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Smart thermoregulation based on fuzzy logic with web of things

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Abstract

Temperature control plays a vital role in numerous applications, and the integration of fuzzy logic and Internet of Things (IoT) technology offers a unique approach to address temperature regulation challenges. In this study, we propose a novel temperature control system that combines fuzzy logic and IoT in a unique way. The system utilizes temperature sensors to collect real-time temperature data and employs a fuzzy logic controller to make intelligent and adaptive control decisions. Unlike conventional approaches, our system incorporates IoT-enabled smart devices, such as thermostats, smart speakers, and mobile applications, to interact with the temperature control system. This allows users to conveniently monitor and adjust temperature settings using voice commands or mobile interfaces. The fuzzy logic controller considers factors such as desired temperature, occupancy patterns, weather conditions, and user preferences to optimize temperature control. Experimental results demonstrate the effectiveness and uniqueness of our system in achieving precise and personalized temperature regulation.

Keywords: Myrio, Fuzzy Logic, Temperature Controller, Labview, IOT.

1. Introduction

Process control systems are groups of electronic devices and equipment that eliminate dangerous transition states from the production process while offering stability and accuracy. In industry, process control is frequently employed to facilitate the mass production of continuous processes. Monitoring temperature changes and adjusting the amount of heat energy entering or leaving water to reach a target temperature is the process of temperature control. Since it supplies a requirement for chemical reactions, distillation, drying, calcinations, fermentation, and other processes, it is crucial for both home and commercial applications. Insufficient control over temperature can result in serious issues with productivity, quality, and security. Relays were employed in the early industrial revolution to power mechanical machinery, particularly in the 1960s and 1970s. They were connected by cables found inside control panels. As a result, the control become increasingly intricate. An industrial computer called a programmable logic controller is used to automate processes. It was harder to locate a system problem fast in more complicated process control systems. Owing to the inflexibility of these panels, the demand for a stable and strong controller grew quickly, leading to the development of new hardware and software.

2. Existing System

2.1. Controller

To properly regulate process temperature, an RTD or thermocouple need a lot of user intervention; a temperature control system has a controller that gets information from temperature sensors to do this. It sends an output to a control element after comparing the set point, also known as the planned control temperature, and the actual temperature. When choosing a controller, take into account the following factors:

- The desired output type, which may be an analog output, SSR, or electromechanical relay.
- The input sensor type and temperature range (thermocouple, RTD).
- You need to use proportional, on/off, or PID control algorithms.
- The kind and quantity of outputs (limit, alert, cold, and hot).
- Control methods are required to keep a process operating in a steady state once the model has been constructed.

3. Need for this Project

In today's market, real-time monitoring, simple control over multiple variables, and prompt defect detection and correction are essential. The cooling process takes time, so the system needs to be sped up.

4. Proposed System

With the help of the Myrio controller, fuzzy controller, LabVIEW software, and water in the tank, this project establishes temperature monitoring and control. This method aims to achieve effective temperature control by attempting to modify the difference between the measured temperature and the predicted set point. The entire process will be monitoring using Internet of Things (IOT).

5. Methodology

Water temperature control is the process of measuring or detecting changes in water temperature as well as altering the amount of heat energy entering or leaving the water to obtain the desired temperature. The ON-OFF system is used to control the temperature in the process. The fuzzy controller takes into consideration the error rate, temperature error, and current values of the input variables while regulating a fuzzy system based on predefined rules. Here, the trapezoidal and triangular versions of the membership function are employed. One component of this strategy is the use of LabVIEW software, which has improved features that allow ongoing process monitoring even after the process variable reaches the set point. When the process variable varies, the parameters automatically adapt to the new conditions, resulting in the desired result. The IOT module will be connected to the microcontroller for the real time monitoring purpose.

5.1. Design of MISO

A fuzzy controller with LabVIEW coding is used in the design and implementation of the MISO temperature control system. Process control uses fuzzy logic, a rule-based decision-making approach.

