Fuzzy Neural Network

→ It is a learning machine that finds the parameters of a fuzzy system (sets, rules) by exploiting approximation techniques from neural networks.

fuzzy sets / Logics

very cold
80% less
70%
[0, 7]
0·5 0·6 0·7
0·8 60%

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→ Used for solving a problem (pattern recognition, regression or destiny estimation)

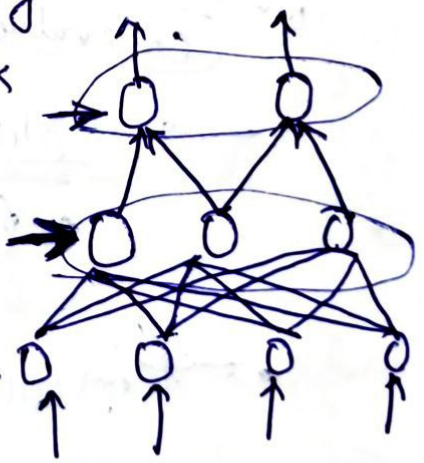
→ Neuro-fuzzy system based on underlying fuzzy system is trained by means of data-driven learning method derived from neural network theory.

→ first Layer corresponds to input variables

→ IInd - fuzzy rules

→ 3rd → output variables

→ fuzzy sets are converted as connected weights.



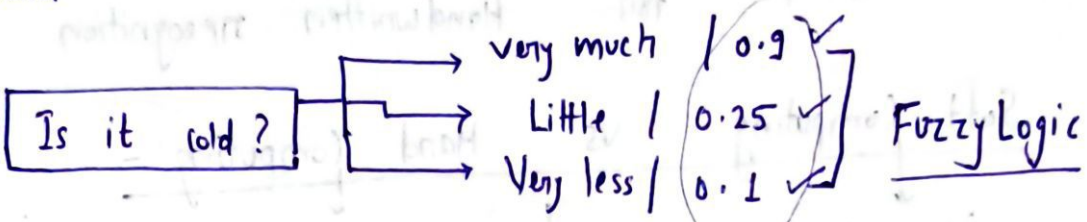
Architecture of NFS

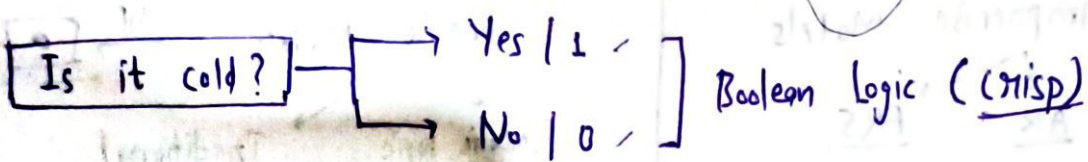
Fuzzy Logic :- Fuzzy logic theory proposed in 1965 by A. Zadeh is a generalization of classical set theory.

In classical set theory, an element either belong to or does not belong to the set & hence, such set are termed as crisp set. [0 & 1] Yes or No

But in fuzzy set, many degrees of membership (blw 0 & 1) are allowed.

Eg.





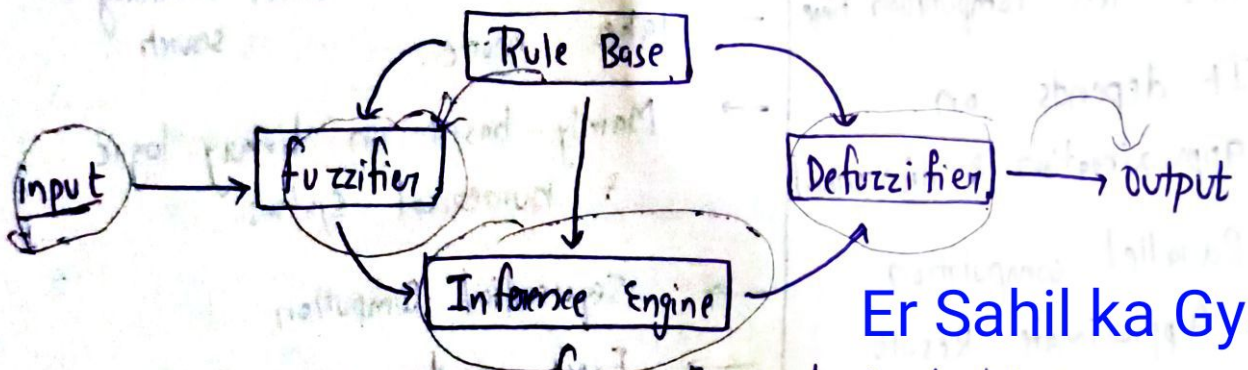


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fig:- Fuzzy Logic Architecture

- The word "fuzzy" means vergueness. Fuzziness occurs when the boundary of a piece of information is not clear-out.
- Fuzzy sets theory described with the aid of a membership function valued in the real unit interval [0, 1].

Artificial Neural Networks [ANN]:— ANNs has developed from a biological model of the brain.

A neural net consists of a set of connected cells as the neurons. The neurons receive impulses from either cells or output cells.

- ANNs are programs designed to solve any problem by trying to mimic the structure & the function of our nervous system.
- A neural network acquires knowledge through learning.

