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Comparative Analysis of Fuzzy Inference Systems for Air Conditioner

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Abstract

In today's world there is exponential increase in the use of air conditioning devices. The enhancement in utilization of such devices makes it essential for them to work with their full capability and efficiency. The fuzzy inference systems are best suited for the applications requiring easy interpretation, human reasoning, accurate decision making and control. The fuzzy inference systems resemble human decision making and generate precise solutions from approximate information. A comprehensive review of fuzzy inference systems with weighted average and defuzzification is covered in this paper. The objective of the paper is to provide the comparative analysis of fuzzy inference systems. This paper is a quick reference for the researchers in studying the characteristics of fuzzy inference system in air conditioner.

Keywords

Decision making, interpretation, weighted average, defuzzification.

1. Introduction

The health and productivity of a person has an effect of the indoor air quality of an enclosed space, as a person may spend much time indoors. Air conditioning systems are designed to regulate the temperature and humidity of the room. The main effort in air conditioning system are uneven conditions, extreme nonlinear factors, interaction between parameters of environment, variation in such parameters and unfeasibility to model the system accurately [1].

Conventionally, the accurate control of temperature and relative humidity of the conditioned space is accomplished by cooling the air to the required specific humidity and reheating it to the desirable temperature. This method increases the energy consumption in buildings and global warming gas release to the atmosphere. Researchers have identified the major factors contributing to the human thermal comfort over many years. Hence air conditioning system has becoming a field to be researched to improve the user convenience by applying intelligent system such as Adaptive Fuzzy controller [1].

A fuzzy system is a growing area in research field of soft computing. Different logics and inference techniques of fuzzy systems are there in the historical data of soft computing. Fuzzy inference system is a computing framework based on the disciplines of fuzzy set theory, fuzzy if-then rules and fuzzy reasoning. The input required to Fuzzy inference system is in fuzzy form or in crisp form but the output it generates is always in fuzzy form. Fuzzy inference system is also called as fuzzy rule based system, fuzzy expert system, fuzzy associative memory, fuzzy controller, fuzzy model or simply fuzzy system on the basis of the target for which the system is designed. For example if the target of a system consist of temperature controlling tasks then the fuzzy system will be called as fuzzy controller [2].

In classical set theory an object can either a member of a given set or not while fuzzy set theory allows an object to belong to a set with a certain degree. Fuzzy system models fuzzy boundaries of linguistic terms by introducing gradual membership. Fuzzy set includes membership function. Membership function maps each element of a set to a membership degree [3]. The fuzzy set (F) is represented by two values, the member x of the fuzzy set (X) and the membership degree (μ_A). The fuzzy set is provided by the membership function (f) to which the member is added to the set as shown by (1) [3].

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$$F = \{(x, \mu_A(x)) \mid x \in X\} \quad (1)$$

Fuzzy Inference System

Fuzzy inference systems are widely applicable in economic, scientific and engineering application areas due to the intuitive nature of the system and ability to analyze human judgments. Fuzzy inference systems captures changing environment as an expert knowledge and easily integrated with fuzzy systems. Fuzzy inference systems have the output expressive power so one can easily understand the results and control the target. In decision making and control applications such as air conditioning system, use of fuzzy inference systems is attractive [4]. Fuzzy system algorithm comprise of three main steps:

A. Fuzzification

Fuzzy system maps the input into fuzzy input by using membership function. There are different types of membership functions such as triangular, trapezoidal and gaussian membership function.

B. Inference

Fuzzy rules are constructed by using the fuzzy input and output variables. These fuzzy rules are used by inference procedure to obtain the output.

C. Defuzzification

The fuzzy output is converted into crisp output by various defuzzification methods.

The structure of fuzzy inference system is composed of three components: rule base, database and reasoning mechanism. In rule base fuzzy rules are selected. Fuzzy rules are built from antecedent and consequent. Fuzzy rules are in 'If-then' form. A database defines membership functions used in fuzzy rules. With this membership function membership degree is decided for the objects of the set so that they can be included in fuzzy sets with the membership degree. Fuzzy reasoning performs inference procedure which uses the input information and available fuzzy rules to conclude the output of reasoning mechanism [4]. Figure 1 presents the structure of fuzzy inference system.

