Introduction to Soft Computing

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Soft Computing

- Soft computing is the reverse of hard (conventional) computing. It refers to 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.
- Zadeh coined the term of soft computing in 1992. The objective of soft computing is to provide precise approximation and quick solutions for complex real-life problems.

Soft Computing

- In simple terms, you can understand soft computing - an emerging approach that gives the amazing ability of the human mind.
- It can map a human mind and the human mind is a role model for soft computing.
- Note: Basically, soft computing is different from traditional/conventional computing and it deals with approximation models.

Soft Computing

Soft Computing

- Soft computing provides an approach to problem-solving using means other than computers.
- With the human mind as a role model, soft computing is tolerant of partial truths, uncertainty, imprecision and approximation, unlike traditional computing models.
- The tolerance of soft computing allows researchers to approach some problems that traditional computing can't process.

Soft Computing

- Fuzzy logic
- Machine learning
- Probabilistic reasoning
- Evolutionary computation
- Perceptron
- Genetic algorithms
- Differential algorithms
- Support vector machines

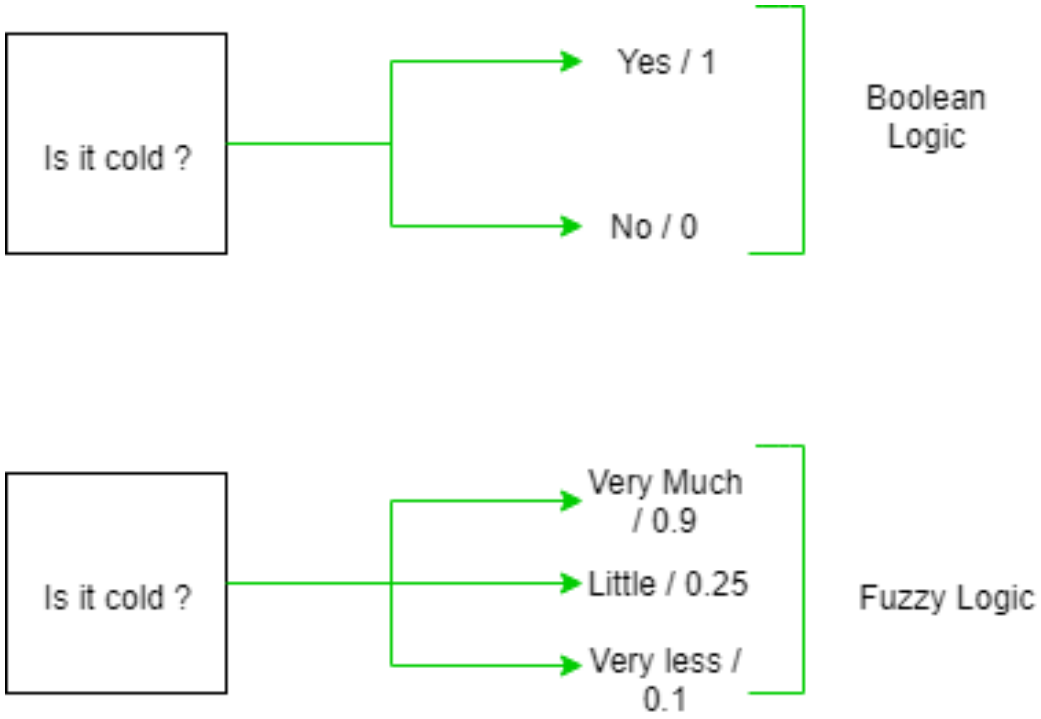
Soft Computing

- Metaheuristics
- Swarm intelligence
- Ant colony optimization
- Particle optimization
- Bayesian networks
- Artificial neural networks
- Expert systems

Fuzzy Logic

- Fuzzy logic is nothing but mathematical logic which tries to solve problems with an open and imprecise spectrum of data.
- It makes it easy to obtain an array of precise conclusions.
- Fuzzy logic is basically designed to achieve the best possible solution to complex problems from all the available information and input data.
- Fuzzy logics are considered as the best solution finders.

Fuzzy Logic


Is it cold ?
Yes / 1
No / 0
Boolean Logic
Is it cold ?
Very Much / 0.9
Little / 0.25
Very less / 0.1
Fuzzy Logic

Machine Learning

- Machine learning is an application of artificial intelligence (AI) that provides systems the ability to automatically learn and improve from experience without being explicitly programmed.
- Machine learning focuses on the development of computer programs that can access data and use it learn for themselves.
- The process of learning begins with observations or data, such as examples, direct experience, or instruction, in order to look for patterns in data and make better decisions in the future based on the examples that we provide.
- The primary aim is to allow the computers learn automatically without human intervention or assistance and adjust actions accordingly.

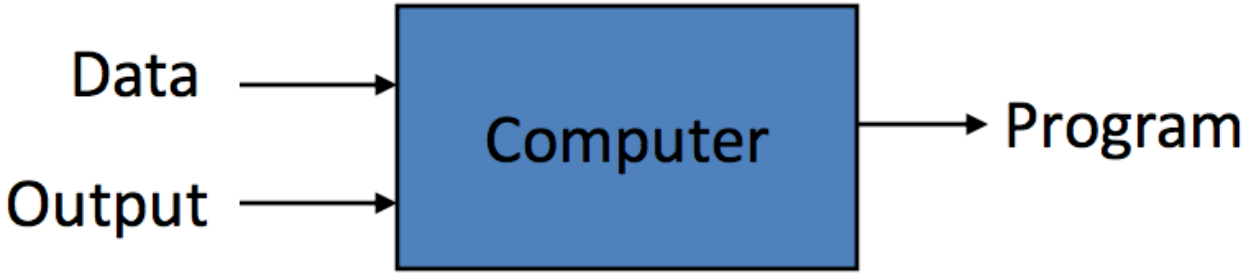
Origins of Machine Learning

- The earliest databases recorded information from the observable environment.
- Astronomers recorded patterns of planets and stars; biologists noted results from experiments crossbreeding plants and animals; and cities recorded tax payments, disease outbreaks, and populations.
- Each of these required a human being to first observe and second, record the observation.
- Today, such observations are increasingly automated and recorded systematically in ever-growing computerized databases.

