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A Comprehensive Review On Fuzzy Logic System

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Abstract— ***Fuzzy Logic has been extremely vital role in the field of computer science, Artificial Intelligence, control theory and mathematic. Fuzzy logic is the way of organising belief or idea that cannot be defined precisely but which depends upon their contexts – human way of thinking, reasoning and perception. In this review paper we also see that the basics of fuzzy logic as well as fuzzy logic system (Fuzzy Inference System) use as decision making technique under a linguistic view of fuzzy sets.***

Keywords— Fuzzy, Fuzzy logic, Fuzzy Set, Fuzzy Rule, Fuzzy Logic system

Introduction:

In computer science, artificial Intelligence field has an extremely important place with effective approaches , methods , techniques and wide working domain. The fuzzy logic is one of these techniques which is widely used in today's intelligent problem solving system and applications [2].

Before going to fuzzy logic first we have to know what is fuzzy. Webster's dictionary defines "fuzzy" as: not clear, distinct, or precise; blurred. In broad sense, fuzzy logic refers fuzzy sets which are sets with blurred boundaries. [3]. Fuzzy logic was initiated in 1965 [1] , [2] , [3] by Lotfi A. Zadeh , professor for computer science at the university of California in Berkeley and it becomes a mathematical tool for dealing with uncertainty . Basically **Fuzzy logic** is a form of many-valued **logic**; it deals with reasoning that is approximate rather than fixed and exact . Compared to traditional binary sets (where variables may take on true or false values), **fuzzy logic** variables may have a truth value that ranges in degree between 0 and 1. Fuzzy logic is a way to make use of natural language in logic. Expert systems, fuzzy controllers, pattern recognition, databases and information retrieval, decision making are the applications of fuzzy logic

Why use fuzzy logic?

Fuzzy Logic – FL is used for solving uncertainties in a given problem. For e.g. consider condition "drive slowly". When we hear about it , we can understand what it means .But for computer it does not have knowledge about which is slow speed , 10 km/h or 15 km/h or 25 km/ h . and if we give a limit as a slowest speed for e.g. 20kmph is speed limit . More than this speed considered as fast. But if 20kmph is speed limit, is 20.1 km/h is fast or 19.9 is slow. In order to solve these uncertainties for computer system Fuzzy Logic (FL) is used.

I. Crisp Set

In crisp sets – either an element belongs to the set or it does not. For example, for the set of integers, either an integer is even or it is not (it is odd). However, either you are in the BANGLORE or you are not. What about flying into BANGLORE, what happens as you are crossing?

Another example is for black and white photographs, one cannot say either a pixel is white or it is black. However, when you digitize a b/w figure, you turn all the b/w and gray scales into 256 discrete tones

crisp sets are also called *classical* (sets).

Lists: A = {apples, oranges, cherries, mangoes}

A = {a_1, a2, a3}

A = {2, 4, 6, 8, …}

Formulas: A = {x | x is an even natural number}

A = {x | x = 2n, n is a natural number}

Membership or characteristic function

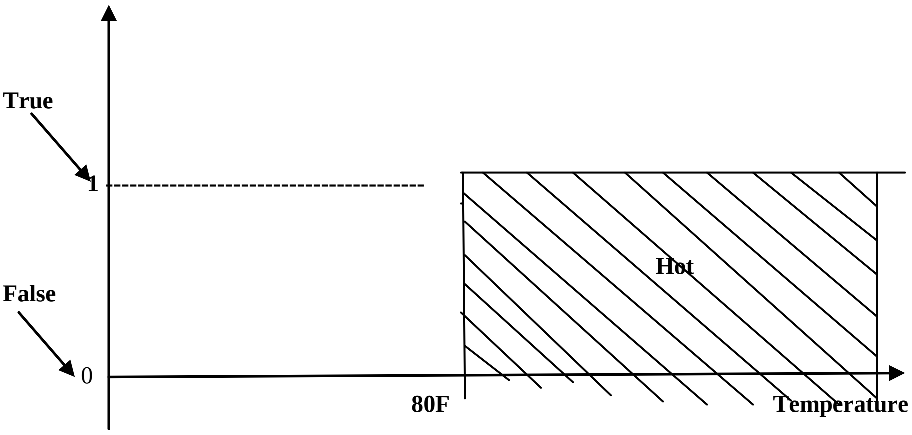
$$X_A(x) = \begin{cases} 1 & \text{if } X \in A \\ 0 & \text{if } X \notin A \end{cases}$$

Crisp logic is concerned with absolutes-true or false, there is no in-between.

