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Design of Air-Conditioning Controller by using Mamdani and Sugeno Fuzzy Inference Systems

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Abstract

In this study, a Fuzzy Logic Controller was designed to provide the conditions necessary for operating room. In which input, output & other necessary parameters were saved in the personnel computer. Consequently, good results are obtained through this study and these result shows that the controlled performed with FLC provide more economical, comfortable, reliable & effective controls and they are feasible in real operating room. Mamdani-type and Sugeno-type fuzzy models are two types of Fuzzy Inference Systems. The results of the two fuzzy inference systems (FIS) are compared. This paper presents the basic difference between the Mamdani-type FIS and Sugeno-type FIS. The relevant simulation and performance of air conditioning system with fuzzy logic controller is performed using MATLAB/Simulink software.

Key word: Air Conditioning, Operating Room, Temperature,Fuzzy Inference System (FIS), Fuzzy Logic, Mamdani, Sugeno.

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1. Introduction

Fuzzy logic has finally been accepted as an emerging technology since the late 1980s. This is largely due to a wide array of successful applications ranging from consumer products, to industrial process control, to automotive applications [1]. Fuzzy logic is closer in spirit to human thinking and natural language than conventional logical systems [2]. Classical control theory is based on the mathematical models that describe the physical plant under consideration. The essence of fuzzy control is to build a model of human expert who is capable of controlling the plant without thinking in terms of mathematical model [3].Fuzzy systems are very useful in two general contexts: (1) in situations involving highly complex systems whose behaviors are not well understood, and (2) in situations where an approximate, but fast, solution is warranted [4]. Fuzzy logic was put forward earliest in 1965 by L.A. Zadeh. One of the primary applications of fuzzy logic was subway system in Sendai city of Japan. The applied result showed that fuzzy logic control was superior to traditional control. But finding out the correct rule set and determining the essence and range of fuzzy variables is time consuming work. Such as in subway system of Sendai, to obtain correct input sets, the engineers spent several months. Similarly, in central air conditioning system field today, there is a long way to find out a mature expert fuzzy control model which must need plenty of project experience [5]. Air conditioning is not only a name of the product, but by using ideas and methods of air conditioning to create comfort and natural living environment while at same
time reduce the ravages of nature and achieve real sense harmony of human and nature to maximum extent [6].

Nowadays, air conditioning systems are commonly found in homes and offices, and in almost all public enclosed spaces.Fuzzy logic basically uses a logic & decision mechanism which doesn‟t have certain boundaries like human logic.One of its most common implementation was in fuzzy-logic based control mechanisms. Fuzzy Logic Control (FLC) systems don‟t require complete model knowledge as other control systems like PID. The Fuzzy Logic Controller (FLC) is easy to perform in industry due to its simple control structure, ease of design and inexpensive cost. In this study we have tried necessary condition and suitable for air balance and temperature in the operating room, using a fuzzy logic controller. The main reason for using fuzzy logic in this type of air conditioning is for energy conservation and human comfort. Fuzzy control systems are specifically used in controlling operating rooms in which complex and uncertain parameters play a difficult role hence, require careful control and vital importance.

II. DETAILS ABOUT THE PROBLEM

Slight modifications [figure 1] in air circulation method around heat exchangers allow a conventional AC to function anywhere between normal AC mode and Dehumidifier only mode. In dehumidifier only mode chilled air is totally passed through hot side of heat exchanger so that the AC dehumidifies without any change in output temperature.

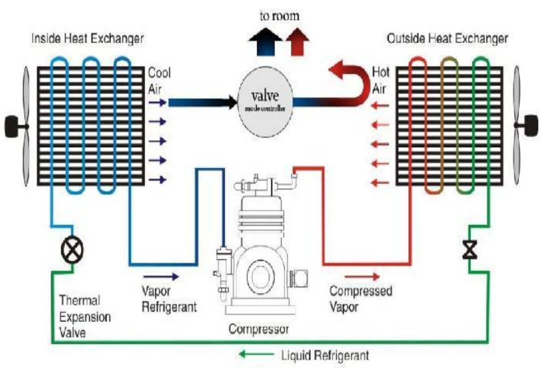


Fig.1. Simplified working diagram of AC

The problem takes three variables into consideration…

- User temperature preference (18ºC~30ºC continuous control).
- Actual room temperature.
- Room dew point temperature.

