Fuzzy Logic Control for Smart Room Temperature Management

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***Abstract*—This paper presents the design and simulation of a fuzzy logic-based temperature control system for a smart room. The system aims to maintain the room temperature within a comfortable range by regulating the power levels of a heater and a fan.The control mechanism is based on two inputs (temperature error and change in temperature) and two outputs (heater power and fan power).MATLAB's Fuzzy Logic Toolbox is employed to design the system and perform simulations under various conditions. The ensuing results substantiate the efficacy of fuzzy control in facilitating smooth transitions and ensuring robust performance.**

I. Introduction

Fuzzy logic control is a sophisticated computational approach that emulates human reasoning to manage systems characterized by uncertainty and imprecision. Contrary to conventional control systems, fuzzy controllers do not necessitate precise mathematical models and are particularly well-suited for nonlinear and complex systems.

Temperature control is a critical component of contemporary smart environments, where ensuring comfort and energy efficiency is of the utmost importance. Conventional controllers frequently encounter challenges such as overshooting or oscillations in such dynamic systems. A fuzzy logic-based temperature controller possesses the advantage of robust performance and adaptability, rendering it particularly well-suited for smart room applications.

This paper describes the design and implementation of a fuzzy logic-based temperature controller using MATLAB. The system employs two inputs—temperature error (e) and change in temperature (Δe)—to regulate heater power (P_{heater}) and fan power (P_{fan}). The goal is to achieve a desired temperature with minimal overshooting and smooth transitions.

II. System Design

A. System Overview

The proposed system maintains a desired temperature (T_{desired}) by controlling a heater and a fan based on the following:

1) **Temperature Error (e):** The difference between the desired and current temperatures:

$$e = T_{\text{desired}} - T_{\text{current}}. \tag{1}$$

2) **Change in Temperature (Δe):** The rate of temperature change over time.

The outputs of the fuzzy controller are:

1) **Heater Power (P_{heater}):** Controls heating to increase temperature.
2) **Fan Power (P_{fan}):** Controls cooling to decrease temperature.

B. Fuzzy Sets and Membership Functions

The fuzzy logic system uses linguistic variables for inputs and outputs. Membership functions (MFs) are designed using triangular shapes for simplicity and computational efficiency.

- **Inputs:**
  - e and Δe are divided into five linguistic terms: Negative Large (NL), Negative Small (NS), Zero (Z), Positive Small (PS), and Positive Large (PL).
  - Ranges:
    * $e \in [-10, 10]$
    * $\Delta e \in [-5, 5]$
- **Outputs:**
  - P_{heater} and P_{fan} are divided into three terms: Low, Medium, and High.
  - Range: $[0, 100]$

C. Rule Base

The rule base comprises 25 rules, mapping input linguistic variables to output actions. For instance:

- If e is Positive Large (PL) and Δe is Positive Small (PS), then P_{fan} is High and P_{heater} is Low.
- If e is Zero (Z), then P_{fan} is Low and P_{heater} is Low.

Table I provides the complete rule base.

III. Implementation in MATLAB

The fuzzy logic system was implemented using MATLAB's Fuzzy Logic Toolbox. The process involved:

1) **Defining Membership Functions:** Inputs and outputs were defined with triangular membership functions.
2) **Creating Rules:** Rules were created using the rule editor in the Fuzzy Logic Designer.
3) **Simulating the System:** Simulations were conducted for different scenarios:
   - $T_{\text{current}} = 15°C, T_{\text{desired}} = 22°C$.
   - $T_{\text{current}} = 28°C, T_{\text{desired}} = 22°C$.

TABLE I
FUZZY RULE BASE

e	Δe	P_{fan}	P_{heater}
NL	NL	Low	High
NL	NS	Low	High
NL	Z	Low	Medium
NL	PS	Low	Medium
NL	PL	Low	Low
NS	NL	Low	High
NS	NS	Low	High
NS	Z	Low	Medium
NS	PS	Low	Medium
NS	PL	Low	Low
Z	NL	Low	Low
Z	NS	Low	Low
Z	Z	Low	Low
Z	PS	Low	Low
Z	PL	Low	Low
PS	NL	Medium	Low
PS	NS	Medium	Low
PS	Z	High	Low
PS	PS	High	Low
PS	PL	High	Low
PL	NL	High	Low
PL	NS	High	Low
PL	Z	High	Low
PL	PS	High	Low
PL	PL	High	Low

IV. RESULTS

Simulation results demonstrate the effectiveness of the fuzzy controller in achieving the desired temperature:

- **Scenario 1:** The room temperature started at $15°C$ and stabilized at $22°C$ without overshooting.
- **Scenario 2:** The system cooled the room from $28°C$ to $22°C$ smoothly.

Figures 1 and 2 show the temperature profile and power levels over time.

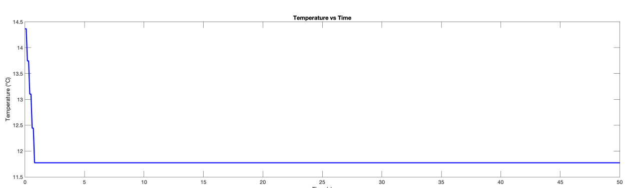

Fig. 1. Temperature vs. Time

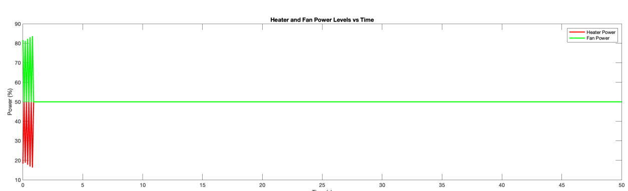

Fig. 2. Heater and Fan Power Levels

V. DISCUSSION

A. Challenges

- **Rule Optimization:** Designing an optimal rule base required multiple iterations.
- **Membership Function Design:** Achieving smooth control while maintaining accuracy was challenging.
- **Simulation Accuracy:** Simplified models may not fully represent real-world dynamics.

B. Possible Improvements

- **Adaptive Control:** Implementing self-tuning fuzzy systems to adapt rules and membership functions in real-time.
- **Hybrid Systems:** Combining fuzzy logic with machine learning for enhanced performance.

VI. CONCLUSION

This paper demonstrates the successful design and simulation of a fuzzy logic-based temperature control system. The controller effectively manages the room temperature while ensuring smooth transitions. Future work will focus on adaptive systems and real-world testing.

REFERENCES

[1] Anuar Baitakulov, "Introduction to Intelligent Systems," *Lectures and Assignment 2*.