Module 1- Introduction to Soft Computing and Neural Network

Lecture1 Topic

Introduction to Soft Computing

- Concept of computing
- Important characteristics of "Computing"
- Soft computing vs. "Hard" Computing
- Few examples of Soft computing applications
- Characteristics of Soft computing
- Hybrid computing

Concept of Computing System

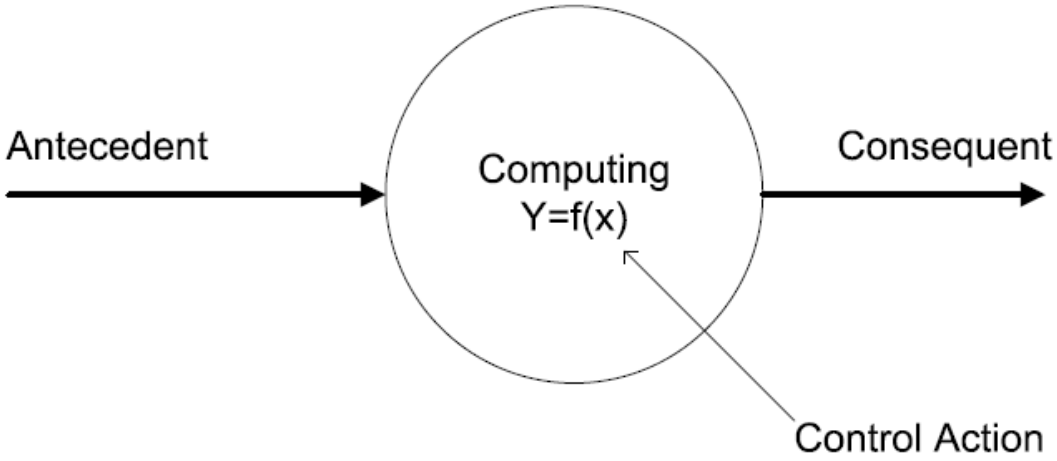


Figure : Basic of computing

$y = f(x)$, f is a mapping function
f is also called a formal method or an algorithm to solve a problem.

Important characteristic of computing

- Should provide **precise** solution
- Control action should be **unambiguous** and **accurate**.
- Suitable for problem, which is easy to model **mathematically**.

Hard computing

- In 1996, L.A. Zade (LAZ) introduced the term hard computing.
- According to LAZ: we term a computing as Hard computing,
  - **Precise result** is guaranteed
  - Control action are **unambiguous**
  - Control action is **formally defined** (i.e. with mathematical model or algorithm)

Examples of Hard computing

- Solving **numerical problems** (e.g., roots of polynomials, integration etc.)
- **Searching and sorting** techniques.
- Solving **computational geometry problems** (e.g., shortest tour in graph, finding closest pair of points given a set of points, etc.)

Soft Computing

- The term soft computing was proposed by the inventor of fuzzy logic, Lotfi A. Zadeh. He describes it as follows.