User temperature is subtracted from actual room temperature before being sent for fuzzyfication. Fuzzy arithmetic and criterion is applied on these variables and final result is defuzzyfied to get following crisp results.[17]

- Compressor Speed.
- Fan Speed.
- Mode of operation.
- Fin Direction.

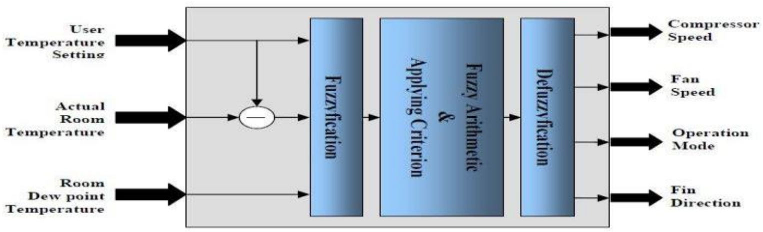


Fig.2. Basic block diagram of controller

The rest of the paper is organized as follows: Section III, gives the difference between Mamdani-type and Sugeno-type FIS. Section IV, shows the development of Mamdani-type FIS. Section V, shows the development of Sugeno-type FIS. Section VI, gives results and discussions and section VII conclusions.

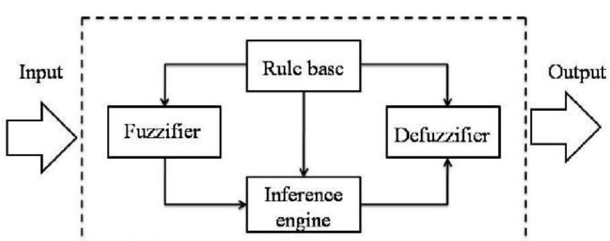
III. MAMDANI-TYPE FIS VS. SUGENO-TYPE FIS

Mamdani method is widely accepted for capturing expert knowledge. It allows us to describe the expertise in more intuitive, more human-like manner. However, Mamdani-type FIS entails a substantial computational burden. On the other hand, Sugeno method is computationally efficient and works well with optimization and adaptive techniques, which makes it very attractive in control problems, particularly for dynamic non linear systems. These adaptive techniques can be used to customize the membership functions so that fuzzy system best models the data. The most fundamental difference between Mamdani-type FIS and Sugeno-type FIS is the way the crisp output is generated from the fuzzy inputs. While Mamdani-type FIS uses the technique of defuzzification of a fuzzy output, Sugeno-type FIS uses weighted average to compute the crisp output. The expressive power and interpretability of Mamdani output is lost in the Sugeno FIS since the consequents of the rules are not fuzzy [7]. But Sugeno has better processing time since the weighted average replace the time consuming defuzzification process. Due to the interpretable and intuitive nature of the rule base, Mamdani-type FIS is widely used in particular for decision support application. Other differences are that Mamdani FIS has output membership functions whereas Sugeno FIS has no output membership functions. Mamdani FIS is less flexible in system design in comparison to Sugeno FIS as latter can be integrated with ANFIS tool to optimize the outputs.

IV. DEVELOPMENT OF MAMDANI-TYPE FIS

Air conditioning system is first developed using mamdani fuzzy model. It consists of two inputs from temperature and humidity sensors providing the temperature and humidity of the room. The system has one output that controls the compressor speed. The temperature and humidity are taken to be in ranges of 0ºC to 45ºC and 0% to 100% respectively. Each of the inputs has four triangular membership functions as shown in Figs.4 and 5. The output i.e. compressor speed is taken in percentage in range from 0% to 100% and have four triangular membership functions shown in Fig. 3. The rules included for the air conditioning system are described in Table I. The performance of Fuzzy logic controller is well documented for improvements of voltage sag. The function of fuzzy logic controller is very useful since exact mathematical model of it is not required. The fuzzy logic control system can be divided into four main functional blocks namely Knowledge base, Fuzzification, Inference mechanism and Defuzzification, Rule base.

Fig. 3 The Basic Elements of a FLC



The main idea underlying the fuzzy logic control is, to highlight the issues involved, Fig. 3 shows the basic element of FLC, which comprises four principal components: a fuzzification, a Rule base, Inference engine, and defuzzification.

