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HVAC Optimization Based on Fuzzy Logic in Official Buildings

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ABSTRACT

Today, heating, cooling, ventilation and air conditioning systems (HVAC) are actively used in most modern buildings. These systems, which receive information such as temperature, humidity and pressure through various sensors, try to keep the temperature of the environment at a certain level by subjecting the received information to various pre-processes. In this work performed, the performance of an HVAC system has been tried to be optimized using fuzzy logic. With the proposed approach, a building with a 5-story and 10-apartment HVAC system is modeled and the building's HVAC system is optimized using fuzzy logic. The proposed approach was confirmed by the simulations conducted and a performance increase of approximately 10% was achieved.

Keywords: *HVAC, Fuzzy Logic, Optimization, Modern Buildings.*

1. INTRODUCTION

In today's modern constructions, HVAC systems are often used and provide a central way to balance the interior temperature [1]. These systems, which fulfill the tasks of heating, cooling, ventilation and air conditioning in their environment, have a centralized mechanism and perform this task by collecting data through various sensors in the environment [2]. HVAC systems provide significant energy efficiency in addition to these tasks [3]. In particular, the central control mechanism operates in a fully optimized manner which greatly increases the performance of these systems [4]. These systems, which are frequently used today, can be easily optimized, remotely controlled and controlled by an automation system since they have a centralized structure [5].

For this purpose, a HVAC system is modeled and optimized using dynamic neural networks in a study on HVAC systems. With this approach applied to an existing HVAC system, the performance of the system has been observed to be significantly increased and energy savings of up to about 30% have been achieved [6]. In another study on the subject, optimization of HVAC system with CO2 concentration control was performed by using genetic algorithms. The proposed approach is simulated in the MATLAB environment and verified using the Energy software [7].

In a related work, a detailed energy simulation environment was designed to optimize building properties and HVAC systems. This simulation environment can determine the quality characteristics of the building and optimize the quality of life costs. As a result of this study, optimal designs achieved 10-25% performance reduction in life cycle cost. A flow diagram of this work is shown in Fig. 1 [8]

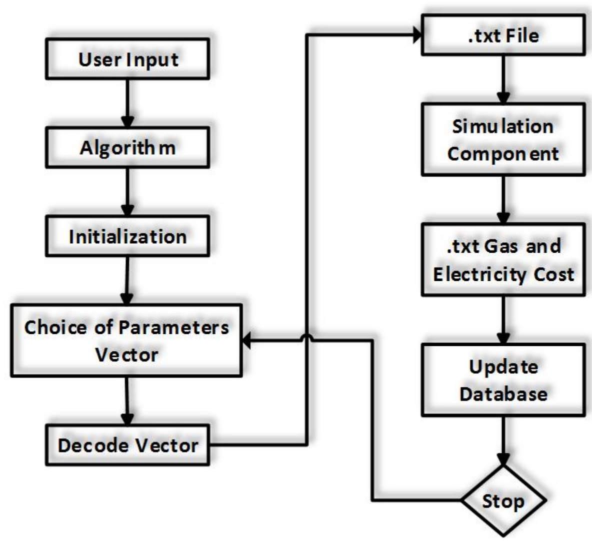


Fig. 1. An example study from literature [8].

In another study on the subject, an HVAC system for air handling subsystem control was modeled and optimized. With the cooling coil model, the optimal control method is used to control the flow of cooled water by changing the outside air temperature. Thus energy saving is achieved [9]. In another study conducted on optimal control of HVAC systems, sensor networks were used for the preferences and continuity of the residents. In the study, an optimization process is presented that takes into account the dynamic relationship between changing preferences and energy use. It has also been taken into account in some limitations as well as the benefits of implementing this approach [10]. There are various optimization techniques in the literature [11]. These techniques are usually used in problems that have a large solution space and cannot be found with the help of a mathematical model of the best solution [12]. There are various applications for HVAC systems using optimization methods available in the literature. In one of these studies, HVAC temperature set point optimization was achieved using genetic algorithm for commercial HVAC systems. This approach has provided substantial energy savings within the building without additional cost [13]. A block diagram of this method is as shown in Fig. 2.