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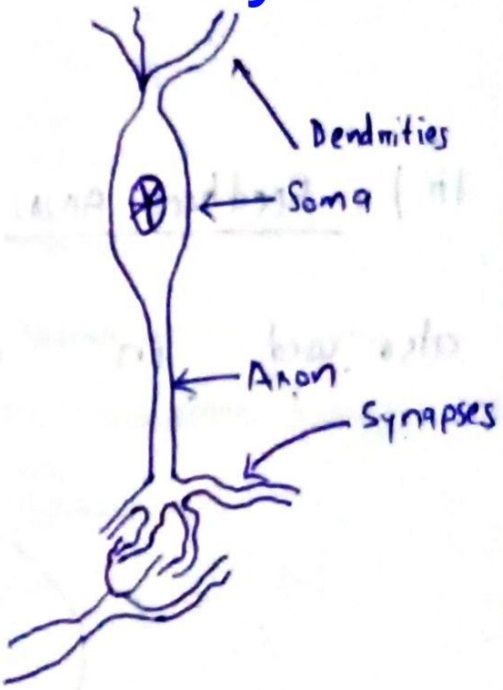
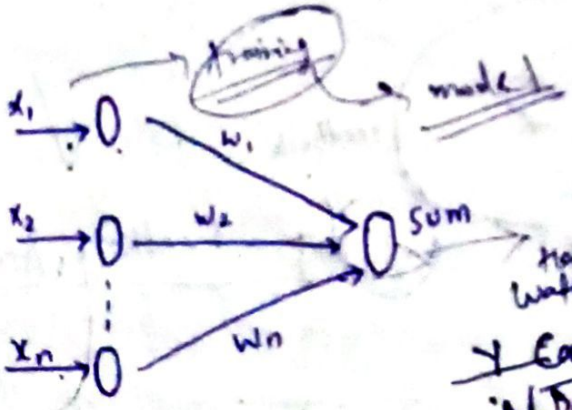
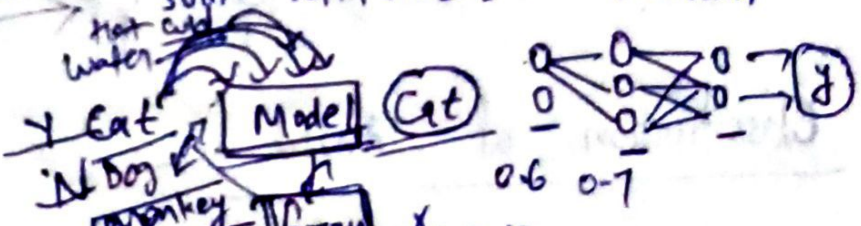
Biological Neuron model:—

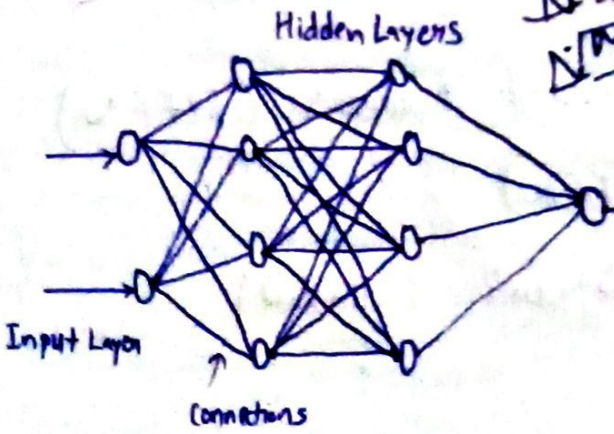
- Dendrities :— Accepts the inputs
- Soma :— process the inputs
- AXON :— Turns the processed i/p into o/ps.
- Synapses :— The electrochemical contact blw neurons

