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Fuzzy Logic: A Review

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***Abstract*— This paper discusses the Fuzzy logic concept based on the fuzzy set theory. Here, Fuzzy logic is discussed as a mathematical theory for the representation of uncertainty. This paper also contains a design outlook for fuzzy controller design.**

Keywords-Fuzzy Logic, Fuzzy Sets, Fuzzy Predicates, Fuzzy Truth Values, Fuzzy Quantifiers,Fuzzy Controller.

1. INTRODUCTION

Fuzzy logic is describe as the way of computing of logic which is obtained from fuzzy set theory in which the logic has numerous values instead of the standard true or false. The truth value of variables in fuzzy logic is numerous and its value lies from 0 to 1. Fuzzy logic is an expansion from the fuzzy set theory where reasoning is rather rough than accurate. Natural language is the main priority of fuzzy logic. The final objective of fuzzy logic is to impart a strong foundation for approximate reasoning with imprecise propositions using fuzzy set theory as a principal tool [1].

2. FUZZY SET

Fuzzy logic cannot be studied without discussing the fuzzy set properties on which fuzzy logic are based. Fuzzy set theory adds some new features on the classical set theory and is an extension to it. If universal set U represents total elements denoted by x, F is a set of ordered pairs. Formally, the fuzzy set F may be defined as follows:

$$F = \{(x, \mu_F(x)) | x \in U\} \quad 1$$

where $\mu_F(x)$ is the membership function that maps x in F to the membership space [0, 1] [2]. Fuzzy set operations include:

- Complementation
- Intersection
- Union

2.1. Properties[2]*:*

2.1.1. Cardinality:
It refers to the complete quantity of element present in the set.

2.1.2. Height:
It can be described as the highest membership grade of its membership function

2.1.3. Normalization:
It discriminates all membership degrees in the similar order until the maximal value of anyone of its member is 1.

3. FUZZY LOGIC

Fuzzy logic expands classical logic by simply expanding the characteristics or the membership function role. Numbers for example has no physical representation [3]. There can be two oranges but there never can be a physical two. As stated earlier fuzzy logic has multiple logic value and its membership function ranges from 0 to 1.

3.1 FUZZY LOGIC CONCEPTS

Fuzzy logic allows the use of the following concepts:

3.1.1. Fuzzy Predicate:
A fuzzy statement x is F, where F is a fuzzy set, is depicted in fuzzy logic by F(x), where F is the fuzzy predicate [2].

3.1.2. Fuzzy Truth values:
In fuzzy logic, there are multivalued truth values such as reasonably true, true, very true, reasonably false, false, very false, etc. [2].

3.1.3. Fuzzy quantifiers:
Fuzzy quantifier is a term used to identify fuzzy numbers participating or is a part in fuzzy propositions [2]. Its types are:

- Fuzzy quantifiers defined on real numbers.
- Fuzzy quantifiers defined on the interval range of 0 to 1.

4. Linguistic variables

Linguistic variables are utilized to express rules and facts. For example TEMP may be utilized to depict a linguistic variable which may have the value hot, warm, cold etc.
Considering,
TEMP= {cold, warm, hot}
Each linguistic term of TEMP has a membership function defined for particular temperature range [2][4]. Each function maps the identical age value to different membership values from 0 and 1. Figure 1 represents membership functions related to each fuzzy term as a sample.

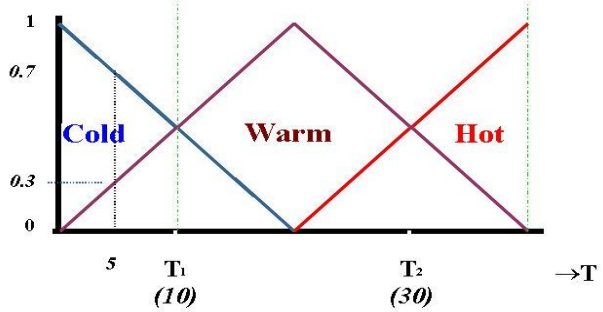

Figure 1: Representation of Linguistic Terms of TEMP

In figure 1, we get the membership value of temperature 5 in cold set as 0.7 (approx.), in warm set as 0.3 and in hot set as 0.

