Artificial Intelligence

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Chapter 6 : Applications of AI

Neural Network: Biological Neural Network

- A neural circuit, is a population of neurons interconnected by synapses to carry out a specific function when activated. Neural circuits interconnect to one another to form large scale brain networks. Biological neural networks have inspired the design of artificial neural networks.

- The human brain incorporates nearly 10 billion neurons and 60 trillion connections, **synapses**, between them. By using multiple neurons simultaneously, the brain can perform its functions much faster than the fastest computers in existence today.

Neural Network: Biological Neural Network

Each neuron has a very simple structure, but an army of such elements constitutes a tremendous processing power

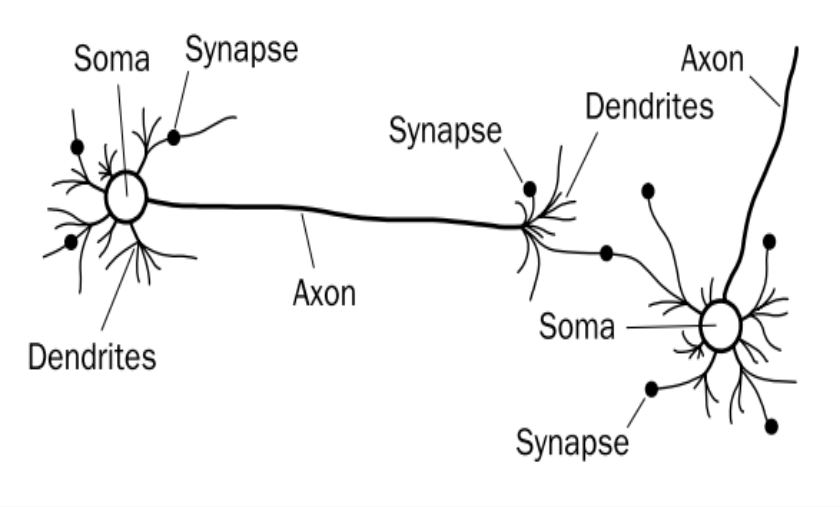
Neuron: fundamental functional unit of all nervous system tissue

Soma: cell body, contain nucleus

Dendrites: a number of fibres, input

Axon: single long fibre with many branches, output

Synapse: junction of dendrites and axon, each neuron form synapse with 10 to 100000 other neurons



Artificial Neural Network (ANN) or Neural Network

- A neural network is a network or circuit of neurons composed of artificial neurons or nodes.
- An Artificial Neural Network (ANN) is an information processing paradigm that is inspired by the way biological nervous systems, such as the brain, process information.
- ANNs, like people, learn by example.
- An ANN is configured for a specific application, such as pattern recognition or data classification, through a learning process.