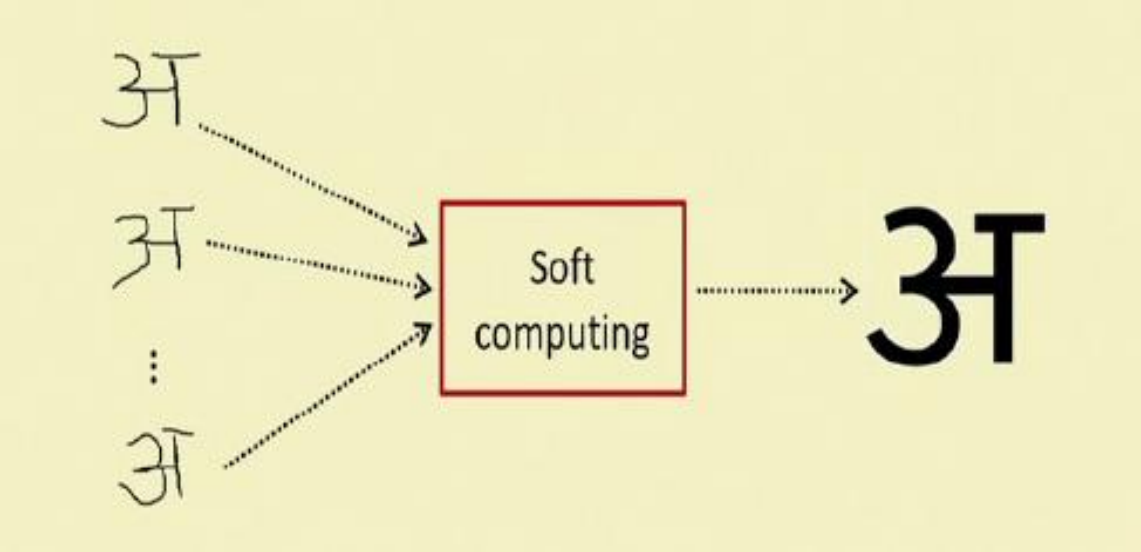
Definition: Soft computing

Soft computing is a collection of methodologies that aim to exploit the tolerance for imprecision and uncertainty to achieve tractability, robustness and low solution cost. It principal constituents are fuzzy logic, neuro-computing and probablistic reasoning. The role model for soft computing is human mind.

Characteristics of soft computing

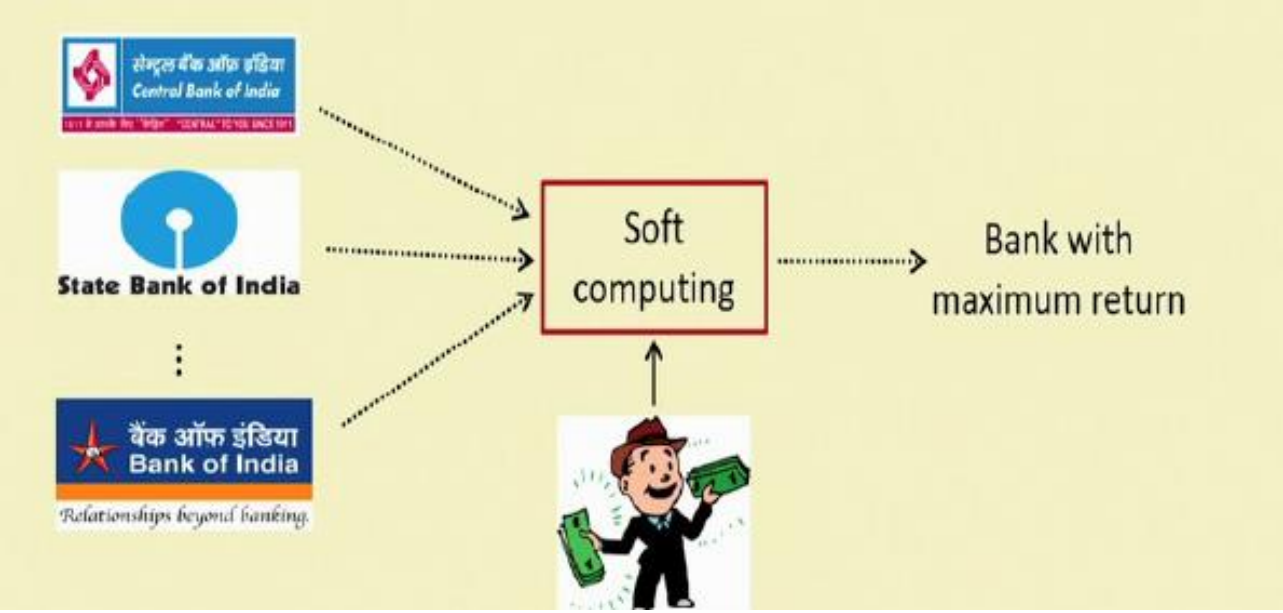
- It **does not require** any mathematical modeling of problem solving.
- It **may not yield** the precise solution.
- Algorithms are **adaptive**(i.e., it can adjust to the change in dynamic environment).
- Use some **biological inspired methodologies** such as genetics, evolution, Ants behaviors, particles swarming, human nervous system etc.)