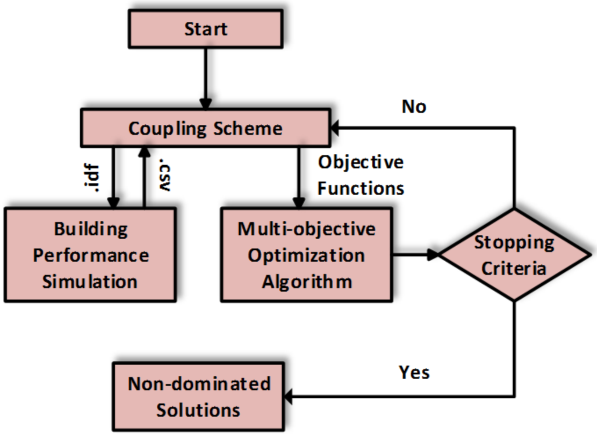


Fig. 2. An example study from literature [13].

In another work on optimization of HVAC systems, a cooler, pump, fan and reheat device were selected to model. As a result of these transactions, it has been observed that the amount of energy consumed by the total ventilation and air conditioning system is reduced by about 7% [14]. Modeling of the cooling coils has been performed by another process operation for the control and optimization of the HVAC systems. It has been observed that the cooling bobbin unit modeled for real-time operating systems is highly efficient in terms of operating performance compared to literature studies [15].

Control and optimization of these systems is required for HVAC systems to operate at high performance. In this study, optimization of HVAC systems was performed using fuzzy logic. Details of the proposed method are presented in the second part of this study prepared for this purpose. In the third part of the study, experimental results are included. In the fourth and last section, the conclusions are presented.

2. PROPOSED APPROACH

HVAC control systems are widely used in today's modern buildings and offer a great deal of convenience to their users. Especially the energy efficiency and the ability to control a single center make these systems extremely useful.

The control and optimization of these systems is compulsory in order for HVAC systems to operate with full performance. These systems, which are connected to a centralized automation, collect various data from the environment they are using and transfer them to the main control unit of the HVAC system, where necessary optimization processes are performed to regulate the temperature balance of the environment. In this work, optimization of HVAC systems is provided. In the proposed approach, fuzzy logic is used, the data received from the environment are processed in the fuzzy logic module and the calculated information is transmitted to the HVAC master control unit. The flow diagram of the proposed fuzzy logic based HVAC optimization method is given in Fig.3 in this framework.

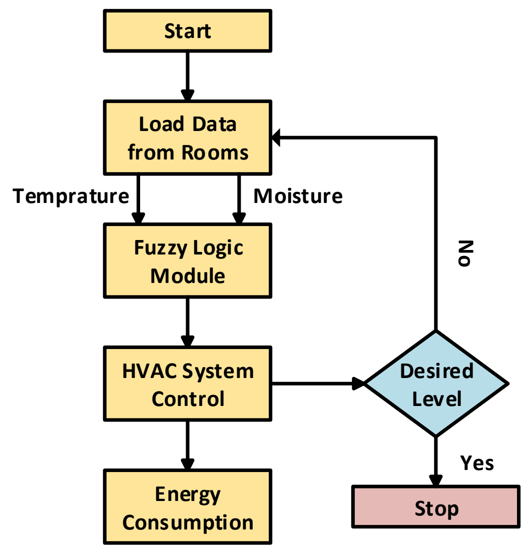
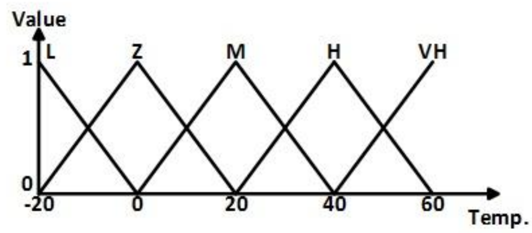


