SCT UNIT-1 - SCT

COMPUTER SCIENCE ENGINEERING (Jawaharlal Nehru Technological University, Kakinada)

SOFT COMPUTING TECHNIQUES

UNIT-1

UNIT -I:

Introduction to soft computing: Introduction, Artificial Intelligence, Artificial Neural Networks, Fuzzy systems, Genetic Algorithm and Evolutionary programming. Swarm Intelligent systems, Expert systems, Comparison among Intelligent systems.

Artificial Intelligence

Artificial Intelligence (AI) refers to the development of computer systems of performing tasks that require human intelligence. AI aids, in processing amounts of data identifying patterns and making decisions based on the collected information. This can be achieved through techniques like Machine Learning, Natural Language Processing, Computer Vision and Robotics. AI encompasses a range of abilities including learning, reasoning, perception, problem solving, data analysis and language comprehension. The ultimate goal of AI is to create machines that can emulate capabilities and carry out diverse tasks, with enhanced efficiency and precision. The field of AI holds potential to revolutionize aspects of our daily lives.

What are examples of AI technology and how is it used today?

1. **Machine learning:** This approach involves building algorithms that can learn patterns in data and make predictions based on that data. There are three types of machine learning, Refer to the article mentioned below:
   - Supervised learning
   - Unsupervised learning
   - Reinforcement learning
2. **Natural language processing (NLP):** This NLP approach deals with the interaction between computers and humans through natural language. It involves tasks such as text and speech recognition, translation, and sentiment analysis.
3. **Robotics:** This Robotics approach involves the use of AI to design, build, and control robots. It involves tasks such as perception, decision-making, and movement.
4. **Computer vision:** This computer vision approach deals with the processing and analysis of visual information from the real world. It involves tasks such as image recognition, object detection, and scene understanding.

AI has the potential to revolutionize many industries and fields, such as healthcare, finance, transportation, and education. However, it also raises important ethical and societal questions, such as the impact on employment and privacy, and the responsible development and use of AI technology.

What are the types of artificial intelligence?

AI can be broadly classified into two:

1. **Narrow AI:** This type of AI is also referred to as “weak AI”. Narrow AI usually carries out one particular task with extremely high efficiency which mimics human intelligence. An example would be any computer game where one player is the user and the other player is the computer. What usually happens is, the machine is fed with all the rules and regulations of the game and the possible outcomes of the game manually. In turn, this machine applies these data to beat whoever is playing against it. A single particular task is carried out to mimic human intelligence.
2. **Strong AI:** Also referred to as “general AI”. Here is where there is no difference between a machine and a human being. This is the kind of AI we see in the movies, the robots. A close example (not the perfect example) would be the world’s first citizen robot, Sophia. She was introduced to the world on October 11, 2017. Sophia talks like she has emotions.

Applications:

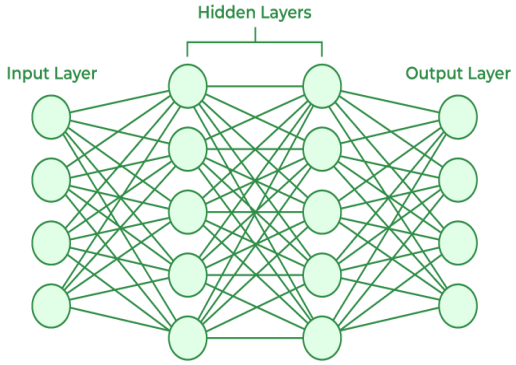
- Healthcare: AI is used in healthcare for various purposes such as diagnosing diseases, predicting patient outcomes, drug discovery, and personalized treatment plans.
- Finance: AI is used in the finance industry for tasks such as credit scoring, fraud detection, portfolio management, and financial forecasting.
- Retail: AI is used in the retail industry for applications such as customer service, demand forecasting, and personalized marketing.
- Manufacturing: AI is used in manufacturing for tasks such as quality control, predictive maintenance, and supply chain optimization.
- Transportation: AI is used in transportation for optimizing routes, improving traffic flow, and reducing fuel consumption.
- Education: AI is used in education for personalizing learning experiences, improving student engagement, and providing educational resources.
- Marketing: AI is used in marketing for tasks such as customer segmentation, personalized recommendations, and real-time audience analysis.
- Gaming: AI is used in gaming for developing intelligent game characters and providing personalized gaming experiences.
- Security: AI is used in security for tasks such as facial recognition, intrusion detection, and cyber threat analysis.
- Natural Language Processing (NLP): AI is used in NLP for tasks such as speech recognition, machine translation, and sentiment analysis.

