Temperature Control System Using Fuzzy Logic Controller

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Abstract—**Temperature is one of the important parameters to be controlled and is widely applied in various fields of industry, such as machinery, petrochemicals, medicine, food, etc. Changes in ambient temperature have a significant impact on the measurements taken. Inappropriate temperature conditions can lead to various problems during measurements that require high precision and accuracy inside a laboratory room. Understanding these discrepancies and taking timely action can increase the accuracy of measurements and prevent gross errors from occurring in the subsequent process. In this article, a fuzzy logic control-based temperature control system in HVAC (Heating, Ventilation, and Air Conditioning) systems has been studied using the Mamdani method to control temperature and ensure air exchange within the environment.**

Keywords—temperature, fuzzy logic control, laboratory, humidity, pressure, heating, cooling

I. INTRODUCTION

Temperature is one of the important parameters to be controlled and is widely applied in various fields of industry, such as machinery, petrochemicals, medicine, food, etc. Controlling predetermined temperature conditions is essential for uninterrupted production in factories and plants, ensuring the comfort of people in homes and workplaces, providing necessary treatment in medical facilities, transporting and storing food from one place to another, and growing plants in greenhouses.

The development of temperature measurements has progressed in parallel with the development of science [1]. The development of the first thermometers (actually thermoscopes) is believed to have begun in the 17th century by the Italian astronomer, physicist, and engineer Galileo Galilei, and this process continued until the mid-19th century. Since then, scales have been developed based on various measurement methods. Currently, in practice, the ITS-90 (International Temperature Scale of 1990), which is internationally accepted by the International Committee of Weights and Measures (CIPM), is used.

According to the International Laboratory Accreditation Cooperation (ILAC), in 2024, 114,600 testing laboratories worldwide (in Azerbaijan, this number is 113) were accredited, and each day hundreds of different types of tests are performed in these laboratories. The standard parameters for conducting these tests are determined according to the ISO 554:1976 International Standard as 23°C (recommended) ÷ 27∘C (for countries located in the tropical climate zone), 50% ÷ 65% for humidity, and 86 kPa ÷ 106 kPa for pressure. However, in special conditions, the temperature for application is 20°C and humidity is 65%.

Changes in ambient temperature have a significant impact on the measurements taken. Inappropriate temperature conditions can lead to various problems during measurements that require high precision and accuracy inside a laboratory room [2]. Thus, in order to ensure the similarity of measurements, the results obtained during measurements of the same quantity, using the same measuring instrument and under the same conditions by the same expert, must be close. However, even a slight change in temperature can lead to different results and, consequently, to measurement errors [3].

However, in order for laboratory technicians to carry out their work process effectively, the ambient temperature must be within certain conditions. Since the normal temperature of the human body is 36.6°C, it has been determined that productivity decreases significantly at temperatures above this temperature. On the other hand, at temperatures of 16°C and below, a phenomenon called cold stress occurs, which is observed with disorientation and excessive shivering. Considering that the temperature in the laboratory environment is low, if this indicator is not properly regulated, it increases the risk of cardiovascular problems and various diseases in people working there [4] [5].

Understanding these discrepancies and taking timely action can increase the accuracy of measurements and prevent gross errors from occurring in the subsequent process.

For this purpose, HVAC (Heating, Ventilation, and Air Conditioning) systems are used to control temperature and ensure air exchange within the environment [6].

II. RESEARCH METHODS

Fuzzy logic, unlike classical logic, is based on the human brain's understanding of events according to their form of perception [7]. This feature allows it to be applied to various fields of science and industry. Since this logic is based on decision-making methods, it can be applied to almost any process. Fuzzy Logic Control (FLC) defines a control model for nonlinear systems without the need for any mathematical model [8].

FLC offers an algorithm-based approach. This approach allows for both the inclusion of uncertainties in the problem and the formation and control of a model of the work without having special mathematical knowledge [9].

In this article, we will look at the study of a fuzzy logic control-based temperature control system using the Mamdani method.

