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Fuzzy Logic: Applications & Theory

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***Abstract:** Fuzzy Logic is defined as a many-valued logic form which may have truth values of variables in any real number between 0 and 1. It is the handle concept of partial truth. In real life, we may come across a situation where we cannot decide whether the statement is true or false. At that time, fuzzy logic offers very flexible for reasoning. Fuzzy logic algorithm helps to solve a problem after considering all available data. Then it takes the best possible decision for the given output. The FL method imitates the way of decision making in a human which consider all the possibilities between digital values T and F.*

***Keywords:** Fuzzy Logic, Algorithms, Truth Tables, Truth VALUES, Digital Values, Set Theory.*

1. INTRODUCTION

The term fuzzy refers to things which are not clear or are vague. In the real world many times we encounter a situation when we cannot determine whether the state is true or false, their fuzzy logic provides a very valuable flexibility for reasoning. In this way, we can consider the inaccuracies and uncertainties of any situation but in the fuzzy system, there is no logic for absolute truth and absolute false value. But in fuzzy logic, there is intermediate value too present which is partially true and partially false.This system can work with any type of inputs whether it is imprecise, distorted or noisy input information.The construction of Fuzzy Logic Systems is easy and understandable.Fuzzy logic comes with mathematical concepts of set theory and the reasoning of that is quite simple.It provides a very efficient solution to complex problems in all fields of life as it resembles human reasoning and decision making.The algorithms can be described with little data, so little memory is required.

2. ARCHITECTURE

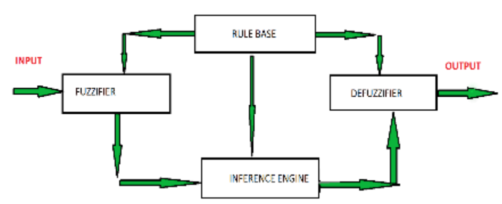
Fuzzy logic architecture contain four parts and every part

1. RULE BASE: It contains the set of rules and the IF-THEN conditions provided by the experts to govern the decision making system, on the basis of linguistic information. Recent developments in fuzzy theory offer several effective methods for the design and tuning of fuzzy controllers. Most of these developments reduce the number of fuzzy rules.

2. FUZZIFICATION: It is used to convert inputs i.e. crisp numbers into fuzzy sets. Crisp inputs are basically the exact inputs measured by sensors and passed into the control system for processing, such as temperature, pressure, rpm's, etc.

3. INFERENCE ENGINE: It determines the matching degree of the current fuzzy input with respect to each rule and decides which rules are to be fired according to the input field. Next, the fired rules are combined to form the control actions.

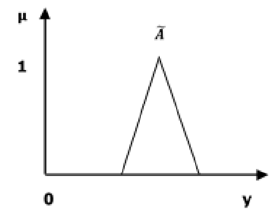
4. DEFUZZIFICATION: It is used to convert the fuzzy sets obtained by inference engine into a crisp value. There are several defuzzification methods available and the best suited one is used with a specific expert system to reduce the error.



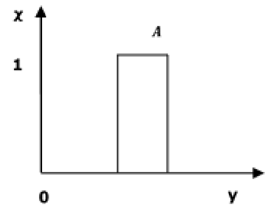
FUZZY LOGIC ARCHITECTURE

3. FUZZY SET THEORY

Fuzzy sets can be considered as an extension and gross oversimplification of classical sets. It can be best understood in the context of set membership. Basically it allows partial membership which means that it contain elements that have varying degrees of membership in the set. From this, we can understand the difference between classical set and fuzzy set. Classical set contains elements that satisfy precise properties of membership while fuzzy set contains elements that satisfy imprecise properties of membership.



Membership Function of Fuzzy set Ã



Membership Function of classical set A

3.1 *Mathematical Concept*

A fuzzy set A˜A~ in the universe of information UU can be defined as a set of ordered pairs and it can be represented mathematically as –

A˜={(y,μA˜(y))|y∈U}A~={(y,μA~(y))|y∈U}

Here μA˜(y)μA~(y) = degree of membership of yy in \widetilde{A}, assumes values in the range from 0 to 1, i.e., μA˜(y)∈[0,1]μA~(y)∈[0,1].

Representation of fuzzy set

Let us now consider two cases of universe of information and understand how a fuzzy set can be represented.