Artificial Neural Networks

Artificial Neural Networks contain artificial neurons which are called units. These units are arranged in a series of layers that together constitute the whole Artificial Neural Network in a system. A layer can have only a dozen units or millions of units as this depends on how the complex neural networks will be required to learn the hidden patterns in the dataset. Commonly, Artificial Neural Network has an input layer, an output layer as well as hidden

layers. The input layer receives data from the outside world which the neural network needs to analyze or learn about. Then this data passes through one or multiple hidden layers that transform the input into data that is valuable for the output layer. Finally, the output layer provides an output in the form of a response of the Artificial Neural Networks to input data provided.

In the majority of neural networks, units are interconnected from one layer to another. Each of these connections has weights that determine the influence of one unit on another unit. As the data transfers from one unit to another, the neural network learns more and more about the data which eventually results in an output from the output layer.



The structures and operations of human neurons serve as the basis for artificial neural networks. It is also known as neural networks or neural nets. The input layer of an artificial neural network is the first layer, and it receives input from external sources and releases it to the hidden layer, which is the second layer. In the hidden layer, each neuron receives input from the previous layer neurons, computes the weighted sum, and sends it to the neurons in the next layer. These connections are weighted means effects of the inputs from the previous layer are optimized more or less by assigning different-different weights to each input and it is adjusted during the training process by optimizing these weights for improved model performance.

What are the types of Artificial Neural Networks?

- Feedforward Neural Network: The feedforward neural network is one of the most basic artificial neural networks. In this ANN, the data or the input provided travels in a single direction. It enters into the ANN through the input layer and exits through the output layer while hidden layers may or may not exist. So the feedforward neural network has a front-propagated wave only and usually does not have backpropagation.
- Convolutional Neural Network: A Convolutional neural network has some similarities to the feed-forward neural network, where the connections between units have weights that determine the influence of one unit on another unit. But a CNN has one or more than one convolutional layer that uses a convolution operation on the input and then passes the result obtained in the form of output to the next layer. CNN has applications in speech and image processing which is particularly useful in computer vision.

- Modular Neural Network: A Modular Neural Network contains a collection of different neural networks that work independently towards obtaining the output with no interaction between them. Each of the different neural networks performs a different sub-task by obtaining unique inputs compared to other networks. The advantage of this modular neural network is that it breaks down a large and complex computational process into smaller components, thus decreasing its complexity while still obtaining the required output.
- Radial basis function Neural Network: Radial basis functions are those functions that consider the distance of a point concerning the center. RBF functions have two layers. In the first layer, the input is mapped into all the Radial basis functions in the hidden layer and then the output layer computes the output in the next step. Radial basis function nets are normally used to model the data that represents any underlying trend or function.
- Recurrent Neural Network: The Recurrent Neural Network saves the output of a layer and feeds this output back to the input to better predict the outcome of the layer. The first layer in the RNN is quite similar to the feed-forward neural network and the recurrent neural network starts once the output of the first layer is computed. After this layer, each unit will remember some information from the previous step so that it can act as a memory cell in performing computations.

