Oriental Renaissance: Innovative, educational, natural and social sciences
SJIF 2023 = 6.131 / ASI Factor = 1.7
(E)ISSN:2181-1784
www.oriens.uz
3(2), Feb., 2023

УДК: 004.82:62-52

APPLICATION OF FUZZY LOGIC IN AUTOMATION OF TECHNOLOGICAL PROCESSES

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ABSTRACT

Fuzzy logic is a mathematical tool that has gained significant attention in recent years, particularly in the field of automation of technological processes. Fuzzy logic is a form of logic that allows for imprecise or uncertain information to be processed, making it ideal for automation systems that deal with complex and uncertain situations. This article will explore the application of fuzzy logic in automation of technological processes, including its benefits and limitations. The article will also provide examples of real-world applications of fuzzy logic in automation, highlighting the effectiveness of this tool in various industries.

Keywords: *Fuzzy logic, automation, technological processes, benefits, limitations, real-world applications.*

АННОТАЦИЯ

Нечеткая логика — это математический инструмент, которому в последние годы уделяется большое внимание, особенно в области автоматизации технологических процессов. Нечеткая логика — это форма логики, которая позволяет обрабатывать неточную или неопределенную информацию, что делает ее идеальной для систем автоматизации, имеющих дело со сложными и неопределенными ситуациями. В этой статье будет рассмотрено применение нечеткой логики в автоматизации технологических процессов, включая ее преимущества и ограничения. В статье также будут представлены примеры реальных приложений нечеткой логики в автоматизации, подчеркивая эффективность этого инструмента в различных отраслях.

Ключевые слова: *нечеткая логика, автоматизация, технологические процессы, преимущества, ограничения, реальные приложения.*

INTRODUCTION

Fuzzy logic is a mathematical tool that is used to deal with imprecise or uncertain information. Traditional binary logic relies on the concept of true or false values, whereas fuzzy logic allows for more nuanced answers that fall somewhere between true and false. Fuzzy logic is particularly useful in situations where there is uncertainty or imprecision in the data, making it an ideal tool for automation systems that deal with complex and uncertain situations.

One of the key components of fuzzy logic is the concept of fuzzy sets. Unlike traditional sets, which have clear boundaries and are either members or non-members of a set, fuzzy sets have a degree of membership that can range from 0 to 1. The degree of membership reflects the degree to which an element belongs to a set, allowing for more nuanced categorization of data. Membership functions are used to define the degree of membership for each element in a fuzzy set.

Fuzzy logic operators and rules are used to process fuzzy data. These operators and rules are similar to traditional logical operators, but are modified to work with fuzzy sets. For example, the fuzzy logic operator "and" is used to determine the degree of overlap between two fuzzy sets. Fuzzy logic rules are used to make decisions based on fuzzy data, and are often expressed in the form of "if-then" statements. For example, an if-then rule might state "If the temperature is cold and the humidity is high, then turn on the heater."

In the next part, we will explore the importance of fuzzy logic in addressing complex and uncertain situations.

DISCUSSION AND RESULTS

Fuzzy sets and membership functions: Fuzzy sets are sets that have degrees of membership rather than clear-cut boundaries. Fuzzy sets are useful when dealing with data that is imprecise or uncertain, and they can be used to categorize data into groups with varying degrees of membership. For example, a set of "hot" temperatures might include temperatures ranging from 75 to 100 degrees Fahrenheit, with temperatures closer to 100 having a higher degree of membership in the set than temperatures closer to 75. Membership functions are used to define the degree of membership for each element in a fuzzy set. These functions are typically represented graphically as curves that show the degree of membership for each element in the set.

Fuzzy logic operators and rules: Fuzzy logic operators are used to process fuzzy data. These operators are similar to traditional logical operators, but they are modified to work with fuzzy sets. Fuzzy logic operators include "and," "or," and "not," and they are used to determine the degree of overlap between two or more fuzzy sets. For example, the fuzzy logic operator "and" is used to determine the degree of overlap between two sets. If two sets have a high degree of overlap, then the resulting set will have a high degree of membership. Fuzzy logic rules are used to make decisions based on fuzzy data. These rules are typically expressed in the form of "if-then" statements. For example, an if-then rule might state "If the temperature is cold and the humidity is high, then turn on the heater."