Mamdani fuzzy logic control systems are fundamentally dependent on the knowledge and skills of the specialist. Because multiple IF-THEN rules must be used based on

linguistic variables. Fuzzy logic consists of three main parts: fuzzification, inference engine and defuzzification [10]. The FLC block diagram is shown in Figure 1.
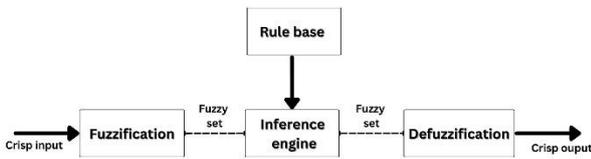

Fig. 1. Block diagram of Fuzzy Control System

Fuzzification is the process of converting crisp values into fuzzy data. Here, fuzzification ensures the fuzziness of the data. The most important feature that distinguishes fuzzy logic is that it avoids all activities that could lead to questionable results. Thus, all indicators for nonlinear systems are obtained by measuring them in real time using measuring instruments and then converted. Each of the indicators obtained from the transformation is assigned to the corresponding membership function (MF). Later, this relationship is illustrated visually using various types of curves (trapezoidal, Gaussian, triangular, etc.) [11]. The choice of MF depends on the type of research being conducted, the researcher's experience, and observations.

The inference engine extracts fuzzy outputs through membership functions using IF-THEN rules. These rules are stored in the rule base [12].

Defuzzification is the opposite process of fuzzification. In the defuzzification phase, the fuzzy values converted in the previous process are converted back into a language that devices can understand (maxima, center of gravity, weighted average and center of sums methods) [13] [14].

III. RESULTS AND DISCUSSION

To model the Mamdani Fuzzy Inference System (Mamdani FIS), inputs are temperature, humidity, pressure, and outputs are cooling, heating, and ventilation.

The fuzzy system in the MATLAB models the correlation between temperature, humidity, pressure, and the operation of ventilation, cooling, and heating in a laboratory environment (Figure 2). This correlation is as follows:

- Temperature's Role

If the temperature is low ($\leq 20°C$), the heating system turns ON to warm the room. If the temperature is normal (between $21°C$ and $25°C$), the ventilation stays in Auto Mode, meaning the system allows air filtration but does not trigger cooling or heating. If the temperature is high ($\geq 26°C$), the cooling system turns ON to lower the temperature.

- Humidity's Role

Humidity values are divided into three ranges (Low humidity (40-50%), Normal humidity (50-65%) and High humidity (65-80%)). Humidity does not directly trigger heating or cooling but influences the ventilation system.

- Pressure's Role

Pressure is classified into three levels (low pressure (80-90 kPa), normal pressure (90-105 kPa) and high pressure (105-110 kPa). Like humidity, pressure does not directly control cooling or heating but is considered when adjusting ventilation.

- Ventilation System Response

If the temperature is normal, the ventilation system operates in Auto Mode, ensuring air filtration and circulation. If temperature is too high or too low, the ventilation remains active, but priority is given to cooling or heating.

The cooling system turns ON if the room gets too warm. The heating system turns ON if the room is too cold. The ventilation system runs in Auto Mode when conditions are stable.

Instead of strict ON/OFF switches, fuzzy logic allows for gradual control, meaning the system adjusts smoothly based on current environmental conditions. This improves energy efficiency and maintains comfort.

In short, the rules are as following (Table 1):

TABLE I.   FUZZY RULES

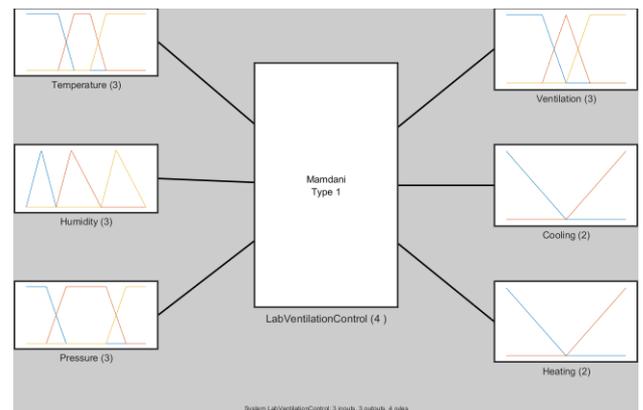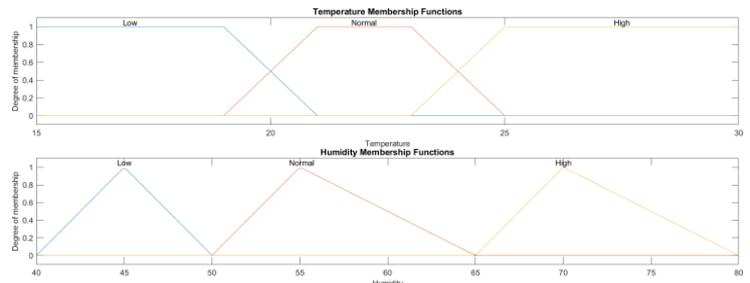| №	Rules
rule1=	"If Temperature is Normal and Humidity is Normal and Pressure is Normal then Ventilation is AutoMode"
rule2=	"If Temperature is High then Cooling is On"
rule3=	"If Temperature is Low then Heating is On"
rule4=	"If Temperature is High and Humidity is Normal and Pressure is Normal then Ventilation is AutoMode"