Applications of Artificial Neural Networks

- Social Media: Artificial Neural Networks are used heavily in Social Media. For example, let's take the 'People you may know' feature on Facebook that suggests people that you might know in real life so that you can send them friend requests. Well, this magical effect is achieved by using Artificial Neural Networks that analyze your profile, your interests, your current friends, and also their friends and various other factors to calculate the people you might potentially know. Another common application of Machine Learning in social media is facial recognition. This is done by finding around 100 reference points on the person's face and then matching them with those already available in the database using convolutional neural networks.
- Marketing and Sales: When you log onto E-commerce sites like Amazon and Flipkart, they will recommend your products to buy based on your previous browsing history. Similarly, suppose you love Pasta, then Zomato, Swiggy, etc. will show you restaurant recommendations based on your tastes and previous order history. This is true across all new-age marketing segments like Book sites, Movie services, Hospitality sites, etc. and it is done by implementing personalized marketing. This uses Artificial Neural Networks to identify the customer likes, dislikes, previous shopping history, etc., and then tailor the marketing campaigns accordingly.
- Healthcare: Artificial Neural Networks are used in Oncology to train algorithms that can identify cancerous tissue at the microscopic level at the same accuracy as trained physicians. Various rare diseases may manifest in physical characteristics and can be identified in their premature stages by using Facial Analysis on the patient photos. So the full-scale implementation of Artificial Neural Networks in the healthcare

environment can only enhance the diagnostic abilities of medical experts and ultimately lead to the overall improvement in the quality of medical care all over the world.

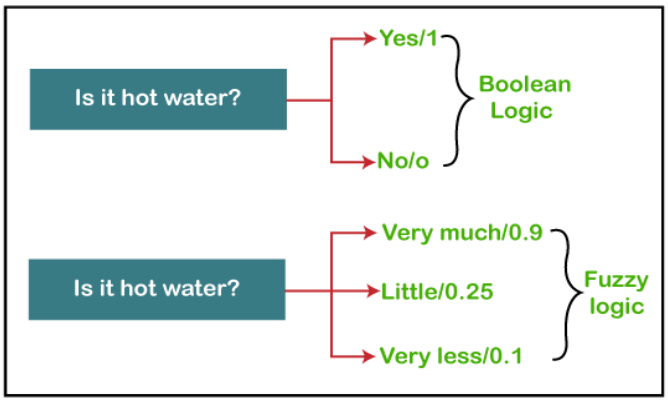
- Personal Assistants: I am sure you all have heard of Siri, Alexa, Cortana, etc., and also heard them based on the phones you have!!! These are personal assistants and an example of speech recognition that uses Natural Language Processing to interact with the users and formulate a response accordingly. Natural Language Processing uses artificial neural networks that are made to handle many tasks of these personal assistants such as managing the language syntax, semantics, correct speech, the conversation that is going on, etc.

Fuzzy systems

What is Fuzzy Logic?

The 'Fuzzy' word means the things that are not clear or are vague. Sometimes, we cannot decide in real life that the given problem or statement is either true or false. At that time, this concept provides many values between the true and false and gives the flexibility to find the best solution to that problem.

Example of Fuzzy Logic as comparing to Boolean Logic



Fuzzy logic contains the multiple logical values and these values are the truth values of a variable or problem between 0 and 1. This concept was introduced by Lofti Zadeh in 1965 based on the Fuzzy Set Theory. This concept provides the possibilities which are not given by computers, but similar to the range of possibilities generated by humans.

In the Boolean system, only two possibilities (0 and 1) exist, where 1 denotes the absolute truth value and 0 denotes the absolute false value. But in the fuzzy system, there are multiple possibilities present between the 0 and 1, which are partially false and partially true.

The Fuzzy logic can be implemented in systems such as micro-controllers, workstation-based or large network-based systems for achieving the definite output. It can also be implemented in both hardware or software.

Characteristics of Fuzzy Logic

Following are the characteristics of fuzzy logic:

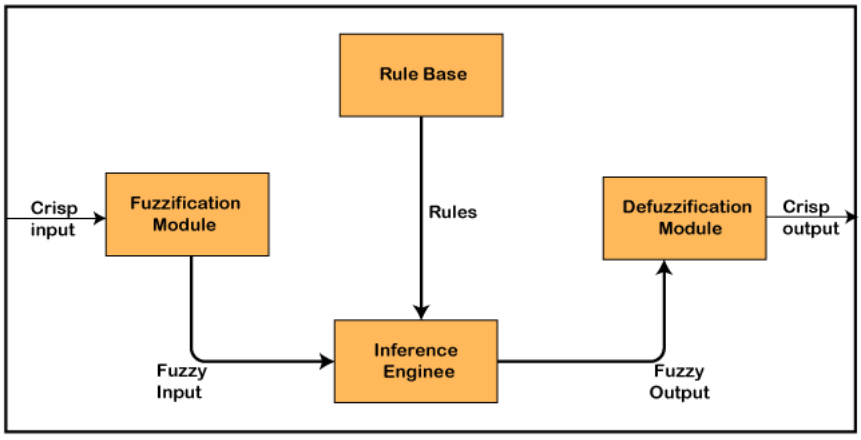
1. This concept is flexible and we can easily understand and implement it.
2. It is used for helping the minimization of the logics created by the human.
3. It is the best method for finding the solution of those problems which are suitable for approximate or uncertain reasoning.
4. It always offers two values, which denote the two possible solutions for a problem and statement.
5. It allows users to build or create the functions which are non-linear of arbitrary complexity.
6. In fuzzy logic, everything is a matter of degree.
7. In the Fuzzy logic, any system which is logical can be easily fuzzified.
8. It is based on natural language processing.
9. It is also used by the quantitative analysts for improving their algorithm's execution.
10. It also allows users to integrate with the programming.

Architecture of a Fuzzy Logic System

In the architecture of the Fuzzy Logic system, each component plays an important role. The architecture consists of the different four components which are given below.

1. Rule Base
2. Fuzzification
3. Inference Engine
4. Defuzzification

Following diagram shows the architecture or process of a Fuzzy Logic system:



1. Rule Base

Rule Base is a component used for storing the set of rules and the If-Then conditions given by the experts are used for controlling the decision-making systems. There are so many updates that come in the Fuzzy theory recently, which offers effective methods for designing and

tuning of fuzzy controllers. These updates or developments decreases the number of fuzzy set of rules.

2. Fuzzification

Fuzzification is a module or component for transforming the system inputs, i.e., it converts the crisp number into fuzzy steps. The crisp numbers are those inputs which are measured by the sensors and then fuzzification passed them into the control systems for further processing. This component divides the input signals into following five states in any Fuzzy Logic system:

- Large Positive (LP)
- Medium Positive (MP)
- Small (S)
- Medium Negative (MN)
- Large negative (LN)

3. Inference Engine

This component is a main component in any Fuzzy Logic system (FLS), because all the information is processed in the Inference Engine. It allows users to find the matching degree between the current fuzzy input and the rules. After the matching degree, this system determines which rule is to be added according to the given input field. When all rules are fired, then they are combined for developing the control actions.

4. Defuzzification

Defuzzification is a module or component, which takes the fuzzy set inputs generated by the Inference Engine, and then transforms them into a crisp value. It is the last step in the process of a fuzzy logic system. The crisp value is a type of value which is acceptable by the user. Various techniques are present to do this, but the user has to select the best one for reducing the errors.

Genetic Algorithm

Genetic Algorithms(GAs) are adaptive heuristic search algorithms that belong to the larger part of evolutionary algorithms. Genetic algorithms are based on the ideas of natural selection and genetics. These are intelligent exploitation of random search provided with historical data to direct the search into the region of better performance in solution space. They are commonly used to generate high-quality solutions for optimization problems and search problems.

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. In simple words, they simulate “survival of the fittest” among individual of consecutive generation for solving a problem. Each generation consist of a population of individuals and each individual represents a point in search space and possible solution. Each

individual is represented as a string of character/integer/float/bits. This string is analogous to the Chromosome.