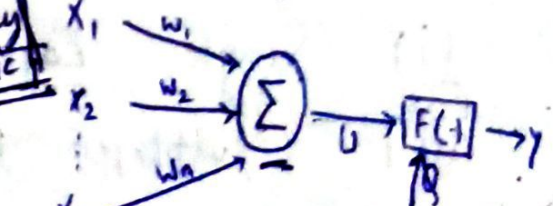




$\text{sum} = w_1x_1 + w_2x_2 + \cdots + w_nx_n$



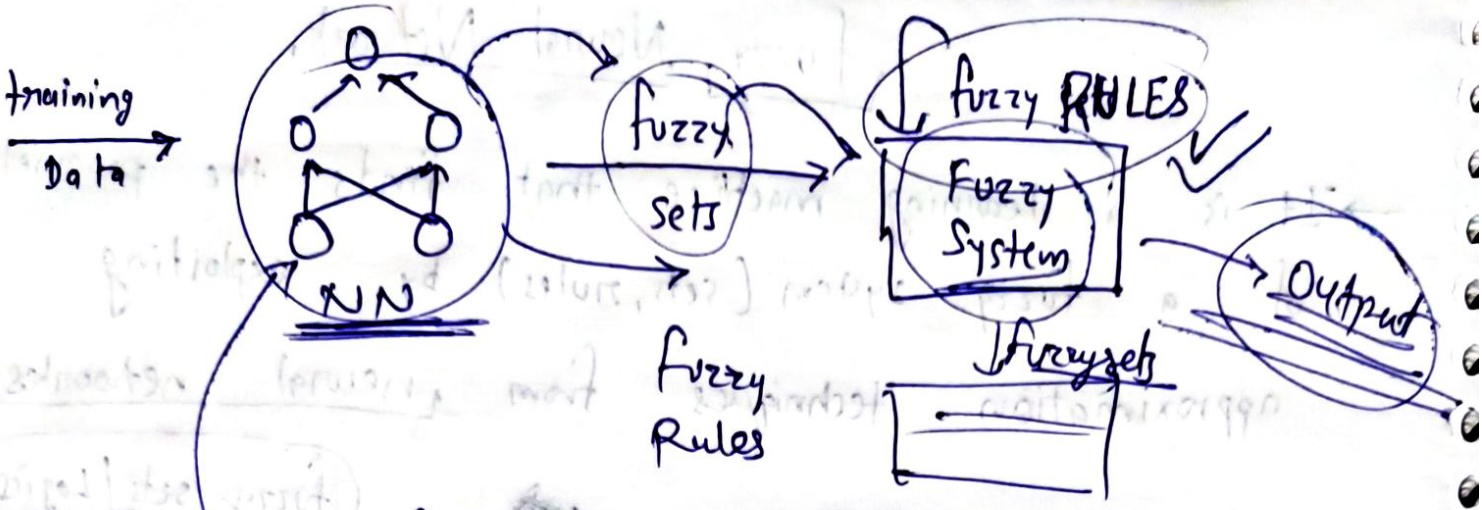




$$U = \sum_{j=1}^{n} w_j x_j$$

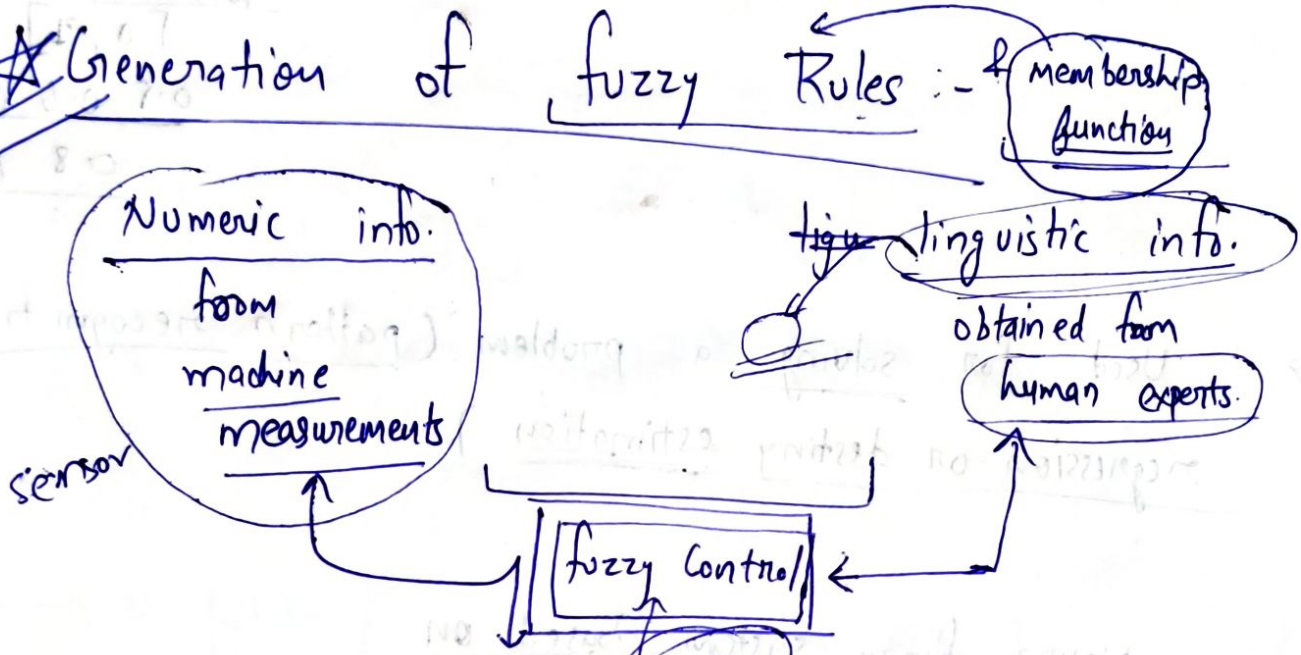
θ = desired o/p

$$y = F(U - \theta)$$



fuzzy Neural Network

✱ Generation of fuzzy Rules :-



0.6 0.7 0.8

crisp value → F → Rule → Infer → DC

$D(Rule) = m_A(x_1)\, m_B(x_2)\, m_C(y)$

→ Numeric Data

- (divide i/p & o/p spaces into fuzzy Regions)
- ~~def~~ from Given Data pairs)
- (Assign a degree to each rule)
- (Create a Combined fuzzy Rule Base)
- (Determine a mapping Based on combined fuzzy Rule Base)

In ANN, weights have useful information about input to solve the problems

→ fuzzy logic is largely used to define weights from fuzzy sets, in neural networks

→ When crisp values are not possible to apply, then fuzzy values are used.

How much? 60%, 70%, 80%.