5.2. Fuzzy Logic System

The three primary components of a fuzzy system are rules, membership functions, and linguistic variables. The following are the fundamental phases in creating fuzzy logic control:

- Determining the input and output variables.
- Assigning a linguistic label to each fuzzy subset created by dividing the time interval between each input and output.
- Establishing the membership functions of the fuzzy subsets.
- Determining the degree of fuzzyness of the "input fuzzy subsets" and "output fuzzy subsets," which together make up the RuleBase.
- It is possible to comprehend the rules by utilizing operators such as fuzzy "AND" and "OR."
- Several rules may operate simultaneously in fuzzy systems, but to differing degrees of intensity.
- Converting processed, hazy data into precise data appropriate for real-time applications.

5.3. Temperature Sensor

Resistance temperature detectors monitor temperature by creating a link between the temperature and the resistance of the RTD element. The pure material that makes up the RTD element has had its resistance measured and recorded at various temperatures. The anticipated change in resistance that a material undergoes as its temperature changes is used to calculate its temperature. Platinum is the material used this time. At 0°C, the resistance of a device called a platinum resistance temperature detector (RTD) Pt100 is typically 100 Ω. Resistance changes with temperature along a positive slope (resistance increases as temperature increases).

5.4. RTD Signal Conditioning Circuit

The process of altering an analog signal to determine what is needed for the next processing step is known as signal conditioning. For example, an analog-to-digital converter (ADC) cannot probably process the output of an electronic temperature sensor directly because it is too low in voltage. Here the voltage level needs to be boosted via signal conditioning and amplification to the level required by an ADC. Broadly speaking, signal conditioning can refer to any required processing, including conversion, amplification, or any other action to get sensor output ready for digital format conversion.

5.5. Closed Loop Temperature Control

The process variable, or system parameter, that needs to be controlled is temperature (ºC). The process is disrupted when water from the tank leaks out continually. A sensor measures the process variable and provides feedback to the control system. The set point is the desired or reference value of the process variable. The control system's compensator algorithm determines the proper actuator output to drive the system (plant) based on the difference between the process variable and the set point at any given time. For instance, if the measured temperature process variable is 40 ºC and the desired temperature set point is 50 ºC, the control algorithm will assign the actuator output to activate a heater. The system warms up and the temperature process variable increases when an actuator signal is used to drive a heater; however, the system reduces temperature more efficiently when an actuator signal is used to drive a pump. This type of control system is called a closed loop control system because the processes of calculating the desired actuator output and reading sensors to provide continuous feedback are done continuously and at a predetermined loop rate.

5.6. Control Configuration

The information structure that links the available measurements to the available controlled variables is called a control configuration. We can identify the control configurations as

(i) Single input single output (SISO),

(ii) Multiple input multiple output (MIMO),

(iii) Multiple input single output (MISO)

(iv) Single input multiple output (SIMO)

Control systems depending on the number of controlled output and manipulated input we have in a chemical process.

5.7. Internet of Things

The term "Internet of Things" (IoT) describes a network of actual physical objects, including cars, appliances, and other items, that have sensors, software, and network connectivity built into them. These systems continuously monitor temperature levels by utilizing real-time sensors that are integrated inside the surroundings. Cloud computing is used to transmit the data that these sensors have gathered to a centralized monitoring platform.

1. IoT Temperature Control System Components:

- A fuzzy logic system called ThingSpeak is utilized in the process of monitoring the temperature.
- To obtain the data, the MyRio and IOT module are connected.

2. How It Operates:

- To maintain a constant temperature range, establish a temperature setpoint and hysteresis.
- Make a LABVIEW VI and add parts to read ThingSpeak palette data.
- Configure the ThingSpeak connection by entering the channel ID and API key.
- Connect the output Data from the IOT device to the input of the VI.
- Run the VI and the data to be monitor will be sent to the application.

6. Multiple Input Signal Output Process

6.1. MISO

A Multiple Input Single Output (MISO) system is a control scheme that has numerous manipulated variables and one control variable. For example, it is possible to assess the reactor feed's temperature and alter the coolant flow rate (a disturbance). These two have an impact on the reactor's temperature.