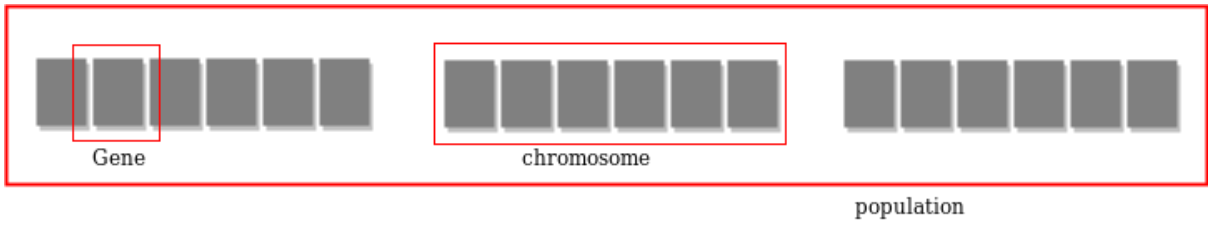
Foundation of Genetic Algorithms

Genetic algorithms are based on an analogy with genetic structure and behavior of chromosomes of the population. Following is the foundation of GAs based on this analogy –

1. Individual in population compete for resources and mate
2. Those individuals who are successful (fittest) then mate to create more offspring than others
3. Genes from "fittest" parent propagate throughout the generation, that is sometimes parents create offspring which is better than either parent.
4. Thus each successive generation is more suited for their environment.

Search space

The population of individuals are maintained within search space. Each individual represents a solution in search space for given problem. Each individual is coded as a finite length vector (analogous to chromosome) of components. These variable components are analogous to Genes. Thus a chromosome (individual) is composed of several genes (variable components).



Fitness Score

A Fitness Score is given to each individual which shows the ability of an individual to "compete". The individual having optimal fitness score (or near optimal) are sought.

The GAs maintains the population of n individuals (chromosome/solutions) along with their fitness scores.The individuals having better fitness scores are given more chance to reproduce than others. The individuals with better fitness scores are selected who mate and produce better offspring by combining chromosomes of parents. The population size is static so the room has to be created for new arrivals. So, some individuals die and get replaced by new arrivals eventually creating new generation when all the mating opportunity of the old population is exhausted. It is hoped that over successive generations better solutions will arrive while least fit die.

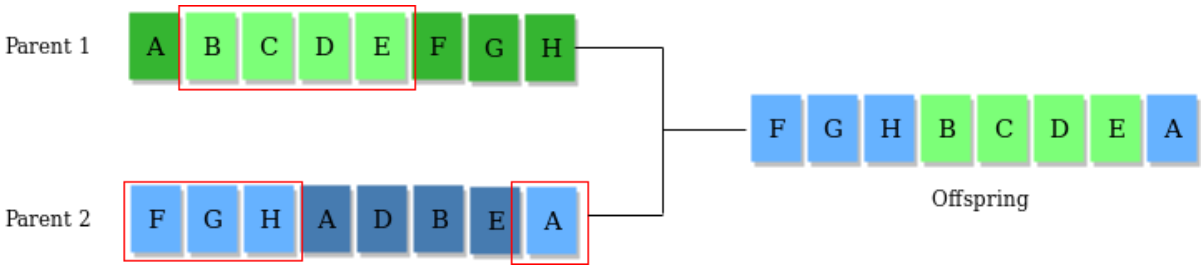
Each new generation has on average more "better genes" than the individual (solution) of previous generations. Thus each new generations have better "partial solutions" than previous generations. Once the offspring produced having no significant difference from offspring produced by previous populations, the population is converged. The algorithm is said to be converged to a set of solutions for the problem.

Operators of Genetic Algorithms

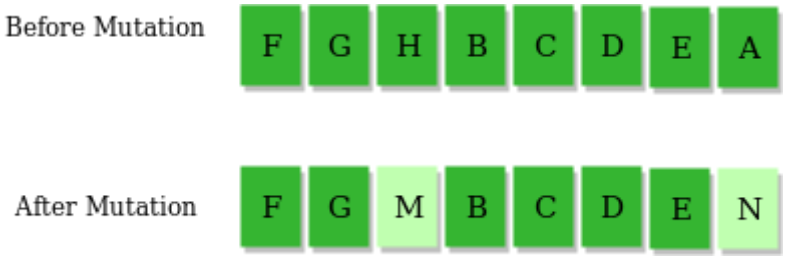
Once the initial generation is created, the algorithm evolves the generation using following operators –

1) Selection Operator: The idea is to give preference to the individuals with good fitness scores and allow them to pass their genes to successive generations.