NFS

Eg- ford motor (idle speed control)

NeuFuz (Semiconductor)

AEG (water & energy conserving machine)

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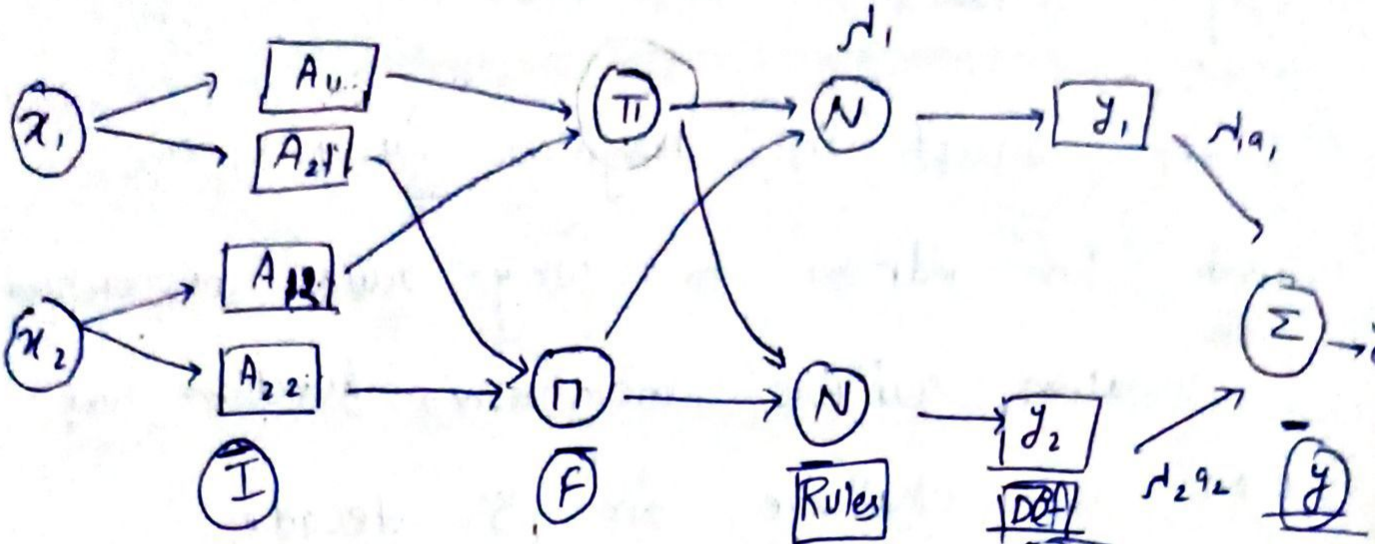