Machine Learning

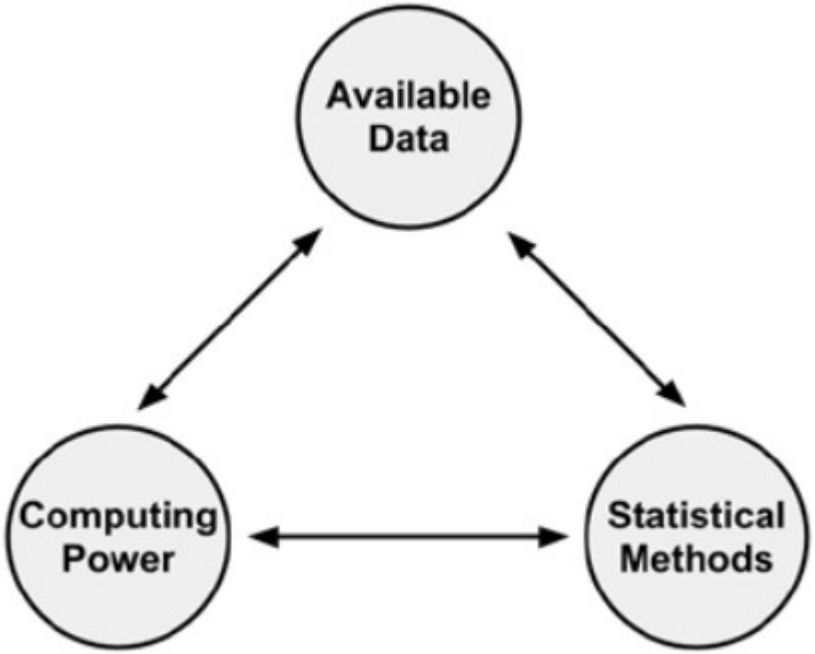
Traditional Programming

Machine Learning



Machine Learning

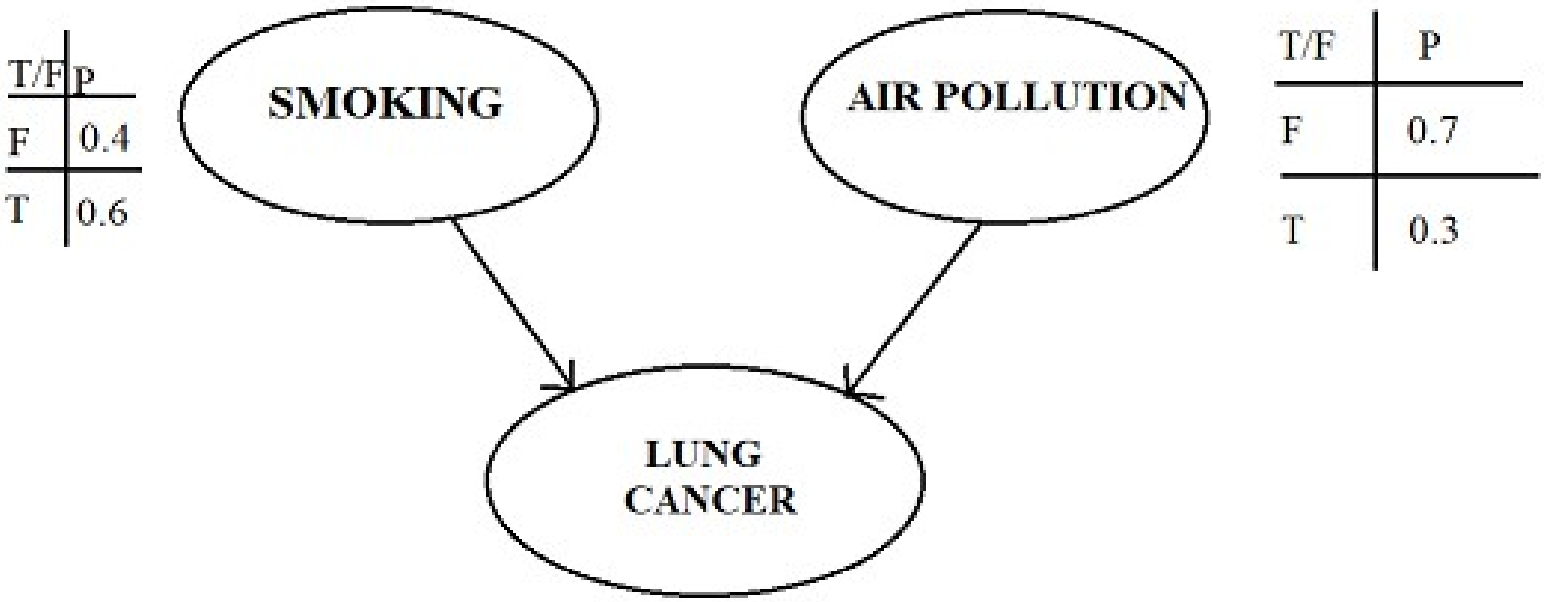
- The field of study interested in the development of computer algorithms for transforming data into intelligent action is known as machine learning.



Probabilistic Reasoning

- Probabilistic reasoning is a way of knowledge representation where we apply the concept of probability to indicate the uncertainty in knowledge.
- In probabilistic reasoning, we combine probability theory with logic to handle the uncertainty.
- We use probability in probabilistic reasoning because it provides a way to handle the uncertainty that is the result of someone's laziness and ignorance.

Probabilistic Reasoning



Probabilistic Reasoning

- In the real world, there are lots of scenarios, where the certainty of something is not confirmed, such as "It will rain today," "behavior of someone for some situations," "A match between two teams or two players." These are probable sentences for which we can assume that it will happen but not sure about it, so here we use probabilistic reasoning.
- Need of probabilistic reasoning in AI:
  - When there are unpredictable outcomes.
  - When specifications or possibilities of predicates becomes too large to handle.
  - When an unknown error occurs during an experiment.

