Soft Computing
Module I
Introduction to Soft Computing

AY 22 -23
Even Semester
Class : TT- AI&ML

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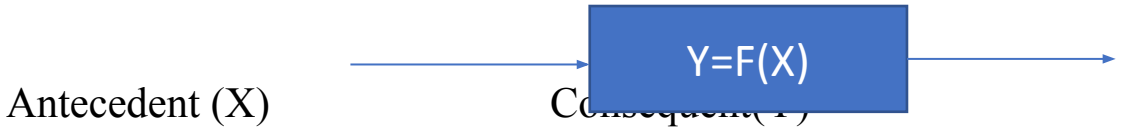
Module 1: Introduction to Soft Computing

1. Concept of computing systems
2. Neural Networks
3. Fuzzy logic
4. Genetic Algorithms
5. Hybrid System

Introduction: Concept of computing systems

- Basics of Computing:



- F: Formal methods/Algorithm/Mapping Function
- Features:
  - Precise Solution
  - Unambiguous and Accurate
  - Mathematical Model

Hard Computing

- **Hard Computing**: It is a conventional approach used in computing and requires an accurately stated analytical model.
- Precise Results: Since proper mathematical model/algorithms exists.
- Control Action
  - Unambiguous
  - Formally defined
- Hard computing uses existing mathematical algorithms to solve certain problems.
- It provides a precise and exact solution of the problem.

Hard Computing(Contd..)

- **Example**:
  - Numerical Problems
  - Searching and Sorting
  - Computational Geometry Problems
- **Outcome**:
  - The outcome of hard computing approach is a warranted, settled, correct result and defines definite management actions employing a mathematical model or algorithmic rule.
  - It deals with binary and crisp logic that need the precise input file consecutive.
- **Drawback**: The major drawback of hard computing is that it is incapable in solving the real-world problems whose behavior is imprecise and their information being changing continuously

Basics of Soft Computing

- **Soft computing** is the reverse of hard (conventional) computing.
- A group of computational techniques that are based on artificial intelligence (AI) and natural selection.
- It provides cost-effective solutions to the complex real-life problems for which hard computing solution does not exist.
- The **objective** of soft computing is to provide precise approximation and quick solutions for complex real-life problems.
- We use soft computing techniques to solve the complex computational problem.
- What it does is gives us the partial truth, uncertainty, and tolerance for imprecision for a given system or a problem.
- It is often termed computational intelligence.

Properties of Soft Computing methods

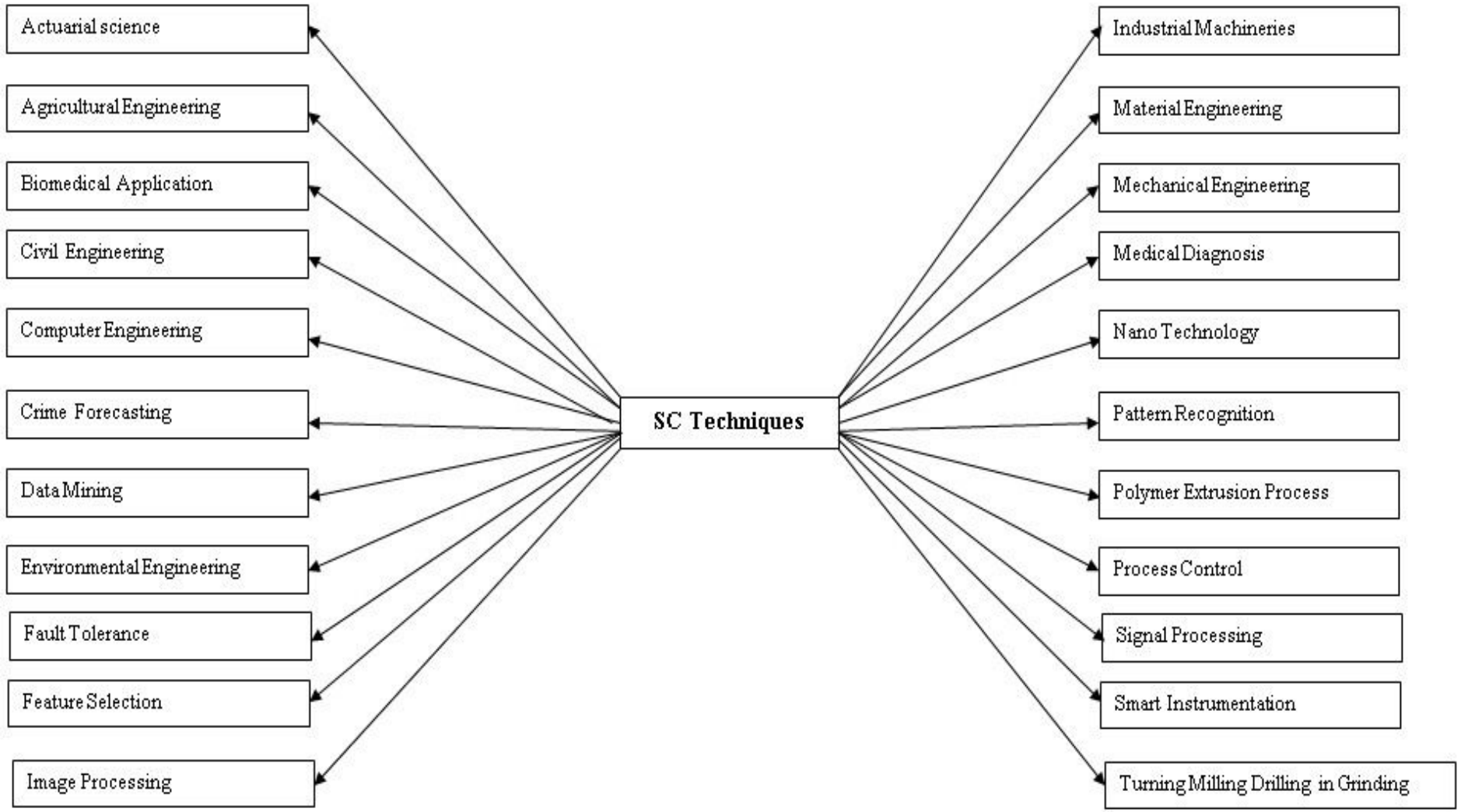
- These methods have in common: They

    1. are nonlinear.
    2. have ability to deal with nonlinearity.
    3. follow more human like reasoning paths than classical methods.
    4. utilize self learning.
    5. utilize yet-to-be proven theorems.
    6. are robust in the presence of noise or errors.

