Unit 1

Introduction

What is 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.

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.

Characteristics of Soft computing

- Soft computing provides an approximate but precise solution for real-life problems.
- The algorithms of soft computing are adaptive, so the current process is not affected by any kind of change in the environment.
- The concept of soft computing is based on **learning from experimental data**. It means that soft computing does not require any mathematical model to solve the problem.

- Soft computing helps users to solve real-world problems by providing approximate results that conventional and analytical models cannot solve.
- It is based on Fuzzy logic, genetic algorithms, machine learning, ANN, and expert systems.

Example

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 = "xyz" and string2 = "xyw"

1. Problem 1
2. Are string1 and string2 same?
3. Solution
4. No, the solution is simply No. It does not require any algorithm to analyze this.

Let's modify the problem a bit.

1. Problem 2
2. How much string1 and string2 are same?
3. Solution
4. Through conventional programming, either the answer is Yes or No. But these strings might be 8 0% similar according to soft computing.

You have noticed that soft computing gave us the approximate solution.

Applications of soft computing

There are several applications of soft computing where it is used. Some of them are listed below:

- It is widely used in **gaming products like Poker and Checker**.

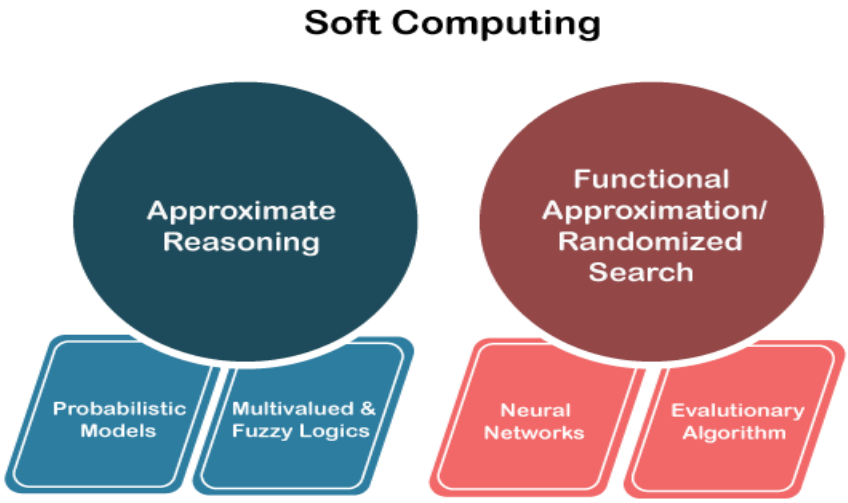
- In kitchen appliances, such as **Microwave and Rice cooker**.
- In most used home appliances - **Washing Machine, Heater, Refrigerator, and AC** as well.
- Apart from all these usages, it is also used in **Robotics work** (Emotional per Robot form).
- **Image processing and Data compression** are also popular applications of soft computing.
- Used for handwriting recognition.

Need of soft 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.
- When conventional mathematical and analytical models fail, soft computing helps, e.g., you can map even the human mind using soft computing.
- 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.
- Soft computing is not only limited to theory; it also gives insights into real-life problems.
- Like all the above reasons, Soft computing helps to map the human mind, which cannot be possible with conventional mathematical and analytical models.

Elements of soft computing

Soft computing is viewed as a foundation component for an emerging field of conceptual intelligence. Fuzzy Logic (FL), Machine Learning (ML), Neural Network (NN), Probabilistic Reasoning (PR), and Evolutionary Computation (EC) are the supplements of soft computing. Also, these are techniques used by soft computing to resolve any complex problem.



Any problems can be resolved effectively using these components. Following are three types of techniques used by soft computing:

- Fuzzy Logic
- Artificial Neural Network (ANN)
- Genetic Algorithms

Fuzzy Logic (FL)

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.

Neural Network (ANN)

Neural networks were developed in the 1950s, which 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.