2) Crossover Operator: This represents mating between individuals. Two individuals are selected using selection operator and crossover sites are chosen randomly. Then the genes at these crossover sites are exchanged thus creating a completely new individual (offspring). For example –



3) Mutation Operator: The key idea is to insert random genes in offspring to maintain the diversity in the population to avoid premature convergence. For example –



The whole algorithm can be summarized as –

1) Randomly initialize populations p

2) Determine fitness of population

3) Until convergence repeat:

a) Select parents from population

b) Crossover and generate new population

c) Perform mutation on new population

d) Calculate fitness for new population

Application of Genetic Algorithms

- Recurrent Neural Network
- Mutation testing
- Code breaking

- Filtering and signal processing
- Learning fuzzy rule base

Evolutionary programming

Evolutionary programming is a specific type of evolutionary algorithm that is used for optimization and search problems. The key concepts include:

- Population-Based Search: A population of potential solutions (individuals) evolves over time. Each individual represents a potential solution to the problem at hand.
- Selection: Individuals from the population are selected for reproduction based on their fitness, i.e., how well they solve the problem. The fittest individuals have a higher chance of being selected.
- Crossover and Mutation: Reproduction involves combining the genetic information of selected individuals through crossover (analogous to genetic recombination) and introducing random changes through mutation.
- Fitness Evaluation: The fitness of individuals is determined by how well they perform the task or solve the problem. This information guides the selection process.
- Termination Criteria: The evolution process continues until a termination condition is met, such as a certain number of generations or the achievement of a satisfactory solution.

Applications:

- Evolutionary programming is applied to a wide range of problems, including:
- Optimization Problems: Finding the best solution in a large solution space.
- Function Optimization: Determining the maximum or minimum of a mathematical function.
- Parameter Tuning: Adjusting parameters of algorithms or models for improved performance.
- Machine Learning: Evolving neural network architectures or optimizing hyperparameters.
- Game Playing: Strategies for playing games can be evolved.

Challenges:

- Computational Complexity: Evolutionary algorithms can be computationally expensive, especially for complex problems and large solution spaces.
- Parameter Tuning: Setting appropriate algorithm parameters is crucial, and their influence on performance may not be straightforward.
- Convergence Issues: Ensuring convergence to a good solution within a reasonable amount of time is a challenge.

In summary, evolutionary programming within the context of soft computing provides a flexible and adaptive approach to solving complex optimization and search problems. Its

application spans various domains, and researchers continue to explore ways to enhance its efficiency and effectiveness.

Swarm Intelligent systems

Swarm Intelligence (S.I.) was introduced by Gerardo Beni and Jing Wang in the year 1989. S.I. simply means using the knowledge of collective objects (people, insects, etc.) together and then reaching the optimized solution for a given problem. “Swarm” means a group of objects (people, insects, etc.). In other words, let’s say we give a problem statement to a single person and tell him or her to go through this problem and then give the solution, then this means that we will consider the solution of that particular person only, but the problem is that the solution given by that person may not be the best solution or maybe, that solution is not good for others. So to avoid that, what we do is we give that problem to a certain amount of people together (swarm) and ask them to reach the best solution possible for that problem, and then computing all the responses together to reach the best solution possible, so here we are using the knowledge of the group as a whole to reach to the best solution or optimized solution for that problem and that solution will be good for all of them individually too, so that is the idea behind swarm intelligence.

Example

Let’s say we have a jar containing 500 marbles in that. The question is without touching the jar a person needs to predict how many marbles are in that jar. Suppose we take only one response from a person and it predicts that according to him the jar contains 400 marbles. So by this result, we can conclude that this estimation of that person is not very bad since the difference (error) is of 100 only, but this might not be the best solution, we can optimize this even more. So now what we will do is instead of taking response from only one person we will be taking response from 10 people let’s say. Let ‘P’ denote a person therefore the responses are as follows:

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
400	450	550	600	480	390	520	490	510	450

So after collecting the responses from 10 different individuals we can take the average of their responses.