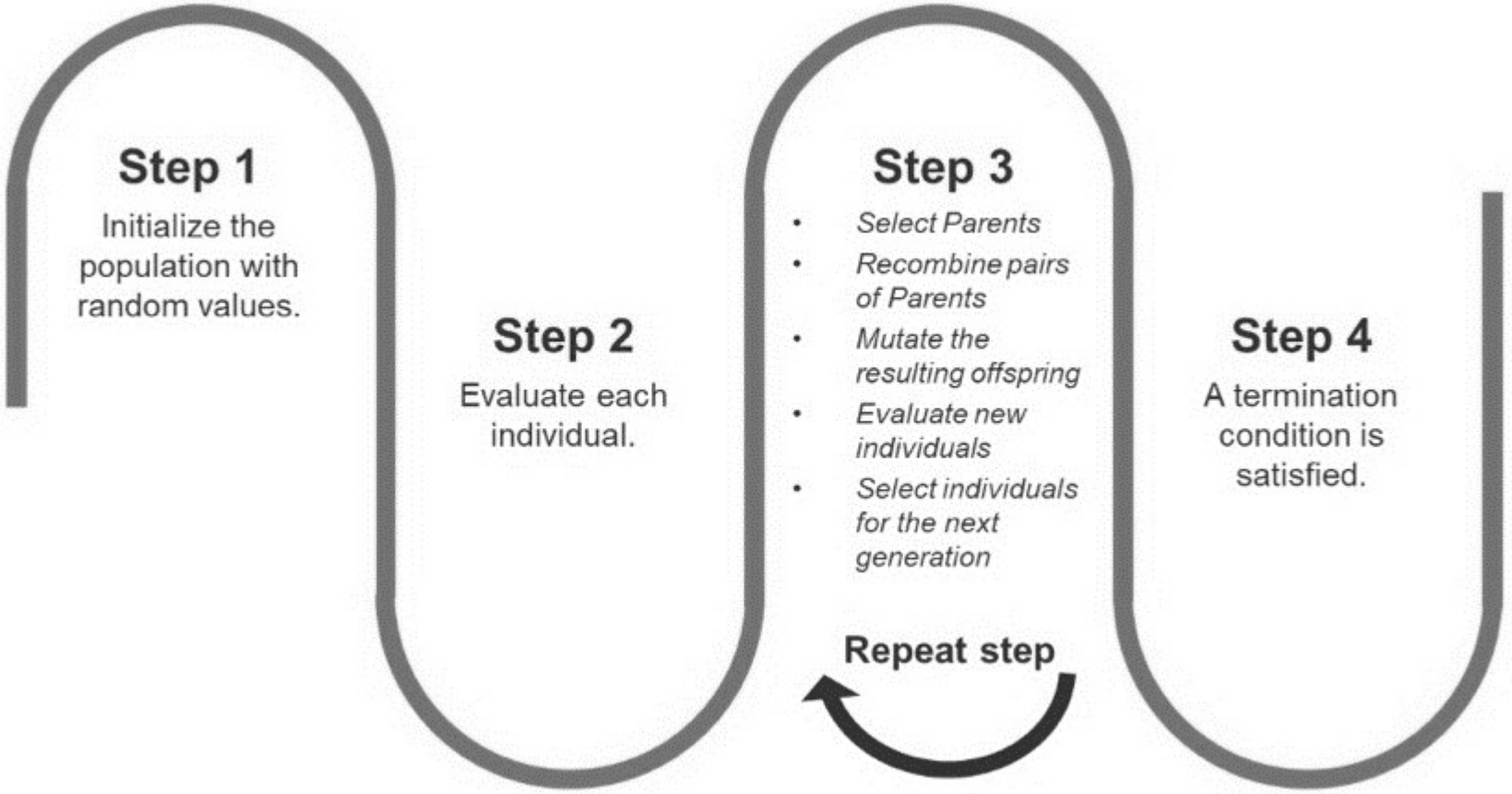
Evolutionary computation

- Evolutionary computation is a family of algorithms for global optimization inspired by biological evolution, and the subfield of artificial intelligence and soft computing studying these algorithms.
- In technical terms, they are a family of population-based trial and error problem solvers with a metaheuristic or stochastic optimization character.

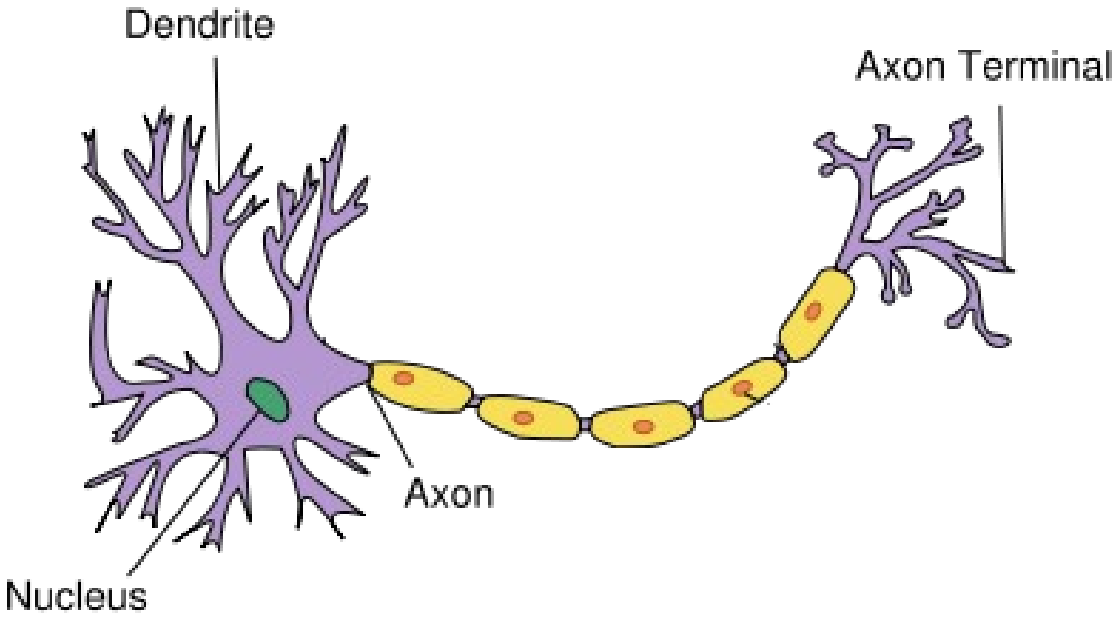
Evolutionary computation

- In evolutionary computation, an initial set of candidate solutions is generated and iteratively updated.
- Each new generation is produced by stochastically removing less desired solutions, and introducing small random changes.
- In biological terminology, a population of solutions is subjected to natural selection (or artificial selection) and mutation.
- As a result, the population will gradually evolve to increase in fitness, in this case the chosen fitness function of the algorithm.

Evolutionary computation



Human Nervous System

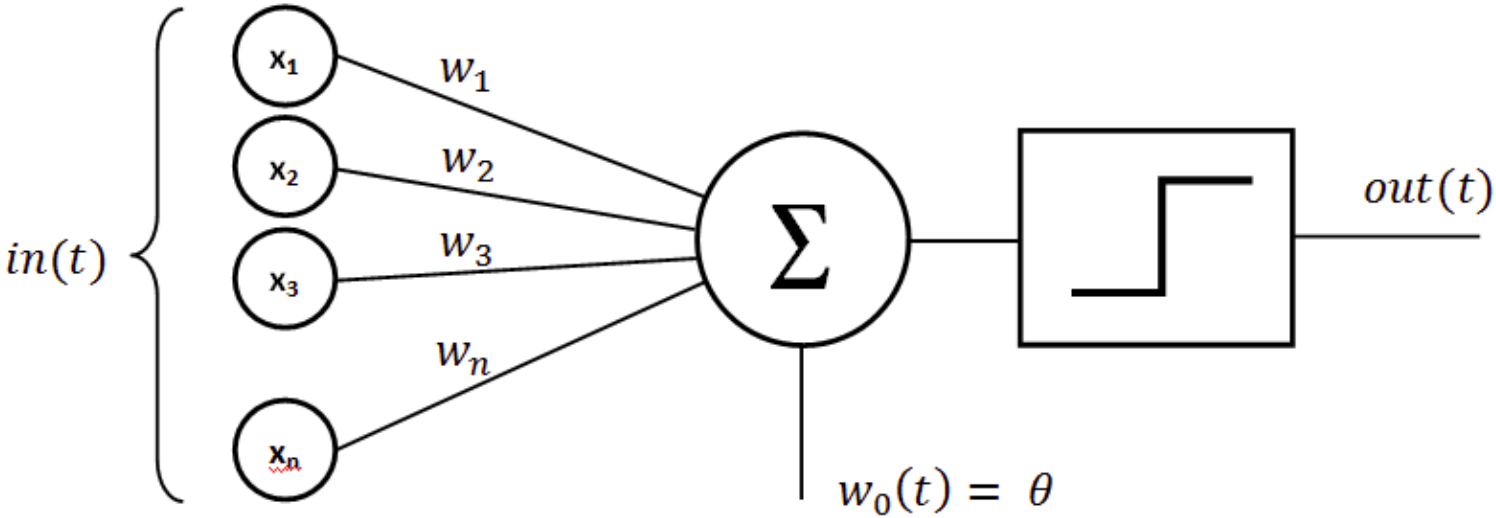


Human Nervous System

- Human nervous system consists of billions of neurons. These neurons collectively process input received from sensory organs, process the information, and decides what to do in reaction to the input.
- A typical neuron in the human nervous system has three main parts: dendrites, nucleus, and axons.
  - The information passed to a neuron is received by dendrites.
  - The nucleus is responsible for processing this information.
  - The output of a neuron is passed to other neurons via the axon, which is connected to the dendrites of other neurons further down the network.