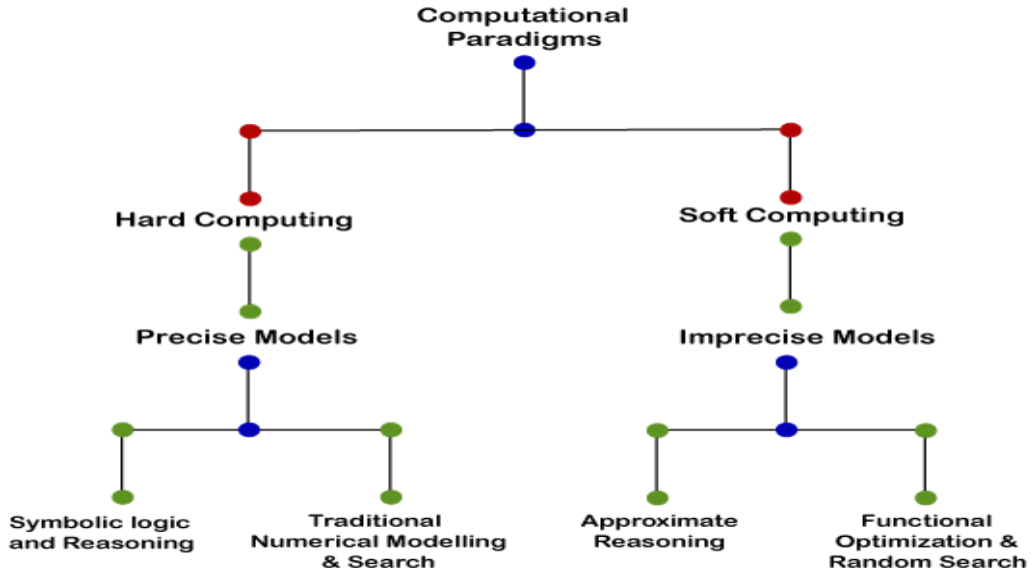
Artificial Neural Networks (ANN) are mutually connected with brain cells and created using regular computing programming. It is like as the human neural system.

Genetic Algorithms (GA)

Genetic algorithm is almost based on nature and takes all inspirations from it. There is no genetic algorithm that is based on search-based algorithms, which find its roots in natural selection and the concept of genetics.

Soft computing vs hard computing

Hard computing uses existing mathematical algorithms to solve certain problems. It provides a precise and exact solution of the problem. Any numerical problem is an example of 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.

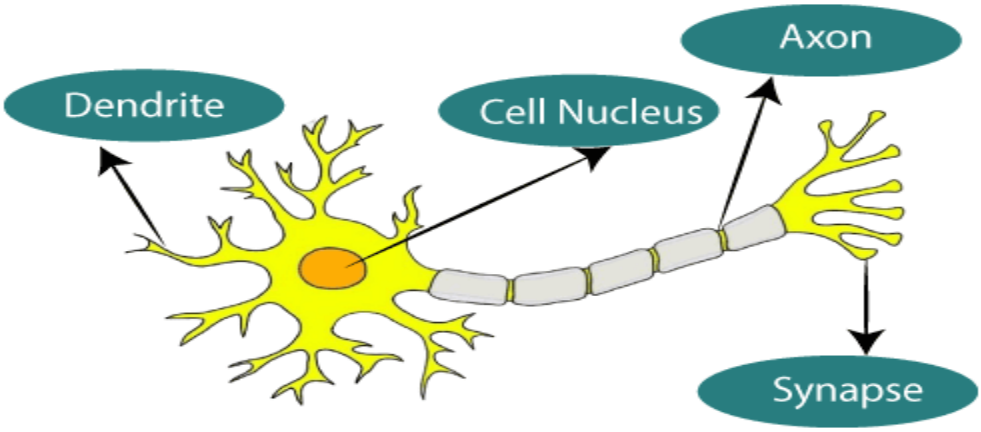
Artificial Neural Network

The term "Artificial neural network" refers to a biologically inspired sub-field of artificial intelligence modeled after the brain. An Artificial neural network is usually a computational network based on biological neural networks that construct the structure of the human brain.

Artificial neural network tutorial covers all the aspects related to the artificial neural network. In this tutorial, we will discuss ANNs, Adaptive resonance theory, Kohonen self-organizing map, Building blocks, unsupervised learning, Genetic algorithm, etc.