Examples of soft computing



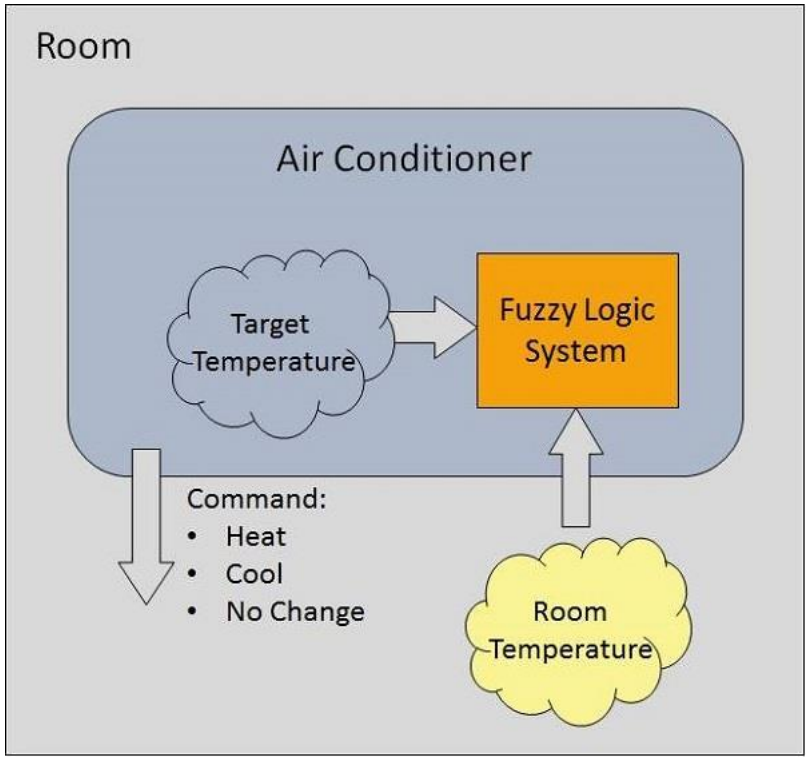
Example: Hand written character recognition
(Artificial Neural networks)

Examples of soft computing



Example: Money allocation problem
(Evolutionary computing)

Examples of soft computing



Example: Air Conditionining System
(Fuzzy logic)

How soft computing?

- How a **student** learns from a **teacher**?
  - Teacher asks questions and tell answer then
  - Teacher puts question and hint answers and asks whether the answers are correct or not.
  - Student thus learns a topic and store in his memory.
  - Based on these knowledge he solves new problems.

- This is way how the human brain works.
- Based on this concept Artificial neural network is used to solve problems

How soft computing?

- How world selects the best?
  - It starts with a population (random).
  - Reproduces another population (next generation).
  - Rank the population and selects the superior individuals.
- Genetic algorithm is based on this natural phenomena.
  - Populations is synonymous to solutions.
  - Selection of superior solution is synonymous to exploring the optimal solution.

How soft computing?

- How doctor treats his patient?
  - Doctor asks the patient about suffering.
  - Doctor find the symptoms of diseases
  - Doctor prescribed tests and medicines

- This is exactly how fuzzy logic works.
  - Symptoms are correlated with diseases with uncertainty.
  - Doctors prescribes tests/medicines fuzzily.

