Soft computing

1. Fuzzy definition with example, fuzzy operation in details

① Fuzzy logic is an approach to computing based on "degree of truth" rather than traditional binary logic (yes/no)
② In fuzzy logic truth values range between 0 & 1 representing partial truth
③ It is g. especially useful for dealing with uncertain, imprecise information
④ Similar to how human make decision
⑤ example

Consider the concept of temperature

- In classical logic

If temp > 30°C → Hot (True)
If temp ≤ 30°C → Not Hot (false)

In fuzzy

At 25°C → Hot = 0.3 (Partially hot)
At 30°C → Hot = 0.6
At 35°C → Hot = 0.9

⑥ This allows more realistic reasoning, especially in control system (like air conditioners, washing machine)
⑦ fuzzy operations -

are mathematical functions used to perform logic based operations on fuzzyset

⑧ operations are

- Fuzzy union (OR representation)
- Fuzzy intersection (AND operation)
- Fuzzy complement (NOT operation

⑨ fuzzy union (OR operation)
Symbol - A ∪ B
formula - $\mu_{A \cup B}(x) = \max(\mu_A(x), \mu_B(x))$
ex - $\mu_A(x) = 0.6 \quad \mu_B(x) = 0.8$

$\mu_{A \cup B}(x) = \max(0.6, 0.8) = 0.8$

⑩ fuzzy intersection (AND operation)
symbol : $A \cap B$
formula - $\mu_{A \cap B}(x) = \min(\mu_A(x), \mu_B(x))$
ex - $\mu_A(x) = 0.6 \quad \mu_B(x) = 0.8$

$\mu_{A \cap B}(x) = \min(0.6, 0.8) = 0.6$

⑪ fuzzy complement (NOT operation)
Symbol - A^c
formula - $\mu_{A^c}(x) = 1 - \mu_A(x)$
ex - $\mu_A(x) = 0.7$

$\mu_{A^c}(x) = 1 - 0.7 = 0.3$

$\mu_{A \cup B}(x) = \max(\mu_A(x), \mu_B(x))$

$\mu_{A^c}(x) = 1 - \mu_A(x)$

$\mu_{A^c}(x) = 1 - \mu_A(x)$

fuzzy set crisp set

② Soft computing vs hard computing

fuzzy cmean k mean

feature	Soft computing	Hard computing
Define	A computing approach that mimics human reasoning & handles uncertainty	A traditional computing method that relies on binary logic
Tolerance to uncertainty	high - deals with uncertainty	Low - requires exact inpu and condition
Computation method	Approximate & heuristic	Precise & deterministic
main component	fuzzy logic, Neural network, Genetic Algorithm	Algorithm, mathematical mode binary logic (0 & 1)
Problem ing	flexible can work with incomplete or noise data	Rigid, requires well-defined inputs and model
Inspired by	human brain & neural intelligence	classical mathematics & formal logic
Example	Speech recognition, control system, Image processing	Calculators, transaction proces control system with fixed rules
error handling	can tolerate & adapt to error	cannot handle error easily
earning daptability	Can learn and evolve over time (eg neural networks)	cannot learn; must be explicitly Programmed

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③ Fuzzy Set Theory, Fuzzy logic - basic, fuzzy rules & fuzzy reasoning.

① Fuzzy set theory is an extension of classical set theory where elements can partially belong to a set with a membership value between 0 & 1

② membership function ($\mu_A(x)$): Represents the degree to which an element x belongs to set A
- classical - $\mu_A(x) \in \{0, 1\}$
- fuzzy - $\mu_A(x) \in [0, 1]$

③ example
let set A = "Tall People"
. Person with height 160 cm : $\mu_A(160) = 0.3$
Person with height 180 cm : $\mu_A(180) = 0.9$

④ Fuzzy logic is a reasoning system based on fuzzy set theory that deals with reasoning that is approximate rather than fixed and exact.