fig:- Architecture of Neural Network

5-Layers

3 Layer

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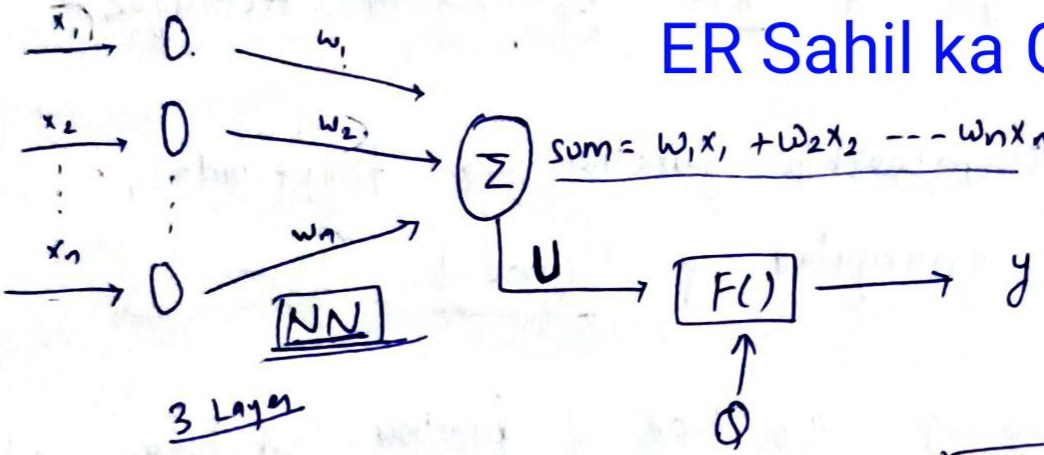
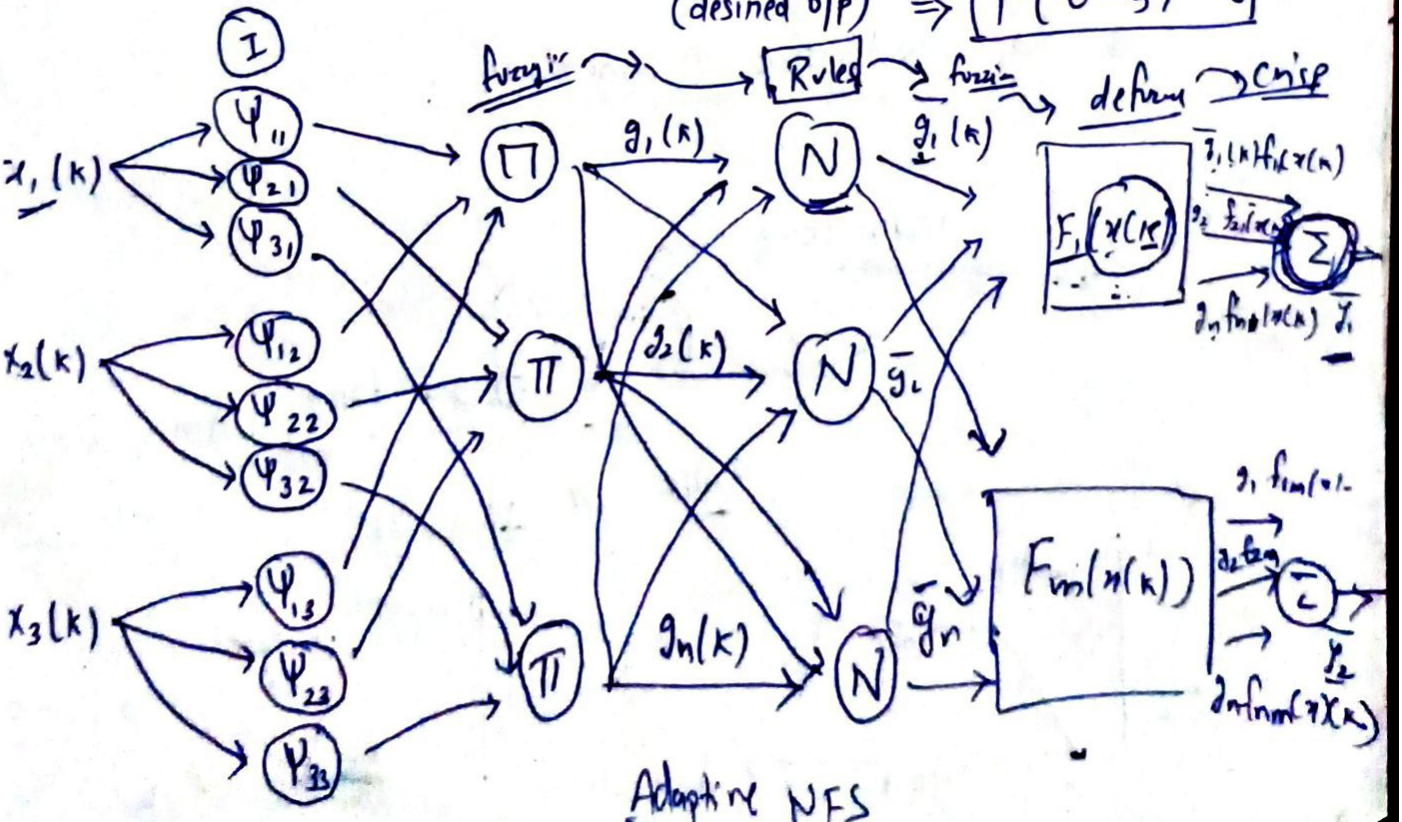




Adaptive NFS

fuzzy Membership functions :-

key concept in designing fuzzy systems. and In addition to fuzzy rules construction, generation suitable membership function has been a challenge for 3 decades.

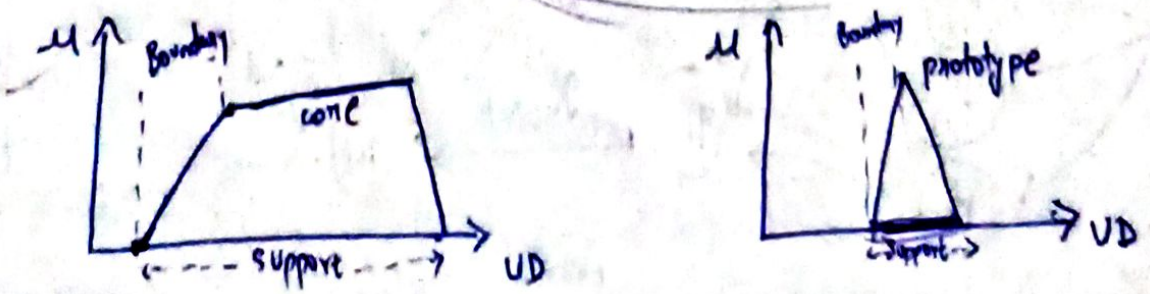
→ Process of generating MFs is achieved through a GA optimization technique.

→ Membership function → trapezoidal, triangular & Sigmoid.

→ Choosing the type of function has been considered as a subjective procedure.

3 parameters :-

Support, Boundary & Core or prototype



If $\underline{X}$ is universe of Discourse (UD) and $\underline{x_i}$ is defined in $\underline{X_i}$

$$X = \{x_1, x_2 \cdots x_n\}$$

we can define subset or partition of X as:

$$X^i = [x_1^i, x_2^i \cdots x_k^i] = \{x_L^i, x_H^i\}, X^i \subset X$$

$$1 \leq i \leq m$$

$$X = \bigcup_{i=1}^{m} X^i = \bigcup_{i=1}^{m} [x_L^i, x_H^i]$$

X^i (membership function) ✓

f(MF) Rules

$$\mu_{X^i}(\cdot) : X^i \subset X$$

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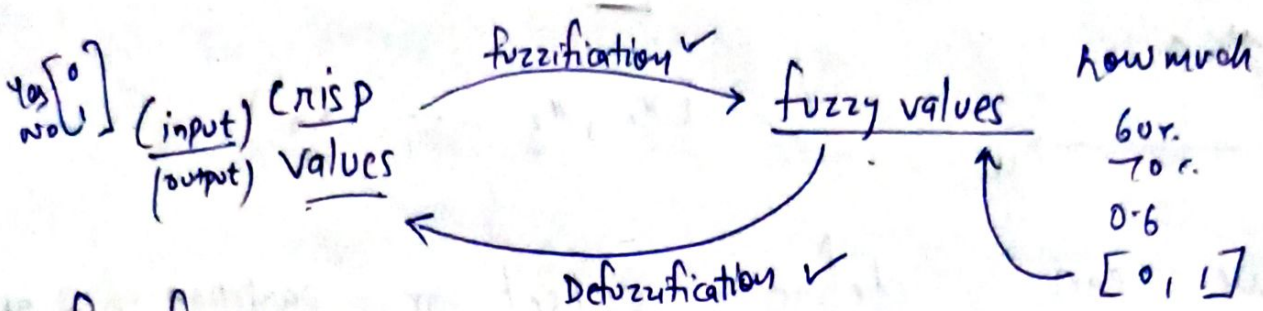
✱ Fuzzification and De-fuzzification in NFS



fuzzification

→ It involves mapping the crisp input values to membership function associated with the linguistic variables used in fuzzy system. → human experts

→ Membership fn determine the degree to which an input value belongs to a specific fuzzy set.

Eg- Controlling Room temperature

so crisp input (temperature) (can be fuzzified into) Fuzzy sets (cold, warm, hot) using MF

Defuzzification

→ It aims to extract single crisp value from these fuzzy sets or values.

→ It considers membership degree of fuzzy sets & determines most representative crisp value that

summarizes the fuzzy output.

- center of gravity
- weighted average
- maximum membership.

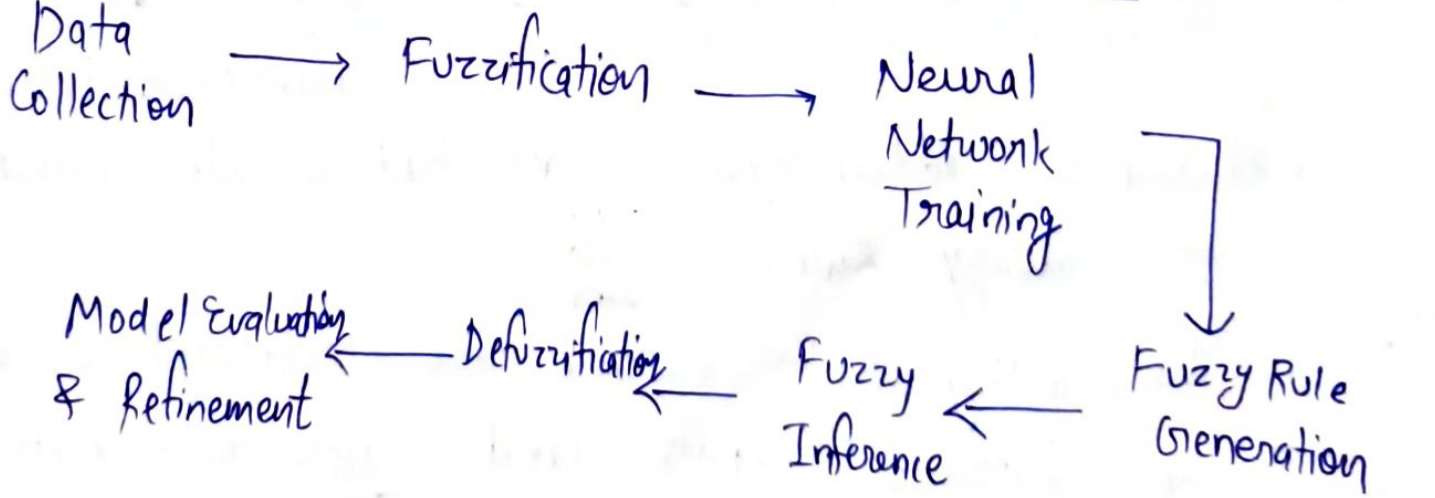
} defuzzification methods.

Eg- fuzzy output sets like "increase AC", "maintain temperature" & "decrease AC" are defuzzified to obtain a crisp o/p.

Neuro - fuzzy Identification :-

(Neuro-fuzzy modelling or Neuro fuzzy inference systems)

It combines the concepts of neural networks and fuzzy logic to create models that can learn and make predictions based on uncertain or imprecise data.

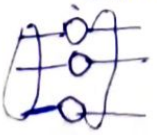


1. Data Collection : Gather a dataset that includes input-output pairs or observations of the system to be modeled. The data should cover a wide range of input conditions and corresponding output values.

2. Fuzzification : Fuzzify crisp data by assigning membership degrees to different fuzzy sets.

3. Neural Network Training : Utilize the fuzzy input data to train a neural network. (input nodes, hidden nodes, output nodes)
   - we use backpropagation or adaptive learnings to train the network.

4. Fuzzy Rule Generation :- Fuzzy Rules are generated based on network's hidden layer. Each hidden node corresponds to fuzzy Rule.



