefficient of the wall $k_{walls}$ is calculated by formula (3):

$$k_{walls} = 1 / R_c \tag{3}$$

where, $R_c$ - heat resistance of enclosure construction m²·hour·°C / kcal.

Since the wall is a multilayered enclosure, the value $R_c$ is determined by the formula [15]:

$$R_c = R_{in} + R_1 + R_2 + ...R_{ex} \tag{4}$$

where, $R_{in}$ - heat resistance at the inner surface of the enclosure; $R_1, R_2$ - thermal resistance of the individual layers of enclosure; $R_{ex}$ – heat resistance at the outer surface of the enclosure.

Thermal resistance of homogeneous enclosure or layer constituting the multilayer enclosures is calculated by the formula (5):

$$R = \delta / \lambda \tag{5}$$

where, $\delta$ - layer thickness, m; $\lambda$ - thermal conductivity of the material, kcal / m·hour·°C.

Heat loss through the window openings are determined according to the expression (6):

$$Q_{windows} = k_{windows} \cdot S_{windows} \cdot (t_{in} - t_{out}) \tag{6}$$

where, $Q_{windows}$ - heat loss through windows, W; $k_{windows}$ - heat transfer coefficient of windows (W /m²·°C); $S_{windows}$ - the area of windows, m².

The heat transfer coefficient of windows $k_{windows}$ calculated by the following formula (7):

$$k_{windows} = \frac{k_{gl}S_{gl} + k_f S_f}{S_t} \tag{7}$$

where, $k_{gl}$ - heat transfer coefficient of the glazing unit, W / (m²·°C); $S_{gl}$ - glazing area, m²; $k_f$ - heat transfer coefficient of frame (plastic profile), W / (m²·°C); $S_f$ - frame area, m²; $S_t$ - window area, m².

Heat loss through the ceiling and floor are calculated similarly to heat loss through exterior walls.

Applying the formulas (2-7) above, the calculation of heat loss through enclosing structures was performed.

## 4. Development of fuzzy controller for temperature control loop in the room

Input variable of fuzzy controller is the difference between set and current temperatures. The output parameter is the corresponding signal to the actuator of conditioner. Terms and data for constructing membership functions of the input and output variables are presented in tables 1, 2.

**Table 1.** Terms of variable "Temperature difference".

| № | Name of the term | Designation of the term | Range, °C |
|---|---|---|---|
| 1 | Negative Big | NB | from -22 to -9 |
| 2 | Negative Middle | NM | from -14 to -4 |
| 3 | Negative Small | NS | from -9 to 0 |
| 4 | Zero | Z | from -4 to 4 |
| 5 | Positive Small | PS | from 0 to 8 |
| 6 | Positive Middle | PM | from 3 to 13 |
| 7 | Positive Big | PB | from 8 to 17 |

**Table 2.** Terms of variable "Heater (Cooler)".

| № | Name of the term | Designation of the term | Range, % |
|---|---|---|---|
| 1 | Stop | ST | 0 |
| 2 | Low Power | LP | 0-30 |
| 3 | Average Power | AP | 30-60 |
| 4 | High Power | HP | 60-100 |

Table 3 shows the formed base of rules:

**Table 3.** The rule base of fuzzy temperature control system in the room.

| № | If the temperature difference is important | Then the conditioner is operating in the mode of | |
|---|---|---|---|
| | | **cooling** | **heating** |
| 1 | Negative Big | At full power | Off |
| 2 | Negative Middle | At average power | Off |
| 3 | Negative Small | At low power | Off |
| 4 | Zero | Off | Off |
| 5 | Positive Small | Off | At low power |
| 6 | Positive Middle | Off | At average power |
| 7 | Positive Big | Off | At full power |

*Development of a model of the fuzzy controller in the package of Matlab application.*
The structure of the model of the fuzzy controller is shown in figure 2.
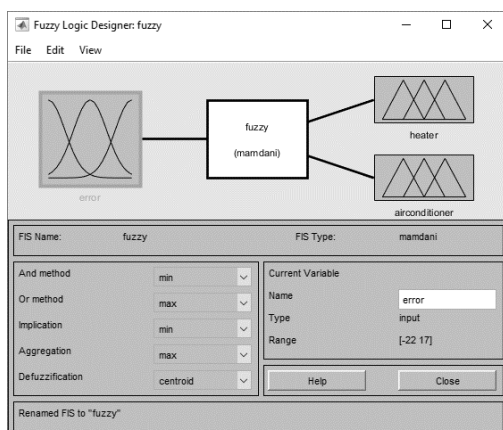