Applications of soft computing

- Gaming products like Poker and Checker.
- Microwave and Rice cooker.
- Washing Machine, Heater, Refrigerator, and AC as well.
- Robotics work (Emotional per Robot form).
- Image processing and Data compression.
- Handwriting recognition.

Application areas of soft computing



Need of Soft Computing

- **Limitations of Hard Computing**
  - Hard computing is used for solving mathematical problems that need a precise answer.
  - It fails to provide solutions for some real-life problems.
  - Thereby for real-life problems whose precise solution does not exist, soft computing helps.
- **Solves real world problem**: Soft computing is not only limited to theory; it also gives insights into real-life problems.
- **Maps Human Brain**: Like all the above reasons, Soft computing helps to map the human mind, which cannot be possible with conventional mathematical and analytical models.
- **Requirements for non-ideal environment**:
  - Analytical models can be used for solving mathematical problems and valid for ideal cases.
  - But the real-world problems do not have an ideal case; these exist in a non-ideal environment.

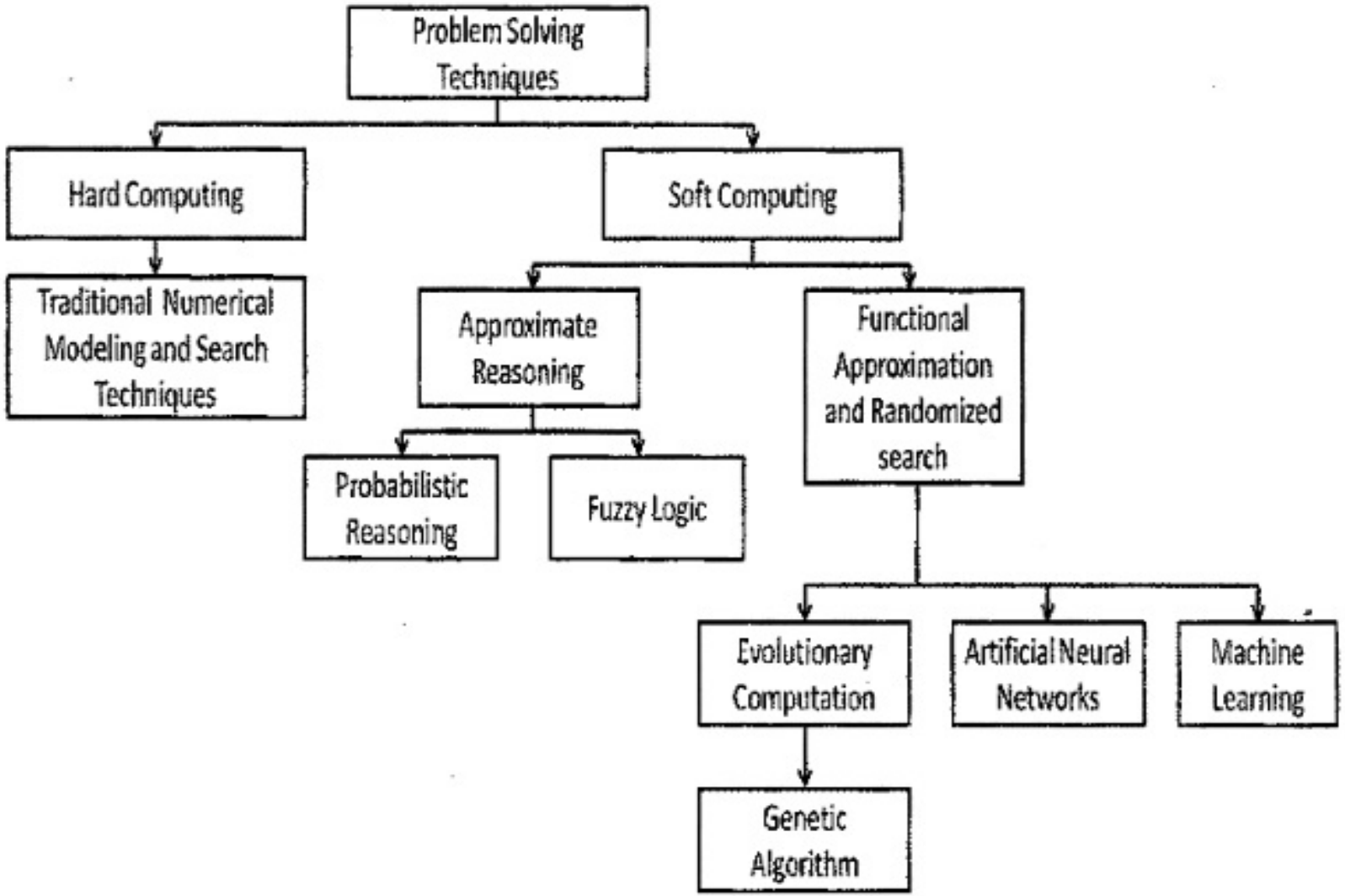
Why Soft Computing approach ?

- Mathematical model & analysis can be done for relatively simple systems.
- More complex systems arising in biology, medicine & management systems remain intractable to conventional mathematical & analytical methods.

“ROLE MODEL OF SOFT COMPUTING IS THE HUMAN MIND.”