Perceptron

- Artificial neural networks are inspired by the human neural network architecture. The simplest neural network consists of only one neuron and is called a perceptron, as shown in the figure below:



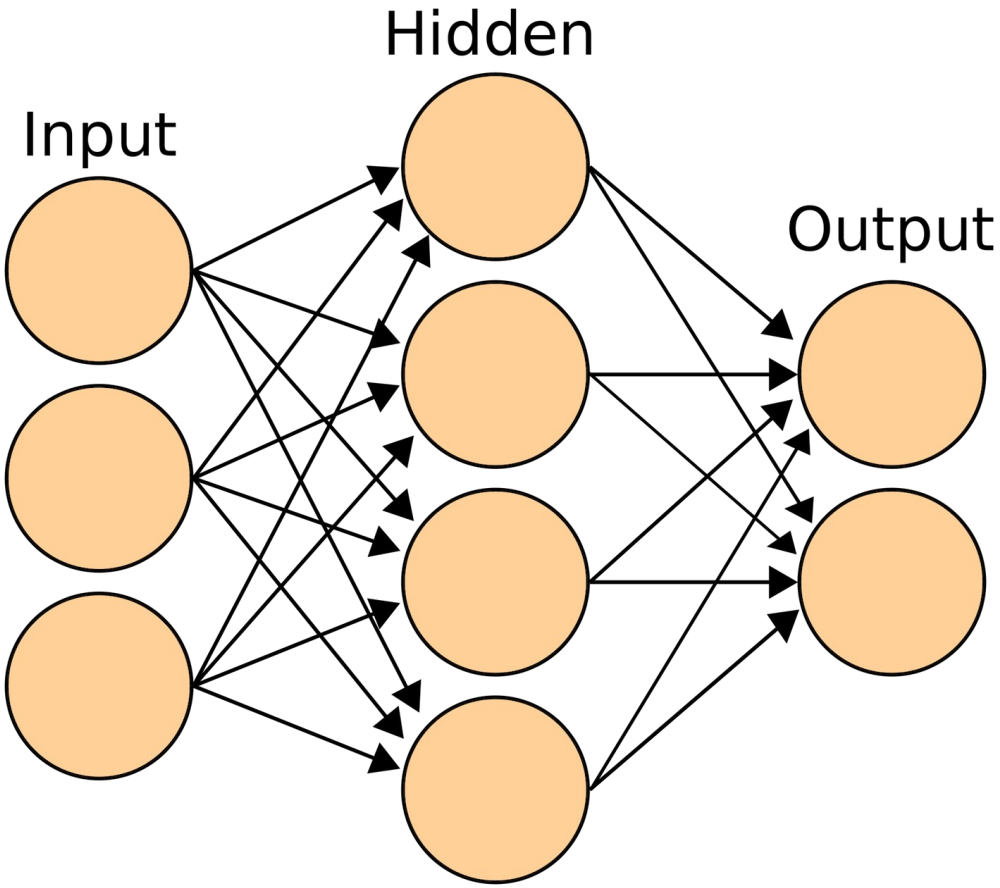
How Perceptron works?

- A perceptron has one input layer and one neuron. Input layer acts as the dendrites and is responsible for receiving the inputs.
- The number of nodes in the input layer is equal to the number of features in the input dataset. Each input is multiplied with a weight (which is typically initialized with some random value) and the results are added together.
- The sum is then passed through an activation function. The activation function of a perceptron resembles the nucleus of human nervous system neuron.
- It processes the information and yields an output. In the case of a perceptron, this output is the final outcome. However, in the case of multilayer perceptrons, the output from the neurons in the previous layer serves as the input to the neurons of the proceeding layer.

Artificial Neural Network

- A multilayer perceptrons, is commonly known as artificial neural networks.
- A single layer perceptron can solve simple problems where data is linearly separable in to 'n' dimensions, where 'n' is the number of features in the dataset. However, in case of non-linearly separable data, the accuracy of single layer perceptron decreases significantly.
- Multilayer perceptrons, on the other hand, can work efficiently with non-linearly separable data.
- Artificial neural networks, are a combination of multiple neurons connected in the form a network. It has an input layer, one or more hidden layers, and an output layer.

Artificial Neural Network



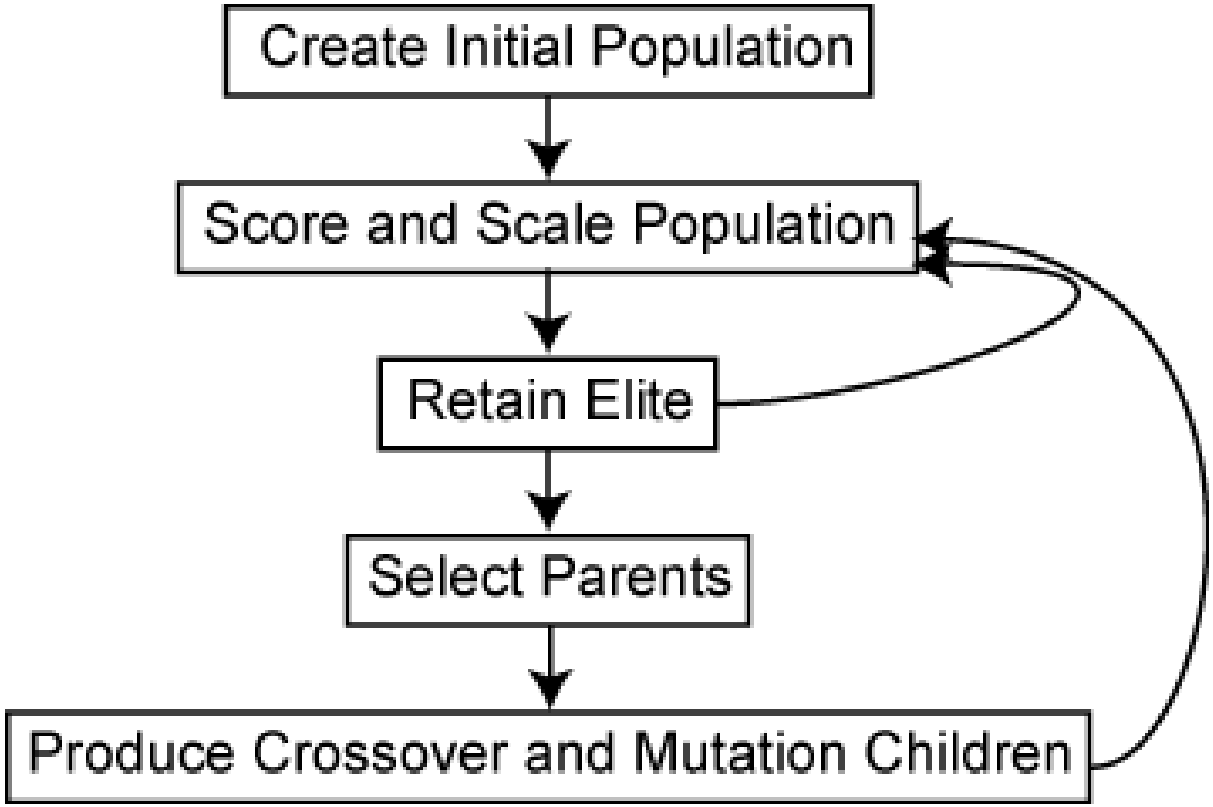
Genetic Algorithm

- The genetic algorithm is a method for solving both constrained and unconstrained optimization problems that is based on natural selection, the process that drives biological evolution.
- The genetic algorithm repeatedly modifies a population of individual solutions.
- At each step, the genetic algorithm selects individuals from the current population to be parents and uses them to produce the children for the next generation.

Genetic Algorithm

- Over successive generations, the population "evolves" toward an optimal solution.
- You can apply the genetic algorithm to solve a variety of optimization problems that are not well suited for standard optimization algorithms, including problems in which the objective function is discontinuous, nondifferentiable, stochastic, or highly nonlinear.
- The genetic algorithm can address problems of mixed integer programming, where some components are restricted to be integer-valued.