Types of Fuzzy Inference System

Fuzzy inference system is classified into three types on the basis of the consequent of the fuzzy rules that are required for the inference procedure: Mamdani fuzzy inference system, Sugeno and Tsukamoto fuzzy inference system. Mamdani fuzzy inference system was initially developed to control the steam engine and boiler combination by using a set of linguistic variables. Mamdani fuzzy inference system generates output in fuzzy form. So there is a need to convert this fuzzy output into crisp form by using different defuzzification techniques to defuzzify fuzzy output into crisp [5].

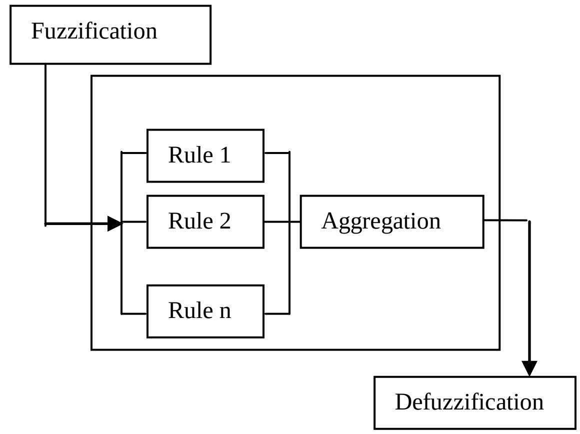

Figure 1: Structure of Fuzzy Inference System

There are five methods of defuzzification. Centroid of area method of defuzzification is mostly used for estimating crisp output compressor speed because of the widespread acceptance in control application. Equation (2) represents formula for centroid of area. In this equation A is a fuzzy set, x is a universe of discourse and $\mu_A(x)$ is aggregated output membership function.

$$\frac{\int_i^n \mu_A(x) x dx}{\int_i^n \mu_A(x) dx} \quad (2)$$

Takagi sugeno kang (TSK) fuzzy inference system is a systematic approach that can generate fuzzy rules from given input output data set. Antecedent of the rule in this system is in fuzzy form and consequent of rule is represented by a function in fuzzy input. In fuzzy inference system with weighted average each rule has crisp output and overall output is calculated by weighted average. The mathematical equation for weighted average is shown by equation (3). Here W_i is the membership degree of the rule R_i and Z_i is a function in p, q and r [3].

$$Z = px + qy + r$$

$$\frac{\sum_i W_i Z_i}{\sum_i W_i} \quad (3)$$

In this paper authors are studying the fuzzy inference system for air conditioning system. The rest of the paper is organized as follows. In Section II, literature review of fuzzy inference system is described which contain fuzzy inference system related work and review table. Section III explains the comparative analysis of the fuzzy inference systems.

2. Literature Review

The Fuzzy system was firstly introduced by Zadeh in 1965. Researchers used the fuzzy systems for applications involving human interpretation due to instinctive power of the fuzzy systems. The fuzzy system was initially developed as a controller. Some of the work done by researchers is explained in this section as follows.

In 2007, I. Saritas et al. [6] proposed a fuzzy system for controlling the room air conditioner. A real operating room is studied by the authors. Triangular membership functions with Mamdani fuzzy inference system are applied to the fuzzy controller. The operating room conditions of the new Selcuklu faculty of medicine are examined. Heat, particle, humidity and oxygen are used as input parameters and motor speed is the output. The system is implemented with C#. The results obtained are recorded with relative time of the day. Such fuzzy expert system of the room air conditioner is economical, comfortable, and consistent. But Mamdani FIS lacks self-learning ability.

In 2011, M. Abbas et al. [7] developed a fuzzy rule based control system for autonomous air cooler. The system utilizes Mamdani fuzzy inference. The inputs to the system are temperature, humidity whereas cooler fan speed, water pump speed, room exhaust fan speed are output. The input and output variables are mapped using triangular membership function. The crisp output values are evaluated by centre of average method of defuzzification. The error in percentage in designed system values and MATLAB simulation is 10.8 for speed of cooler fan. The percentage errors for the speed of water pump and speed of room exhaust fan are respectively 4.6 and 7.8. The designed model of autonomous air cooler makes thesystem easy to control but huge amount of parameters needs to be identified.