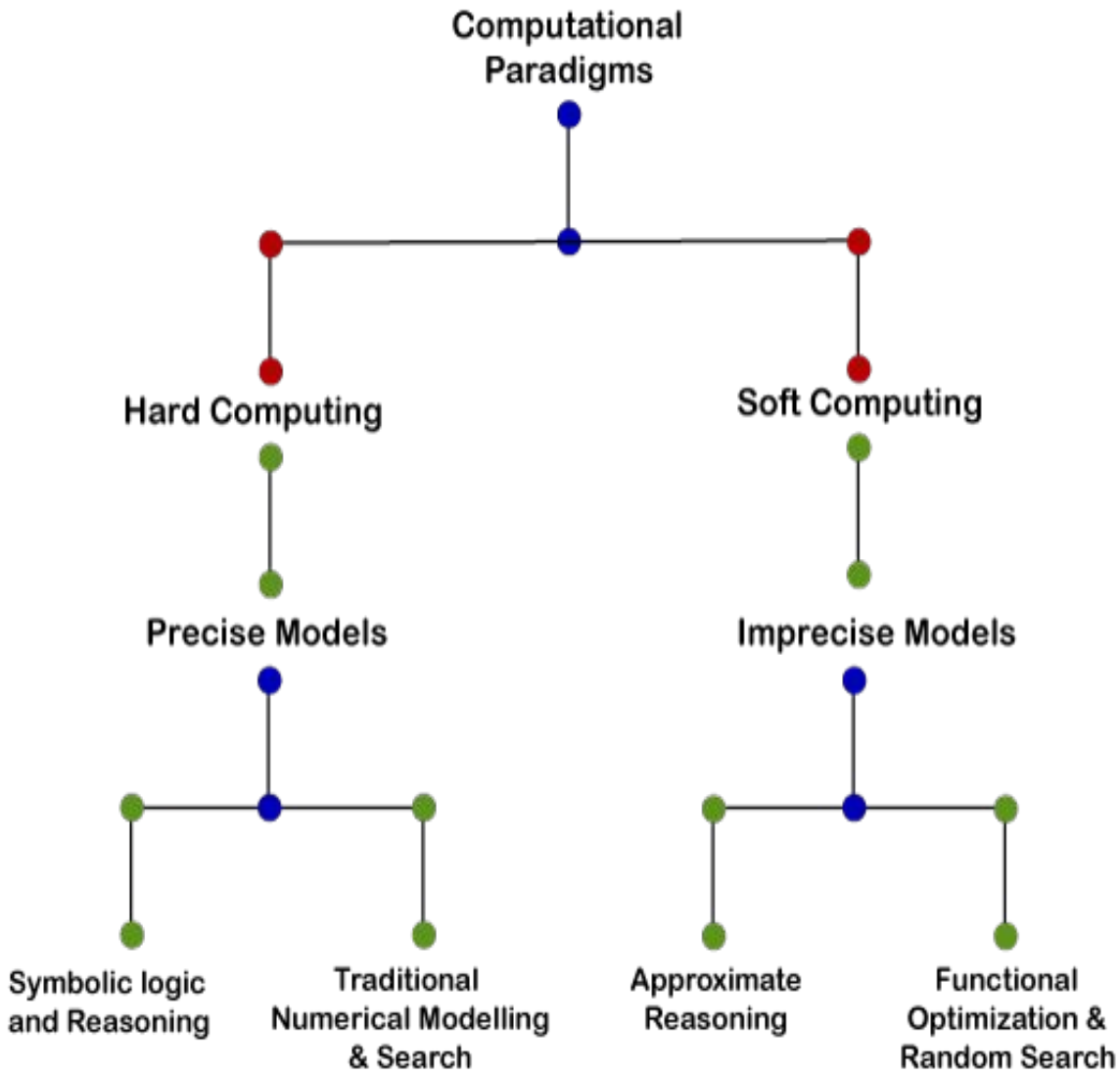
- Typically, human can:
    1. Take decisions
    2. Derive inference from previous situations experienced.
    3. Expertise in an area.
    4. Adapt to changing environment
    5. Learn to do better
    6. Social behavior of collective intelligence.

Various problem-solving techniques



Soft computing vs hard computing

Parameters	Soft Computing	Hard Computing
Computation time	Takes less computation time.	Takes more computation time.
Dependency	It depends on approximation and dispositional.	It is mainly based on binary logic and numerical systems.
Computation type	Parallel computation	Sequential computation
Result/Output	Approximate result	Exact and precise result
Example	Neural Networks, such as Madaline, Adaline, Art Networks.	Any numerical problem or traditional methods of solving using personal computers.



Soft computing vs hard computing

- Soft computing deals with the approximation model. Yoi will understand with the help of examples of how it deals with the approximation model.
- Let's consider a problem that actually does not have any solution via traditional computing, but soft computing gives the approximate solution.

- string1 = “abc" and string2 = “abe"

Problem 1

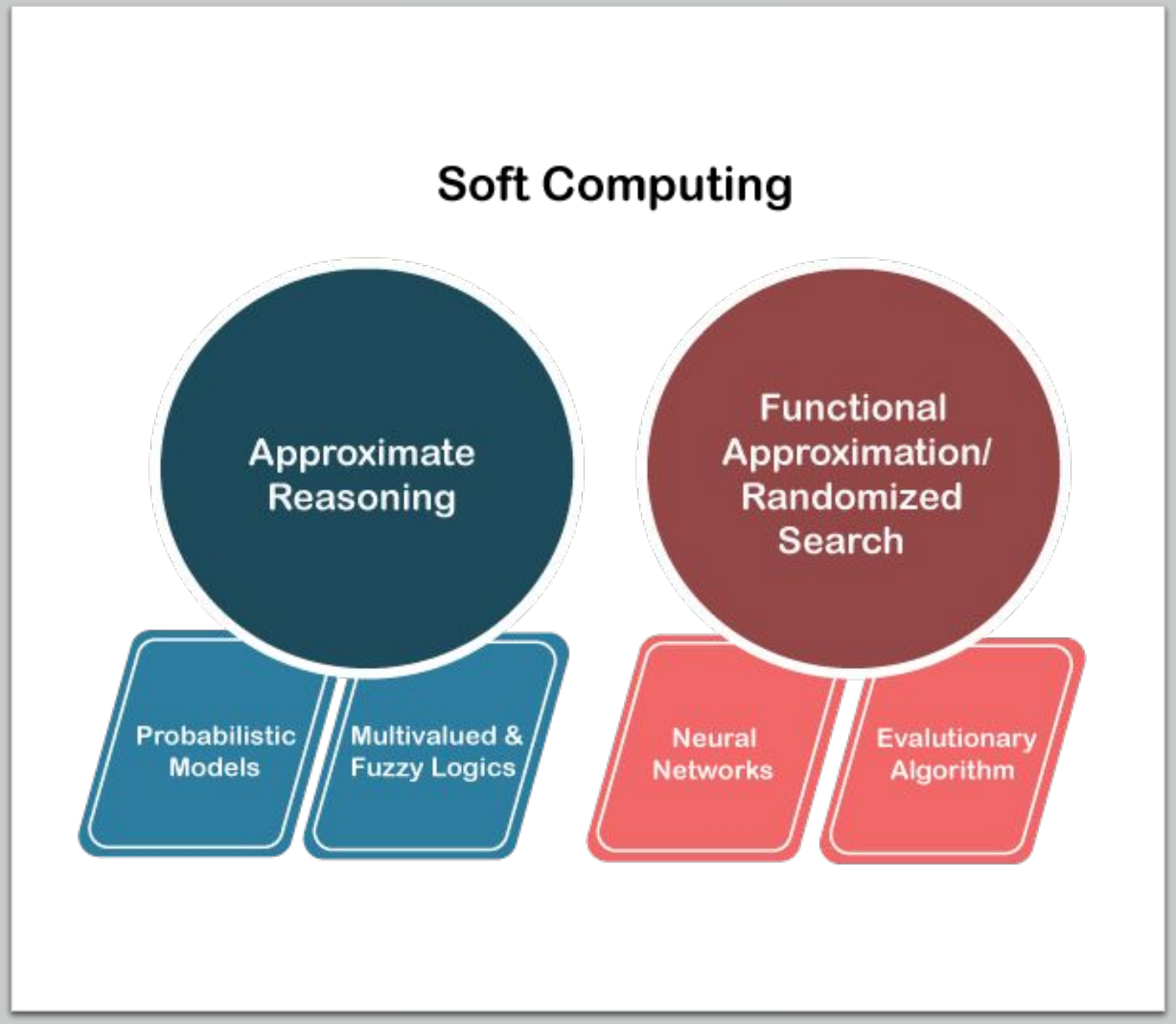
Are string1 and string2 same?