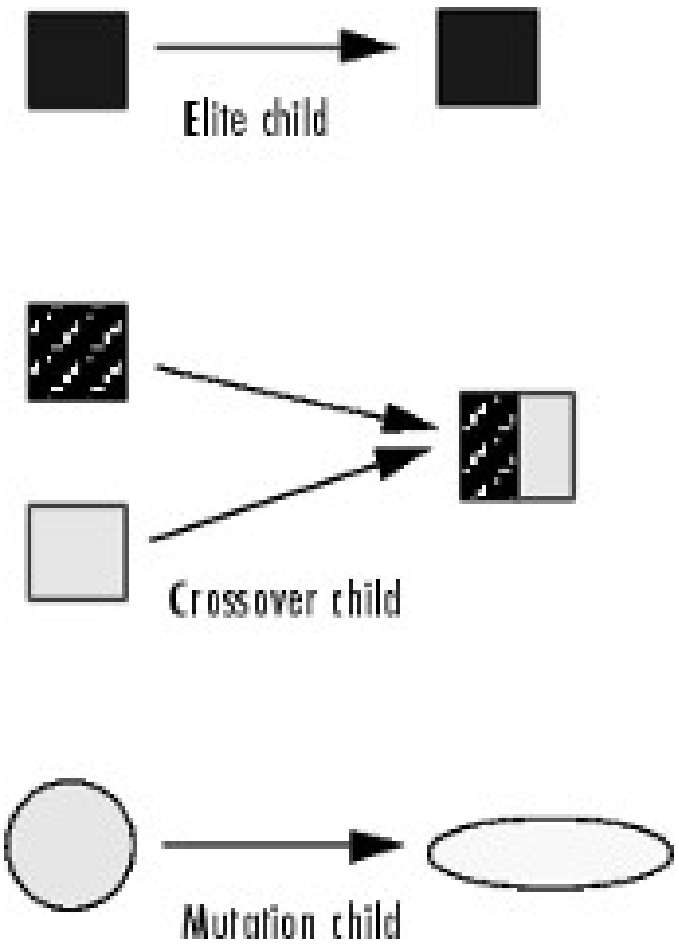
Genetic Algorithm



Genetic Algorithm

- The genetic algorithm uses three main types of rules at each step to create the next generation from the current population:
- Selection rules select the individuals, called parents, that contribute to the population at the next generation. The selection is generally stochastic, and can depend on the individuals' scores.
- Crossover rules combine two parents to form children for the next generation.
- Mutation rules apply random changes to individual parents to form children.

Genetic Algorithm



Genetic Algorithm

Classical Algorithm	Genetic Algorithm
Generates a single point at each iteration. The sequence of points approaches an optimal solution.	Generates a population of points at each iteration. The best point in the population approaches an optimal solution.
Selects the next point in the sequence by a deterministic computation.	Selects the next population by computation which uses random number generators.
Typically converges quickly to a local solution.	Typically takes many function evaluations to converge. May or may not converge to a local or global minimum.

Differential Evolution

- In evolutionary computation, differential evolution (DE) is a method that optimizes a problem by iteratively trying to improve a candidate solution with regard to a given measure of quality.
- Such methods are commonly known as metaheuristics as they make few or no assumptions about the problem being optimized and can search very large spaces of candidate solutions.
- However, metaheuristics such as DE do not guarantee an optimal solution is ever found.

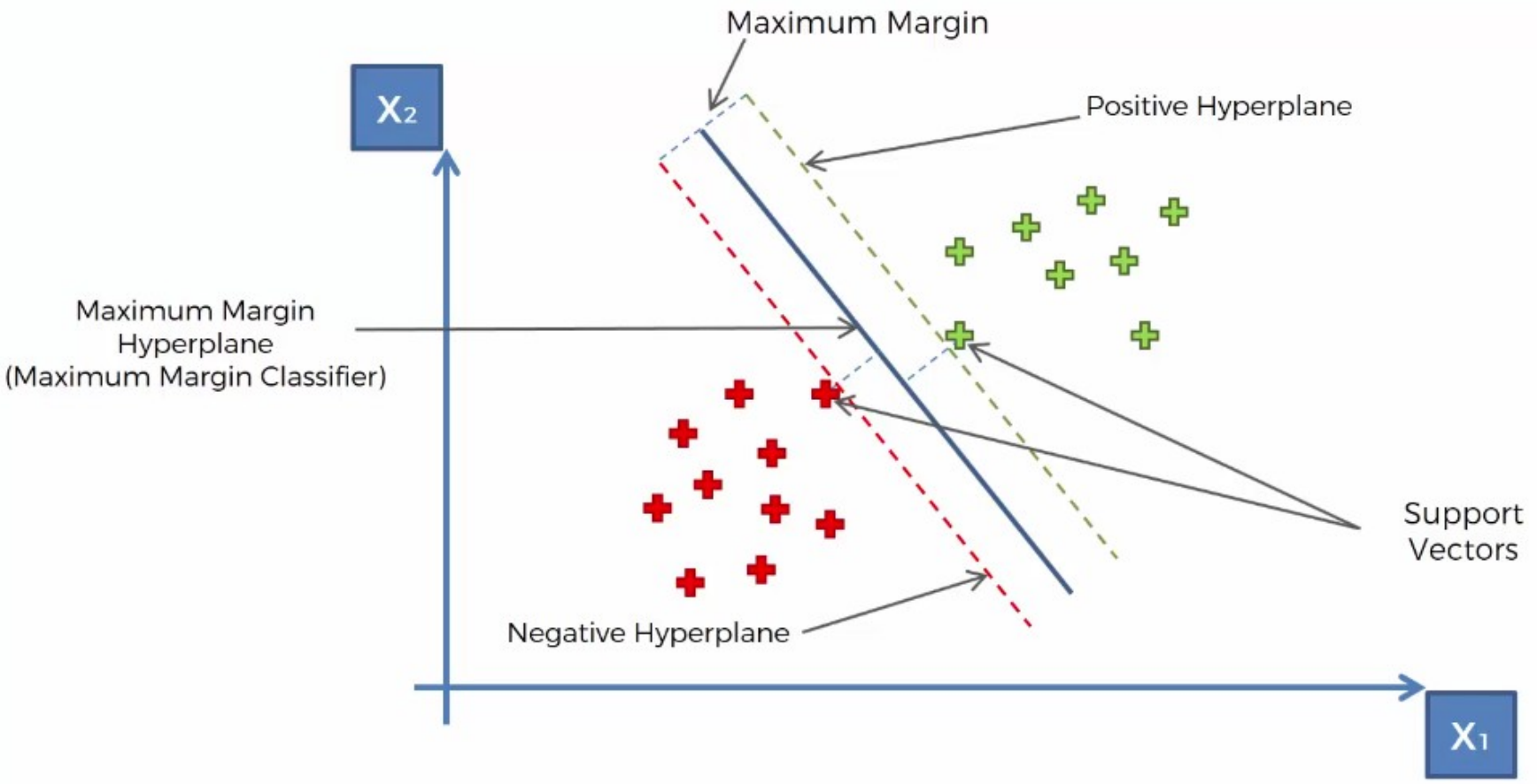
What is support vector?

- “Support Vector Machine” (SVM) is a supervised machine learning algorithm which can be used for both classification or regression challenges. However, it is mostly used in classification problems.
- In this algorithm, we plot each data item as a point in n-dimensional space (where n is number of features you have) with the value of each feature being the value of a particular coordinate.
- Then, we perform classification by finding the hyperplane that differentiate the two classes very well.

