computing → process to complete a given goal oriented task.

input → (computing $y = f(x)$) → output is generated.

function (mapping) / control action.

features of computing :-

1) Control actions unambiguous and accurate.
2) Control actions should be easy to conceptualize, construct and operate.
3) should provide precise and optimized solution.

Hard computing → (L. A Zadeh).

primal procedure for solving engineering problems that can be formulated mathematically.
Input-output relationship expressed in terms of mathematical expression.
Control actions must be accurate, suitable to problem defined, stable, highly predictable.
examples → shortest tour in a graph.
searching, sorting

soft computing example → (Fuzzy logic) [values lies btw 0 and 1].
↳ Human oriented.

Crisp logic [Machine oriented] [values 0 or 1 nothing else].

example → Micro controllers, Workstation.

GA (Genetic Algo) → search based optimization algo based on principles of Genetic and Natural selection.
[TSP, Image segmentation].

ANN → Pattern recog, E-commerce, control systems.

Hybrid Computing

Autonomous Robotics.

(combination of Conventional hard computing and softcomputing)

Hard Computing	Soft Computing
1) Involves binary logic, crisp systems and numerical analysis	1) Involves fuzzy logic, genetic algo, neural networks.
2) Exact input data required.	2) Ambiguous and noisy data.
3) sequential computation follows.	3) parallel computation follows.
4) produce precise results.	4) produce approximate results.

Fuzzy logic → cognetive process (ex :- human brain).

mathematical tool dealing with uncertainty.

Crisp logic → deals with crisp sets and Boolean algebra.

Is water colourless → yes
→ No.

Is Ram honest → Extremely honest I.
→ 0.80
→ 0.4
→ 0.

features → 1) flexible, easy to understand.
2) It is used for helping the minimization of logics by human.
3). allow users to build or create the functions which are non-~~linear~~ linear of arbitary complexity.

Crisp set :- $A \subset U$ (universe of discourse).

either $x \in A$ or $x \notin A$

total no of elements belonging to A, is

cardinality of A.

~~crisp function~~ membership function of A —

$$\mu_A(x) = 1 \{ \text{if } x \in A \}$$
$$0 \{ \text{if } x \notin A \}$$

Fuzzy allows partial memberships.

$$\underset{\sim}{A} = \left\{ \sum_{i=1}^{n} \frac{\mu_A(x_i)}{x_i} \right\}, \; n \text{ is finite} \rightarrow U \text{ is finite}$$

↓

Fuzzy set.

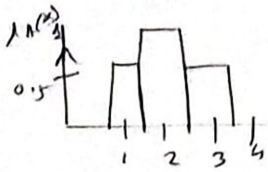
[$\mu_A(x)$ is degree of membership of x in A and indicates that x belongs to A,

$$A = \left\{ \int \frac{\chi_A(x_i)}{x_i} \right\} \rightarrow U \text{ continuous}, \text{ finite}.$$

Example - 1

$X = \{1, 2, 3, 4, 5, 6\}$

$\mu_A(x) = 0.5$, 0.2, 0.5, 0

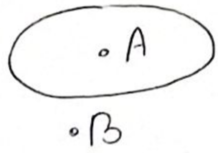


Discrete fuzzy set,

fuzzy example - 2

Diff Crisp set and fuzzy set

1) Sharp boundaries. by 0/F and 1/T	1) fuzzy boundaries with membership value.
2) some crisp set can be fuzzy	2) some fuzzy set can make crisp.
3) logic is bi-valued	3) logic is infinite-valued.

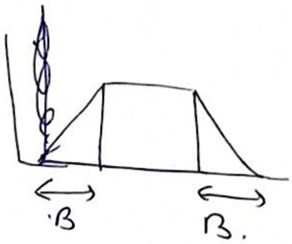


Crisp

fuzzy set

Boundary of A

$\{x \in U \mid 0 < \mu_A(x) < 1\}$



$\mu_U(x) = 1$ for all $x \in U$.

universal fuzzy set.

$\mu_\phi(x) = 0$ for all $x \in U$.

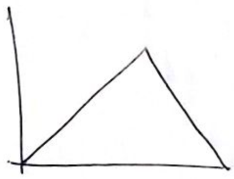
empty fuzzy set.

$\underbrace{\mu_A(x) = \mu_B(x)}$. for $x \in U$.

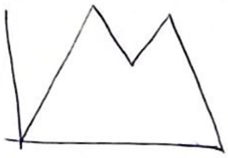
equal fuzzy sets.