Soft Computing

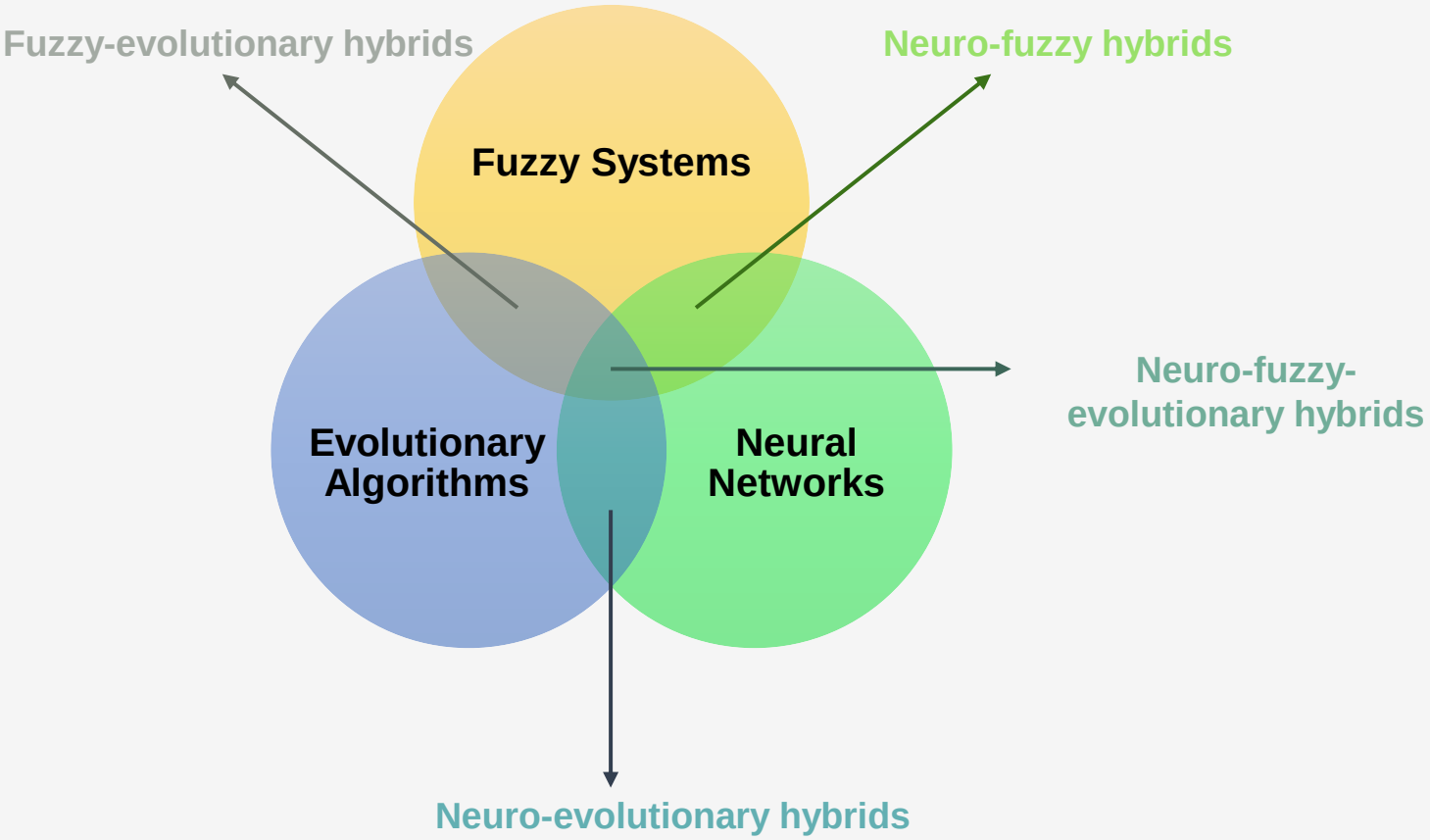
- Introduced by Lotfi A. Zadeh, University of California, Berkley
- Collection of computational methods
- Includes Fuzzy Systems, Neural Networks and Evolutionary Algorithms
- Deployment of *soft computing* for the solution of *machine learning* problems has led to high *Machine Intelligence Quotient*