- **Case 1**

  When universe of information UU is discrete and finite –

  A˜={μA˜(y1)y1+μA˜(y2)y2+μA˜(y3)y3+...}A~={μA~(y1)y1+μA~(y2)y2+μA~(y3)y3+...}

  ={∑ni=1μA˜(yi)yi}={∑i=1nμA~(yi)yi}

- **Case 2**

  When universe of information UU is continuous and infinite –

  A˜={∫μA˜(y)y}A~={∫μA~(y)y}

  In the above representation, the summation symbol represents the collection of each element.

3.2 *Operations on Fuzzy Sets*

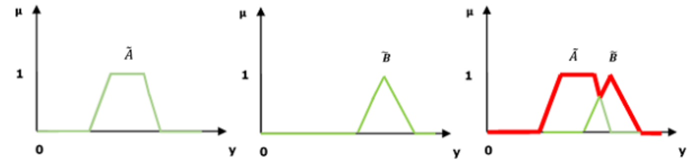
Having two fuzzy sets A˜A~ and B˜B~, the universe of information UU and an element *y* of the universe, the following relations express the union, intersection and complement operation on fuzzy sets.

3.2.1 Union/Fuzzy 'OR'

Let us consider the following representation to understand how the **Union/Fuzzy 'OR'** relation works –

μA˜∪B˜(y)=μA˜∨μB˜∀y∈UμA~∪B~(y)=μA~∨μB~∀y∈U

Here ∨ represents the 'max' operation.



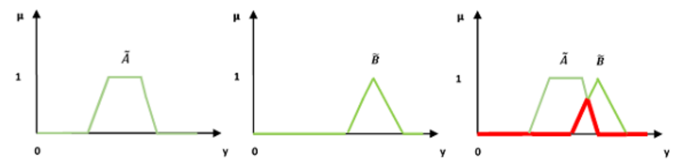
Fuzzy set Ã Fuzzy set B̃ Union of two Fuzzy sets

3.2.2 Intersection/Fuzzy 'AND'

Let us consider the following representation to understand how the **Intersection/Fuzzy 'AND'** relation works –

μA˜∩B˜(y)=μA˜∧μB˜∀y∈UμA~∩B~(y)=μA~∧μB~∀y∈U

Here ∧ represents the 'min' operation.

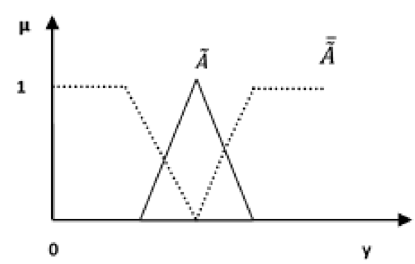


Fuzzy set Ã Fuzzy set B̃ Intersection of two Fuzzy sets

3.2.3 Complement/Fuzzy 'NOT'

Let us consider the following representation to understand how the **Complement/Fuzzy 'NOT'** relation works –

μA˜=1−μA˜(y)y∈UμA~=1−μA~(y)y∈U



Complement of a fuzzy set

3.3 *Properties of Fuzzy Set*

3.3.1 Commutative Property

Having two fuzzy sets A˜A~ and B˜B~, this property states –

A˜∪B˜=B˜∪A˜A~∪B~=B~∪A~

A˜∩B˜=B˜∩A˜A~∩B~=B~∩A~

3.3.2 Distributive Property

Having three fuzzy sets A˜A~, B˜B~ and C˜C~, this property states –

A˜∪(B˜∩C˜)=(A˜∪B˜)∩(A˜∪C˜)A~∪(B~∩C~)=(A~∪B~)∩(A ~∪C~)

A˜∩(B˜∪C˜)=(A˜∩B˜)∪(A˜∩C˜)A~∩(B~∪C~)=(A~∩B~)∪(A ~∩C~)

3.3.3 Idempotency Property

For any fuzzy set A˜A~, this property states –

A˜∪A˜=A˜A~∪A~=A~

A˜∩A˜=A˜A~∩A~=A~

3.3.4 Identity Property

For fuzzy set A˜A~ and universal set UU, this property states –

A˜∪φ=A˜A~∪φ=A~

A˜∩U=A˜A~∩U=A~

A˜∩φ=φA~∩φ=φ

A˜∪U=UA~∪U=U

3.3.5 Transitive Property

Having three fuzzy sets A˜A~, B˜B~ and C˜C~, this property states –

IfA˜⊆B˜⊆C˜,thenA˜⊆C˜IfA~⊆B~⊆C~,thenA~⊆C~

3.3.6 Involution Property

For any fuzzy set A˜A~, this property states –

A˜¯¯¯¯¯¯¯¯=A˜A~¯¯=A~

De Morgan's Law

This law plays a crucial role in proving tautologies and contradiction. This law states –