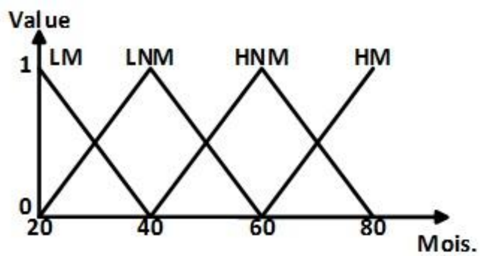
Fig. 3. The flowchart of the proposed approach

In this study, a single input fuzzy system with two inputs is used. The fuzzy logic module, which takes the temperature and humidity values of the environment as input parameters, measures the amount of heat that will be given to the output. In addition, the energy consumption calculation module in the system is in constant communication with the HVAC control system and the energy consumption quantities are continuously recorded.

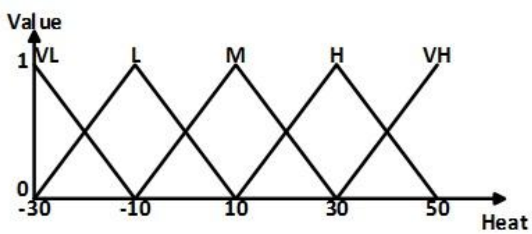
As can be seen from Fig. 3, if the ambient temperature reaches the desired level, the flow of the system is terminated. Otherwise, the steps are carried out again and the information of the environment is taken and transmitted to the fuzzy mode. As mentioned at the beginning of the chapter, the system has two inputs and one output. The block diagrams for these input and output membership functions of fuzzy logic are as shown in Fig.4.



a) Input 1-Temperature



b) Input 2-Moisture



c) Output-Heat

Fig. 4 Fuzzy input and output membership functions

As can be seen from Fig. 4, the system has two input and one output membership functions. The first entry is the temperature of the system, and this function has a total of 5 membership values. The second input of the system is the humidity value of the environment. This function has a membership value of 4 and expresses the humidity of the environment in percentage (%). Finally, the output function of the system is heat. The heat membership function has a total of 5 membership functions. The rule table of the proposed approach based on fuzzy logic in this frame is presented in Table 1.

Table 1: Fuzzy rule based

Rule No	***Temperature***	***Moisture***	***Heat***
1	L	LM	VH
2	Z	LM	VH
3	M	LM	H
4	H	LM	M
5	VH	LM	L
6	L	LNM	VH
7	Z	LNM	H
8	M	LNM	M
9	H	LNM	L
10	VH	LNM	VL
11	L	HNM	H
12	Z	HNM	H
13	M	HNM	M
14	H	HNM	L
15	VH	HNM	VL
16	L	HM	H
17	Z	HM	M
18	M	HM	L
19	H	HM	L
20	VH	HM	VL

As can be seen from Table 1, there are a total of 20 rules in the proposed approach. These rules come into play due to the combination of temperature and humidity membership values. The system calculates a heat value by using the rule table with the temperature and humidity values input to it, and transmits this information to the main control unit of the HVAC system.

3. SIMULATION RESULTS

Optimization of HVAC systems has been implemented with the proposed approach in this study. In the proposed approach, fuzzy logic is used as the basic method and temperature and humidity values which are fed back to the system are used as input parameters. The heat value calculated and obtained as a result of these input parameters is distributed to the rooms located in the building via the HVAC central control system.

A simulation system with 5 floors and 10 rooms was designed. There are also sensors in the rooms that collect temperature and humidity information and send them to the fuzzy calculation module. These sensors are located separately for each section. Thus, the HVAC system evaluates the incoming information separately and can generate separate output values for each section. As mentioned in the beginning of the chapter, there are 2 rooms on each floor. The block diagrams of this model in which the simulation is performed are as given in Fig. 5 and 6.