1. The fuzzification interface involves the following functions

a. Measure the values of input variables,

b. Performs a scale mapping that transfers the rang of values of input variables, into corresponding universes of discourse,

c. Performs the function of fuzzification that converts input data into suitable linguistic values.

2. The Knowledge based comprises a knowledge the application domain and attendant control goal. It consists of a “data base” and a “linguistic (fuzzy) Control rule base’’

a. The data base provides necessary definitions, which are used to Defined linguistic control rules and fuzzy data manipulations in fuzzy logic control

b. The Rule base characterizes the control goals and control policy of the domain experts by means of set linguistic control rules.

3. The decision-making logic is the kernel of fuzzy logic control. It has the capability of simulating human decision-making based on fuzzy concepts and inferring fuzzy control action employing fuzzy implication and the rule of inference fuzzy logic.

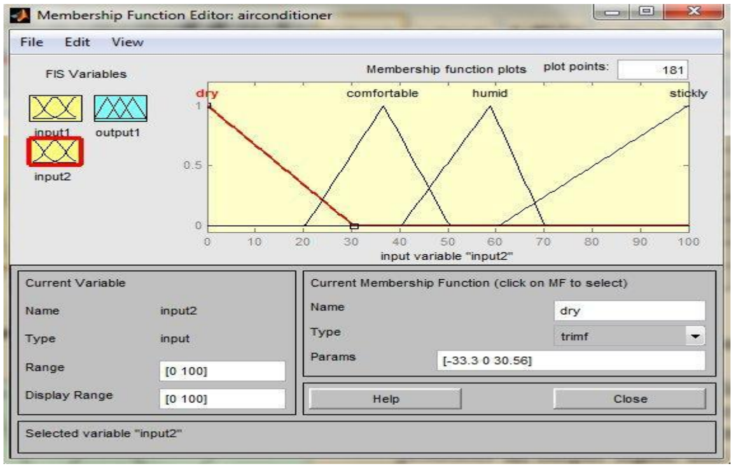


Fig.4. Temperature membership functions

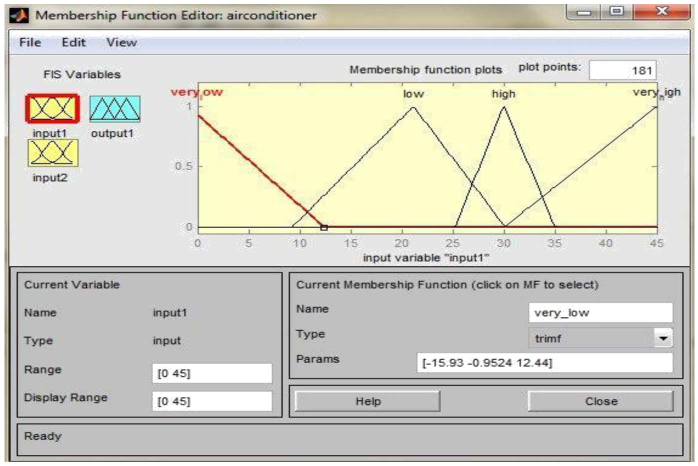


Fig.5. Humidity membership functions

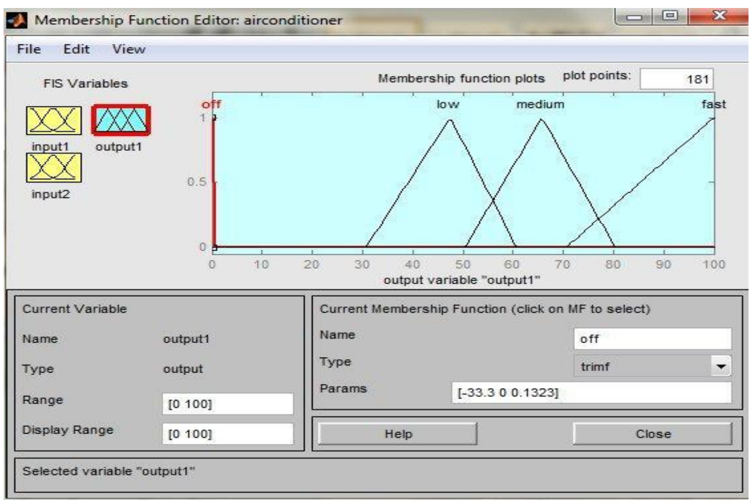


Fig.6. Compressor speed membership functions

4. The defuzzification interface performs the following functions:

a. A scale mapping, which converts the range of values output variables into corresponding universe of discourse

b. Defizzification, which yields a non-fuzzy control action from an inferred fuzzy control action. [13]