A˜∩B˜¯¯¯¯¯¯¯¯¯¯¯¯¯¯=A˜¯¯¯¯∪B˜¯¯¯¯A~∩B~¯=A~¯∪B~¯

A˜∪B˜¯¯¯¯¯¯¯¯¯¯¯¯¯¯=A˜¯¯¯¯∩B˜¯¯¯¯

4. APPLICATION

It is used in the aerospace field for altitude control of spacecraft and satellite.It has used in the automotive system for speed control, traffic control.It is used for decision making support systems and personal evaluation in the large company business.It has application in chemical industry for controlling the pH, drying, chemical distillation process.Fuzzy logic are used in Natural language processing and various intensive applications in Artificial Intelligence.Fuzzy logic are extensively used in modern control systems such as expert systems.Fuzzy Logic is used with Neural Networks as it mimics how a person would make decisions, only much faster. It is done by Aggregation of data and changing into more meaningful data by forming partial truths as Fuzzy sets.

4.1 Application Areas of Fuzzy Logic

1. Aerospace

In aerospace, fuzzy logic is used in the following areas –

- Altitude control of spacecraft
- Satellite altitude control
- Flow and mixture regulation in aircraft deicing vehicles

2. Automotive

In automotive, fuzzy logic is used in the following areas –

- Trainable fuzzy systems for idle speed control
- Shift scheduling method for automatic transmission
- Intelligent highway systems
- Traffic control
- Improving efficiency of automatic transmissions

3. Business

In business, fuzzy logic is used in the following areas –

- Decision-making support systems
- Personnel evaluation in a large company

4. Defense

In defense, fuzzy logic is used in the following areas –

- Underwater target recognition
- Automatic target recognition of thermal infrared images
- Naval decision support aids
- Control of a hypervelocity interceptor
- Fuzzy set modeling of NATO decision making

5. Electronics

In electronics, fuzzy logic is used in the following areas –

- Control of automatic exposure in video cameras
- Humidity in a clean room
- Air conditioning systems
- Washing machine timing
- Microwave ovens
- Vacuum cleaners

6. Finance

In the finance field, fuzzy logic is used in the following areas –

- Banknote transfer control
- Fund management
- Stock market predictions

7. Sector

In industrial, fuzzy logic is used in following areas –

- Cement kiln controls heat exchanger control
- Activated sludge wastewater treatment process control
- Water purification plant control
- Quantitative pattern analysis for industrial quality assurance
- Control of constraint satisfaction problems in structural design
- Control of water purification plants

Manufacturing

In the manufacturing industry, fuzzy logic is used in following areas –

- Optimization of cheese production
- Optimization of milk production

8. Marine

In the marine field, fuzzy logic is used in the following areas –

- Autopilot for ships
- Optimal route selection
- Control of autonomous underwater vehicles
- Ship steering

9. Medical

In the medical field, fuzzy logic is used in the following areas –

- Medical diagnostic support system
- Control of arterial pressure during anesthesia
- Multivariable control of anesthesia
- Modeling of neuropathological findings in Alzheimer's patients
- Radiology diagnoses
- Fuzzy inference diagnosis of diabetes and prostate cancer

10. Securities

In securities, fuzzy logic is used in following areas –

- Decision systems for securities trading
- Various security appliances

11. Transportation

In transportation, fuzzy logic is used in the following areas –

- Automatic underground train operation
- Train schedule control
- Railway acceleration
- Braking and stopping

12. Pattern Recognition and Classification

In Pattern Recognition and Classification, fuzzy logic is used in the following areas –

- Fuzzy logic based speech recognition
- Fuzzy logic based
- Handwriting recognition
- Fuzzy logic based facial characteristic analysis
- Command analysis
- Fuzzy image search

13. Psychology

In Psychology, fuzzy logic is used in following areas –

- Fuzzy logic based analysis of human behavior
- Criminal investigation and prevention based on fuzzy logic reasoning.

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