**Figure 2.** The structure of the model of the fuzzy controller.

Figures 3 a, b, c illustrate the plots of membership functions of the input and output variables.
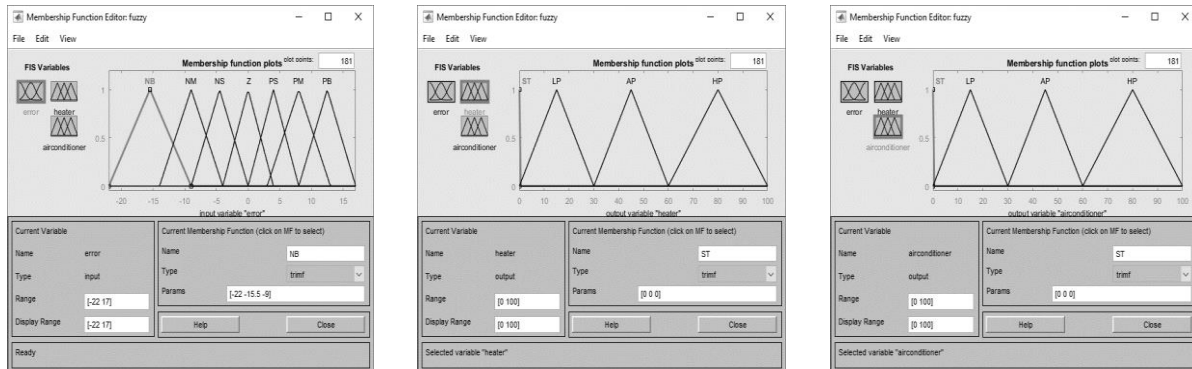


**Figure 3.** a - Plot of membership functions of the input variable "Temperature difference"; b - Plot of membership functions of the output variable "Performance of conditioner in the heating mode"; c - Plot of membership functions of the output variable " Performance of conditioner in the cooling mode".

The formed base of the rules in the application window is shown in figure 4.
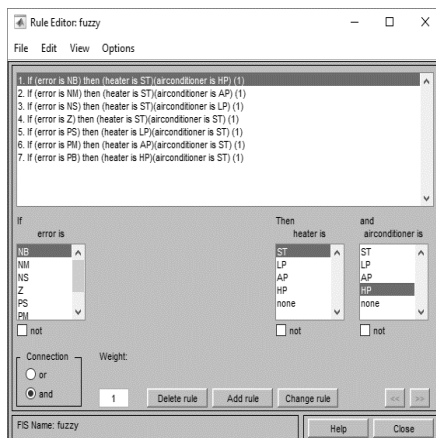


**Figure 4.** The formed base of the rules in Rule Editor.

At the next stage, the verification of the adequacy of the developed control system based on a fuzzy controller for temperature control loop will be produced in Simulink package of Matlab software environment.

Set temperature of Tset = 18°C is defined for modeling. According to the simulation results, the temperature difference is equal to 0.2823°C. In response to this difference, the controller initiates a control signal to the conditioner for turning on the heating mode with performance of 10.3% (figure 5). This scenario indicates that rule №5 is implemented, when the error has a positive small value (it is slightly cold in the room), it is required to turn off the cooling and turn on the heating at low power. The modeling results show that the fuzzy controller is suitable for maintaining microclimate parameters at the desired level (figure 6).
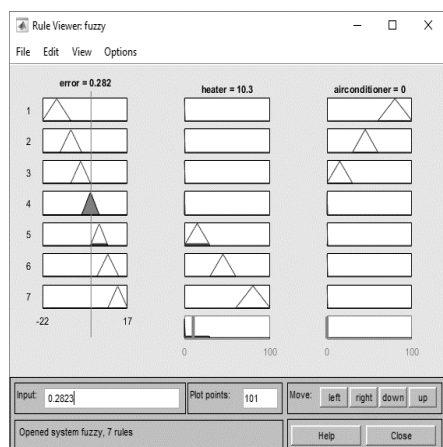
**Figure 5.** The value of the control signal for 0.2823°C temperature difference.
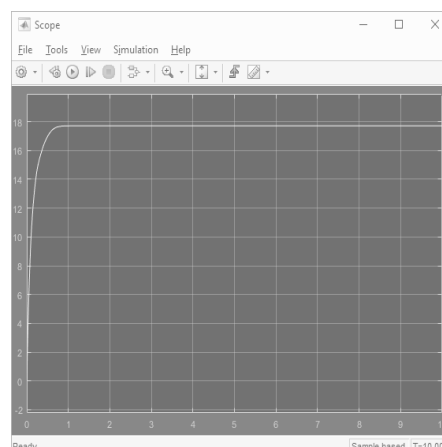