The design of FCSs with Mamdani FC is usually performed by heuristic means incorporating human skills and experience, and it is often carried out by a model-free approach. The immediate shortcoming resulted from the model-free design and Fuzzy Controller tuning concerns the lack of general-purpose design methods. Although the performance indices of such control systems are generally satisfactory, a major problem is the analysis of the structural properties possessed by the FCSs including stability, controllability, parametric sensitivity and robustness. The Rule base for membership function is shown Table I.[14]

Table I. Rule base of Mamdani-type FIS

Rules	**Temperature**	**Humidity**	**Compressed Speed**
1.	Very Low	Dry	Off
2.	Very Low	Comfortable	Off
3.	Very Low	Humid	Off

4.	Very Low	Sticky	Low
5.	Low	Dry	Off
6.	Low	Comfortable	Off
7.	Low	Humid	Low
8.	Low	Sticky	Medium
9.	High	Dry	Low
10.	High	Comfortable	Medium
11.	High	Humid	Fast
12.	High	Sticky	Fast
13.	Very High	Dry	Medium
14.	Very High	Comfortable	Fast
15.	Very High	Humid	Fast
16.	Very High	Sticky	Fast

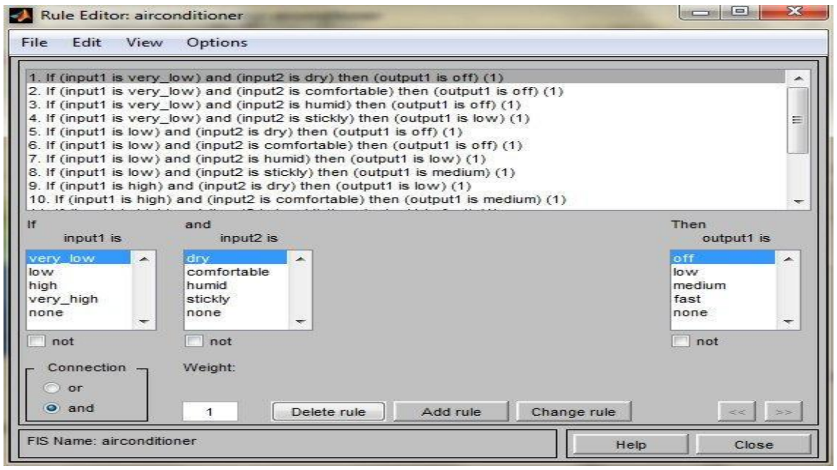


Fig.7. Rules for Mamdani-type model

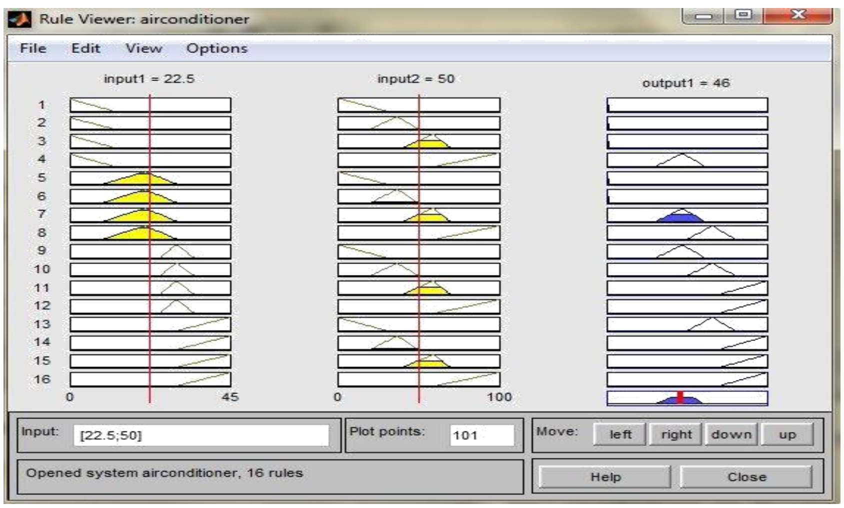


Fig.8. Rule Viewer of mamdani type model