Support Vector Machine

- Generally, Support Vector Machines is considered to be a classification approach, it but can be employed in both types of classification and regression problems.
- It can easily handle multiple continuous and categorical variables.
- SVM constructs a hyperplane in multidimensional space to separate different classes. SVM generates optimal hyperplane in an iterative manner, which is used to minimize an error.
- The core idea of SVM is to find a maximum marginal hyperplane(MMH) that best divides the dataset into classes.

Decision Vectors



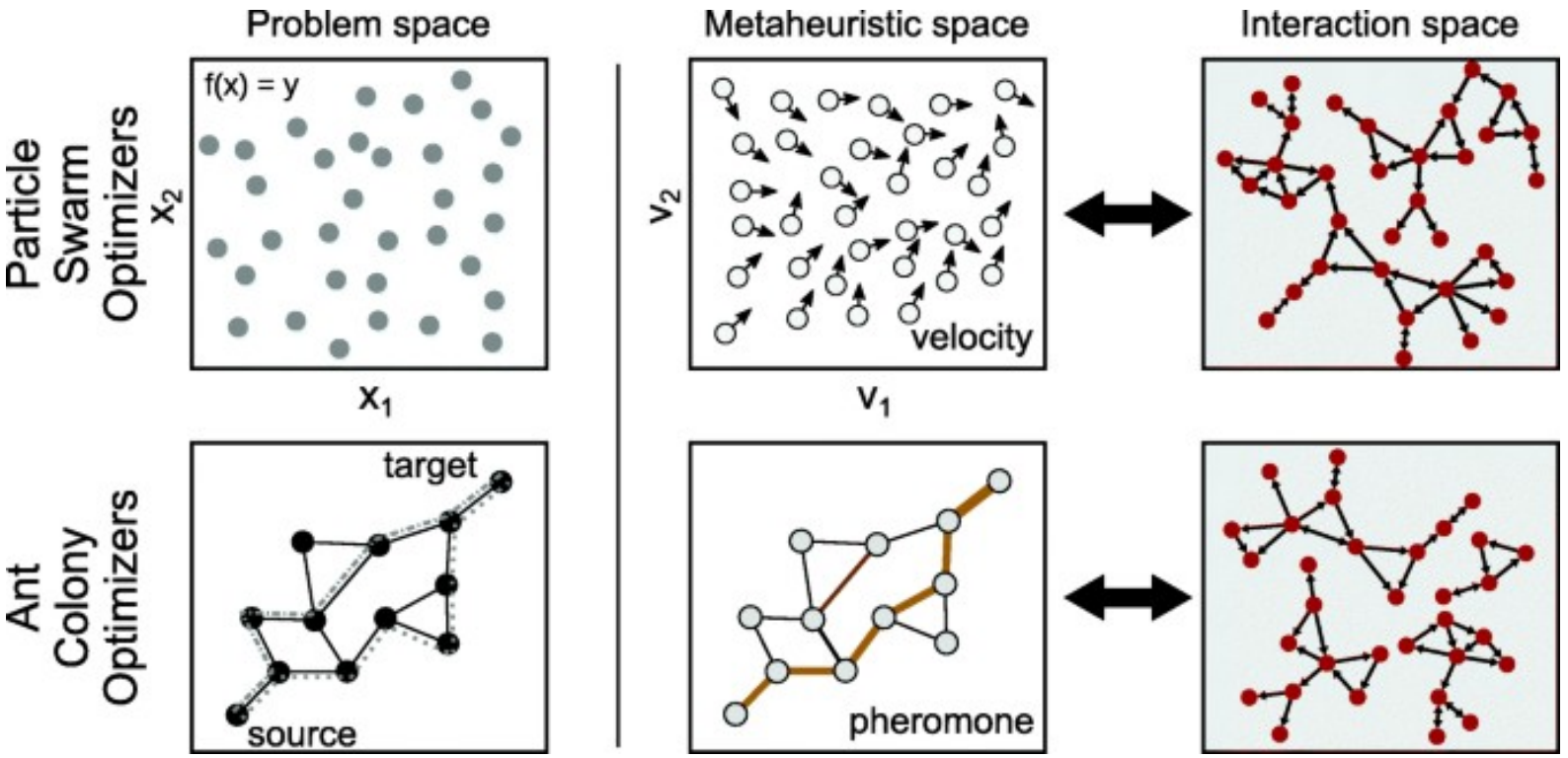
Swarm Intelligence

- Swarm intelligence (SI) is the collective behavior of decentralized, self-organized systems, natural or artificial.
- The concept is employed in work on artificial intelligence. The expression was introduced by Gerardo Beni and Jing Wang in 1989, in the context of cellular robotic systems

Swarm Intelligence

- SI systems consist typically of a population of simple agents or boids interacting locally with one another and with their environment.
- The inspiration often comes from nature, especially biological systems.
- The agents follow very simple rules, and although there is no centralized control structure dictating how individual agents should behave, local, and to a certain degree random, interactions between such agents lead to the emergence of "intelligent" global behavior, unknown to the individual agents.
- Examples of swarm intelligence in natural systems include ant colonies, bee colonies, bird flocking, hawks hunting, animal herding, bacterial growth, fish schooling and microbial intelligence

Swarm Intelligence



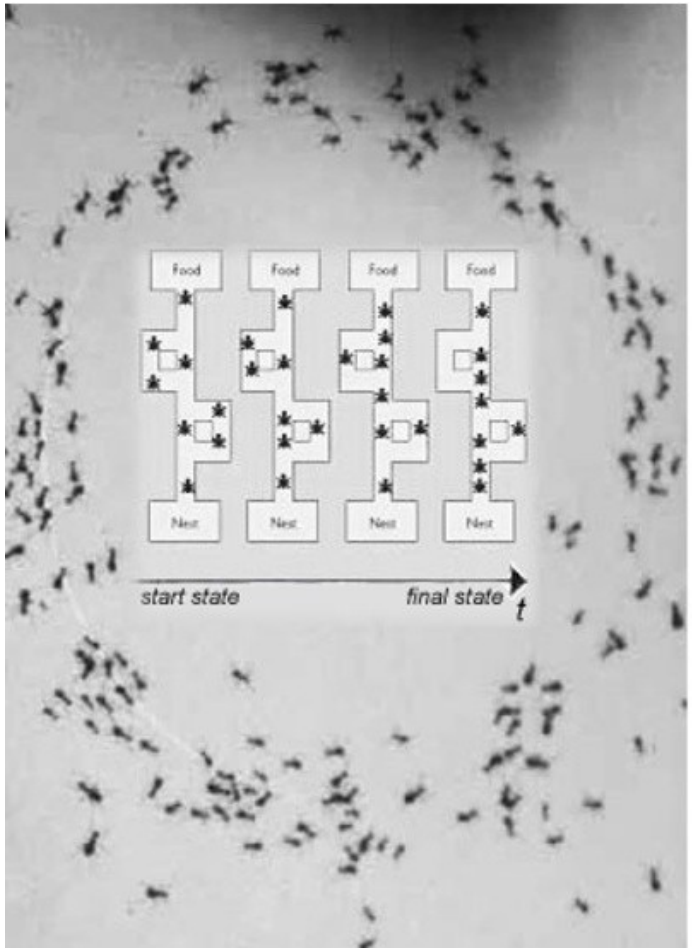
Ant Colony Optimization

- Ant colony optimization algorithm (ACO) is a probabilistic technique for solving computational problems which can be reduced to finding good paths through graphs.
- Artificial ants stand for multi-agent methods inspired by the behavior of real ants. The pheromone-based communication of biological ants is often the predominant paradigm used.
- Combinations of artificial ants and local search algorithms have become a method of choice for numerous optimization tasks involving some sort of graph, e.g., vehicle routing and internet routing.