6.2. Procedure Configuration

A solitary water tank with an integrated heater serves as the process's setup. First, water is introduced and removed at a predetermined flow rate. The setup's temperature is monitored using a Resistance Temperature Detector (RTD). This signal is conditioned and then sent to the analog input module of the DAQ, which sends it to LabVIEW. Through signal conditioning, the RTD's output, which is given in ohms, is received in volts (0–5V).

LabVIEW generates a digital signal that is delivered to the analog output module of the DAQ after comparing this signal to the set point. The output from this module is connected to the pump and heater control unit via SSR and SCR. The heater's and pump's respective current flows are adjusted by the proportional SSR and SCR.

6.3. Implementation of Fuzzy Rules

A fuzzy system is a set of variables connected by fuzzy logic. A fuzzy controller utilizes established rules to regulate a fuzzy system based on the current values of the input variables. A fuzzy system is made up of three main parts: linguistic variables, membership functions, and rules. Language Terms and Variables Linguistic variables are the words used to express the input and output variables of the system that needs to be regulated. Linguistic variables frequently have an odd number of linguistic terms, with symmetric terms at each end and a middle term. Every linguistic variable has a range of predicted values. For both the anticipated and actual temperatures, the language terms "cold," "moderate," and "hot" may be included in the variables.

In the linguistic variable heater setting, the terms "off," "low," and "high" could be present. Membership Purposes Membership functions are numerical functions that correspond to concepts in language. A membership function represents the degree of membership of linguistic variables within their linguistic terms. A continuous scale with 0 denoting 0% membership and 1 denoting 100% membership makes up the membership degree. Among the different types that are accessible are the Ÿ-type (triangular shape), Π-type (trapezoidal shape), singleton-type (vertical line form), Sigmoid-type (wave shape), and Gaussian-type (bell shape) membership functions.

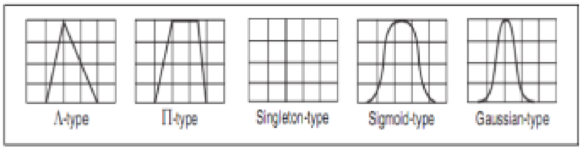

Figure.1. Different types of shapes in the fuzzy graph

7. Inputs and Outputs of Fuzzy System

Uncertain Input and Output In our project, two inputs are used, and the output is created by combining the two inputs. Each of these inputs consists of seven subsets.

Input 1: Temperature Error

Input 2: Temperature Error Rate

Output : Fuzzy output to Heating rod or Pump Subsets

7.1. Inputs

Input 1(Temperature Error) : Positive Big, Positive Medium, Positive Small, Zero, Negative Small, Negative Medium, Negative Big.

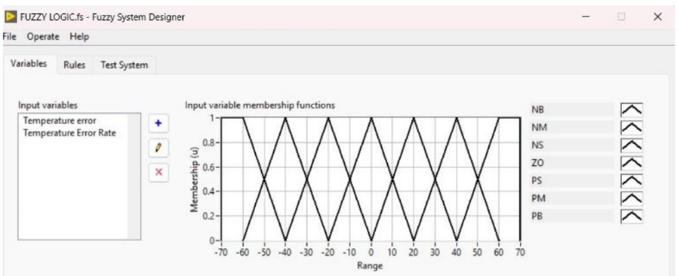

Figure.2. Table of Input 1

Input 2 (Temperature Error Rate) : Positive Big, Positive Medium, Positive Small, Zero, Negative Small, Negative Medium, Negative Big

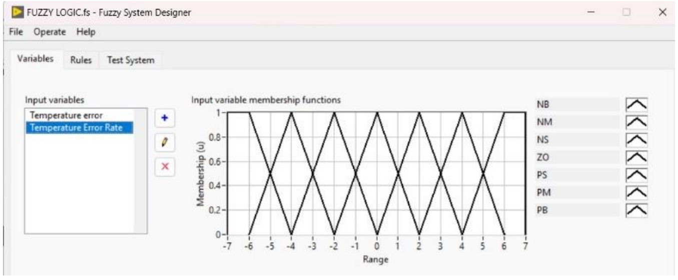

Figure.3. Table of Input 2

7.2. Outputs

Positive Big, Positive Medium, Positive Small, Zero, Negative Small, Negative Medium, Negative Big