In 2012, S. Das et al. [8] designed an intelligent air conditioning system with Mamdani fuzzy inference system. The intelligent air conditioning system executes the cooling process without considering the relationship between physical parameters. The environmental factors like temperature, humidity are assessed by the designed system to come across the comfortable level of cooling. Automation in air conditioning system causes to carry out various operations related to consumer preferences instead of simply cooling the rooms. Mamdani fuzzy inference in the system requires defuzzification for calculating the output.

In 2012, A. Kaur et al. [9] proposed fuzzy system approach for air conditioning system. Mamdani type and Sugeno type of fuzzy inference systems are designed for air conditioner. These systems take the inputs from temperature and humidity sensors which gives the temperature and humidity of the room. Output is produced in the form of signals that controls the compressor speed. Mamdani type and Sugeno type of fuzzy inference system are compared in this work. However, proposed Mamdani and Sugeno system gives unstable output.

In 2012, N. Hasim et al. [10] proposed a fuzzy system for temperature control in water bath. Max min Mamdani fuzzy inference system with centre of gravity defuzzification method is used. External environmental temperature and water tank level are taken as input and required temperature is the output of the system. The input and output variables are mapped with triangular and trapezoidal membership functions. The fuzzy logic controller of water bath temperature control system achieves accurate results and conserves the energy of the water bath system. The fuzzy water bath temperature controller does not train itself so in order to enhance the operational performance training routine is required.

In 2013, A. Shleeg et al. [11] designed Mamdani and Sugeno type FIS for estimation of breast cancer risk. In this work authors comparatively presented both the fuzzy inference systems and Gaussian membership functions are used. The inputs to the system are age, Size of tumor and output is risk of cancer. The clinical breast cancer dataset is used for evaluation of the risk using fuzzy inference rules. The developed Mamdani and Sugeno fuzzy inference system for breast cancer works with similar effectiveness but the Sugeno system has smooth operational performance. The Sugeno fuzzy inference system can be integrated with optimization algorithms to obtain improved results despite the fact that such approach cannot control the system perfectly.

In 2013, P. Adewuyi [12] proposed Mamdani and Sugeno type fuzzy inference system for controlling computer fan speed. The inputs for the system are computer operating temperature, load of the computer and output is speed of the fan. Operational performance of Mamdani and Sugeno type of fuzzy inference system is studied by the author. However, the proposed approach does not give stable speed of fan.

In 2014, N. Octavia et al. [13] used fuzzy logic controller for temperature control in water-bath. The Max-min Mamdani fuzzy system and center of gravity singleton method for defuzzification is used in the inference engines. Seven linguistic variables and 7×7 matrix of rules is utilized for the fuzzy logic control system. The input is mapped with gaussian membership function. MATLAB Fuzzy Logic Toolbox is used to simulate the result of the water-bath temperature control system. The desired output temperature is obtained from the water bath system. This model gives efficient and good performance in water-bath temperature control but to increase the efficiency, additional method is required.

In 2013, T. Das et al. [14] designed a room temperature and humidity controller using fuzzy system. The designed structure contains two fuzzy controllers. The current temperature and its deviation from user set temperature are the input to the first controller which controls the speed of heating and cooling fan. The achieved set point temperature is the input for second fuzzy controller that controls the humidity. Triangular membership function is used to map the fuzzy input. MATLAB simulation is used to attain the designed goal. The proposed controller works perfectly over a wider range of temperature and has more accuracy. Such fuzzy logic control system has increased capability in process automation with probable benefits.

In 2012, O. Verma et al. [15] implemented water bath temperature control system using fuzzy logic. Non-linear control of water bath temperature is made by employing Fuzzy Logic Controller. In water bath system, cold water enters in the water tank from one end and hot water leaves from the other end. The aim is to obtain the output water at the desired temperature. The inputs to the system are error and change in error of temperature. Inputs are mapped with Gaussian membership function. The desired output water temperature of water bath is achieved through fuzzy logic controller.