Image Credit: Electrical Engineering and Computer Sciences, UC. Berkeley

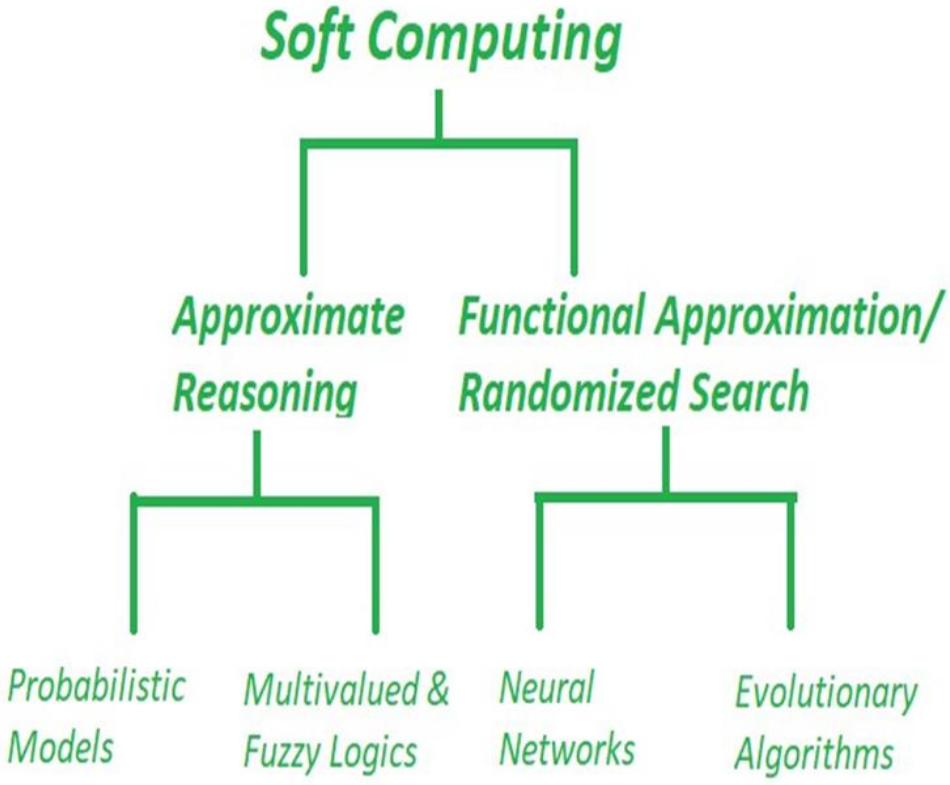
"Soft computing differs from hard computing (conventional computing) in its tolerance to imprecision, uncertainty and partial truth"

-Lotfi A. Zadeh

Soft Computing (Contd…)