**Figure 6.** Plot of current temperature based on simulation results.

## 5. Conclusion

The study has produced the following results, which have a scientific and practical importance:

- A model of fuzzy controller in Matlab environment based on proposed methods in this paper using Fuzzy Logic Toolbox package.
- A simulation of developed control system is performed taking into account the characteristics of the rooms in Simulink package of Matlab software environment.
- The study results have demonstrated that the developed intelligent microclimate control system of buildings based on the fuzzy logic ensures the maintenance of microclimate parameters (temperature) at the desired level.

The further researches in this direction refer to the exploring the possibility of using a fuzzy controller to optimize the performance of various climatic equipment (heater, humidifier, fan plants, etc.).

## References

[1]   Kuvshinov Iu Ia and Samarin O D  2012 *The basics of microclimate of buildings: Tutorials for universities* (Moscow: Publishing house of Association of construction universities) p 200

[2]   Orazbayev B B, Ospanov E A, Orazbayeva K N and Kurmangazieva L T 2018 A Hybrid Method for the Development of Mathematical Models of a Chemical Engineering System in Ambiguous Conditions *J.Mathematical Models and Computer Simulations* **10** 748–58

[3]   Ospanov  E A, Orazbayev B B, Orazbayeva K N, Mukataev N S  and Demyanenko A L 2016 Mathematical modeling and decision-making on controlling modes of technological objects in the fuzzy environment *Proc. of the World Congress on Intelligent Control and Automation (WCICA) (Guilin, China, 12–17 June 2016)* pp 103–108

[4]   Bregeda S Iu, Burkovskii V L and Choporov O N 2009 Fuzzy-Logic Traffic Control System *J.Bulletin of Voronezh State Technical University* **5(5)** 17–21

[5]   Tararushkin E V 2016 Application of fuzzy logic to assess the physical wear of load-bearing structures of buildings *J.Bulletin of Belgorod State Technological University named after V.G. Shukhov* **10** 77–82

[6]   Sansyzbay L Zh and Orazbaev B B 2017 Intelligent control system of microclimate formation process in the premises *J.Bulletin of L.N.Gumilyov Eurasian National University* **4** 161–69

[7]   Zadeh L 1990 Fuzzy sets and systems *Int.J. of General Systems* **17** 129–38

[8]   Hasim N and Aras M S M 2014 Intelligent room temperature controller system using MATLAB

fuzzy logic toolbox *Int.J. of Science and Research (IJSR)* **3** 1748–53

[9]  Das T K and Das Y 2013 Design of A Room Temperature And Humidity Controller Using Fuzzy Logic *American J. of Engineering Research (AJER)* **2** 86–97

[10]  Alcalá R, Alcalá-Fdez J,  Gacto M J and  Herrera F 2006 Fuzzy Rule Reduction and Tuning of Fuzzy Logic Controllers for a HVAC System *J. Fuzzy Applications in Industrial Engineering* **201** 89–117

[11]  Calvino F, Gennusa M L, Rizzo G and Scaccianoce G 2004 The control of indoor thermal comfort conditions: introducing a fuzzy adaptive controller *J. Energy and Buildings* **36** 97–102

[12]  Eftekhari M and Marjanovic L 2003 Application of fuzzy control in naturally ventilated buildings for summer conditions *J. Energy and Buildings* **35** 645–55

[13]  Kolokotsa D 2003 Comparison of the performance of fuzzy controllers for the management of the indoor environment  *J. Building and Environment* **38** 1439–50

[14]  Mirinejad H, Welch K C and Spicer L 2012 A review of intelligent control techniques in HVAC systems *Proc. of the IEEE Energytech (Cleveland, Ohio, USA, 29–31 May 2012)* pp 1–5

[15]  Hannanova V N 2013 Mathematical model of temperature control system *J. Bulletin of Kazan National Research Technological University* **18** 309–13