Example:
Rule: If the temperature is higher than 80F, it is hot; otherwise, it is not hot.
Cases:

- Temperature = 100F Hot
- Temperature = 80.1F Hot
- Temperature = 79.9F Not Hot
- Temperature = 50F Not Hot

Membership functions of crisp logic:



If temperature > = 80F, it is hot (1 or true);
If temperature < 80F, it is not hot (0 or false).

Drawback of crisp logic is the membership function of crisp logic fails to distinguish between members of the same set.

II. Foundations Of fuzzy logic

FUZZY SETS

Fuzzy sets, on the other hand , allow elements to be partially in a set. Each element is given a degree of membership in a set. This membership function can range from 0 (not an element of the set) to 1 (a member of set). It is clear that if one only allowed the extreme membership values of 0 and 1, that this would actually be equivalent to crisp sets. A membership function is the relationship between the values of an element and its degree of membership in a set. [6]

A fuzzy set has a graphical description that express how the transition from one to another takes place. This graphical description is called a membership function. An example of membership functions are shown in Figure 3-1. In this example, the sets (or classes) are numbers that are negative large, negative medium, negative small, near zero, positive small, positive medium, and positive large. The value, μ, is the amount of membership in the set.[6]

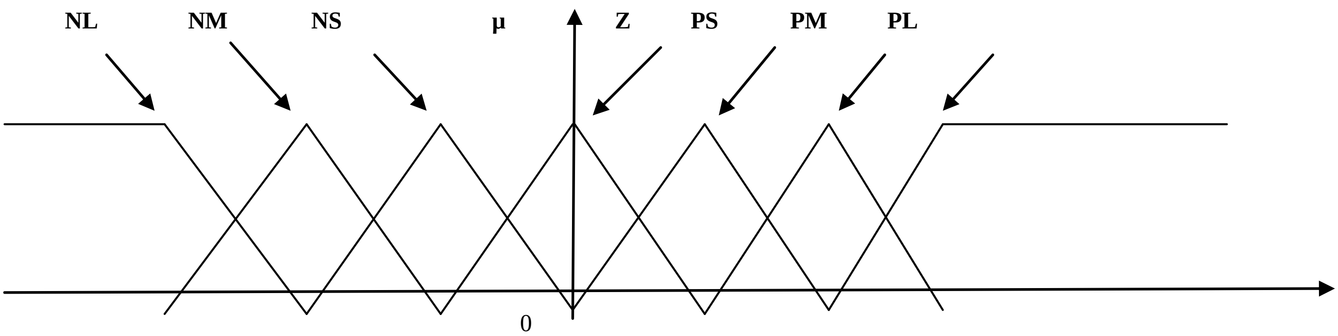


Figure 3-1: Membership Functions For the Set of All Numbers (N=Negative, P=Positive, L= Large, M= Medium, S= Small)

Membership functions are used to describe the situation graphically**.** Fuzzy logic deals with degree of membership and degree of truth. Membership functions for fuzzy sets can be defined in any number of ways as long as they follow the rules of the definition of a fuzzy set. The Shape of the membership function used defines the fuzzy set and so the decision on which type to use is dependent on the purpose. There are many different types of membership functions used in fuzzy logic. Most used once are triangle, Gaussian and trapezoid membership functions. [6]

LINGUISTIC VARIABLES:

A fuzzy set can be used to describe the value of variable. A linguistic variable is a fuzzy variable .A linguistic variable is "a variable whose values are words or sentence in natural or artificial language". Linguistic variables are used to represent qualities spanning a particular spectrum. Each linguistic variable may be assigned one or more linguistic values.