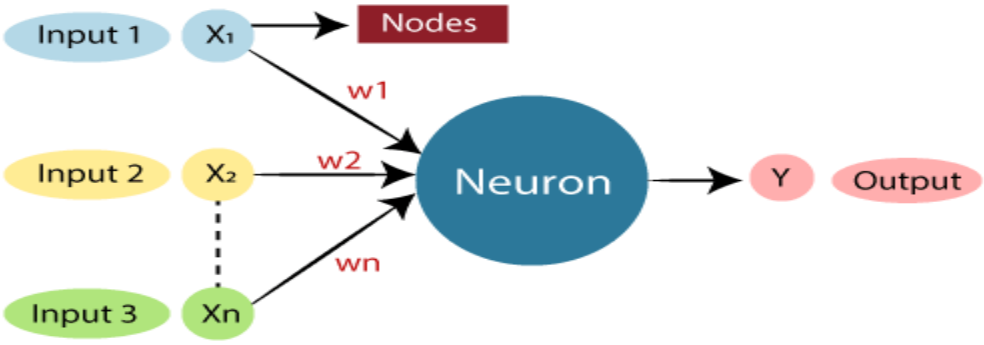
What is Artificial Neural Network?

The term "**Artificial Neural Network**" is derived from Biological neural networks that develop the structure of a human brain. Similar to the human brain that has neurons interconnected to one another, artificial neural networks also have neurons that are interconnected to one another in various layers of the networks. These neurons are known as nodes.



Biological Neural Network.

The typical Artificial Neural Network looks something like the given figure.



Dendrites from Biological Neural Network represent inputs in Artificial Neural Networks, cell nucleus represents Nodes, synapse represents Weights, and Axon represents Output.

Relationship between Biological neural network and artificial neural network:

Biological Neural Network	Artificial Neural Network
Dendrites	Inputs
Cell nucleus	Nodes
Synapse	Weights

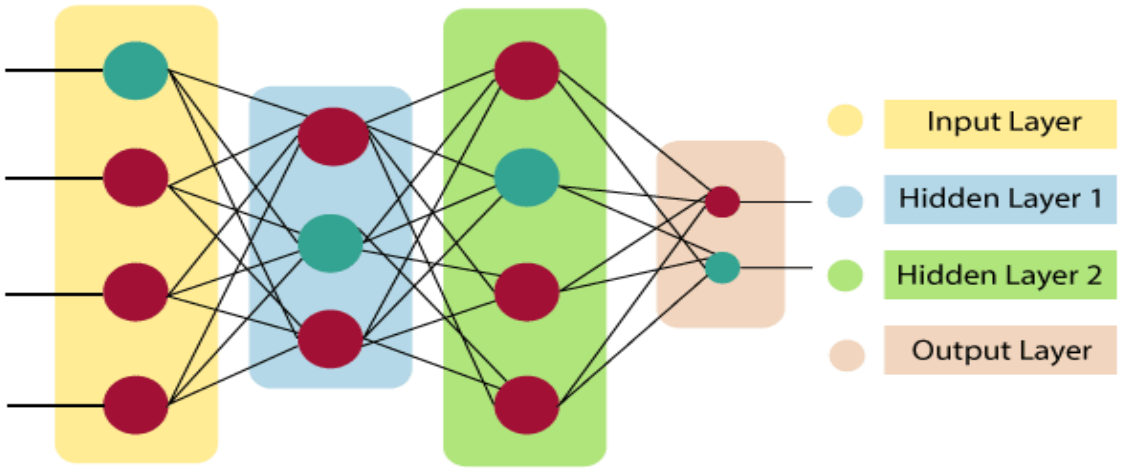
Axon	Output

An **Artificial Neural Network** in the field of **Artificial intelligence** where it attempts to mimic the network of neurons makes up a human brain so that computers will have an option to understand things and make decisions in a human-like manner. The artificial neural network is designed by programming computers to behave simply like interconnected brain cells.

The architecture of an artificial neural network:

To understand the concept of the architecture of an artificial neural network, we have to understand what a neural network consists of. In order to define a neural network that consists of a large number of artificial neurons, which are termed units arranged in a sequence of layers.

Artificial Neural Network primarily consists of three layers:



Input Layer:

As the name suggests, it accepts inputs in several different formats provided by the programmer.