The fuzzy Rules capture the relationships b/w the fuzzified inputs and network's output.

5. Fuzzy Inference:- Perform fuzzy inference by applying the fuzzified inputs & generated fuzzy Rules. Fuzzy inference combines the fuzzy rules to determine the appropriate output based on input conditions.

6. Defuzzification:- Convert the fuzzy output obtained from fuzzy inference process into a crisp output.

7. Model Evaluation & Refinement :- Evaluate the performance of neuro-fuzzy model using additional test data Measure the accuracy of the model's predictions and refine the model as needed by adjusting the neural network parameters or modifying the fuzzy Rules.

Combination of Genetic Algorithm with Neural Networks

→ It can really accelerate learning process to solve a certain problem.

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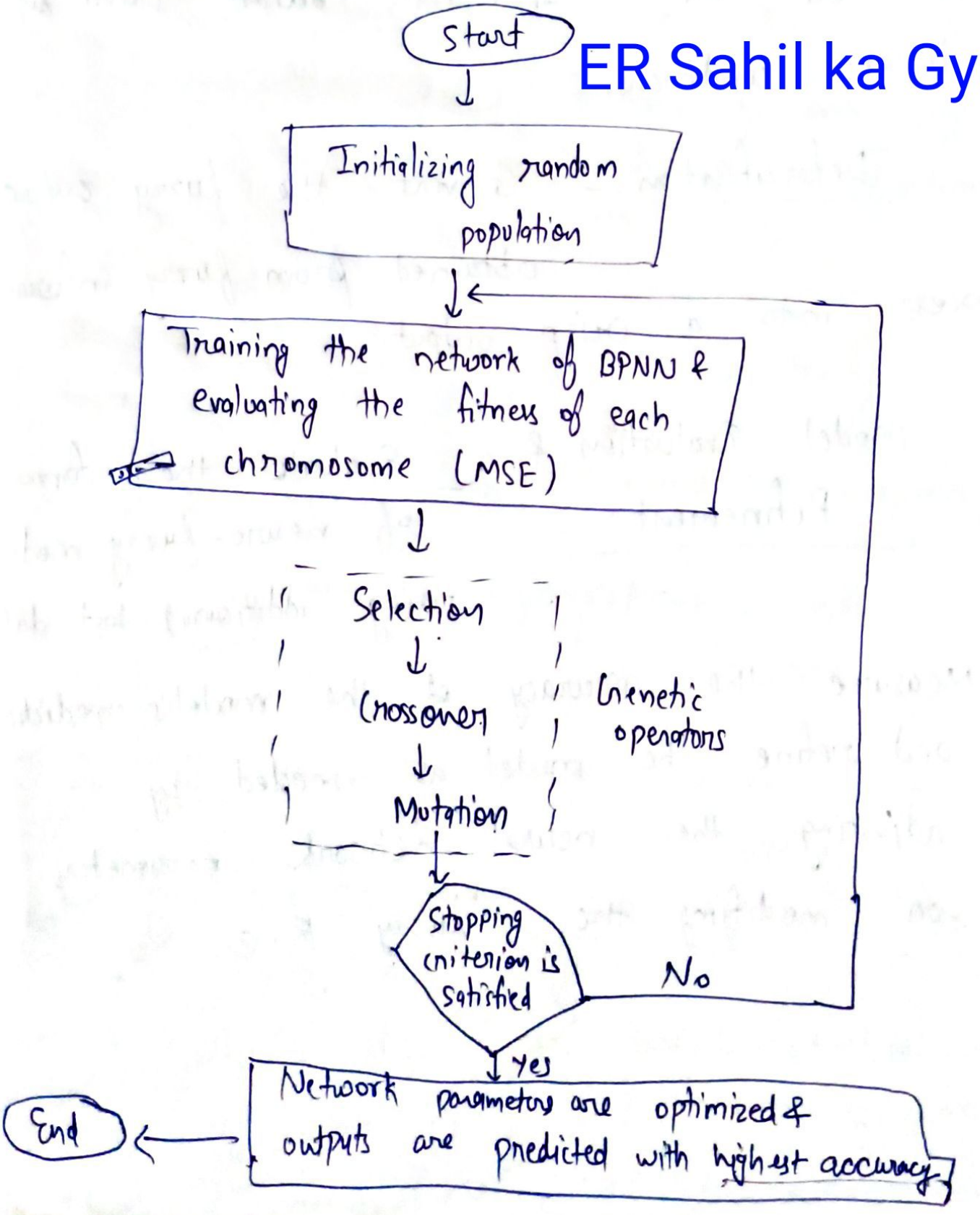
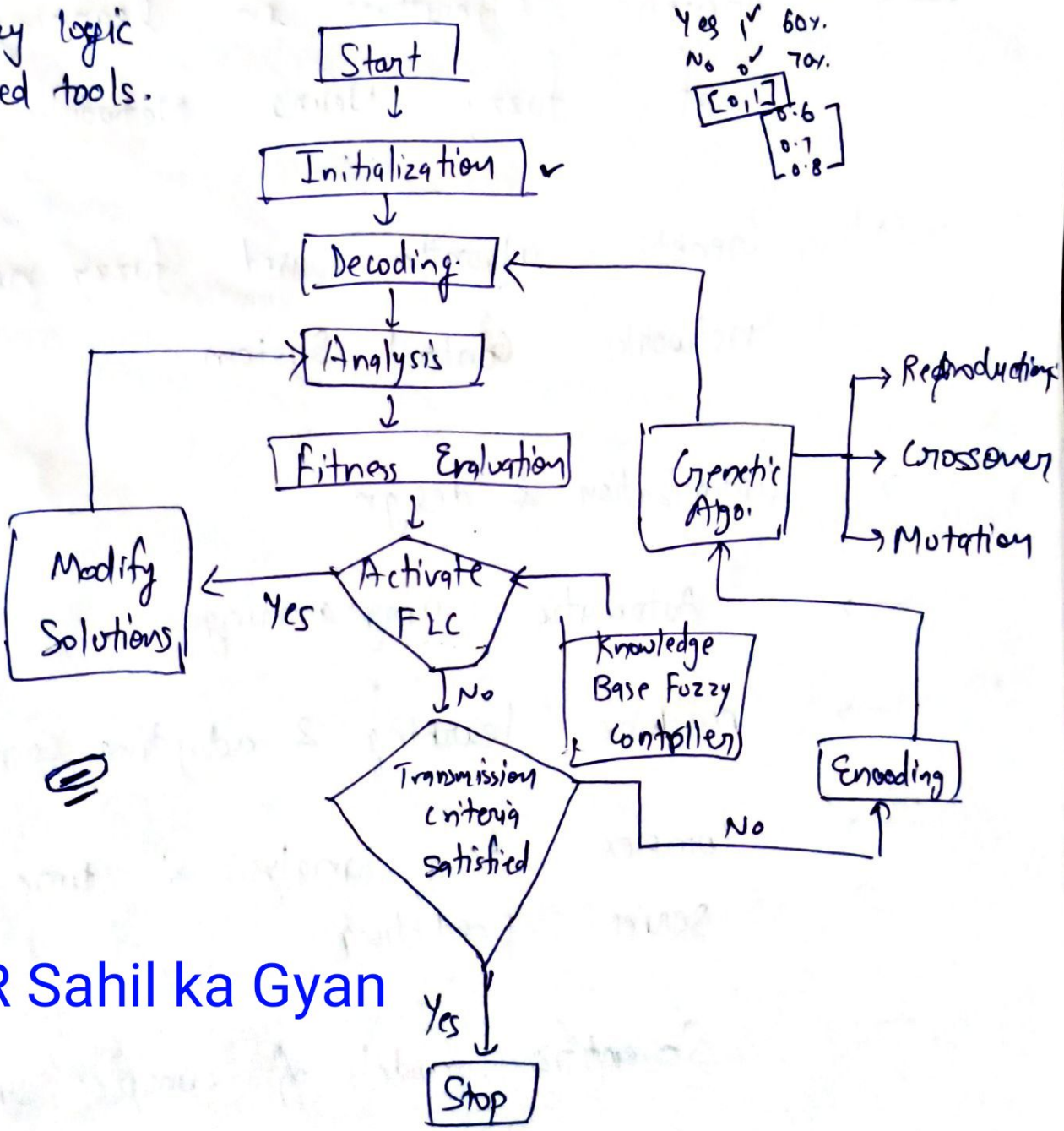