Ant Colony Optimization

- As an example, ant colony optimization is a class of optimization algorithms modeled on the actions of an ant colony.
- Artificial 'ants' (e.g. simulation agents) locate optimal solutions by moving through a parameter space representing all possible solutions.
- Real ants lay down pheromones directing each other to resources while exploring their environment.

Ant Colony Optimization



The main quality of the colonies of insects, ants or bees lies in the fact that they are part of a self-organized group in which the keyword is simplicity.

Every day, ants solve complex problems due to a sum of simple interactions, which are carried out by individuals.

The ant is, for example, able to use the quickest way from the anthill to its food simply by following the way marked with pheromones.

Image: Wikipedia

Particle Swarm Optimization

- Particle swarm optimization (PSO) is a computational method that optimizes a problem by iteratively trying to improve a candidate solution with regard to a given measure of quality.
- It solves a problem by having a population of candidate solutions, here dubbed particles, and moving these particles around in the search-space according to simple mathematical formula over the particle's position and velocity.
- Each particle's movement is influenced by its local best known position, but is also guided toward the best known positions in the search-space, which are updated as better positions are found by other particles.
- This is expected to move the swarm toward the best solutions.

Particle Swarm Optimization

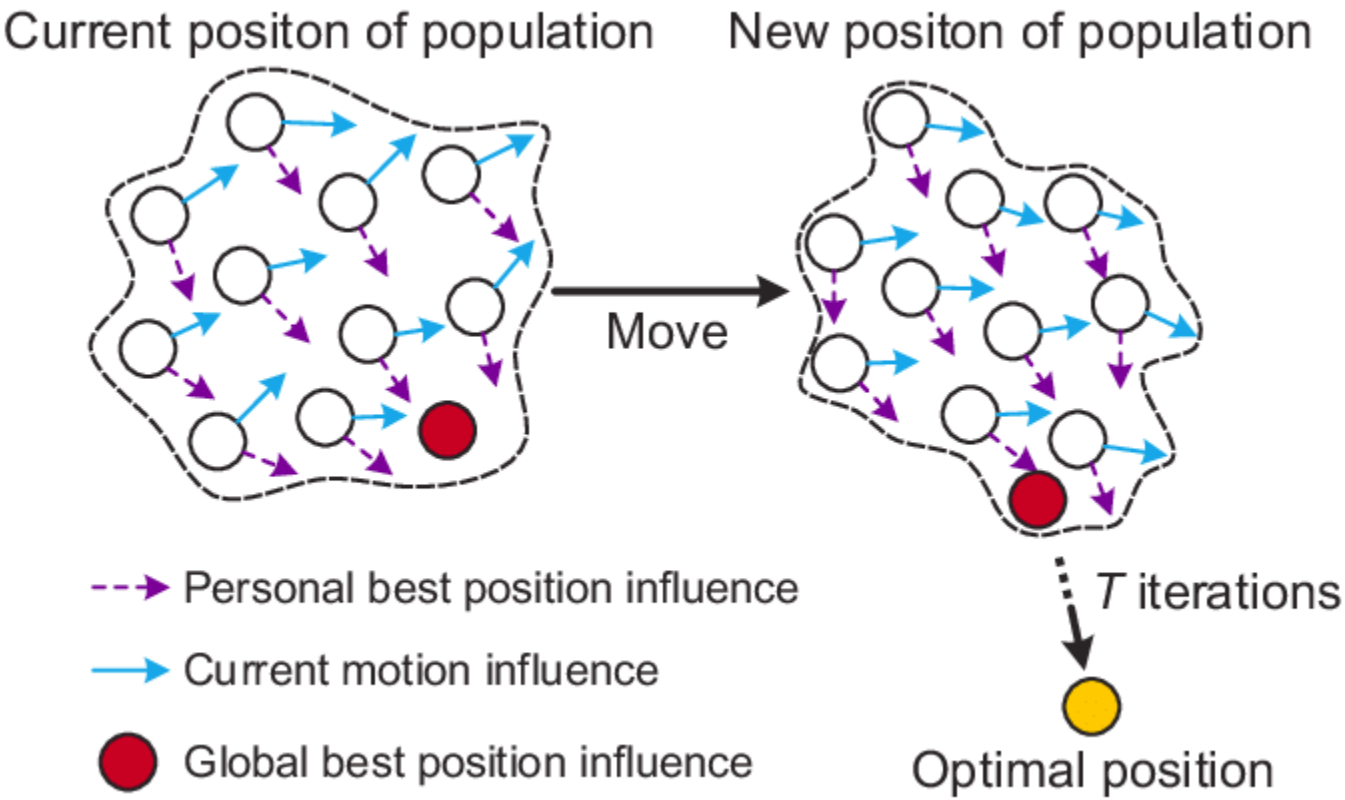


Image: Research Gate

Bayesian Belief Networks

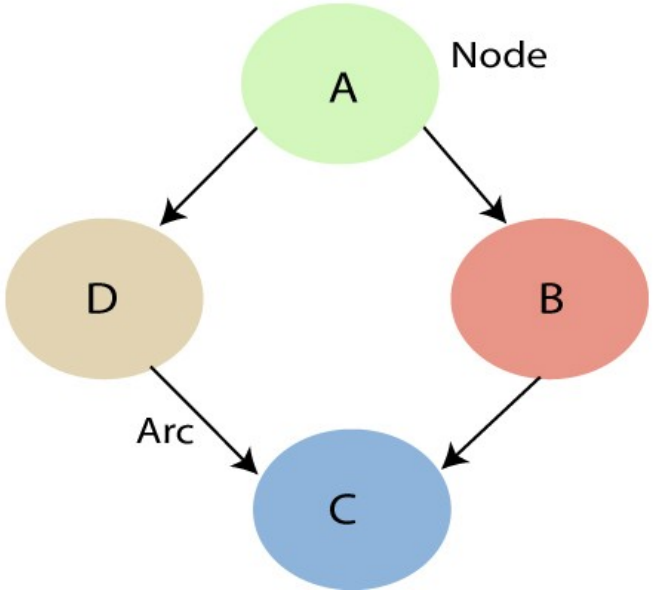
- Bayesian belief network is key computer technology for dealing with probabilistic events and to solve a problem which has uncertainty. We can define a Bayesian network as:
  - "A Bayesian network is a probabilistic graphical model which represents a set of variables and their conditional dependencies using a directed acyclic graph."
- It is also called a Bayes network, belief network, decision network, or Bayesian model.
- Bayesian networks are probabilistic, because these networks are built from a probability distribution, and also use probability theory for prediction and anomaly detection.

Bayesian Belief Networks

- Real world applications are probabilistic in nature, and to represent the relationship between multiple events, we need a Bayesian network.
- It can also be used in various tasks including prediction, anomaly detection, diagnostics, automated insight, reasoning, time series prediction, and decision making under uncertainty.
- Bayesian Network can be used for building models from data and experts opinions, and it consists of two parts:
  - Directed Acyclic Graph
  - Table of conditional probabilities.