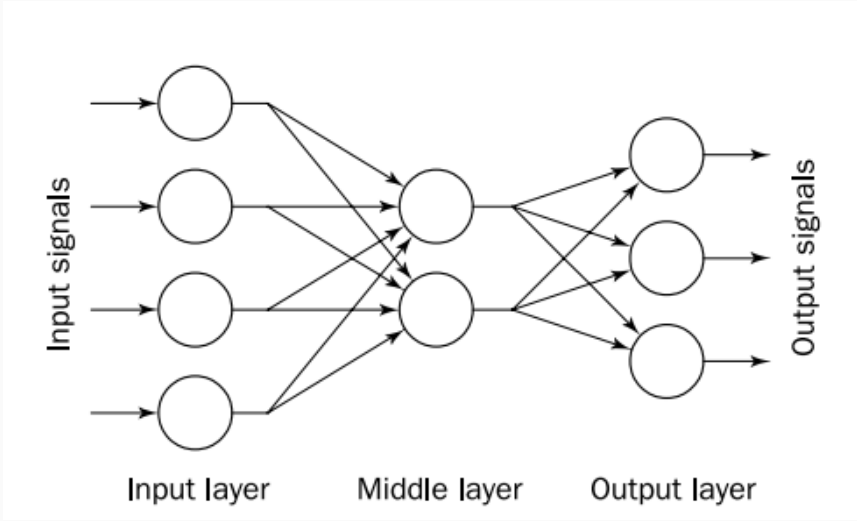


Fig. Neural Network

Artificial Neural Network (ANN) or Neural Network

- A neural network usually involves a large number of processors operating in parallel and arranged in tiers.
- The first tier receives the raw input information -- analogous to optic nerves in human visual processing.
- Each successive tier receives the output from the tier preceding it, rather than from the raw input – in the same way neurons further from the optic nerve receive signals from those closer to it.
- The last tier produces the output of the system.

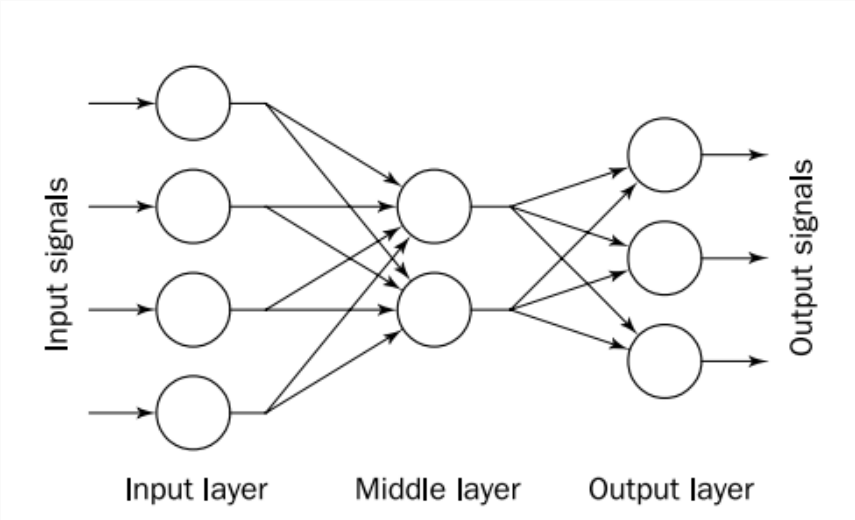


Fig. Neural Network

Neural Network : Advantages

1. **Pattern Extraction:** can be used to extract patterns and detect trends that are too complex to be noticed by either humans or other computer techniques.
2. **Expert Systems**: A trained neural network can be thought of as an expert in the category of information it has been given to analyze.
3. **Adaptive learning:** An ability to learn how to do tasks based on the data given for training or initial experience.
4. **Fault Tolerance via Redundant Information Coding**: Partial destruction of a network leads to the corresponding degradation of performance. However, some network capabilities may be retained even with major network damage.

Neural Network : How Do Neural Networks Differ From Conventional Computing?

- ANNs are not sequential or necessarily deterministic.
- There are no complex central processors, rather there are many simple ones which generally do nothing more than take the weighted sum of their inputs from other processors.
- ANNs do not execute programed instructions; they respond in parallel (either simulated or actual) to the pattern of inputs presented to it.
- There are also no separate memory addresses for storing data. Instead, information is contained in the overall activation 'state' of the network.

Neural Network : Units of neural network

1. **Nodes** (units): Nodes represent a cell of neural network.
2. **Links**: Links are directed arrows that show propagation of information from one node to another node.
3. **Activation**: Activations are inputs to or outputs from a unit.
4. **Weight**: Each link has weight associated with it which determines strength and sign of the connection.
5. **Activation function**: A function which is used to derive output activation from the input activations to a given node is called activation function.
6. **Bias**: Bias is a feature of a statistical technique or of its results whereby the expected value of the results differs from the true underlying quantitative parameter being estimated.