Problem 2

How much string1 and string2 are same?

Soft Computing

- **Supplements** of soft computing:
  - Fuzzy Logic
  - Machine Learning
  - Neural Network
  - Probabilistic Reasoning
  - Evolutionary Computation



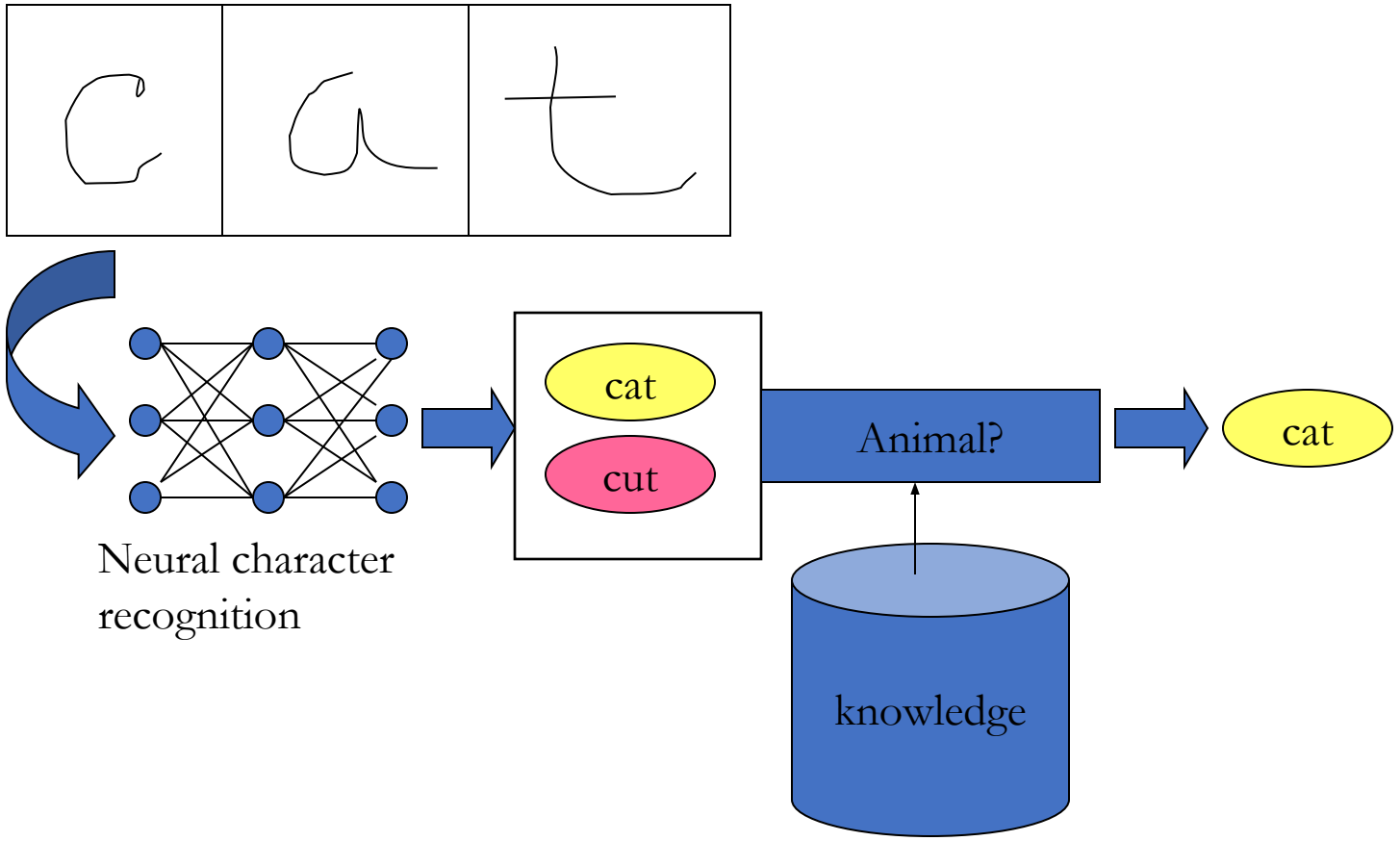
Elements of Soft Computing

- Fuzzy Logic
  - E.g Doctor-patient
- Neural Network

E.g: A, a, *A*, a 

- Evolutionary/Genetic Computing
- Decision based computing.
  - E.g: IPL

AI and Soft Computing



Neural Networks

- **Neurons:**
- Scientists agree that our brain has around 100 billion neurons.
- These neurons have hundreds of billions connections between them.
- Neurons (Nerve Cells) are the fundamental units of our brain and nervous system.
- The neurons are responsible for receiving input from the external world, for sending output (commands to our muscles), and for transforming the electrical signals in between.

Neural Networks

- Neural Networks is one of the most significant discoveries in history.
- Neural Networks can solve problems that can't be solved by algorithms:
  - Medical Diagnosis
  - Face Detection
  - Voice Recognition
- **Neural Networks** is the essence of **Deep Learning**.
- Artificial Neural Networks are normally called Neural Networks (NN).

- Neural networks are in fact multi-layer Perceptrons.

- The perceptron defines the first step into multi-layered neural networks.