⑤ core component →
fuzzification: converting crisp input values into fuzzy values using membership function
Inference engine → Applies fuzzy rules to make decision
Defuzzification → converting fuzzy output into a crisp result

⑥ fuzzy operation →
union = max($\mu_A(x), \mu_B(x)$), intersection = min($\mu_A(x), \mu_B(A)$)
Complement : $\mu_A^C(x) = 1 - \mu_A(x)$

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⑦ fuzzy rules and fu
fuzzy rules are if-then sentences. that form the basis of fuzzy inference system
Structure →
IF <fuzzy condition> Then <fuzzy action>
ex- If temperature is high then fan speed is fast

⑧ here temperature is high and speed is fast are variables ~~is~~ defined using fuzzy set

⑨ fuzzy reasoning is the process of deriving the conclusion from fuzzy rule & fuzzy input

⑩ steps of fuzzy reasoning
1. Fuzzify the inputs using membership function
2. Apply fuzzy rules to fuzzified output
3. Aggregate the result of each rule
4. Defuzzify the output to get crisp value

ex- fan control system
Input - Temperature 30°C

fuzzy set → Temperature → low, high, medium
fan speed → slow, medium, fast

Rules →
if temp is low Then fan speed slow
if — " — medium — " — medium
If — " — high — " — fast

Triangular Trapezoidal
Gaussian sig

fuzzy reasoning process

1. fuzzify 30°C : μMedium(30) = 0.6 & μHigh(30) = 0.4
2. Apply rules using fuzzy logic operation
3. Aggregate output fan speed set
4. Defuzzify to get final speed value

4 Membership function

A membership function defines how each point in the input space is mapped to a membership value (between 0 & 1) in fuzzy set.

It quantifies the degree of truth as an extension of valuation

membership degree → expresses how strongly an input belongs to a fuzzy set.

Trapezoidal

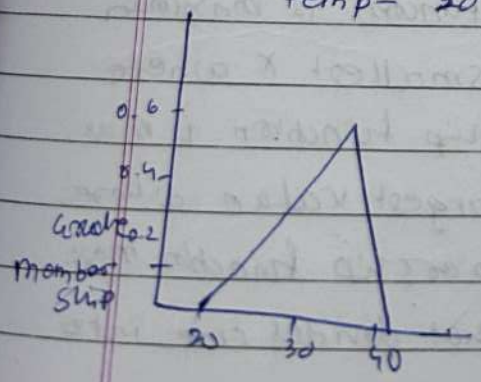
* Types of membership function

Triangular

Simple and widely used.

Defined by 3 Point (a,b,c)

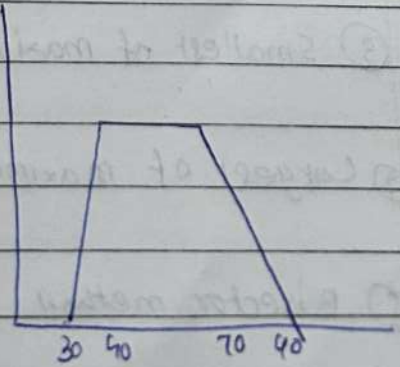
temp- 20, 30, 40



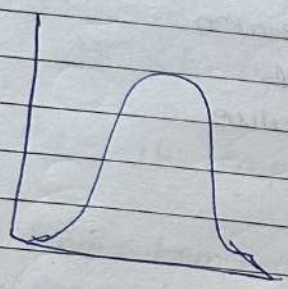
Trapezoidal

Like triangular but has flat on top, defined by 4 Point (a,b,c,d)

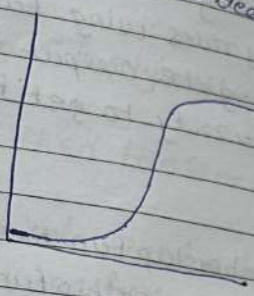
speed- 30, 40, 70, 90



Gaussian
Bell shaped curved
Smooth & Symmetric



Sigmoid
Represent gradual change
Good for open ended ranges



5 Defuzzification

Defuzzification is the process of converting the fuzzy output into crisp result.