Neural Network : Neuron as a simple computing element

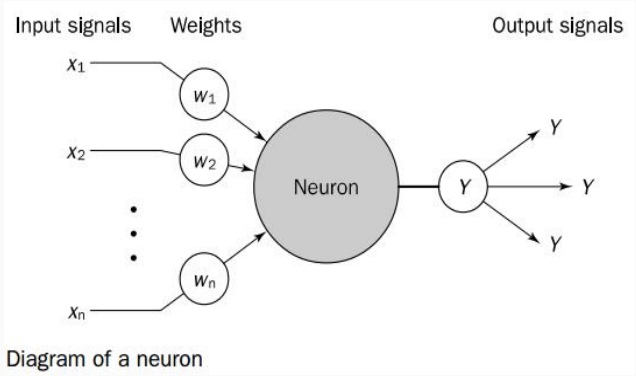
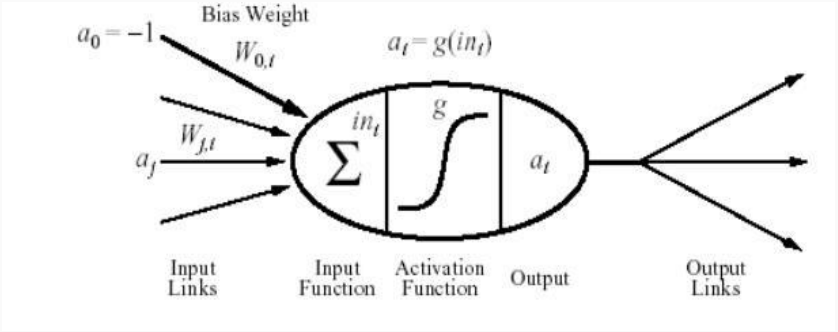


Diagram of a neuron



- The neuron has two modes of operation; the **training mode** and the **using mode**. In the training mode, the neuron can be trained to fire (or not), for particular input patterns. In the using mode, when a taught input pattern is detected at the input, its associated output becomes the current output.

- The neuron computes the weighted sum of the input signals and compares the result with a **threshold value**, θ. If the net input is less than the threshold, the neuron output is –1. But if the net input is greater than or equal to the threshold, the neuron becomes activated and its output attains a value +1.
- The neuron uses the following transfer or **activation function.**

$$X = \sum_{i=1}^{n} x_i w_i \qquad Y = \begin{cases} +1 \; if \; X \geq \theta \\ -1 \; if \; X \leq \theta \end{cases}$$