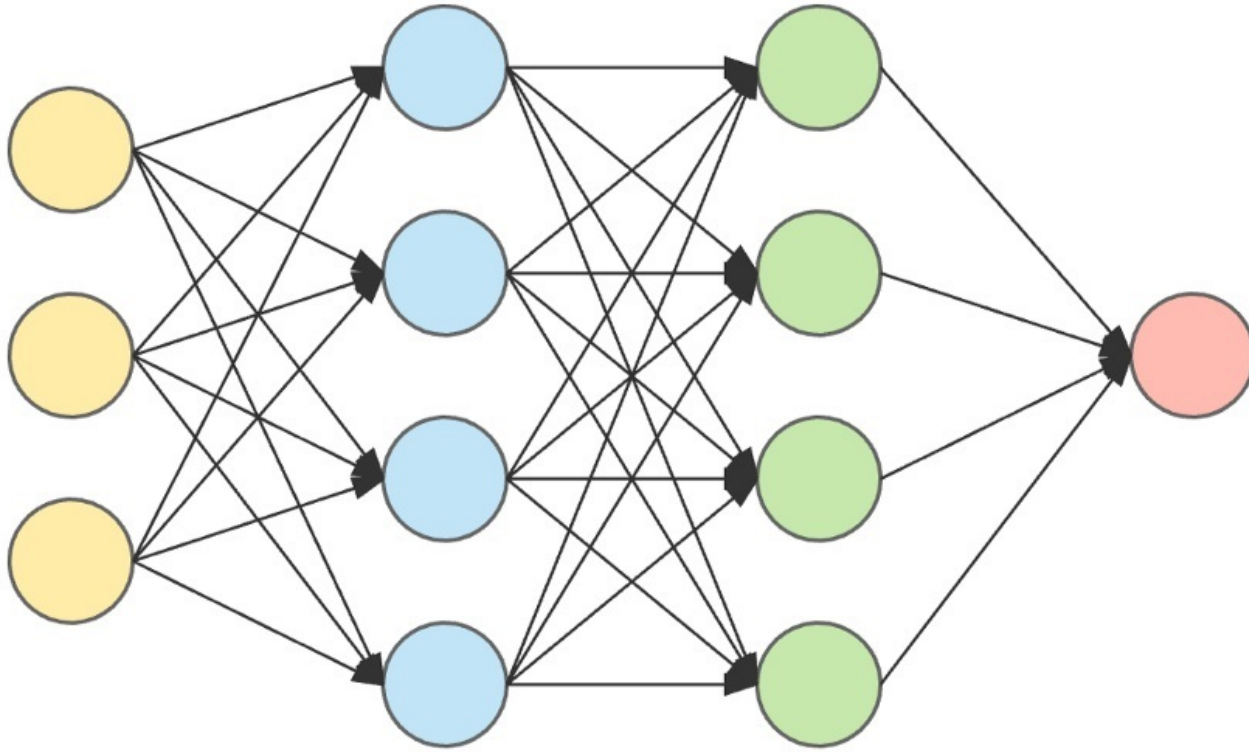
Neural Networks

- Neural networks helped soft computing to solve real-world problems, which a computer cannot do itself.
- We all know that a human brain can easily describe real-world conditions, but a computer cannot.
- An artificial neural network (ANN) emulates a network of neurons that makes a human brain (means a machine that can think like a human mind).
- Thereby the computer or a machine can learn things so that they can take decisions like the human brain.
- Artificial Neural Networks (ANN) are mutually connected with brain cells and created using regular computing programming.
- It is like as the human neural system.

Neural Networks

- ANN is a parallel distributed information processing structure consisting of several nonlinear processing units called neurons.
- The neuron operates as a **mathematical processor** performing specific **mathematical operations** on its inputs to generate an output.
- It can be **trained** to recognize patterns and **to identify incomplete patterns** by resembling the human-brain processes of recognizing information, burying noise literally and retrieving information correctly.
- ANN are strongly interconnected systems of neurons which have simple behavior, but when connected they can solve complex problems.

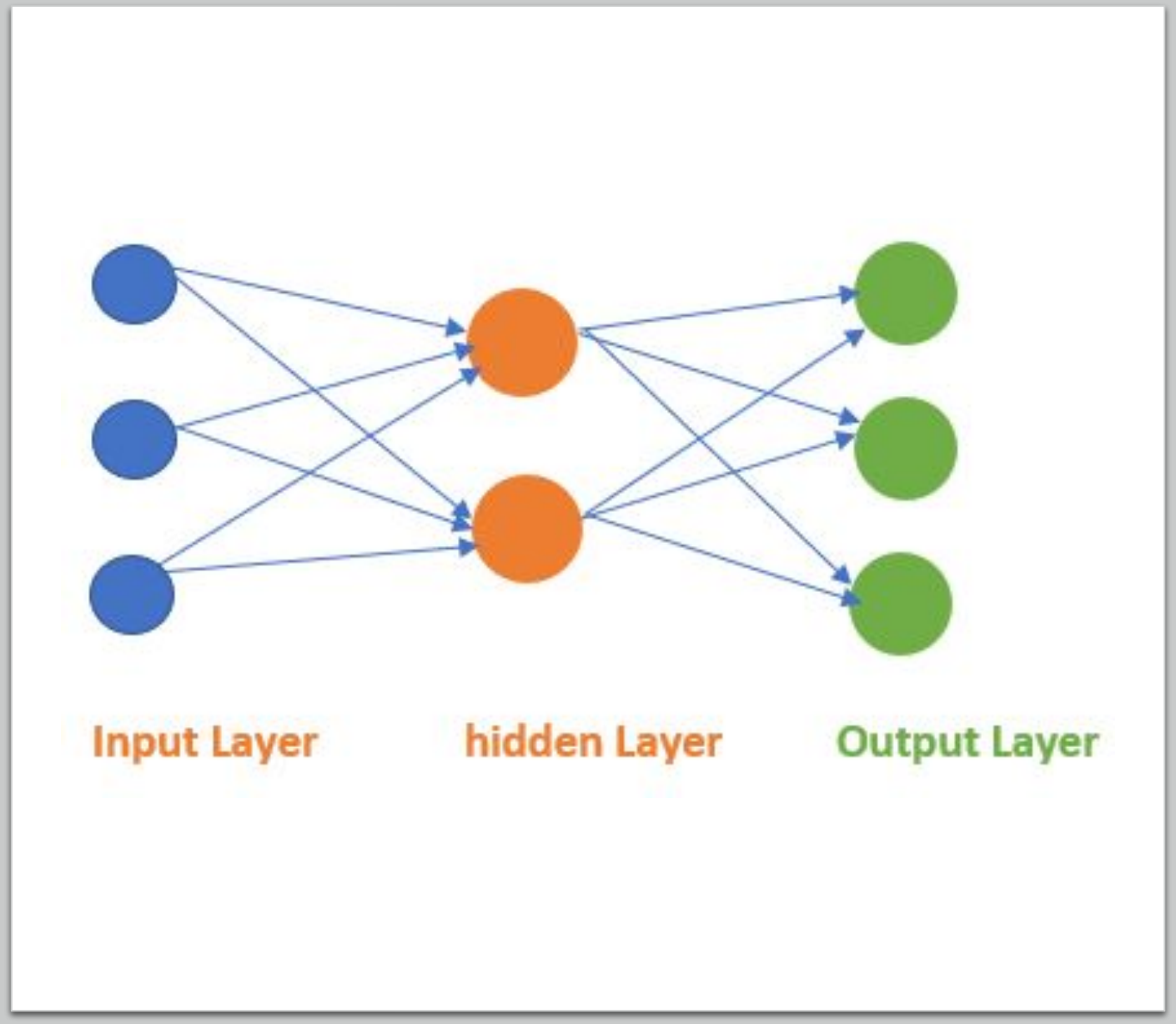
The Neural Network Model



- Input data (Yellow) are processed against a hidden layer (Blue) and modified against another hidden layer (Green) to produce the final output (Red).