Average:

(400 + 450 + 550 + 600 + 480 + 390 + 520 + 490 + 510 + 450) / 10

Average = 4840 / 10

= 484 (marbles in the jar)

Now from this, we can say that from the collective predictions from 10 different persons we have reached a more optimal answer that is 484 marbles in the jar. We are very close to the actual result of 500 marbles in the jar, here in this case the difference (error) reduces to only

16 marbles as compared to the previous error which was 100. So that is the main idea behind swarm intelligence, that is to use the collective knowledge of objects.

Why Swarm Intelligence?

The answer to this is simple now and we proved this in our previous marble example, which is collecting the answers (responses) from different objects individually and then computing all responses as a whole to a solution that best fits our given problem. So here, with this approach, we are having a more optimized solution for a given problem and that is the reason why swarm intelligence came into the picture, because of this reason we can use it in different scenarios of life e.g. Forecasting, Which policy is good for the business, etc. So simply we are using the 'Brain of Brains' to reach the solution for a given problem. If we will observe in our surroundings (nature) then we will be able to find many examples of swarm intelligence like 'ant colony', 'swarm of bees', 'flock of birds' etc. and in reality, also the idea of swarm intelligence was taken from nature only. Some are explained below:

Ant Colony

If we will observe closely then the ants also follow the principle of swarm intelligence, for example, to build the home they collect mud particles from the surroundings and individually have a responsibility to build their home. They communicate through signals and pheromones (ants use this for tracing other ants) and regardless of what other ants are doing, an individual ant is responsible for only its own contribution to build the home. Similarly when they search for food then at first they search individually for food leaving the pheromones behind and once they find the food source then that ant communicates with other ants and then other ants can trace it and follow that path to reach the source of food instead of just randomly searching food in different locations every time.

Swarm of Bees

Bees also use the same principle for their survival that is when they search for the place like where they can build their hive, then the task of each bee is to consider several parameters that the hive which will be built should be on good height to avoid predators, should be near water resource, should be near pollens (flowers to collect nectar), etc. then they use their collective research and finally a place is decided that where the hive would be built considering all those parameters and they reach the best solution for that problem.

Artificial Swarm Intelligence (ASI)

It is also known as Human Swarm. Here also the idea is same that we randomly make some of the persons participating in a real-time system and tell them to find the solution for that particular problem individually, the final solution is then computed after taking responses from each participant and the final solution is presented which is more optimized as compared to the solution taking from only one participant.

Applications of Swarm Intelligence

- Used in military services.
- NASA is generating the idea to use swarm intelligence for planetary mapping.

- Used in Data Mining.
- M. Anthony Lewis and George A. Bekey presented the idea that with the help of swarm intelligence we can control nanobots in our body to kill cancer tumors.
- Used in business to reach better financial decisions etc.

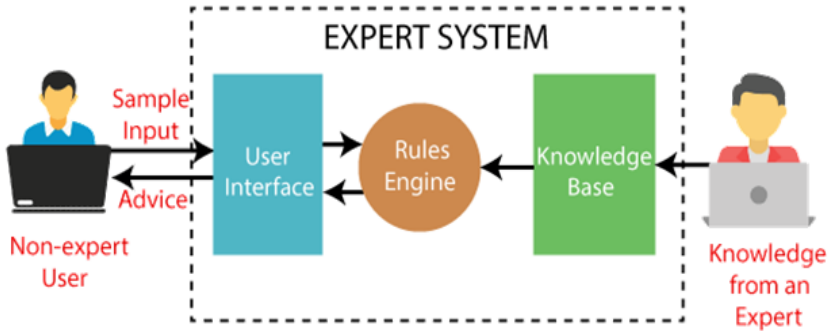
Expert System

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.

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 complex 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.

The performance of an expert system is based on the expert's knowledge stored in its knowledge base. The more knowledge stored in the KB, the more that system improves its performance. One of the common examples of an ES is a suggestion of spelling errors while typing in the Google search box.