In 2006, D. Delgado et al. [16] developed fuzzy based controller, as an advisory system that incorporates expert knowledge about the treatment of disease. The advisory system regulates blood's glucose level. The control framework is based on feedback structure. The inner loop decides the amount of long and short acting insulin which is needed three times in a day before meal. The outer loop suggests the maximum amount of insulin required by patient in a time scale of days. The inner loop controller is designed with Mamdani type fuzzy architecture with fuzzy sets that uses three types of membership functions. The shape membership function is selected according to the fuzzy classification of input and output values. The output of this controller is evaluated with centroid of area method. But there are some flaws in this system such as there is less flexibility in system design of the Mamdani type fuzzy controller. The Survey of fuzzy inference systems for air conditioner is presented in Table 1.

Table 1: Survey of Fuzzy Inference System

Author	Type of FIS	Membership Function	Limitation
I. Saritas et al.	Mamdani FIS	Triangular MF	It does not train itself
M. Abbas et al	Mamdani FIS	Triangular MF	Huge amount of parameters need to be identified
S. Das et al.	Mamdani FIS	Triangular MF	Defuzzification is needed
A. Kaur et al.	Mamdani and Sugeno FIS	Triangular MF	Provides unstable output
N. Hasim et al.	Mamdani FIS	Triangular MF & Trapezoidal MF	It does not train itself
A. Shleeg et al.	Mamdani and Sugeno FIS	Gaussian MF	Cannot control the system perfectly
P. Adewuyi	Mamdani and Sugeno FIS	Triangular MF	Produces unstable fan speed
N. Octavia et al.	Mamdani FIS	Gaussian MF	Lacks self-learning ability

In 2014, S. Manocha et al. [17] developed a system fuzzy to control the indoor thermal comfort level.

The outer atmospheric constraints collectively named as Sol Air Temperature (SAT). Similarly internal and open air surface heat transfer coefficient and thermal properties of the materials employed in the buildings are collectively named as Overall Thermal Transmittance (OTT). SAT and OTT are the input parameters of the system for sustaining the thermal comfort level. A fuzzy knowledge based model is constructed in this work for estimating the indoor thermal comfort level based on the defuzzification approach. The linguistic variables are assigned to the parameters and mapped using triangular membership function. Centre of gravity method of calculating output is used to evaluate thermal comfort level. Results reveal that Fuzzy Inference System is capable to deal with problems based on user knowledge and experience.

3. Comparative Analysis and Discussion

Fuzzy inference systems (FIS) with defuzzification and weighted average for air conditioning system are studied in this paper. The study reveals some of the characteristics of both the fuzzy inference system. This section provides the comparative analysis of the FIS with specific parameters. Table 2 presents the comparison of fuzzy inference systems.

Table 2: Comparison of Fuzzy Inference Systems

Parameter	Mamdani FIS	TSK FIS
Adaptability to other algorithms	Not adaptive	Adaptive to other algorithms
Method of output evaluation	Defuzzification	Weighted average
Control on the systems	Can control the system perfectly	Cannot control the system perfectly
Parameter Initialization	Huge amount of parameters needs to be identified	Less parameters needs to be initialized
Intuitiveness	More intuitive	Less intuitive

Controlling the temperature is the major issue in many industries which motivates to use fuzzy inference system in air conditioning system with changing environment. This necessitates discovering new algorithms for employing air conditioning system. Following these facts a lot of work is done by researchers in this area. The analysis of such research work is completed in this paper. The analysis proves that, Mamdani FIS is not adaptive to the algorithms that can enhance the performance of the system by adding self-learning facility. While TSK FIS are adaptive to such methods. Mamdani FIS can control the systems efficiently which requires quick and effective control in comparison to TSK FIS. Creation of Mamdani FIS involve huge amount of parameter initialization. However in TSK FIS only few parameters need to be initialized. Mamdani FIS is used often due to the intuitive nature of the system and ease in designing.

4. Conclusion and Future Work

A variety of fuzzy inference systems exist and employed these days. Primarily two types of fuzzy inference systems have been used namely Mamdani fuzzy inference system and Sugeno fuzzy inference system. In this paper authors have studied these fuzzy inference systems with defuzzification and weighted average for air conditioning system. From the comparative analysis it is evident that Mamdani fuzzy inference system is best suited for controlling applications. However, Mamdani FIS lacks the adaptive nature to other algorithms. TSK FIS can be used with other algorithms but requires intuitiveness. Each FIS has certain limitations that lead to imprecise and unstable results when used separately. Therefore, an approach combining both the FIS can be used for air conditioner as a future work.