Neural Network

- NN mostly inspired or ideal for the biological neural networks, whose performance can be compared with most of the **human brain functions**.
- Below we explain the working of the neural networks in details;
    1. Input Layer
    2. Hidden Layer
    3. Output Layer
- The layers are interconnected vis nodes or neurons with each layer using the output of the previous layer as its input.
- Its main function is **to take a set of inputs**, **perform calculations** and then **use the output to solve the problem.**



Neural Network

- The term “DEEP” usually refers to the number of hidden layers in the neural network. A traditional neural network contains 2-3 hidden layers, but a deep neural network can have as many as 150 layers.

- Forward Propagation: In this, we pass several inputs to the input layer, and it processes those inputs to multiple neurons which again passes through HIDDEN LAYER and produces the output layer.

- Backward propagation: Now we compare our result with the actual output. But while doing the forward propagation we can have some error, so we try to minimize the value/weight of that neuron those are contributing more to the error. For this, we need to backtrack the process. To match the desired output.

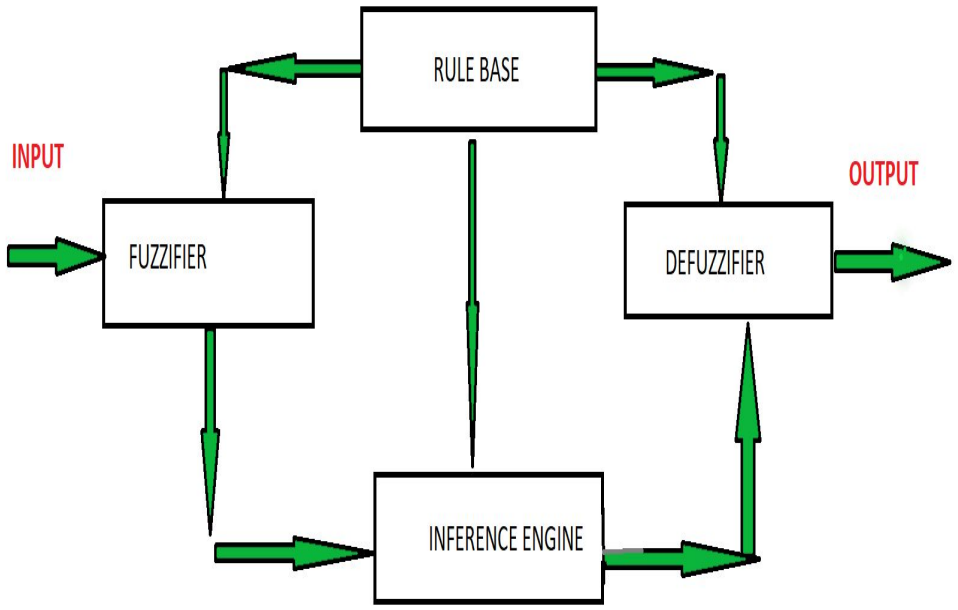
Fuzzy logic

- 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.
- In the Boolean system truth value, 1.0 represents the absolute truth value and 0.0 represents the absolute false value.
- But in the fuzzy system, there is no logic for the absolute truth and absolute false value.
- But in fuzzy logic, there is an intermediate value too present which is partially true and partially false.

Fuzzy logic

- Traditional sets include or do not include an individual element; there is no other case than true or false. Fuzzy sets allow partial membership.
- Fuzzy Logic is basically a multi-valued logic that allows intermediate values to be defined between conventional evaluations like yes/no, true/false, black/white, etc. Notions like rather warm or pretty cold can be formulated mathematically and processed with the computer.
- In this way, an attempt is made to apply a more humanlike way of thinking in the programming of computers.
- Fuzzy logic is an extension of the classical propositional and predicate logic that rests on the principles of the binary truth functionality.

Fuzzy Logic | Introduction



FUZZY LOGIC ARCHITECTURE

- Its Architecture contains four parts :
- RULE BASE: It contains the set of rules and the IF-THEN conditions provided by the experts to govern the decision-making system, on the basis of linguistic information. Recent developments in fuzzy theory offer several effective methods for the design and tuning of fuzzy controllers. Most of these developments reduce the number of fuzzy rules.
- FUZZIFICATION: It is used to convert inputs i.e. crisp numbers into fuzzy sets. Crisp inputs are basically the exact inputs measured by sensors and passed into the control system for processing, such as temperature, pressure, rpm’s, etc.
- INFERENCE ENGINE: It determines the matching degree of the current fuzzy input with respect to each rule and decides which rules are to be fired according to the input field. Next, the fired rules are combined to form the control actions.
- DEFUZZIFICATION: It is used to convert the fuzzy sets obtained by the inference engine into a crisp value. There are several defuzzification methods available and the best-suited one is used with a specific expert system to reduce the error.

Fuzzy Logic

- **Membership function**
- **Definition:** A graph that defines how each point in the input space is mapped to membership value between 0 and 1. Input space is often referred to as the universe of discourse or universal set (u), which contains all the possible elements of concern in each application.
- There are largely three types of fuzzifiers:
- Singleton fuzzifier
- Gaussian fuzzifier
- Trapezoidal or triangular fuzzifier

Fuzzy Logic

- **Advantages of Fuzzy Logic System**
- This system can work with any type of inputs whether it is imprecise, distorted or noisy input information.
- The construction of Fuzzy Logic Systems is easy and understandable.
- Fuzzy logic comes with mathematical concepts of set theory and the reasoning of that is quite simple.
- It provides a very efficient solution to complex problems in all fields of life as it resembles human reasoning and decision-making.
- The algorithms can be described with little data, so little memory is required.
- **Disadvantages of Fuzzy Logic Systems**
- Many researchers proposed different ways to solve a given problem through fuzzy logic which leads to ambiguity. There is no systematic approach to solve a given problem through fuzzy logic.
- Proof of its characteristics is difficult or impossible in most cases because every time we do not get a mathematical description of our approach.
- As fuzzy logic works on precise as well as imprecise data so most of the time accuracy is compromised.