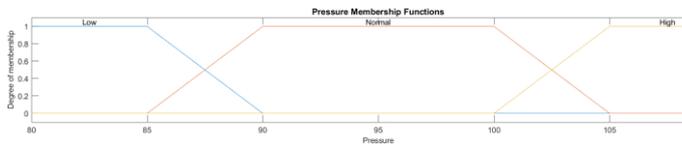Fig. 1. Fuzzy Logic-Based Control System

Fig. 2. Membership functions

A control surface in Figure 3 shows how a fuzzy system determines the output based on two selected inputs. It helps visualize how changes in temperature and humidity (in this case) influence ventilation, cooling, and heating.
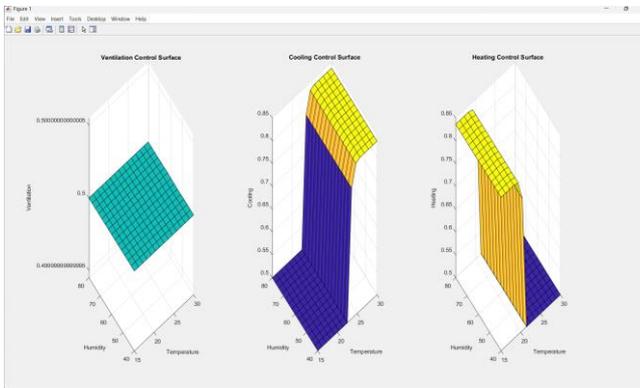

Fig. 3. Control Surface Visualization

This window depicts a MATLAB GUI (Figure 4) for simulating the fuzzy control of ventilation, cooling, and heating based on temperature, humidity, and pressure. We can easily connect this script to the mobile application, so it provides us controlling from everywhere.
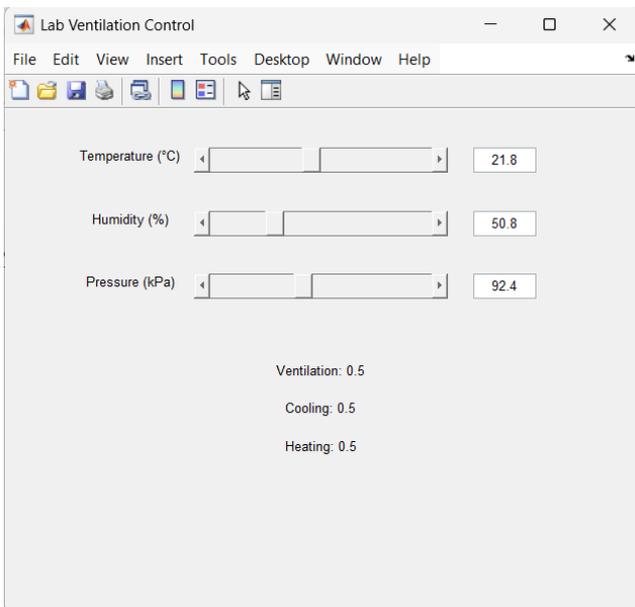

Fig. 4. MATLAB GUI

IV. CONCLUSION

As a result of the research work conducted, it is clear that it is possible to make more accurate measurements at the set point of the quantities determined using the Fuzzy Logic Controller compared to traditional controllers. Moreover, the deviations in these measurements are quite small.

One recommendation for future research is to re-examine the processes using other Fuzzy Inference Systems (Takagi-Sugeno-Kang, Tsukamoto, etc.). This will also allow us to give an opinion on which FIS is more efficient.

Another issue is the development of integrated programs for smartphones running on various operating systems (Android, IOS, etc.) of applications developed based on graphical interfaces of control systems. This allows for effective control of changing environmental parameters even outside the laboratory.

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