Combination of Genetic Algorithm with Fuzzy Logic

→ Fuzzy Genetic Algo. is defined as an ordering sequence of instructions in which some of the instructions or algo. components designed with use of fuzzy logic based tools.



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→ Fuzzy logic controller monitors the evolution of different variables during optimization and adjust the bounding intervals for each design variable

Neuro - fuzzy and Genetic Approach in Engineering applications

- Neuro - fuzzy Systems Optimization
- Genetic Algorithms in learning of fuzzy Neural Networks
- Genetic algorithm based fuzzy neural networks Control System
- Optimization & design
- Automatic programming
- Machine learning & adaptive Control
- Complex data analysis & time-series prediction
- Scientific models of complex systems.

Programming Using MATLAB
[matrix laboratory]

→ It is a high level PL designed that expresses matrix & array mathematics directly.

→ Simplest type of MATLAB program is called a script.

⇒ Using Neural network ToolBox :—

- It provides algos, pre-trained models & apps to create, train, visualize & simulate ~~netw~~ neural networks with one hidden layer.
- We can perform classification, regression, clustering, dimensionality reduction, time series forecasting & dynamic system modelling & control.

⇒ Using Genetic Algorithm & ToolBox :—
directed search

- Extends the capabilities of optimization toolbox & matlab numeric computing environment.

. You must first write an M-file that computes function you want to optimize

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1. Install DS toolBox
2. Define fitness function
3. Configure Genetic Algorithm
4. Run Genetic Algorithm (using 'ga' fn)
5. Access the Best Solution
6. Post-Processing & Analysis.

Thank you for being through this 🙏

⇒ Using fuzzy Logic ToolBox

1. Define fuzzy Inference System (FIS)
   [use 'newfis' fn]
2. Define fuzzy sets & membership fn
   [use 'addvar' & 'addmf' fn]
3. Define Fuzzy Rules
4. Set Input Values & Perform fuzzy Inference
5. Defuzzify Output
6. Analyze & Validate Results