Below is the block diagram that represents the working of an expert system:



Below are some popular examples of the Expert System:

- DENDRAL: It was an artificial intelligence project that was made as a chemical analysis expert system. It was used in organic chemistry to detect unknown organic molecules with the help of their mass spectra and knowledge base of chemistry.
- MYCIN: It was one of the earliest backward chaining expert systems that was designed to find the bacteria causing infections like bacteraemia and meningitis. It was also used for the recommendation of antibiotics and the diagnosis of blood clotting diseases.
- PXDES: It is an expert system that is used to determine the type and level of lung cancer. To determine the disease, it takes a picture from the upper body, which looks like the shadow. This shadow identifies the type and degree of harm.

- CaDeT: The CaDet expert system is a diagnostic support system that can detect cancer at early stages.

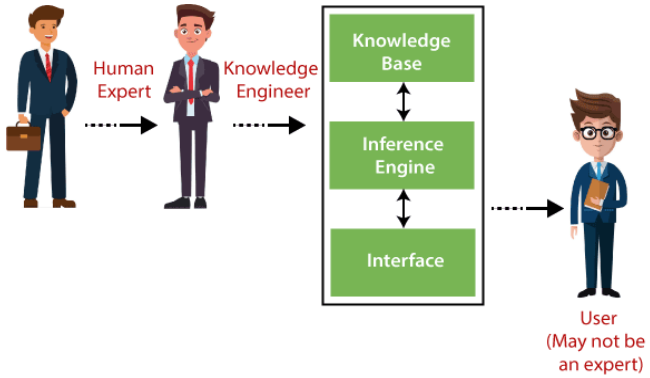
Characteristics of Expert System

- High Performance: The expert system provides high performance for solving any type of complex problem of a specific domain with high efficiency and accuracy.
- Understandable: It responds in a way that can be easily understandable by the user. It can take input in human language and provides the output in the same way.
- Reliable: It is much reliable for generating an efficient and accurate output.
- Highly responsive: ES provides the result for any complex query within a very short period of time.

Components of Expert System

An expert system mainly consists of three components:

- User Interface
- Inference Engine
- Knowledge Base



1. User Interface

With the help of a user interface, the expert system interacts with the user, takes queries as an input in a readable format, and passes it to the inference engine. After getting the response from the inference engine, it displays the output to the user. In other words, it is an interface that helps a non-expert user to communicate with the expert system to find a solution.

2. Inference Engine (Rules of Engine)

- The inference engine is known as the brain of the expert system as it is the main processing unit of the system. It applies inference rules to the knowledge base to derive a conclusion or deduce new information. It helps in deriving an error-free solution of queries asked by the user.
- With the help of an inference engine, the system extracts the knowledge from the knowledge base.
- There are two types of inference engine:

- Deterministic Inference engine: The conclusions drawn from this type of inference engine are assumed to be true. It is based on facts and rules.
- Probabilistic Inference engine: This type of inference engine contains uncertainty in conclusions, and based on the probability.

3. Knowledge Base

The knowledgebase is a type of storage that stores knowledge acquired from the different experts of the particular domain. It is considered as big storage of knowledge. The more the knowledge base, the more precise will be the Expert System.

It is similar to a database that contains information and rules of a particular domain or subject.

One can also view the knowledge base as collections of objects and their attributes. Such as a Lion is an object and its attributes are it is a mammal, it is not a domestic animal, etc.

Advantages of Expert System

- These systems are highly reproducible.
- They can be used for risky places where the human presence is not safe.
- Error possibilities are less if the KB contains correct knowledge.
- The performance of these systems remains steady as it is not affected by emotions, tension, or fatigue.
- They provide a very high speed to respond to a particular query.

Limitations of Expert System

- The response of the expert system may get wrong if the knowledge base contains the wrong information.
- Like a human being, it cannot produce a creative output for different scenarios.
- Its maintenance and development costs are very high.
- Knowledge acquisition for designing is much difficult.
- For each domain, we require a specific ES, which is one of the big limitations.
- It cannot learn from itself and hence requires manual updates.