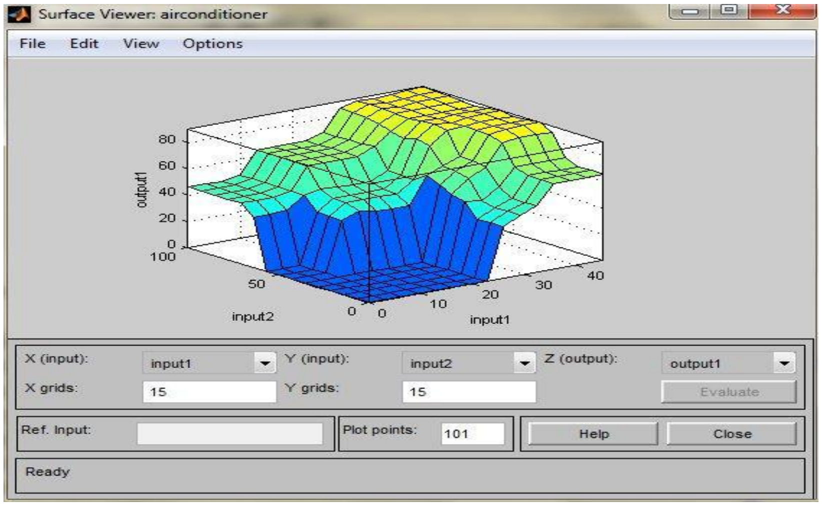


Fig.9. Surface view of Mamdani-type FIS

V. DEVELOPMENT OF SUGENO-TYPE FIS

For development of air conditioning system using Sugeno-type model, the initial steps are same as Mamdani-type model. It also takes inputs from temperature and humidity sensors and produces an output signal that controls the compressor speed. Inputs temperature and humidity have four triangular membership functions over the range of 0ºC to 45ºC and 0% to 100% respectively (as already shown in Figs. 1 and 2). The output compressor speed can only be either constant or linear in this FIS, so four membership functions for the output are "off", "low", "medium" and "fast" which are constant and are shown in Table II. The output in Sugeno-type FIS can only be in range of 0-1. The rule base for Sugeno-type FIS is same as for Mamdani-type FIS as shown in Table I.

Table II. Compressor speed membership functions

Compressor Speed	**Constant Value**
Off	0
Low	0.3333
Medium	0.6667
Fast	1

VI. RESULTS AND DISCUSSIONS

The plots obtained after simulating Mamdani-type of FIS for air conditioning system are shown in Figs.7, 8 and 9.Following are the plots obtained after simulating the Sugeno-type FIS for air conditioning system (as shown in Fig. 10, 11 and 12):[18]