Hidden Layer:

The hidden layer presents in-between input and output layers. It performs all the calculations to find hidden features and patterns.

Output Layer:

The input goes through a series of transformations using the hidden layer, which finally results in output that is conveyed using this layer.

The artificial neural network takes input and computes the weighted sum of the inputs and includes a bias. This computation is represented in the form of a transfer function.

$$\sum_{i=1}^{n} Wi * Xi + b$$

It determines weighted total is passed as an input to an activation function to produce the output. Activation functions choose whether a node should fire or not. Only those who are fired make it to the output layer. There are distinctive activation functions available that can be applied upon the sort of task we are performing.

Advantages of Artificial Neural Network (ANN)

Parallel processing capability:- Artificial neural networks have a numerical value that can perform more than one task simultaneously.

Storing data on the entire network:- Data that is used in traditional programming is stored on the whole network, not on a database. The disappearance of a couple of pieces of data in one place doesn't prevent the network from working.

Capability to work with incomplete knowledge:- After ANN training, the information may produce output even with inadequate data. The loss of performance here relies upon the significance of missing data.

Having a memory distribution:- For ANN is to be able to adapt, it is important to determine the examples and to encourage the network according to the desired output by demonstrating these examples to the network. The succession of the network is directly proportional to the

chosen instances, and if the event can't appear to the network in all its aspects, it can produce false output.

Disadvantages of Artificial Neural Network:

Assurance of proper network structure:- There is no particular guideline for determining the structure of artificial neural networks. The appropriate network structure is accomplished through experience, trial, and error.

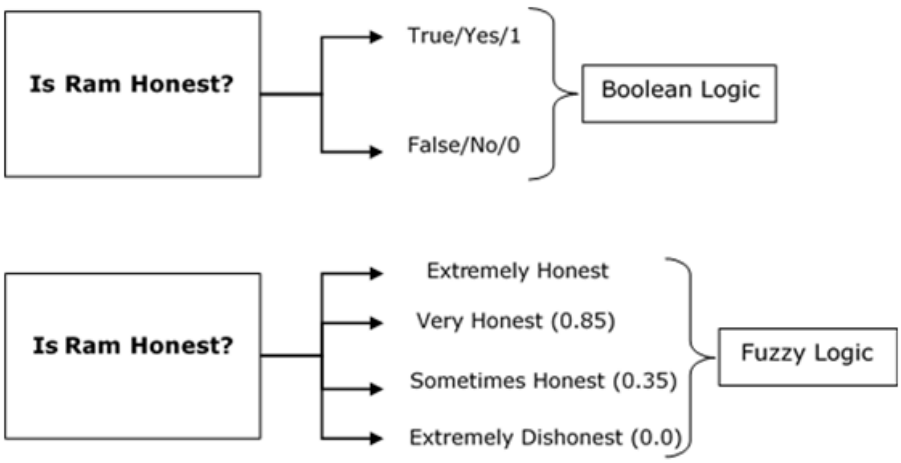
Unrecognized behavior of the network:- It is the most significant issue of ANN. When ANN produces a testing solution, it does not provide insight concerning why and how. It decreases trust in the network.

Hardware dependence:- Artificial neural networks need processors with parallel processing power, as per their structure. Therefore, the realization of the equipment is dependent.

Fuzzy Logic - Introduction

What is Fuzzy Logic?

Fuzzy Logic resembles the human decision-making methodology. It deals with vague and imprecise information. This is gross oversimplification of the real-world problems and based on degrees of truth rather than usual true/false or 1/0 like Boolean logic.



Characteristics of Fuzzy Logic-

Following are the characteristics of fuzzy logic:

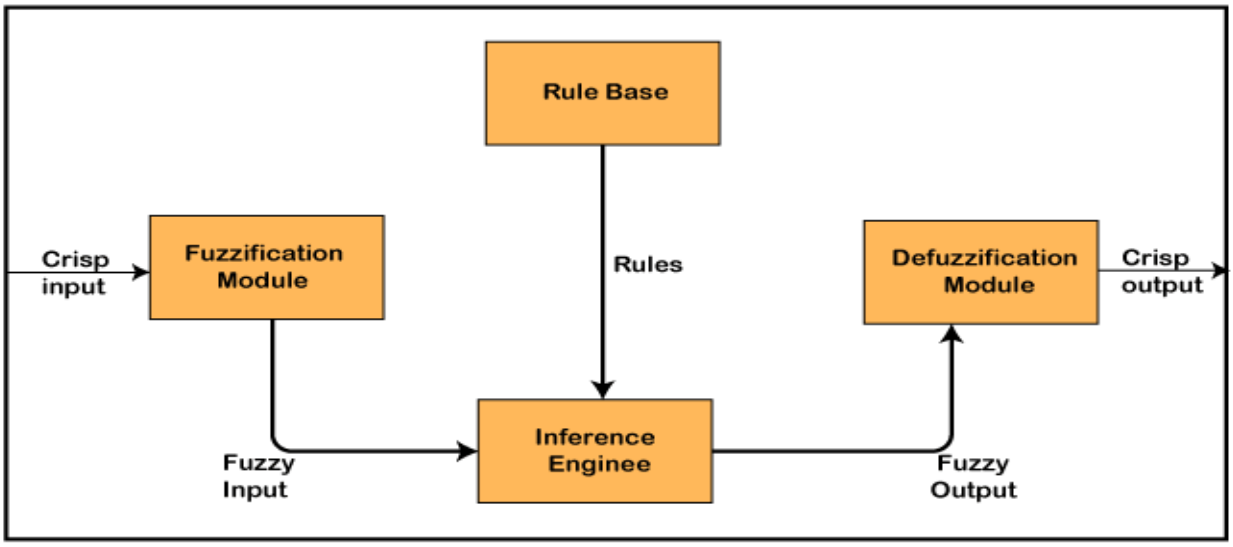
1. This concept is flexible and we can easily understand and implement it.
2. It is used for helping the minimization of the logics created by the human.
3. It is the best method for finding the solution of those problems which are suitable for approximate or uncertain reasoning.
4. It always offers 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 decrease 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.

Classical and Fuzzy Set Theory

1. Set- A set is a term, which is a collection of unordered or ordered elements. Following are the various examples of a set:

1. A set of all-natural numbers
2. A set of students in a class.
3. A set of all cities in a state.
4. A set of upper-case letters of the alphabet.

Operations on Classical Set

Following are the various operations which are performed on the classical sets:

1. Union Operation
2. Intersection Operation
3. Difference Operation
4. Complement Operation

1. Union:- This operation is denoted by (A U B). A U B is the set of those elements which exist in two different sets A and B. This operation combines all the elements from both the sets and makes a new set. It is also called a Logical OR operation.

It can be described as:

$A \cup B = \{ x \mid x \varepsilon A \text{ OR } x \varepsilon B \}$.

Example:

Set A = {10, 11, 12, 13}, Set B = {11, 12, 13, 14, 15}, then $A \cup B$ = {10, 11, 12, 13, 14, 15}

2. Intersection- This operation is denoted by ($A \cap B$). $A \cap B$ is the set of those elements which are common in both set A and B. It is also called a Logical OR operation.

It can be described as:

$A \cap B = \{ x \mid x \varepsilon A \text{ AND } x \varepsilon B \}$.

Example:

Set A = {10, 11, 12, 13}, Set B = {11, 12, 14} then $A \cap B$ = {11, 12}

3. Difference Operation- This operation is denoted by (A - B). A-B is the set of only those elements which exist only in set A but not in set B.

It can be described as:

$A - B = \{ x \mid x \varepsilon A \text{ AND } x \varepsilon B \}$.

4. Complement Operation: This operation is denoted by (A`). It is applied on a single set. A` is the set of elements which do not exist in set A.

It can be described as:

$A' = \{x \mid x \varepsilon A\}$.

Fuzzy Set

The set theory of classical is the subset of Fuzzy set theory. Fuzzy logic is based on this theory, which is a generalization of the classical theory of set (i.e., crisp set) introduced by Zadeh in 1965.

A fuzzy set is a collection of values which exist between 0 and 1. Fuzzy sets are denoted or represented by the tilde (~) character. The sets of Fuzzy theory were introduced in 1965 by Lofti A. Zadeh and Dieter Klaua. In the fuzzy set, the partial membership also exists. This theory released as an extension of classical set theory.