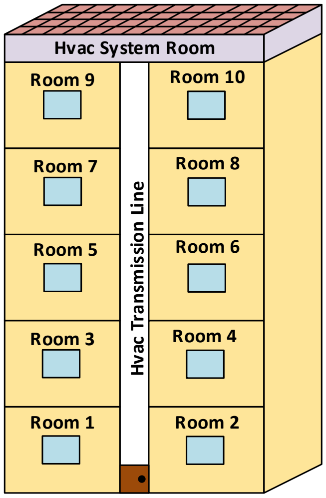


Fig. 5. Building block diagram

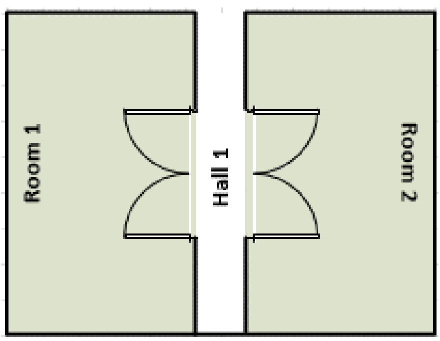


Fig. 6. An example floor block diagram

As can be seen from Fig. 5, there are a total of 10 apartments within the building. There are 5 floors in total, with two apartments on each floor. Fig. 6 shows a sample room distribution. Within each room are sensors that can measure temperature and humidity values. These sensors are connected to the HVAC control center via a single line. Later on, the information from these sensors is processed in the room and the amount of heat that the HVAC system must deliver according to the room is calculated. The result of this fuzzy logic based operation is that the HVAC system can be operated optimally. HVAC systems cause a large percentage of energy consumption in a building. A graph of this situation is presented in Fig.7.

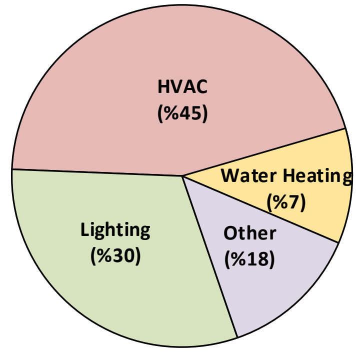


Fig. 7. Energy consumption distribution for general buildings

As can be seen from Fig. 7, the HVAC system is the most energy consuming part of a general purpose building. This consumption followed by lighting, other consumption and water heating systems, respectively. With this approach, the optimization of the HVAC systems has been carried out and energy saving has been achieved. The results of simulations in this frame are presented in Fig. 8 and Table 2, respectively.

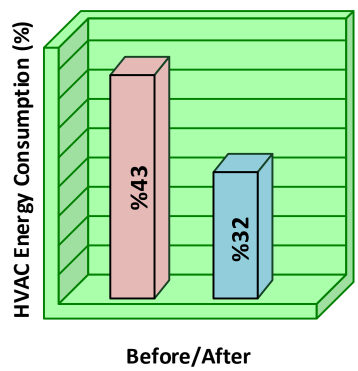


Fig. 8. Energy consumption for proposed approach

Table 2: Calculated energy consumption amounts from simulation

	Before		After	
Rooms	Energy Cons. (kWh)	Cumulative Energy Cons. (kWh)	Energy Cons. (kWh)	Cumulative Energy Cons. (kWh)
1	16.0	16.0	14.4	14.4
2	16.5	32.5	14.8	29.2
3	15.4	47.9	13.9	43.1
4	15.3	63.2	13.6	56.7
5	13.8	77.0	12.4	69.1
6	13.8	90.8	12.1	81.2
7	12.5	103.3	11.3	92.5
8	12.3	115.6	11.1	103.6
9	10.7	126.3	9.6	113.2
10	10.7	137.0	9.7	122.9

4. CONCLUSIONS

HVAC control systems are systems that are frequently used in most modern buildings today, and which can be controlled from a central automation system and which provide significant energy savings. But the inability to work with the full performance of the control algorithms it contains causes both energy loss and financial loss.

With this study, a fuzzy logic optimization method is proposed for HVAC control systems. The proposed approach is a two-input, one-output fuzzy system, simulated for a 5-story and 10-apartment building. As a result of simulation studies, it has been observed that the proposed method provides about 10% energy saving. As a result of this study for general purpose buildings, HVAC control system which causes significant energy loss for the buildings has been successfully optimized and the system can be operated with full performance.

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