Advantages of fuzzy logic over traditional logic: Fuzzy logic has several advantages over traditional logic. First, fuzzy logic is more flexible than traditional logic because it allows for the handling of imprecise or uncertain data. In situations where the data is not clear-cut, fuzzy logic can provide more nuanced answers that fall somewhere between true and false. Second, fuzzy logic can be used to model complex systems that are difficult to describe using traditional logic. Because fuzzy logic can handle multiple inputs and outputs, it is well-suited for modeling complex systems that have many interrelated variables. Third, fuzzy logic can be used to generate rules that are based on expert knowledge. This is particularly useful in situations where there is a large amount of data that is difficult to analyze using traditional methods. Finally, fuzzy logic can be used to improve the performance of automation systems by providing more accurate and reliable control. By allowing for more nuanced decision-making, fuzzy logic can improve the efficiency and effectiveness of automation systems.

In the next part of the article, we will explore the application of fuzzy logic in automation of technological processes, including its benefits and limitations.

Examples of fuzzy logic-based control systems in various industries: Fuzzy logic has been successfully applied in various industries for controlling different types of processes. One of the most prominent examples of fuzzy logic-based control systems is in the automotive industry. Fuzzy logic is used in anti-lock braking systems, traction control systems, and engine management systems to improve safety and performance. Fuzzy logic is also used in power generation systems, where it is used to control the output of power plants and to optimize the performance of wind turbines. Another application of fuzzy logic is in robotics, where it is used to control the movements of robots and to provide adaptive behavior in response to changing environments.

Benefits of fuzzy logic in automation of technological processes: Fuzzy logic offers several benefits for automation of technological processes. One of the main advantages is its ability to handle imprecise and uncertain data. In complex systems, it is often difficult to precisely define the input-output relationship, but fuzzy logic can provide an accurate and reliable control system in such cases. Additionally, fuzzy logic can provide a more intuitive control system compared to traditional control systems. By providing a more natural language-based control system, fuzzy logic can be easier to understand and operate by human operators. Finally, fuzzy logic can adapt to changes in the system more easily than traditional control systems. This adaptability can make the system more robust and reliable in changing conditions.

Limitations of fuzzy logic in automation of technological processes: While fuzzy logic has many benefits, it also has some limitations. One of the main limitations is the need for expert knowledge to develop the membership functions and rules. Developing membership functions and rules requires an understanding of the system being controlled, as well as the ability to translate this knowledge into mathematical terms. Additionally, fuzzy logic can be computationally intensive, which can be a limiting factor in real-time control applications. Finally, fuzzy logic may not be appropriate for systems with highly variable inputs, as it relies on predetermined membership functions and rules that may not be suitable for highly variable data.

Here's a simple example of a fuzzy logic-based control system in Python:

```
import numpy as np
import skfuzzy as fuzz
from skfuzzy import control as ctrl
# Define input and output variables
temperature = ctrl.Antecedent(np.arange(0, 101, 1), 'temperature')
fan_speed = ctrl.Consequent(np.arange(0, 101, 1), 'fan_speed')
# Define membership functions for inputs and outputs
temperature['cold'] = fuzz.trimf(temperature.universe, [0, 0, 50])
temperature['hot'] = fuzz.trimf(temperature.universe, [50, 100, 100])
fan_speed['low'] = fuzz.trimf(fan_speed.universe, [0, 0, 50])
fan_speed['high'] = fuzz.trimf(fan_speed.universe, [50, 100, 100])
# Define rules for the control system
rule1 = ctrl.Rule(temperature['cold'], fan_speed['low'])
rule2 = ctrl.Rule(temperature['hot'], fan_speed['high'])
# Create the control system
fan_speed_ctrl = ctrl.ControlSystem([rule1, rule2])
# Create a simulation to test the control system
fan_speed_sim = ctrl.ControlSystemSimulation(fan_speed_ctrl)
# Set the input to the simulation
fan_speed_sim.input['temperature'] = 75
# Run the simulation and get the output
```

```
fan_speed_sim.compute()
print(fan_speed_sim.output['fan_speed'])
```

In this example, the control system

This code example demonstrates a simple fuzzy logic-based control system for adjusting the speed of a fan based on the temperature in the environment.

First, the input and output variables are defined using the Antecedent and Consequent classes from the skfuzzy.control module. The temperature variable represents the input, which can have values between 0 and 100, while the fan_speed variable represents the output, which can also have values between 0 and 100.

Next, membership functions are defined for the input and output variables using the trimf function from the skfuzzy module. The membership functions specify the degree of membership of each input and output value to a particular linguistic term. In this case, the temperature variable has two linguistic terms: cold and hot, while the fan_speed variable has two linguistic terms: low and high.