This theory is denoted mathematically asA fuzzy set (Ã) is a pair of U and M, where U is the Universe of discourse and M is the membership function which takes on values in the interval [0, 1]. The universe of discourse (U) is also denoted by Ω or X.

$$\tilde{A} = \{(x, \mu_{\tilde{A}}(x)) | x \in X\}$$

Operations on Fuzzy Set

Given Ã and B are the two fuzzy sets, and X be the universe of discourse with the following respective member functions:

$$\mu_{\tilde{A}}(x) \text{ and } \mu_{\tilde{B}}(x)$$

The operations of Fuzzy set are as follows:

1. Union Operation: The union operation of a fuzzy set is defined by:

μA∪B(x) = max (μA(x), μB(x))

Example:

Let's suppose A is a set which contains following elements:

A = {(X1, 0.6), (X2, 0.2), (X3, 1), (X4, 0.4)}

And, B is a set which contains following elements:

B = {(X1, 0.1), (X2, 0.8), (X3, 0), (X4, 0.9)}

then,

AUB = {(X1, 0.6), (X2, 0.8), (X3, 1), (X4, 0.9)}

Because, according to this operation

For X1

$\mu A \cup B(X1) = \max(\mu A(X1), \mu B(X1))$
$\mu A \cup B(X1) = \max(0.6, 0.1)$
$\mu A \cup B(X1) = 0.6$

For X2

$\mu A \cup B(X2) = \max(\mu A(X2), \mu B(X2))$
$\mu A \cup B(X2) = \max(0.2, 0.8)$
$\mu A \cup B(X2) = 0.8$

For X3

$\mu A \cup B(X3) = \max(\mu A(X3), \mu B(X3))$
$\mu A \cup B(X3) = \max(1, 0)$
$\mu A \cup B(X3) = 1$

For X4

$\mu A \cup B(X4) = \max(\mu A(X4), \mu B(X4))$
$\mu A \cup B(X4) = \max(0.4, 0.9)$
$\mu A \cup B(X4) = 0.9$

Classical Set Theory	Fuzzy Set Theory
1. This theory is a class of those sets having sharp boundaries.	1. This theory is a class of those sets having un-sharp boundaries.
2. This set theory is defined by exact	2. This set theory is defined by ambiguous

boundaries only 0 and 1.	boundaries.
3. In this theory, there is no uncertainty about the boundary's location of a set.	3. In this theory, there always exists uncertainty about the boundary's location of a set.
4. This theory is widely used in the design of digital systems.	4. It is mainly used for fuzzy controllers.

Applications of Fuzzy Logic

Following are the different application areas where the Fuzzy Logic concept is widely used:

1. It is used in **Businesses** for decision-making support system.
2. It is used in **Automotive systems** for controlling the traffic and speed, and for improving the efficiency of automatic transmissions. **Automotive systems** also use the shift scheduling method for automatic transmissions.
3. This concept is also used in the **Defense** in various areas. Defense mainly uses the Fuzzy logic systems for underwater target recognition and the automatic target recognition of thermal infrared images.
4. It is also widely used in the **Pattern Recognition and Classification** in the form of Fuzzy logic-based recognition and handwriting recognition. It is also used in the searching of fuzzy images.
5. Fuzzy logic systems also used in **Securities**.
6. It is also used in **microwave oven** for setting the lines power and cooking strategy.
7. This technique is also used in the area of **modern control systems** such as expert systems.
8. **Finance** is also another application where this concept is used for predicting the stock market, and for managing the funds.
9. It is also used for controlling the brakes.
10. It is also used in the **industries of chemicals** for controlling the ph, and chemical distillation process.

Advantages of Fuzzy Logic

Fuzzy Logic has various advantages or benefits. Some of them are as follows:

1. The methodology of this concept works similarly as the human reasoning.
2. Any user can easily understand the structure of Fuzzy Logic.
3. It does not need a large memory, because the algorithms can be easily described with fewer data.
4. It is widely used in all fields of life and easily provides effective solutions to the problems which have high complexity.
5. This concept is based on the set theory of mathematics, so that's why it is simple.