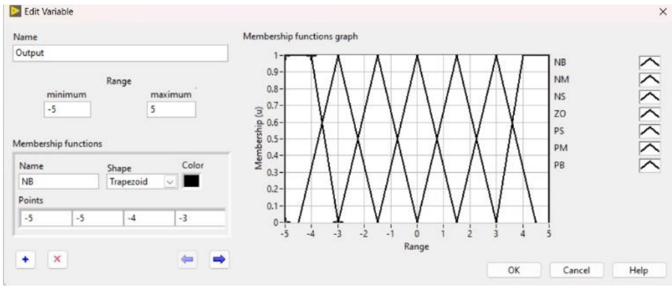

Figure.4. Table of Outputs

7.3. Rule Description

The Basic Rules Table Rules translate the relationships between input and output linguistic variables into words based on their linguistic language. The total number N of possible rules for a fuzzy system is defined by the following formula: N = p1 × p2 × … × pn is the number of linguistic phrases for the input linguistic variable n. If every input linguistic variable has the same number of linguistic terms, then the total number N of feasible rules is defined by the following equation: N is equal to p^m, where p is the quantity of linguistic phrases for every input linguistic variable and m is the total number of input linguistic variables.

Plotting a rule base as a matrix could be helpful in finding discrepancies, such as contradicting rules. However, matrix plotting of a rule basis works best for relatively small rule bases. Large rule bases make discrepancies difficult to discover. Huge rule bases in fuzzy systems with several controller inputs can be avoided with the usage of cascaded fuzzy systems.

Table.1. Rules Table

ERROR RATE / ERROR	PB	PM	PS	ZO	NS	NM	NB
PB	PB	PB	PB	PB	PM	PM	PS
PM	PB	PB	PB	PB	PB	PM	PS
PS	PB	PB	PB	PB	PM	PS	NM
ZO	PB	PM	PM	PM	PS	ZO	NS
NS	PM	PS	ZO	NS	NM	NB	NB
NM	PM	ZO	NS	NM	NB	NB	NB
NB	ZO	NS	NM	NB	NB	NB	NB

8. Developing Fuzzy Logic Controller

8.1. Brief Description

Fuzzy controllers are used to control fuzzy systems. Most traditional control approaches need you to have a mathematical model of the system you want to regulate. However, many physical systems are difficult or impossible to model mathematically. Moreover, many processes are too intricate or nonlinear to be handled by traditional means. If you can qualitatively characterize a control strategy, you can use fuzzy logic to create a fuzzy controller that resembles a heuristic rule-of-thumb approach. The fuzzy controller uses the matching input linguistic terms and rule base to determine the resultant linguistic terms of the output linguistic variables after fuzzification of the input values of a fuzzy system.

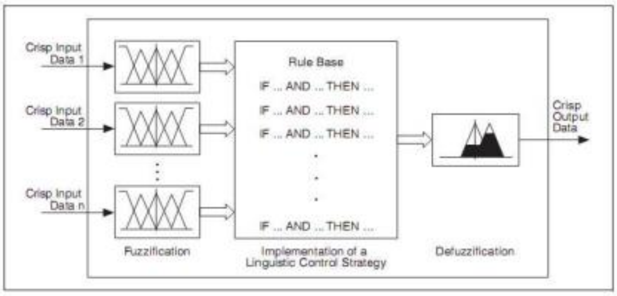

Figure.5. Table of Rules in Fuzzy Logic

8.2. Objective of the fuzzy in our Paper

Fuzzy systems are controlled using fuzzy controllers. The majority of conventional control techniques require that you have a mathematical model of the system that you wish to govern. Mathematical modeling of many physical systems is challenging or impossible, nevertheless. Furthermore, a lot of processes are too complex or nonlinear to be managed with conventional methods. A fuzzy controller that mimics a heuristic rule-of-thumb approach can be made using fuzzy logic if a control strategy can be qualitatively described. After fuzzifying the input values of a fuzzy system, the fuzzy controller employs the matching input linguistic words and rule base to determine the consequent linguistic terms of the output linguistic variables.