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References

[1] J. Singh, N. Singh, J. K. Sharma, "Fuzzy Modelling and Control of HVAC Systems – a Review", Journal of Scientific and Industrial Research, vol. 65, pp. 470-476, June 2006.

[2] H. Mirinejad, S. H. Sadati, M. Ghasemian, and H. Torab, "Control Techniques in Heating, Ventilating and Air Conditioning (HVAC) Systems", Journal of Computer Science, vol. 4, no. 9, pp. 777-783, August 2008.

[3] JhyShing Roger, Chuen Tsai Sun and EijiMizutani, "Neuro- Fuzzy and Soft Computing", Prentice Hall International Limited UK, 1997.
[4] P. Gupta and N. Kulkarni, "An Introduction of Soft Computing Approach over Hard Computing," International Journal of Latest Trends in Engineering and Technology (IJLTET), vol. 3, no. 1, pp. 254-258, September 2013.
[5] H. Takagi, "Introduction to fuzzy systems, neural networks, and genetic algorithms", Springer US, 1997.
[6] I. Saritas, N. Etik, N. Allahverdi, I. Sert "Fuzzy Expert System Design for Operating Room Air Condition Control System", International Conference on Computer Systems and Technologies, ACM, 2007.
[7] M. Abbas, M. Khan, F. Zafar, "Autonomous Room Air Cooler Using Fuzzy Logic Control System", International Journal of Scientific & Engineering Research, vol. 2, Issue 5, pp. 74-81, 2011.
[8] S. Das, G. Mohanty, A. Mohanty, "Intelligent Air Conditioning System using Fuzzy Logic", International Journal of Scientific & Engineering Research, vol. 3, Issue 12, pp. 1-6, 2012.
[9] A.Kaur and A. Kaur, "Comparison of Mamdani Type and Sugeno Type Fuzzy Inference System for Air Conditioning System", International Journal of Soft Computing and Engineering, vol. 2, pp. 323-325, 2012.
[10] N. Haseem, M. Rashid, M. Aras, A. Kassim, S. Abdullah, "Development of Fuzzy Logic Water Bath Temperature Controller using MATLAB", IEEE International Conference on Control System, Computing and Engineering, pp. 11-16, 2012.
[11] A. Shleeg, I. Ellabib, "Comparison of Mamdani and Sugeno Fuzzy Inference Systems for the Breast Cancer Risk", International Journal of Computer, Information, Systems & Control Engineering, 2013.
[12] P. Adewuyi, "Performance Evaluation of Mamdani-type and Sugeno-type Fuzzy Inference System Based Controllers for Computer Fan", I.J. Information Technology and Computer Science, Vol. 5, Issue 1,pp. 26-36, 2013.
[13] N. Octavia, M. M. Maung, and H. M. Tun, "Performance Evaluation of Fuzzy Logic Controller in Water Bath Temperature Control System," International Journal of Science, Engineering and Technology Research, vol. 3, no. 6, pp. 1623–1629, June 2014.
[14] T. K. Das and Y. Das, "Design of a Room Temperature and Humidity Controller Using Fuzzy Logic," American Journal of Engineering Research, vol. 2, no. 11, pp. 86–97, 2013.
[15] O. P. Verma and H. Gupta, "Fuzzy Logic Based Water Bath Temperature Control System," International Journal of Advanced Research in Computer Science and Software Engineering, vol. 2, no. 4, pp. 333–336, April 2012.
[16] D. U. Delgado, M. Ordonez, R. Femat, and A. G. Moscoso, "Fuzzy Based Controller for Glucose Regulation in Type1 Diabetic Patients by Subcutaneous Route," IEEE Transactions on Biomedical Engineering, vol. 53, no. 11, November 2006.
[17] S. K. Manocha, H. K. Singh, P. K. Yadav, and B. M. Suman, "Predictions Of Indoor Thermal Comfort Level Using Fuzzy Logic," IOSR Journal of Mechanical and Civil Engineering, vol. 11, no. 3, May 2014.

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