19EE701 – AI TECHNIQUES IN ELECTRICAL ENGINEERING

UNIT 3 – FUZZY LOGIC & ANFIS

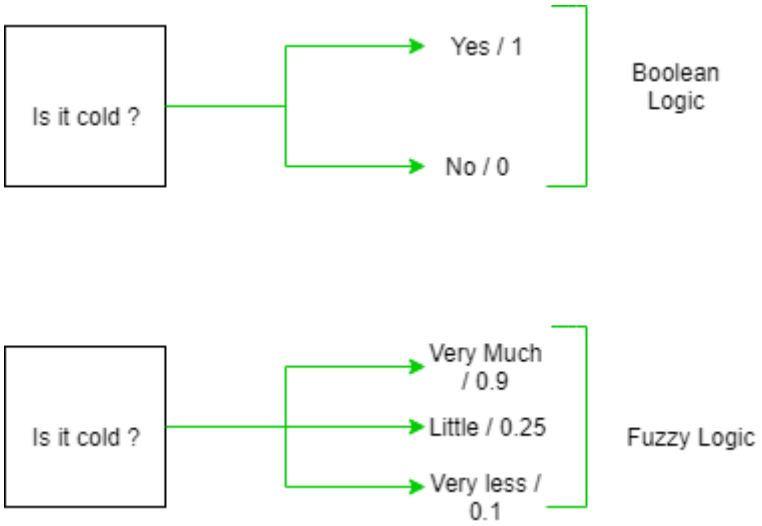
Topic : Introduction–fuzzy sets

The term fuzzy refers to things that are not clear or are vague. In the real world many times we encounter a situation when we can't determine whether the state is true or false, their fuzzy logic provides very valuable flexibility for reasoning. In this way, we can consider the inaccuracies and uncertainties of any situation.

Fuzzy Logic is a form of many-valued logic in which the truth values of variables may be any real number between 0 and 1, instead of just the traditional values of true or false. It is used to deal with imprecise or uncertain information and is a mathematical method for representing vagueness and uncertainty in decision-making.

Fuzzy Logic is based on the idea that in many cases, the concept of true or false is too restrictive, and that there are many shades of gray in between. It allows for partial truths, where a statement can be partially true or false, rather than fully true or false.

Fuzzy Logic is used in a wide range of applications, such as control systems, image processing, natural language processing, medical diagnosis, and artificial intelligence.



1. Concept of Fuzzy Sets

- **Definition:** A fuzzy set is a set without a crisp, clearly defined boundary. Unlike classical sets where an element either belongs or does not belong to a set, fuzzy sets allow partial membership, where elements can have a degree of membership ranging between 0 and 1.

- **Origin:** Introduced by Lotfi A. Zadeh in 1965 as a way to handle the uncertainty and vagueness inherent in many real-world problems.

2. Classical Sets vs. Fuzzy Sets

- **Classical Sets:** Membership is binary (an element either belongs to the set or not).
  - **Membership Function:** μA(x)\mu_A(x)μA(x) where μA(x)∈{0,1}\mu_A(x) \in \{0, 1\}μA(x)∈{0,1}.
- **Fuzzy Sets:** Membership is a continuum between 0 and 1.
  - **Membership Function:** μA(x)\mu_A(x)μA(x) where μA(x)∈[0,1]\mu_A(x) \in [0, 1]μA(x)∈[0,1].

3. Membership Function

- **Definition:** A function that defines how each point in the input space is mapped to a membership value between 0 and 1.
- **Types of Membership Functions:**
  - **Triangular Membership Function:** μA(x)={0if x<ax−ab−aif a≤x≤bc−xc−bif b<x≤c0if x>c\mu_A(x) = \begin{cases} 0 & \text{if } x < a \\ \frac{x - a}{b - a} & \text{if } a \leq x \leq b \\ \frac{c - x}{c - b} & \text{if } b < x \leq c \\ 0 & \text{if } x > c \end{cases}μA(x)=⎩⎨⎧0b−ax−ac−bc−x0if x<aif a≤x≤bif b<x≤cif x>c
  - **Trapezoidal Membership Function:** μA(x)={0if x<ax−ab−aif a≤x≤b1if b<x≤cd−xd−cif c<x≤d0if x>d\mu_A(x) = \begin{cases} 0 & \text{if } x < a \\ \frac{x - a}{b - a} & \text{if } a \leq x \leq b \\ 1 & \text{if } b < x \leq c \\ \frac{d - x}{d - c} & \text{if } c < x \leq d \\ 0 & \text{if } x > d \end{cases}μA(x)=⎩⎨⎧0b−ax−a1d−cd−x0 if x<aif a≤x≤bif b<x≤cif c<x≤dif x>d
  - **Gaussian Membership Function:** μA(x)=e−(x−c)22σ2\mu_A(x) = e^{-\frac{(x - c)^2}{2\sigma^2}}μA(x)=e−2σ2(x−c)2

where a,b,c,da, b, c, da,b,c,d are parameters defining the shape of the function, and σ\sigmaσ is the standard deviation.

4. Operations on Fuzzy Sets

- **Union:** μA∪B(x)=max⁡(μA(x),μB(x))\mu_{A \cup B}(x) = \max(\mu_A(x), \mu_B(x))μA∪B(x)=max(μA(x),μB(x))
- **Intersection:** μA∩B(x)=min⁡(μA(x),μB(x))\mu_{A \cap B}(x) = \min(\mu_A(x), \mu_B(x))μA∩B(x)=min(μA(x),μB(x))

- **Complement:** μ¬A(x)=1−μA(x)\mu_{\neg A}(x) = 1 - \mu_A(x)μ¬A(x)=1−μA(x)

5. Fuzzy Relations

- **Definition:** A fuzzy relation is a generalization of a classical relation, where the degree of association between elements is represented by a membership value.
- **Example:** A fuzzy relation RRR between sets AAA and BBB is defined as a membership function μR(a,b)\mu_R(a, b)μR(a,b) that represents the degree to which element a∈Aa \in Aa∈A is related to element b∈Bb \in Bb∈B.

6. Fuzzy Logic

- **Definition:** Fuzzy logic extends classical logic to handle the concept of partial truth, where truth values range between completely true and completely false.
- **Fuzzy Rules:** Rules in fuzzy logic are often of the form:
  - **IF** (condition) **THEN** (action)
- **Inference Methods:** Common methods include:
  - **Mamdani Inference:** Uses fuzzy rules and aggregation.
  - **Sugeno Inference:** Uses fuzzy rules with weighted averages.

7. Applications of Fuzzy Sets

- **Control Systems:** Used in fuzzy control systems to handle uncertain and imprecise inputs (e.g., washing machines, air conditioners).
- **Decision Making:** Helps in decision-making processes where information is vague or imprecise.
- **Pattern Recognition:** Applied in areas like image processing and speech recognition.

8. Advantages and Limitations

- **Advantages:**
  - Handles uncertainty and imprecision effectively.
  - Models human reasoning and decision-making more naturally.
- **Limitations:**
  - Can be complex to design and tune fuzzy systems.
  - Requires expertise to set appropriate membership functions and rules.