For example: The statement **Jeba** is **Tall** - implies that Jeba is *linguistic variable* take the *linguistic value* Tall.

In fuzzy logic, linguistic variables take on linguistic values which are words (linguistic terms) with associated degrees of membership in the set.

FUZZY LOGIC OPERATIONS

1. Fuzzy union (∪): the *union* of two fuzzy sets is the maximum (MAX) of each element from two sets.

   E.g.

   A = {1.0, 0.20, 0.75}

   B = {0.2, 0.45, 0.50}

   A ∪ B = {MAX(1.0, 0.2), MAX(0.20, 0.45), MAX(0.75, 0.50)}

   = {1.0, 0.45, 0.75}

2. Fuzzy intersection (∩): *the intersection* of two fuzzy sets is just the MIN of each element from the two sets

   E.g.

   a. A ∩ B = {MIN(1.0, 0.2), MIN(0.20, 0.45), MIN(0.75, 0.50)} = {0.2, 0.20, 0.50}

   b.

3. Complement ($\_^c$): The *complement* of a fuzzy set is composed of all elements' *complement.*

   Example:

   A^c = {1 – 1.0, 1 – 0.2, 1 – 0.75} = {0.0, 0.8, 0.25}

IF –THEN RULE

Human beings make decisions based on rules. Although, we may not be aware of it, all the decisions we make are all based on computer like if-then statements. If the weather is fine, then we may decide to go out. If the forecast says the weather will be bad today, but fine tomorrow, then we make a decision not to go today, and postpone it till tomorrow. Rules associate ideas and relate one event to another. Fuzzy machines, which always tend to mimic the behaviour of man, work the same way. However, the decision and the means of choosing that decisions are replaced by fuzzy sets and the rules are replaced by fuzzy rules. Fuzzy rules also operate using a series of if-then statements. For instance, if X then A, if y then b, where A and B are all sets of X and Y. Fuzzy rules define fuzzy *patches*, which is the key idea in fuzzy logic [7].

III.FUZZY INFERENCE SYSTEM

Fuzzy logic system can be defined as nonlinear mapping of an input data set to a scalar output data. Fuzzy inference is actual process of mapping from given input to an output using fuzzy logic. Because of multidisciplinary nature the fuzzy inference system is known by a number of names such as fuzzy-rule-based system, fuzzy expert system, fuzzy model, fuzzy associative memory , fuzzy logic controller and simply fuzzy system.

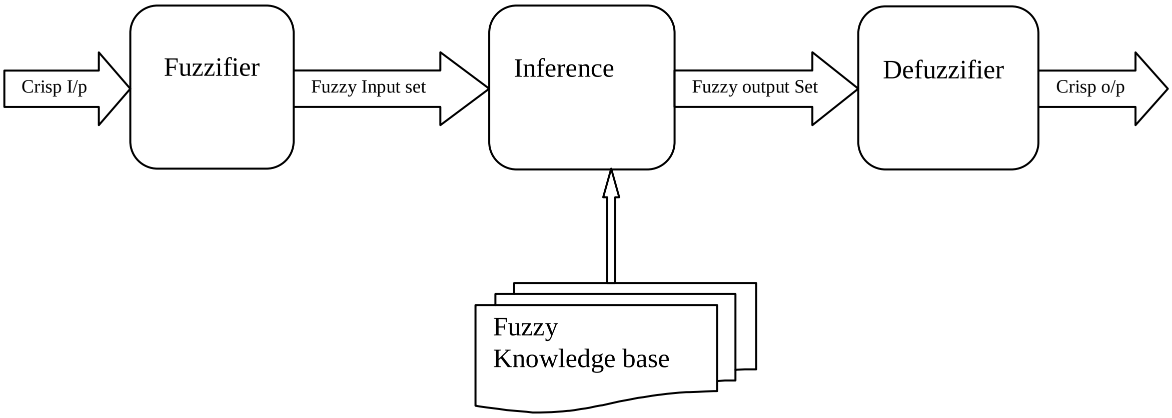


Figure: Fuzzy Inference System

Fuzzy inference is a computer paradigm based on fuzzy theory, fuzzy if- then- rules and fuzzy reasoning. Fuzzy logic is implemented with three stages:

1. Fuzzifier
2. Inference(Rule Definition)
3. Defuzzifier

- **Fuzzifier**: Converts the crisp input to a linguistic variable using the membership functions stored in the fuzzy knowledge base. This process is known as fuzzification .
- **Inference**: Using If-Then type fuzzy rules converts the fuzzy input to the fuzzy output.
- **Defuzzifier**: Converts the fuzzy output of the inference engine to crisp using membership functions analogous to the ones used by the Fuzzifier. This process is known as Defuzzification.

Fuzzy system consists of a formulation of the mapping from a given input set to and output using fuzzy logic, which consists of the following five steps.

Step 1: Fuzzification of input variables, defining the control objectives and criteria.

Step 2: Application of fuzzy operators (AND, OR, NOT) in the IF (antecedent) part of the rule. Determine the output and input relationships and choose a minimum number of variables for input to the fuzzy logic engine.

Step 3: implication from antecedent to the consequent (THEN part of the rule) for the desired system output response for a given system input conditions.

Step 4: aggregation of the consequents across the rules by creating fuzzy logic membership functions that define the meaning (values) of input/output terms used in the rule.

Step 5: defuzzification to obtain a crisp result.

The following example shows how the above five steps can be implemented in a non technical environment for a restaurant tipping where food and service are the inputs fuzzy variable (0 -10 range) and tip is the output variable (0-25% range). The input variable service is represented by three fuzzy sets poor, good, and excellent which corresponds to curved MFs. While variable food is represented by two fuzzy sets bad and delicious this corresponds to straight-line MFs. The output variable tip is represented by three sets cheap, average, and generous which correspond to triangular MFs. Three rules are developed as shown in figure 3.

If the quality of service is 3 which implies MF poor gives the output μ=0.3 which is a result of fuzzification (step 1) and if the score for food is 8 which is referred to a MF bad, the result of fuzzification is μ=0. After all the inputs have be fuzzified and each degree of the antecedent if a rule has been satisfied, the OR or max operator is specified and therefore between the two values 0.3 and 0, the result of the operator is 0.3 which is selected in (step 2) this defined as the degree of fulfillment (DOF).