Fuzzy Logic

- **Application**
- It is used in the **aerospace field** for altitude control of spacecraft and satellites.
- It has been used in the **automotive system for speed control**, traffic control.
- It is used for **decision-making support systems** and personal evaluation in the large company business.
- It has application in the **chemical industry** for controlling the pH, drying, chemical distillation process.
- Fuzzy logic is used in **Natural language processing** and various intensive applications in Artificial Intelligence.
- Fuzzy logic is extensively used in **modern control systems** such as expert systems.

Probabilistic reasoning:

- In this technique, we use the probability or the concept of probability which will help us to indicate and identify the uncertainty of the value.
- In this approach what we do, we combine the probability theory or concept with the logic to handle the uncertainty of the value.
- Like we have so many examples in the real world also like the things will happen or not we are not sure about it.
- We can use Probabilistic reasoning in the below three cases provided;

  a) When we are trying to do an experiment, and something happened like an unknown error.

  b) When we are not sure about uncertain outcomes.

  c) when we have predicates too large to handle.

- Below we have the formula to calculate it,

  We can find the probability of an event by using the below formula,

  Probability of occurrence = no. of desired outcomes/ total no of outcomes

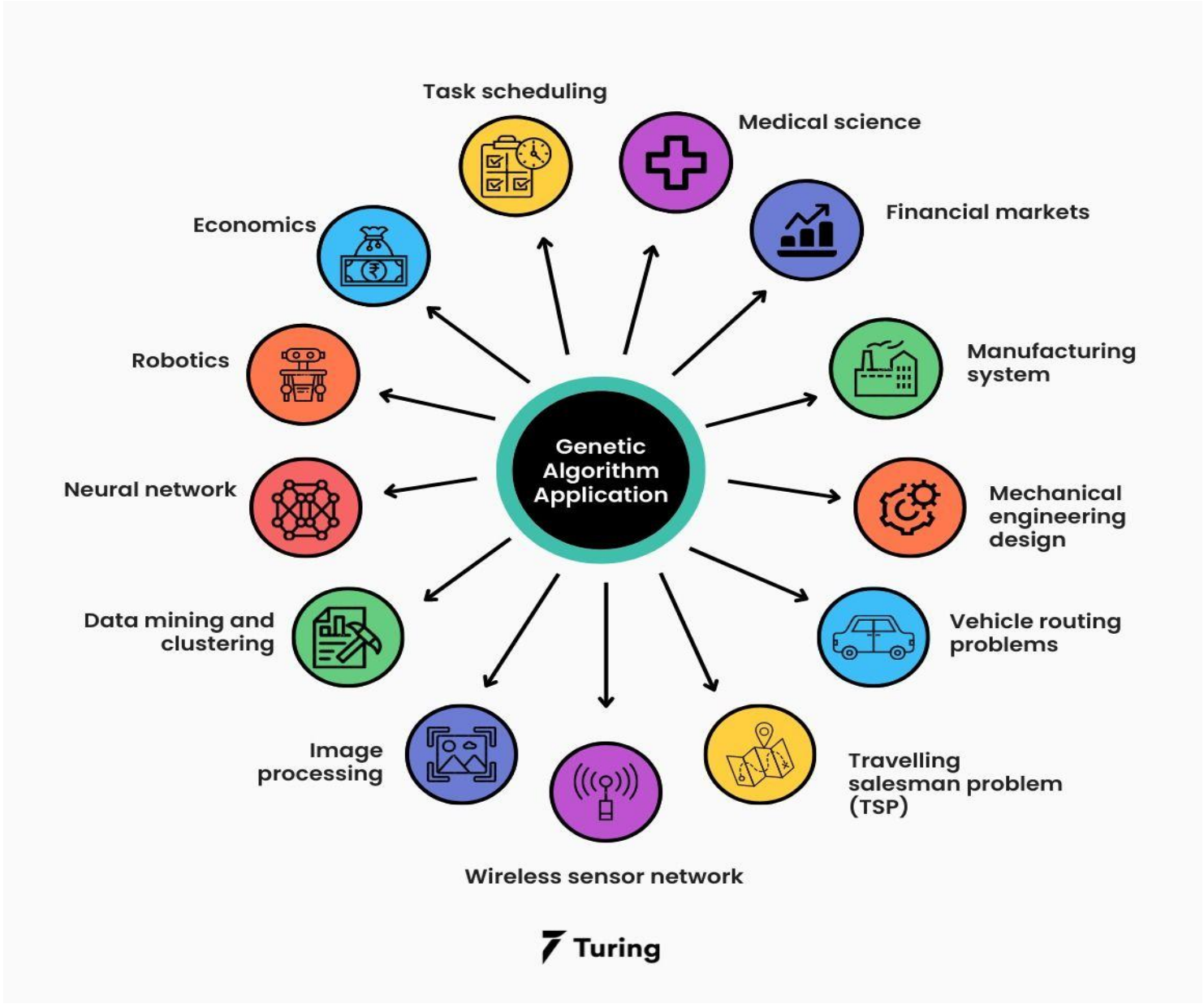
Genetic Algorithms

- Genetic Algorithm (GA) is a search-based optimization technique based on the principles of **Genetics and Natural Selection**.
- It is frequently used to solve optimization problems, in research, and in machine learning.
- **Genetic algorithms simulate the process of natural selection** which means those species who can adapt to changes in their environment are able to survive and reproduce and go to next generation.
- Optimization is the process of **making something better**. In any process, we have a set of inputs and a set of outputs as shown in the following figure.

Genetic Algorithms

- Genetic Algorithms can deliver a “good-enough” solution “fast-enough”.
- his makes genetic algorithms attractive for use in solving optimization problems.
- In computer science, there is a large set of problems, which are **difficult.**
- What this essentially means is that, even the most powerful computing systems take a very long time (even years!) to solve that problem.
- In such a scenario, GAs prove to be an efficient tool to provide **usable near-optimal solutions** in a short amount of time.