8.3. Steps in Designing the Fuzzy Logic

- Figuring out which variables are input and output.
- Assigning linguistic titles to each fuzzy subset created from each input and output period.
- Determining the membership function of a fuzzy subset.
- Figuring out how the "input fuzzy subsets" and "output fuzzy sets," which together make up the Rule-Base, relate to one another.
- Interpreting the rules using fuzzy "AND" and "OR" operators. In fuzzy systems, several rules may fire concurrently, but at varying intensities.
- Transforming the fuzzy, processed data into crisp data suitable for real-world use.

8.4. Formulation

$$CoA = \frac{\int_{x_{min}}^{x_{max}} f(x) \cdot x \, dx}{\int_{x_{min}}^{x_{max}} f(x) dx}$$

8.5. Result

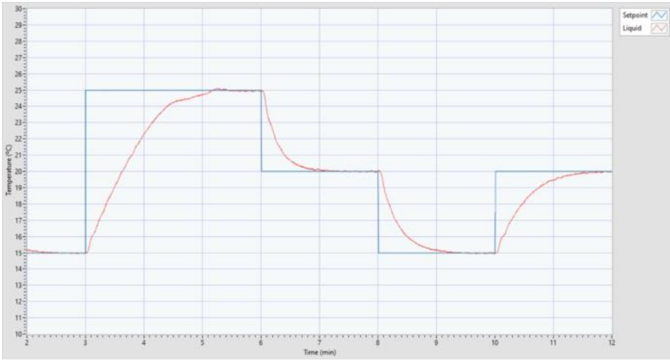

Figure.6. Output of the fuzzy rules in graph

9. Implementation in IOT

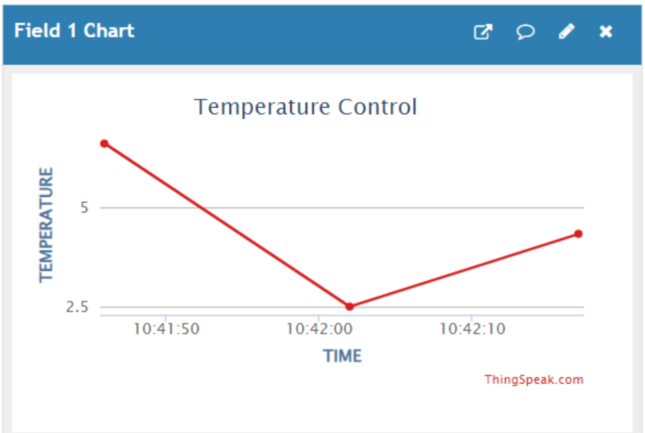

Figure.7. Real-Time monitoring in IOT

10. Conclusion

In conclusion, we have presented a unique temperature control system that integrates fuzzy logic and IoT technology in a novel way. By incorporating IoT-enabled smart devices, our system provides users with enhanced convenience and personalized control over temperature settings. The fuzzy logic controller, considering various factors such as desired temperature, occupancy patterns, weather conditions, and user preferences, adapts intelligently to optimize temperature regulation. The experimental results confirm the effectiveness of our unique approach in achieving precise and personalized temperature control. The integration of fuzzy logic and IoT technology in our system opens up new possibilities for temperature regulation in various domains, including smart homes, office spaces, and commercial buildings. The use of voice commands and mobile interfaces simplifies the user experience and enables seamless interaction with the temperature control system. Additionally, the system's adaptability and intelligent decision-making contribute to energy efficiency and user comfort. Future work can focus on further expanding the capabilities of our unique system, such as incorporating advanced machine learning algorithms to continuously learn and improve temperature control based on user preferences and environmental conditions. Moreover, the integration of additional IoT devices and sensors can enhance the system's capabilities for comprehensive environmental monitoring and control. Overall, the unique combination of fuzzy logic and IoT technology in our temperature control system offers a promising solution for precise and personalized temperature regulation, revolutionizing the way we interact with and manage temperature in various settings.

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