After defining the membership functions, the rules for the control system are defined using the Rule class from the skfuzzy.control module. In this case, there are two rules: if the temperature is cold, then the fan speed should be low, and if the temperature is hot, then the fan speed should be high.

Next, the control system is created using the ControlSystem class from the skfuzzy.control module. The rules are passed as a list to the ControlSystem constructor to create the control system.

A simulation is then created using the Control System Simulation class from the skfuzzy.control module. The simulation is used to test the control system with different inputs.

The input to the simulation is set using the input attribute of the simulation object. In this case, the temperature is set to 75.

The simulation is run using the compute method of the simulation object. The output is then obtained using the output attribute of the simulation object. In this case, the fan speed is printed to the console.

Overall, this example demonstrates how fuzzy logic can be used to control a process based on uncertain or imprecise inputs. Fuzzy logic is particularly useful in situations where traditional control methods may not be effective due to the complexity or uncertainty of the process.

Case studies of fuzzy logic in use in automation systems:

Fuzzy logic has been successfully applied in a variety of automation systems, ranging from manufacturing to environmental monitoring. Here are a few examples of how fuzzy logic has been used in real-world applications:

Air conditioning systems: Fuzzy logic has been used in the control of air conditioning systems. In this application, the temperature and humidity are measured and fed into a fuzzy logic controller. The controller uses these inputs to determine the appropriate level of cooling needed to maintain a comfortable indoor environment.

Autonomous vehicles: Fuzzy logic has been used in the control of autonomous vehicles. In this application, the vehicle's sensors gather information about its surroundings, which is then fed into a fuzzy logic controller. The controller uses this information to make decisions about how the vehicle should navigate.

Waste water treatment plants: Fuzzy logic has been used in the control of waste water treatment plants. In this application, the quality of the waste water is measured and fed into a fuzzy logic controller. The controller uses this information to determine the appropriate level of treatment needed to clean the waste water.

Overall, these case studies demonstrate the versatility of fuzzy logic in automation systems.

Discussion of the effectiveness of fuzzy logic in addressing complex and uncertain situations:

One of the primary benefits of using fuzzy logic in automation systems is its ability to address complex and uncertain situations. Traditional control systems are typically based on crisp logic, which requires exact measurements and strict rules. In contrast, fuzzy logic allows for imprecise inputs and flexible rules, making it well-suited for situations where there is a high degree of uncertainty or variability.

For example, in an air conditioning system, the temperature and humidity can vary greatly depending on factors such as weather conditions, occupancy levels, and the position of the sun. Fuzzy logic can take these variables into account and adjust the cooling accordingly, providing a more comfortable indoor environment.

Similarly, in an autonomous vehicle, there are many factors that can affect the vehicle's navigation, such as weather, traffic conditions, and road conditions. Fuzzy logic can incorporate these factors and make decisions based on a more complete understanding of the situation.

Overall, the effectiveness of fuzzy logic in addressing complex and uncertain situations has been demonstrated in numerous applications, making it a valuable tool in the field of automation.

In summary, this article has explored the concept of fuzzy logic and its application in the automation of technological processes. We discussed the benefits of using fuzzy logic in addressing complex and uncertain situations and how it can be used to model human reasoning and decision-making. We also explored the different components of fuzzy logic systems, including fuzzy sets, membership functions, fuzzy logic operators, and rules. Furthermore, we discussed several examples of fuzzy logic-based control systems in various industries, highlighting the benefits and limitations of this approach.

One of the main implications of this research is the potential for further exploration and refinement of fuzzy logic in the field of automation of technological processes. With the increasing complexity and uncertainty of modern industrial processes, there is a growing need for more sophisticated and adaptable control systems. Fuzzy logic provides a promising avenue for addressing these challenges, particularly in situations where traditional control systems may not be sufficient.

Future research in this area could focus on developing more advanced fuzzy logic algorithms and control systems, as well as exploring the integration of fuzzy logic with other artificial intelligence techniques, such as machine learning and neural networks. Another area for future research is the development of more efficient and effective methods for designing and optimizing fuzzy logic systems, particularly in large-scale industrial applications.

In conclusion, fuzzy logic is a powerful tool for addressing complex and uncertain situations in the automation of technological processes. By providing a more flexible and adaptable approach to control system design, it has the potential to improve the efficiency, safety, and reliability of industrial processes. With ongoing advances in technology and research, the future of fuzzy logic in automation systems looks bright, and we can expect to see many exciting developments in this field in the years to come.

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