Applications



Applications

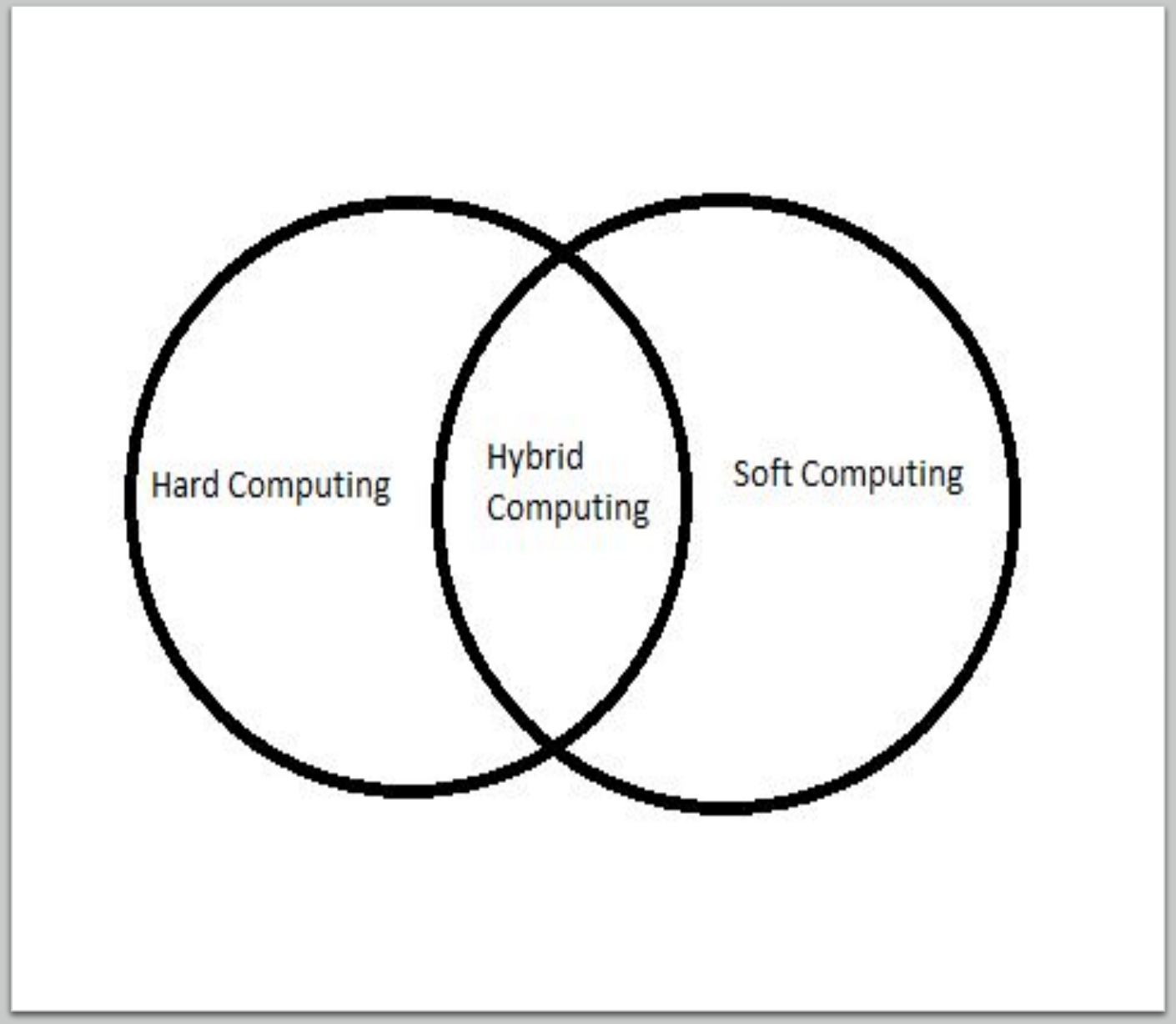
- **Optimization** − Genetic Algorithms are most used in optimization problems. It generates solutions to optimization problems using techniques inspired by natural evolution, such as inheritance, mutation, selection, and crossover.
- **Economics** − GAs are also used to characterize various economic models like the cobweb model, game theory equilibrium resolution, asset pricing, etc.
- **Neural Networks** − GAs are also used to train neural networks, particularly recurrent neural networks.
- **Parallelization** − GAs also have very good parallel capabilities and prove to be very effective means in solving certain problems, and also provide a good area for research.
- **Image Processing** − GAs are used for various digital image processing (DIP) tasks as well like dense pixel matching.
- **Vehicle routing problems** − With multiple soft time windows, multiple depots and a heterogeneous fleet.

Applications

- **Scheduling applications** − GAs are used to solve various scheduling problems as well, particularly the time tabling problem.
- **Machine Learning** − as already discussed, genetics based machine learning (GBML) is a niche area in machine learning.
- **Robot Trajectory Generation** − GAs have been used to plan the path which a robot arm takes by moving from one point to another.
- **Parametric Design of Aircraft** − GAs have been used to design aircrafts by varying the parameters and evolving better solutions.
- **DNA Analysis** − GAs have been used to determine the structure of DNA using spectrometric data about the sample.
- **Multimodal Optimization** − GAs are obviously very good approaches for multimodal optimization in which we have to find multiple optimum solutions.
- **Traveling salesman problem and its applications** − GAs have been used to solve the TSP, which is a well-known combinatorial problem using novel crossover and packing strategies.

Hybrid System

- Hybrid Systems computing uses more than one computational technique to solve various real-world problems.
- This integration of multiple systems in one enables us to get highly intelligent results.
- These results are potent as well as adaptive to any new environment.
- H ∩ S = Hybrid Computing



Hybrid System

- A Hybrid system is **an intelligent system** that is framed by **combining at least two intelligent technologies** like Fuzzy Logic, Neural networks, Genetic algorithms, reinforcement learning, etc.
- The combination of different techniques in one computational model makes these systems possess an **extended range of capabilities**.
- These systems are **capable of reasoning and learning in an uncertain and imprecise environment**.
- These systems can provide **human-like expertise** like domain knowledge, adaptation in noisy environments, etc.

Examples of Hybrid Systems

- **Neuro-Fuzzy Hybrid systems**
  - The Neuro-fuzzy system is based on fuzzy system which is trained based on the working of neural network theory.
- **Neuro Genetic Hybrid systems**
  - A Neuro Genetic hybrid system is a system that combines Neural networks and a Genetic algorithm
- **Fuzzy Genetic Hybrid systems**
  - A Fuzzy Genetic Hybrid System is developed to use fuzzy logic-based techniques for improving and modeling Genetic algorithms and vice-versa.

Application of Hybrid Systems

- Handwriting recognition
- Automotive systems and manufacturing
- Image processing and data compression
- Architecture etc.