- This type of activation function is called a **sign function.**

Neural Network : Neuron as a simple computing element

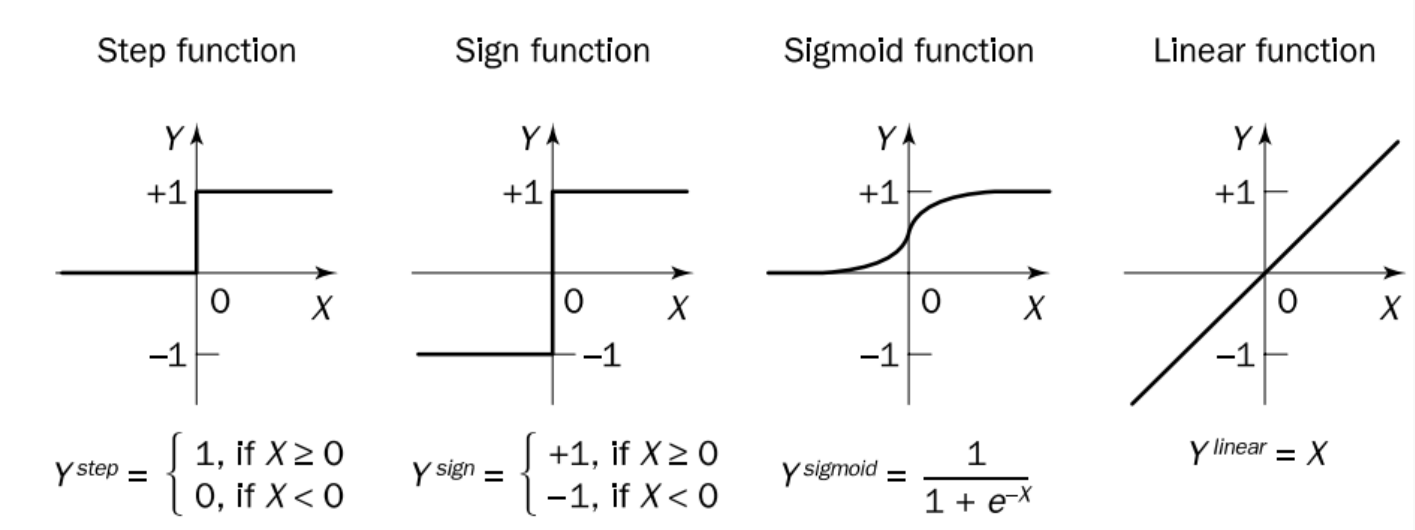


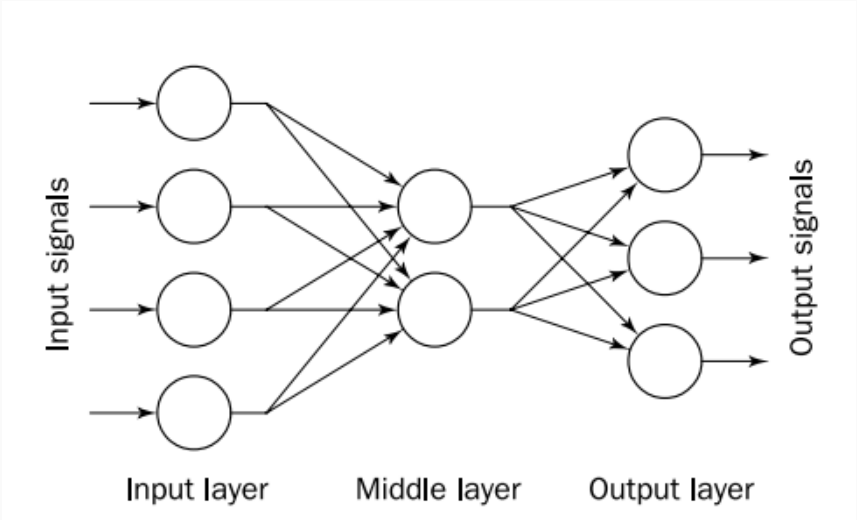
Fig. Activation functions for Neuron

Neural Network : Types of NN

- Neural Networks are complex structures made of artificial neurons that can take in multiple inputs to produce a single output.
- This is the primary job of a Neural Network – to transform input into a meaningful output. Usually, a Neural Network consists of an input and output layer with one or multiple hidden layers within.
- In a Neural Network, all the neurons influence each other, and hence, they are all connected.
- The network can acknowledge and observe every aspect of the dataset at hand and how the different parts of data may or may not relate to each other. This is how Neural Networks are capable of finding extremely complex patterns in vast volumes of data.

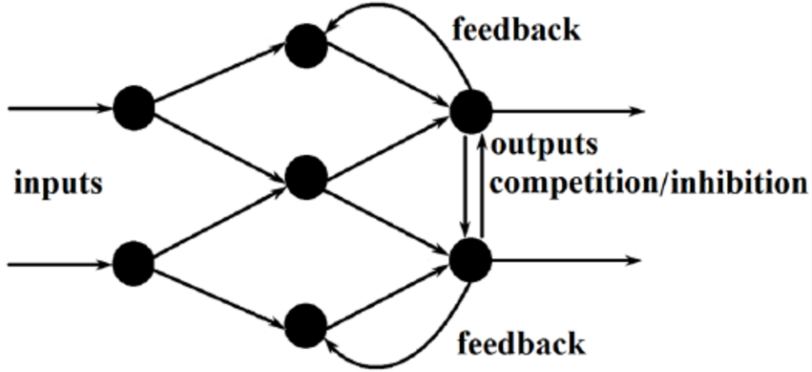
Neural Network : Types of NN

Feed forward Networks: In this model, the signals only travel in one direction, towards the output layer. Feedforward Networks have an input layer and a single output layer with zero or multiple hidden layers. They are widely used in pattern recognition.