Soft computing methodologies

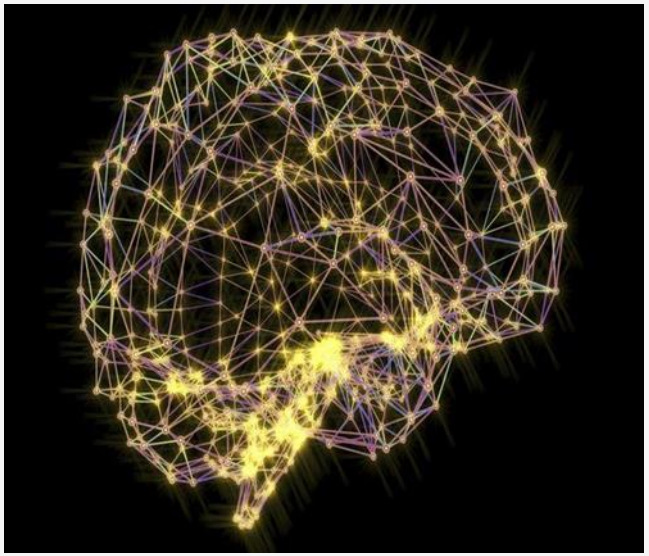


Techniques in soft computing

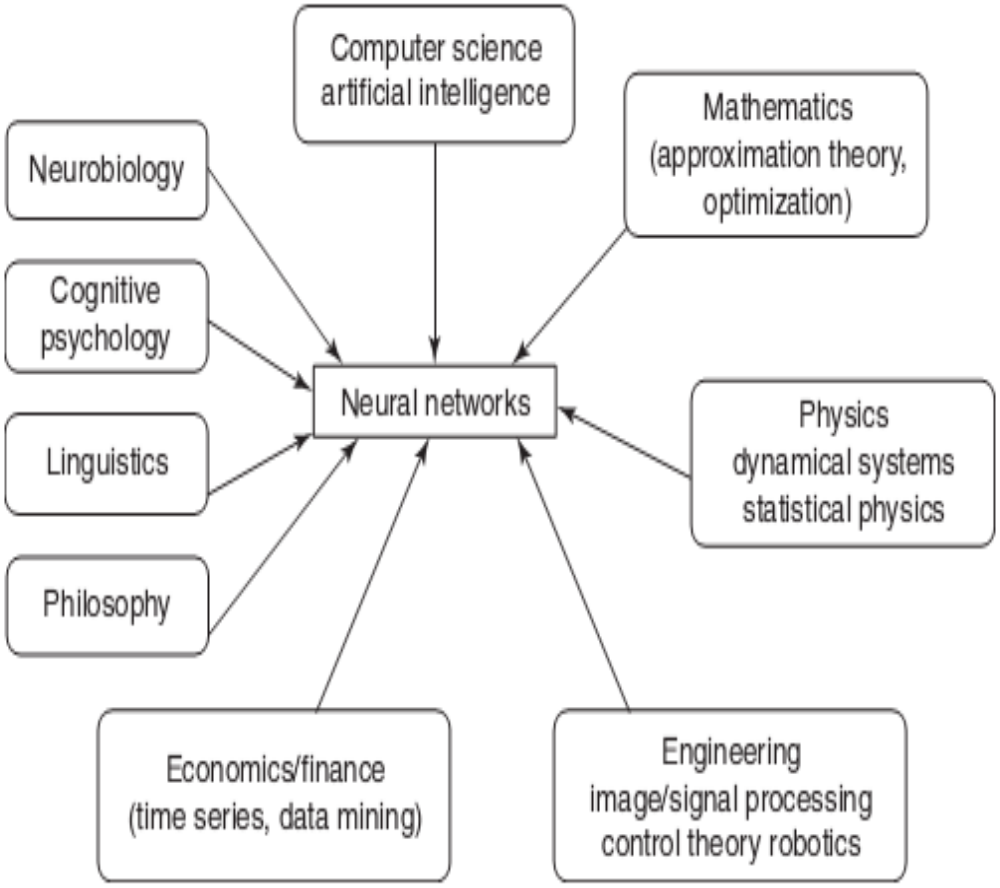
1. Neural Network
2. Fuzzy Logic
3. Genetic Algorithm
4. Hybrid Systems

Neural Networks

- Simplified models of the biological nervous system
- Processing elements called neurons – inspired by the brain
- Parallel distributed processing
- Characteristics:
  - mapping capabilities or pattern association
  - robustness
  - fault tolerance
  - parallel and high speed information processing
  - nonlinearity
  - adaptivity



Multidisciplinary view of neural network



Fuzzy Logic

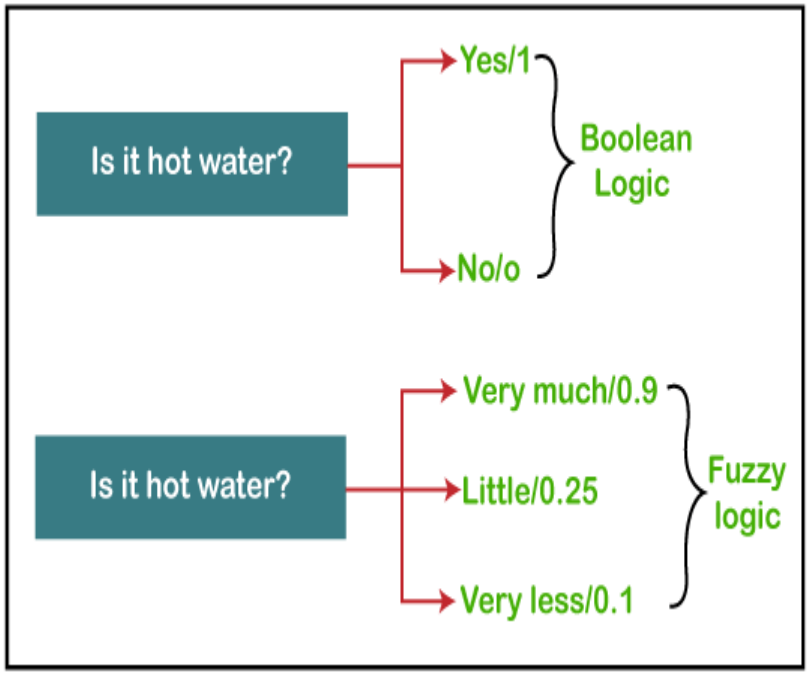
- It was developed in 1965, by Professor Lofti Zadeh, at University of California, Berkley. The first application was to perform computer data processing based on natural values.
- In more simple words, **A Fuzzy logic stat can be 0, 1 or in between these numbers i.e. 0.17 or 0.54**.
- **For example,** In **Boolean**, we may say glass of hot water (i.e 1 or High) or glass of cold water i.e. (0 or low), **but in Fuzzy logic,** We may say glass of warm water (neither hot nor cold).