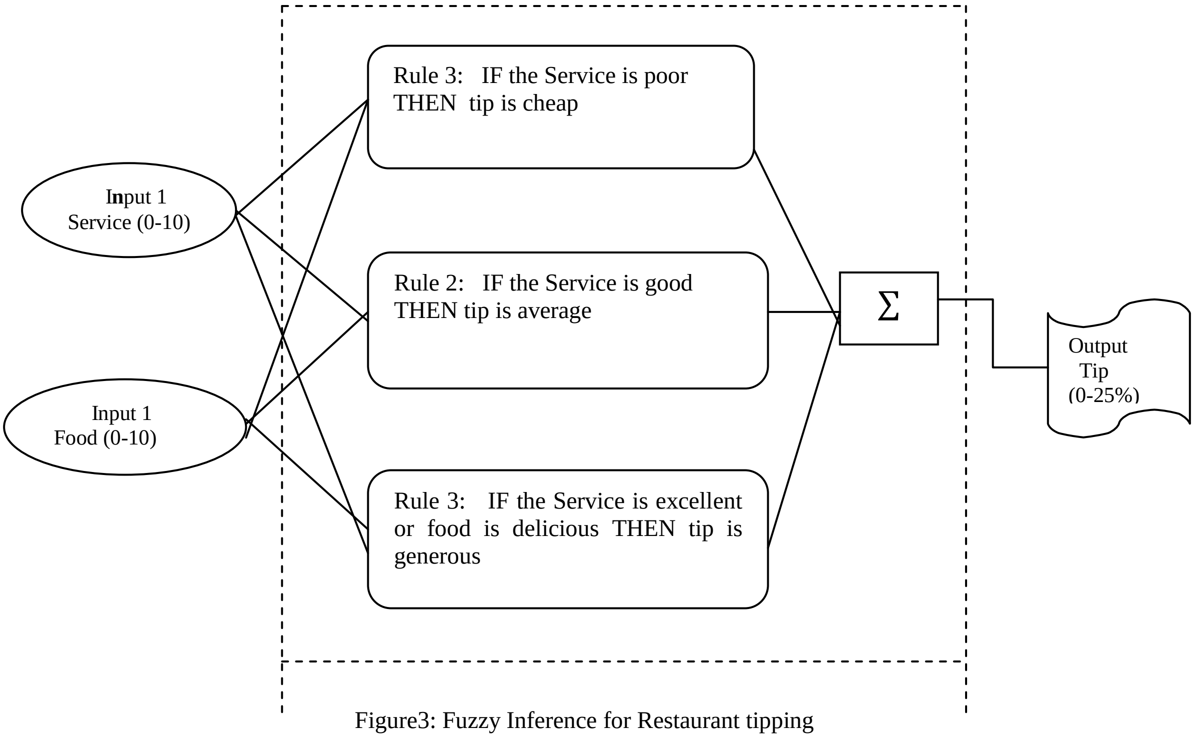


Figure3: Fuzzy Inference for Restaurant tipping

The implication stage helps to evaluate the consequent part of a rule. For this rule the output MF cheap is truncated at the value μ=0.3 to give a fuzzy output (step 3). All the rules are evaluated the same manner and their outputs are combined or aggregated in a cumulative manner to result a final fuzzy output (step 4). Finally, the fuzzy output (area) is converted into crisp which is defined as defuzzification (step 5).[5]

IV.APPLICATIONS OF FUZZY LOGIC

- Engine Idle Speed Control
- Automatic control of dam gates for hydroelectric-power **plants**
- Simplified control of robots
- Camera aiming for the telecast of sporting events
- Substitution of an expert for the assessment of stock exchange activities
- Efficient and stable control of car-engines
- Efficient and stable control of car-engines
- Cruise-control for automobiles
- Improved efficiency and optimized function of industrial control applications
- Positioning of wafer-steppers in the production of semiconductors
- Optimized planning of bus time-tables
- Archiving system for documents
- Prediction system for early recognition of earthquakes
- Medicine technology: cancer diagnosis
- Combination of Fuzzy Logic and Neural Nets
- Recognition of handwritten symbols with pocket computers
- Recognition of motives in pictures with video cameras
- Automatic motor-control for vacuum cleaners with recognition of surface condition and degree of soiling
- Back light control for camcorders
- Single button control for washing-machines
- Recognition of handwriting, objects, voice
- Flight aid for helicopters
- Flowing Shift-Point Determination
- Simulation for legal proceedings
- Software-design for industrial processes
- Controlling of machinery speed and temperature for steel-works
- Controlling of subway systems in order to improve driving comfort, precision of halting and power economy
- Fuzzy Logic and Knowledge Discovery in Databases
- Fuzzy Clustering
- Improved fuel-consumption for automobiles

IV. CONCLUSION

Fuzzy Logic provides a different way to approach a control or classification problem. This method focuses on what the system should do rather than trying to model how it works. One can concentrate on solving the problem rather than trying to model the system mathematically, if that is even possible. On the other hand the fuzzy approach requires a sufficient expert knowledge for the formulation of the rule base, the combination of the sets and the defuzzification. In General, the employment of fuzzy logic might be helpful, for very complex processes, when there is no simple mathematical model (e.g. Inversion problems), for highly nonlinear processes or if the processing of (linguistically formulated) expert knowledge is to be performed. According to literature the employment of fuzzy logic is not recommendable, if the conventional approach yields a satisfying result, an easily solvable and adequate mathematical model already exists, or the problem is not solvable.

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