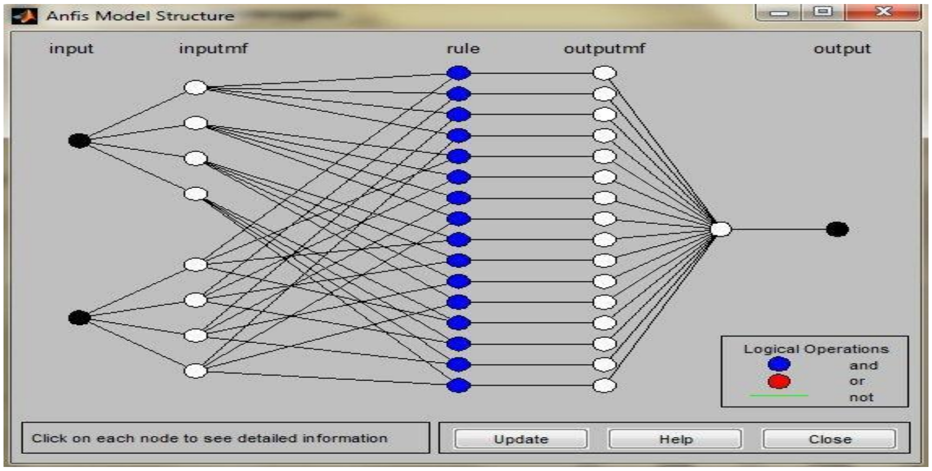


Fig.10.ANFIS Model Structure

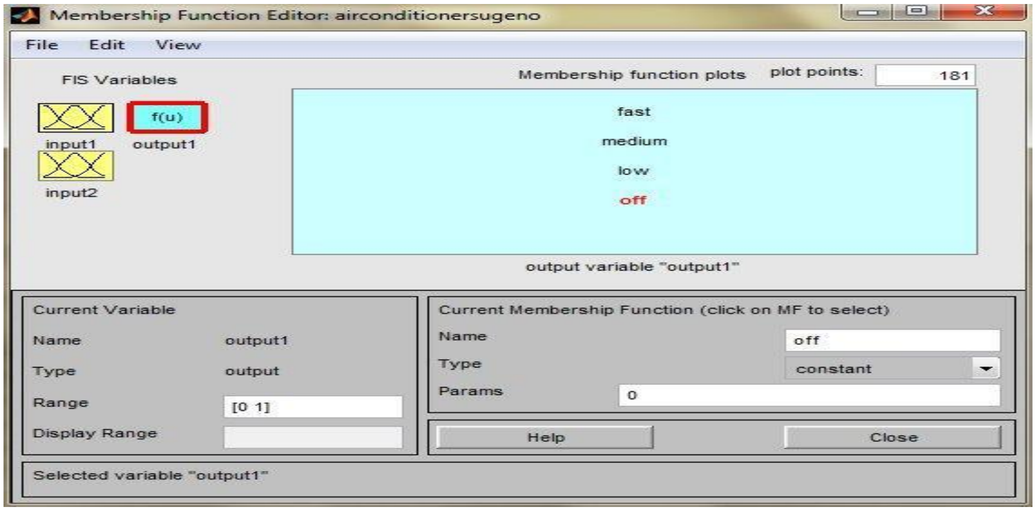


Fig.11.Output Membership Function of Sugeno

The results obtained show that for the given application of air conditioning system Mamdani-type FIS and Sugeno-type FIS works similarly.

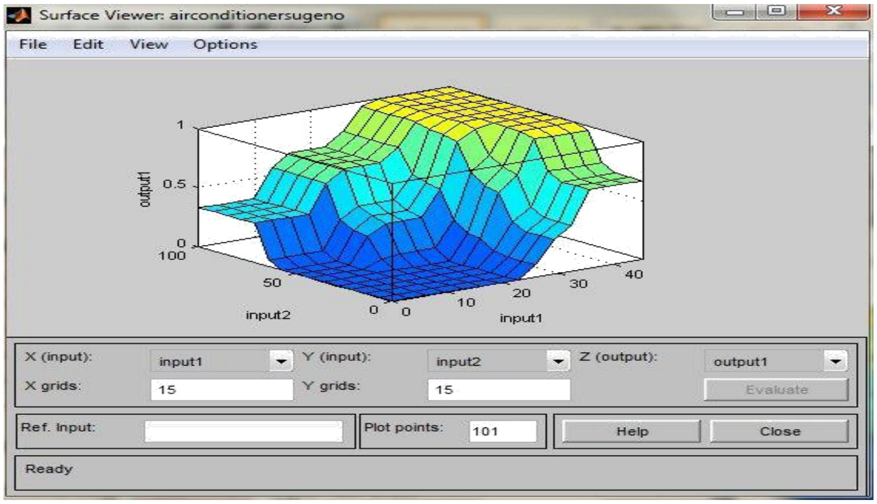


Fig.12. Surface View of Sugeno -type FIS

The only difference noticed is that in Sugeno-type FIS air conditioning system works upto its full capacity whereas in Mamdani-type FIS it does not work upto full capacity.

VII. CONCLUSION

In present paper work a novel fuzzy control methodology for air conditioning in operating room is proposed. A fully automatic air conditioning system is designed using fuzzy logic. It can be concluded from this work that for air conditioning system Mamdani-type FIS and Sugeno-type FIS performs similarly but by using Sugeno-type FIS model it allows the air conditioning system to work at its full capacity. Although the designing of both the FIS is same but the output membership functions of Sugeno-type can only be either constant or linear and also the crisp output is generated in different ways for both the FIS. Sugeno-type FIS has an advantage that it can integrated with neural networks and genetic algorithm or other optimization techniques so that the controller can adapt to individual user, environment and weather. The entire system is analyzed with FIS using MATLAB7.7/Simulink under various conditions.

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