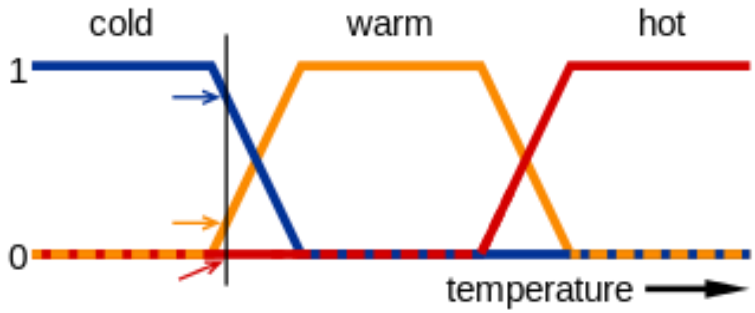
Fuzzy Logic

Fuzzy-"Not Clear, distinct, or precise; blurred"

Fuzzy logic is a reasoning method that is **similar to human *reasoning***. In other words, a fuzzy logic-based system can make decisions similar to a human.

Fuzzy Logic is a technique that understands the vagueness of a solution and presents the solution with a ***degree of vagueness which is practical to human decision***. It is widely applied in several applications of Artificial Intelligence for reasoning.





Advantages of Fuzzy Logic

1. A Fuzzy Logic System is flexible and allow modification in the rules.
2. Even imprecise, distorted and error input information is also accepted by the system.
3. The systems can be easily constructed.
4. Since these systems involve human reasoning and decision making, they are useful in providing solutions to complex solutions in different types of applications.

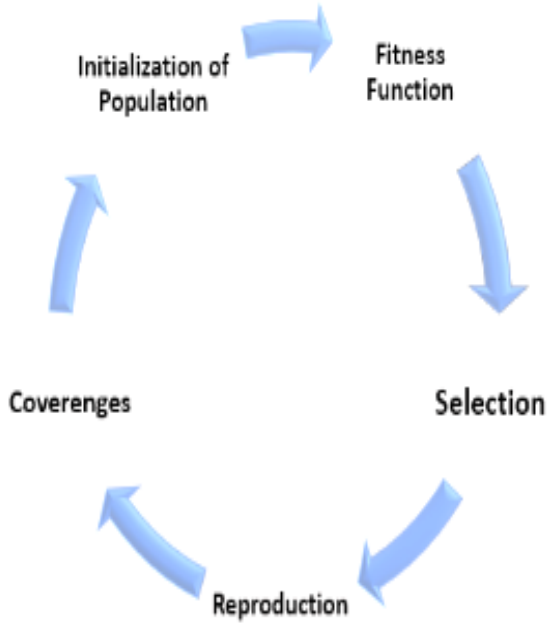
Applications of Fuzzy Logic

- Fuzzy Logic system can be used in Automotive systems, for applications like 4-Wheel steering, automatic gearboxes etc.
- Applications in the field of Domestic Applications include Microwave Ovens, Air Conditioners, Washing Machines, Televisions, Refrigerators, Vacuum Cleaners etc.
- Other applications include Hi-Fi Systems, Photo-Copiers, Humidifiers etc.