Defuzzification process

① combine all outputs of fuzzy set into single fuzzy set
② Application of membership function
③ Defuzzification → apply a method (eg. centroid

methods

① Centroid – Calculate the center of area under the curve.
② Mean of maximum – average all value where membership function is maximum.
③ Smallest of maximum – choose smallest x where membership function is max.
④ Largest of maximum – choose largest value whose x membership function max.
⑤ Bisector method – find value that divides curve into two.

$\frac{1}{1+e^{-x}}$ $\max(0, x)$

$\frac{e^x - e^{-x}}{e^x + e^{-x}}$

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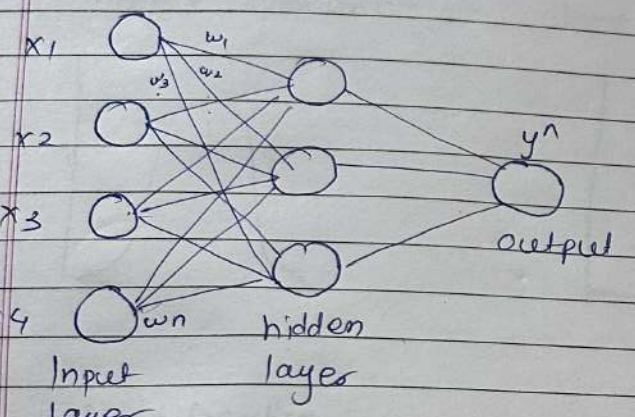
* feedforward network



neural network

① Typically consists 3 layer
② Input layer - receive input data
③ hidden layer - 1 or more layer, computation perform in this layer
④ out layer - predict the result

⑤ neural network is class in ML inspired by human brain
⑥ layers of interconnected neurons designed to recognize pattern in data
⑦ Nural network: Image recog, NLP, Time series predic
⑧ FNN - simplest time Ann
⑨ flow one direction in input to output with out looping back.
⑩ No cycles, feedback connection
⑪ Thats why different from RNN

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$\frac{e^x - e^{-x}}{e^x + e^{-x}}$ $\frac{1}{1+e^{-x}}$ $\frac{1}{1+e^{-x}}$ max (0, x)

(12) each neuron connected to next layer neuron
(13) ~~we use weighted sum first checks the from~~
(14) Activation function
Sigmoid (binary classification) (0 or 1)
$\frac{1}{1+e^{-x}}$ ← weighted sum value Softmax (multi-class

relu
max(0, x)

Tanh (better than sigmoid but complex)
$\frac{e^x - e^{-x}}{e^x + e^{-x}}$

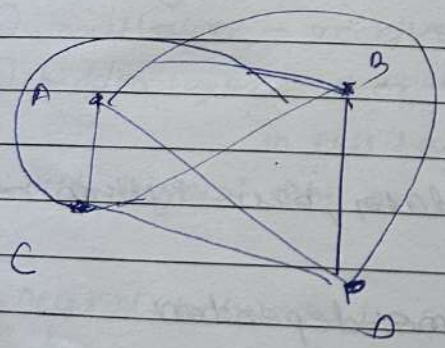
For
ex - basic OCR, MNIST
Simple
~~effective~~ for structured data, basic pattern recognition
dis →
limited in handling time dependency
overfitting if network is complex
required ~~very~~ significant amount of data

TSP

- Optimization problem in CS
- is NP problem
  ex- weight planning, circuit planning, DNA sequence

GA - charles Darun Theory of natural selection

Population —
fitness function =
selection =
crossover —
mutation =



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best output
for very complex example
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PSO - Particle swarm optimization

1. Population based optimization technique
2. inspired by social behaviour of birds flocking or fish schooling
3. developed by James Kennedy
4. widely used to solve optimization problem where traditional gradient-based method may not work effectively.
5. belongs to category of swarm intelligence algorithms and is particularly effective for continuous, nonlinear & multidimensional space.

6. each individual swarm called particle
7. particle characterized by
   - particle position - $\vec{x}_i$
   - velocity - $\vec{v}_i$
   - personal best - $\vec{p}_i$
   - global best $\vec{g}$

8. stoping criteria

   PSO stops when

   1. maximum no of iteration reached
   2. A solution with acceptable fitness found
   3. There is no significant improvement overal it several iteration

guaran

guarantee