Bayesian Belief Networks

- The generalized form of Bayesian network that represents and solve decision problems under uncertain knowledge is known as an Influence diagram.
- A Bayesian network graph is made up of nodes and Arcs (directed links), where:



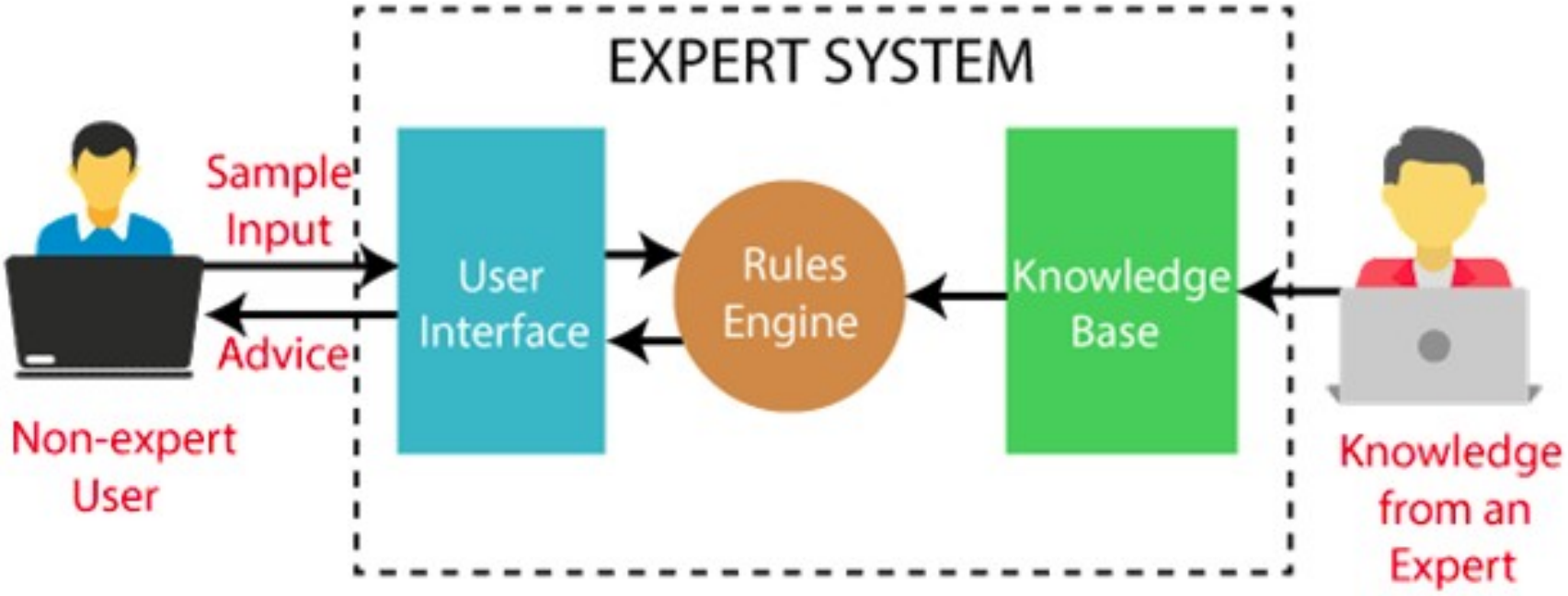
Expert Systems

- An expert system is a computer program that is designed to solve complex problems and to provide decision-making ability like a human expert.
- It performs this by extracting knowledge from its knowledge base using the reasoning and inference rules according to the user queries.

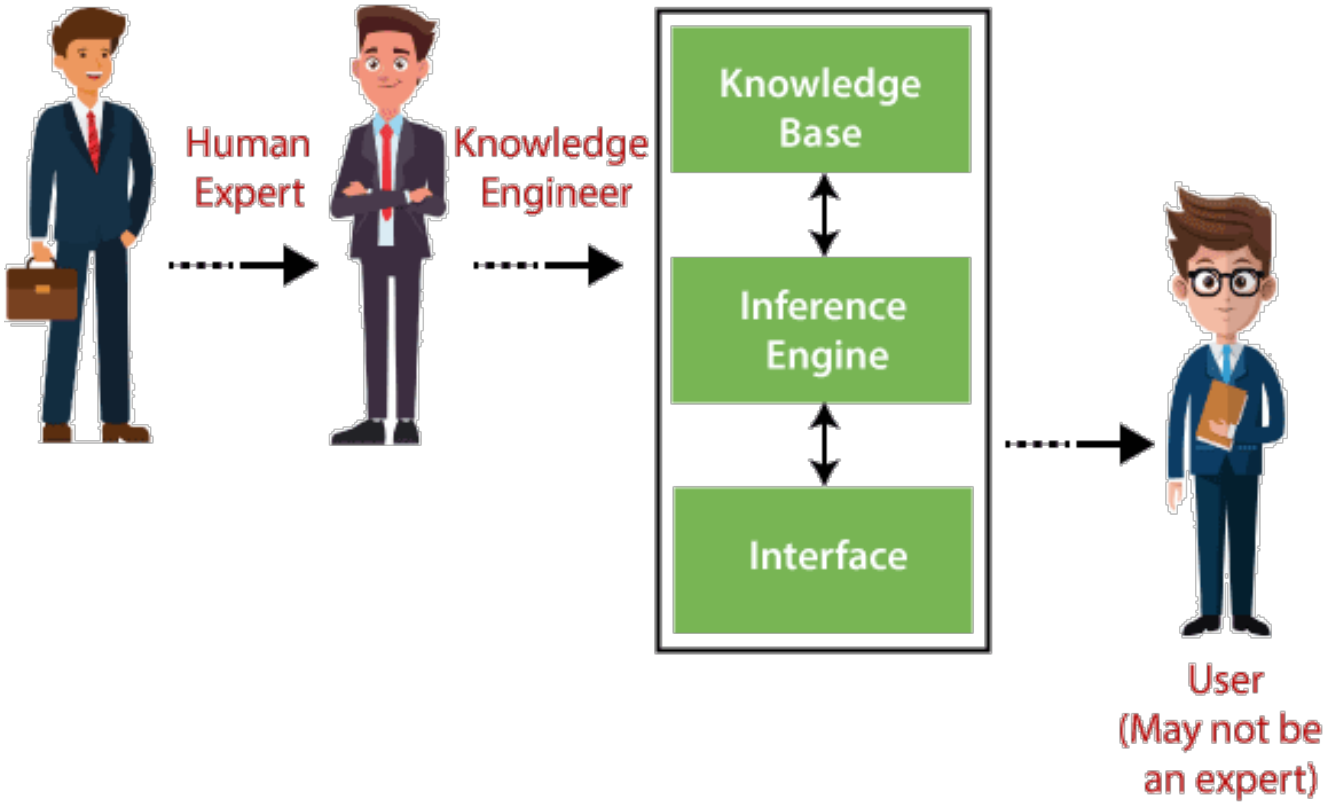
Expert Systems

- The expert system is a part of AI, and the first ES was developed in the year 1970, which was the first successful approach of artificial intelligence.
- It solves the most complex issue as an expert by extracting the knowledge stored in its knowledge base. The system helps in decision making for compsex problems using both facts and heuristics like a human expert.
- It is called so because it contains the expert knowledge of a specific domain and can solve any complex problem of that particular domain.
- These systems are designed for a specific domain, such as medicine, science, etc.

Expert Systems



Expert Systems



Conclusion

- Soft computing is an emerging approach to computing which parallel the remarkable ability of the human mind to reason and learn in an environment of uncertainty and imprecision.
- Soft computing is based on some biological inspired methodologies such as genetics, evolution, ant's behaviors, particles swarming, human nervous systems, etc

Thank you

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