Genetic Algorithm

- A genetic algorithm is an adaptive heuristic search algorithm inspired by "Darwin's theory of evolution in Nature."
- In GAs, we have a **pool or a population of possible solutions** to the given problem. These solutions then undergo recombination and mutation (like in natural genetics), producing new children, and the process is repeated over various generations.
- During this procedure a certain strings of symbols, known as chromosomes, evaluate toward better solution.

Genetic Algorithm



- In this way we keep “evolving” better individuals or solutions over generations, till we reach a stopping criterion.

Applications of Genetic Algorithms

- Data mining and clustering.
- Image processing.
- Wireless sensor network.
- Traveling salesman problem (TSP)
- Vehicle routing problems.
- Mechanical engineering design.
- Manufacturing system.

HYBRID SYSTEMS

Hybrid systems enables one to combine various soft computing paradigms and result in a best solution. The major three hybrid systems are as follows:

- Hybrid Fuzzy Logic (FL) Systems
- Hybrid Neural Network (NN) Systems
- Hybrid Evolutionary Algorithm (EA) Systems

Applications of Soft Computing

Hard computing vs Soft computing

Hard Computing	Soft Computing
• It requires a precisely stated analytical model and often a lot computation time	• It is tolerant of imprecision, uncertainty, partial truth, and approximation.
• It is based on binary logic, crisp systems, numerical analysis and crisp software	• It is based on fuzzy logic, neural nets and evolutionary algorithms
• It has characteristics of precision and categoricity	• It has characteristics of approximation and dispositionality

Hard computing vs Soft computing

Hard Computing	Soft Computing
• It is deterministic	• It incorporates stochasticity
• It requires exact input data	• It can deal with ambiguous and noisy data
• It is strictly sequential	• It allows parallel computations
• It produces precise answers	• It can yield approximate answers

Hybrid Computing

It is a combination of the conventional hard computing and emerging soft computing

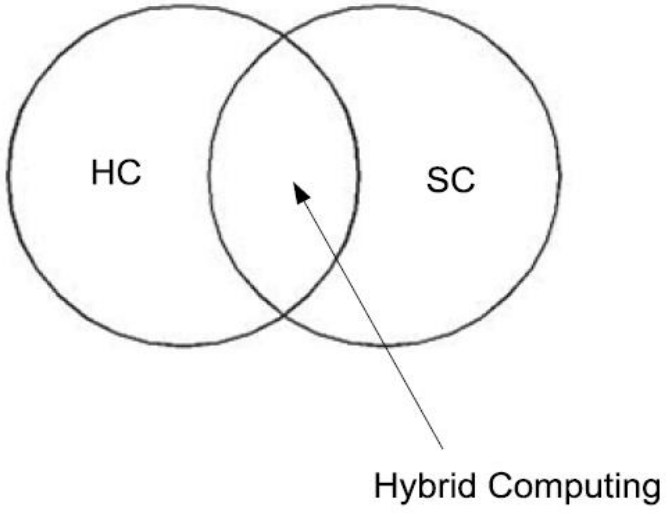


Figure : Concept of Hybrid Computing

Hybrid computing in action

Autonomous Vehicle

- Autonomous vehicles require a combination of various computational techniques to operate effectively:
  - **Neural Networks**: For image and object recognition, helping the vehicle identify pedestrians, other vehicles, and road signs.
  - **Fuzzy Logic**: To make decisions in uncertain environments, such as when to change lanes or how to handle ambiguous traffic situations.
  - **Genetic Algorithms**: To optimize the vehicle's route and improve fuel efficiency.
  - **Traditional Algorithms**: For precise control of vehicle dynamics and ensuring safety through rigorous calculations.

hybrid computing enables autonomous vehicles to navigate complex environments, make real-time decisions, and continuously improve their performance through learning and optimization.