A convex fuzzy set 1) rules -

1) membership values monotonically increasing decreasing or increasing then decreasing.

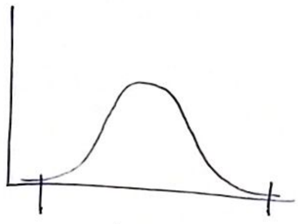


Convex



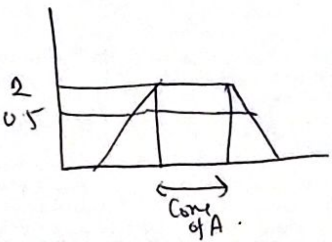
Non convex.

Support of A $= \{x \in U \mid \mu_A(x) > 0\}$



Core of A. $\Rightarrow \{x \in U \mid \mu_A(x) = 1\}$.

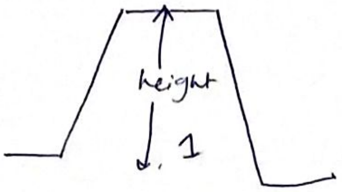
Fuzzy set



Height of A is defined as max value of membership function of all elements contained in that set.

$$\text{Height}(A) = \{\max(\mu_A(x)) \mid x \in U\}$$

It may not be 1 always, If core is non empty, height of fuzzy set is 1.

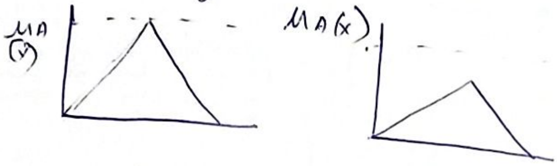


Normality :-

A fuzzy set A is defined as normal whose membership func has at least one element x in the universe such that: $\mu_A(x) = 1$.

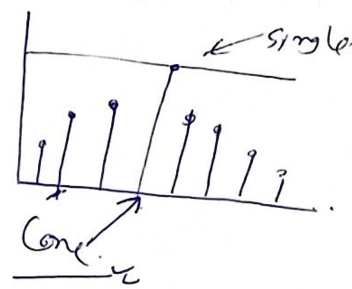
$\mu_A(x) < 1 \rightarrow$ subnormal.

height of fuzzy set is always 1 and less than 1 for subnormal.



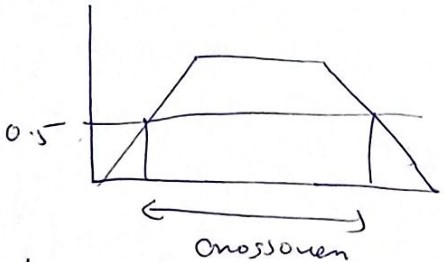
Fuzzy Singleton.

$|A| = \{x \in U \mid \mu_A(x) = 1\}$.



Crossover points :-

$$\text{Crossover}(A) = \{x \in U \mid \mu_A(x) = 0.5\}.$$

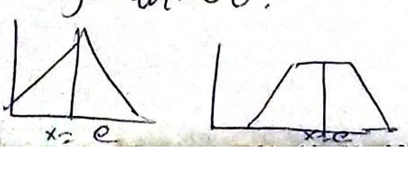


Fuzzy Bandwidth.

Bandwidth(A)
$= |x_1 - x_2|$ where $x_1, x_2 \in U$ $\mu_A(x_1) = \mu_A(x_2) = 0.5$

Symmetry :-

$\mu_A(x+c) = \mu_A(x-c)$ for all $x \in U$.



α cut :- $A_\alpha = \{x \mid \mu_A(x) \geq \alpha\}$.

$A_\alpha' = \{x \mid \mu_A(x) > \alpha\}$ → strong α cut.

If $\alpha_1 > \alpha_2$, $A_{\alpha 1} \subseteq A_{\alpha 2}$.

Cardinality.

Scalar. $|A| = \sum_{x \in U} \mu_A(x)$.

Relative $||A|| = \frac{|A|}{|U|}$.

$|A_3| = 0 + 0.2 \ldots 3.1$.

Fuzzy.

$|A_F| = \{(|A_\alpha|, \alpha)\}$.

$||A_3|| = \frac{3.1}{|U|} = \frac{3.1}{9} = \_$

Fuzzy logic vs Probability.

Identifies partial truth	Identifies the partial knowledge.
Takes degree of membership in a set	Take mathematical likehood of events to occur.
based on math.	

Adv, Disadv. →