5. Fuzzy Propositions

A fuzzy proposition is a statement that has multivalued truth values [5]. Fuzzy proposition types are:

5.1. Unqualified and unconditional propositions
It is expressed as:
P: x is S, where xϵU and S is a fuzzy set.

5.2. Qualified and Unconditional propositions
It is expressed as:
P: x is S is R, where R is a fuzzy truth qualifier.

5.3. Unqualified and Conditional propositions
It is expressed as:
P: if x is S then y is B

5.4. qualified and Conditional propositions
It is expressed as:
P: if x is S, then y is B is R.

6. Inference rules

6.1. Modus Ponen Rule[3]
It is expressed as:
Rule: if x is P then y is Q
Fact: x is P1
Inference: y is Q1
Here, P and Q are fuzzy sets.

6.2. Modus Tollen Rule[3]
It is expressed as:
Rule: if x is P then y is Q
Fact: y is not Q1
Inference: x is not P1

6.3. Hypothetical Syllogism Rule[3]
Rule 1: if x is P then y is Q
Rule 2: if y is Q then x is R
Inference: if x is P then x is R

7. Advantages of fuzzy logic

Fuzzy logic is conceptually easy to understand. It is adaptable. For a system, addition of more functionality is simple. It is permissive of inaccurate data. It can combine and be incorporated with standard control techniques. Fuzzy systems does not replace standard control methods unless necessary. It is efficient and reliable. Its Systems are easy to construct and implement.

8. DISAVANTAGES

Formal and organized approach to fuzzy system designing is absent. They are understandable only when simple. Problems not involving high accuracy utilizes them.

9. APPLICATIONS

Fuzzy logic applications in current scenario have expanded remarkably due to advancement in this field. End-user products such as Television, refrigerators, Humidifiers, and microwave ovens incorporate its technology onto them. It has also been used for traffic signal optimization and flow control as explained in [6]. Recently its applications have vastly gained wide usage in fields such as medical instrumentation, portfolio selection, decision-support systems and industrial process control [7].

10. Fuzzy Controllers

Fuzzy controller applications are applied in areas like controlling consumer products. Applications of controllers include appliances such as washing machines, rice cookers, cameras and also various industrial purposes. Fuzzy control are control method derived from fuzzy logic [7,8]. Fuzzy control maybe described as "control with sentences rather than equations". A fuzzy controller typically comprises of empirical rules that are helpful in plants controlled by operators [8,9].

10.1. Fuzzy Controller Structure

The various blocks in the structure also represented in Figure 2 are:

10.1.1. Pre-processing/Input

These are the information provided to the controller. The inputs are usually hard or crisp measurements from some measuring device instead of linguistic nature.

10.1.2. Fuzzification

It changes every portion of input data to membership degrees by a look up in one or additional membership functions.

10.1.3. Rule Base

The complete set of all the rules is called a Rule Base. Well-known if-then structure represents the rules and if-side is known as condition and then-side is known as conclusion [7][8]. It is represented by the following format:

- Natural language
- Relational Format
- Tabular linguistic form

10.1.4. Inference engine

The inference engine looks up the membership values in the condition of the rule for each of them. It also performs the tasks of aggregation, activation and accumulation to find the resulting set [8].

10.1.5. Defuzzification

The arising fuzzy set from the inference engine must be changed to a number that can be sent to the process as a control signal. This procedure is called Defuzzification. Some of the Defuzzification methods are:

- Centre of gravity(COG)
  Given by

$$u = \frac{\sum_i \mu(x_i) x_i}{\sum_i \mu(x_i)} \qquad 2$$

Where x_i is a running point in the universe, $\mu(x_i)$ is its membership value.

- Mean of maxima(MOM)
- Bisector of area(BOA)

10.1.6. Post processing/Output

The controlled output from the fuzzy controller is the product. Here the output is converted to standard units.

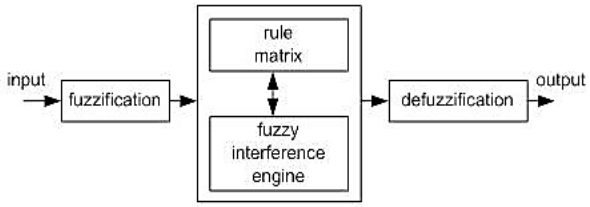

Figure 2: Blocks of fuzzy controller [8]

11. Conclusion

Fuzzy Logic Systems give reasonable but specific output in response to incomplete, ambiguous, distorted, or inaccurate input. Thus its applications are increasing rapidly presenting a wide scope for research and study present in this area. The input-output mappings shown in controller design provide an instinctive understanding which from hypothetically point of view is not of much importance, but in practice they are worth using.

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