Neural Network : Types of NN

Feed back Networks: In this model, the recurrent or interactive networks use their internal state (memory) to process the sequence of inputs. In them, signals can travel in both directions through the loops (hidden layer/s) in the network. They are typically used in time-series and sequential tasks.



Perceptron

- The perceptron is the simplest form of a neural network. It consists of a single neuron with adjustable synaptic weights and a hard limiter.

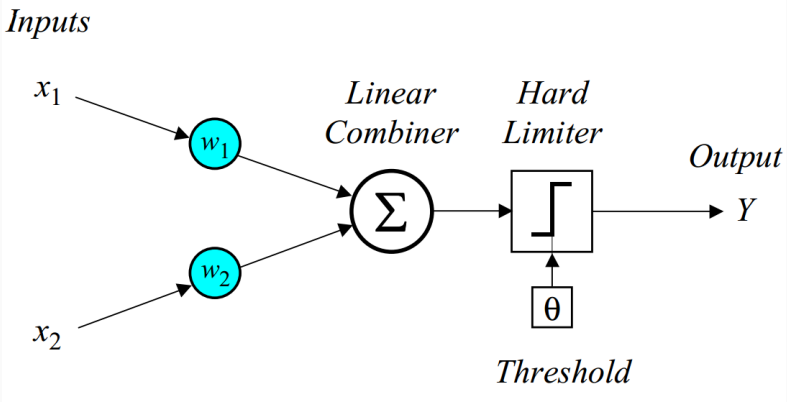


Fig: Single Layer two input Perceptron

- The perceptron is an algorithm for supervised learning.
- Functions that can decide whether an input, represented by a vector of numbers, belongs to some specific class or not.

Perceptron Algorithm

1. Initialization

- Set the initial weights wi and threshold to ϖ random numbers in the range [-0.5, +0.5]

- If the error, e(p) is positive, we need to increase perceptron output Y(p), but if it is negative, we need to decrease Y(p)

2. Activation

- Activate the perceptron by applying inputs $x_i(p)$ and desired output $Y_d(p)$.

Calculate the actual output at iteration p=1

$$Y(p) = step\left[\sum_{i=1}^{n} x_i(p)\, w_i(p) - \theta\right]$$

Where n is the number of the perceptron inputs, and step is step activation function

3. Weight Training

- Update the weights of the perceptron

$w_i(p+1) = wi(p) + \Delta wi(p)$, Where $\Delta wi(p)$ is the weight correction at iteration p. the weight correction is computed by the delta rule.

$\Delta wi(p) = \alpha . Xi(p) . e(p)$, α is learning rate

- Adaline network is a variation on the Perceptron Network

Inputs are +1 or -1

Outputs are +1 or -1

Uses a bias input

- It is trained using the Delta Rule which is also known as the least mean squares (LMS) or Widrow-Hoff rule. The activation function, during training is the identity function. After training the activation is a threshold function.
- Algorithm:

Step 0: initialize the weights to small random values and select a learning rate, a

Step 1: for each input vector s, with target output, t set the input to s

Step 2: compute the neuron inputs

Step 3: use the delta rule to update the bias and weights

$$b(new) = b(old) + \alpha(t - y\_in)$$
$$w_i(new) = w_i(old) + \alpha(t - y\_in)x_i$$

Step 4: stop if the largest weight change across all the training samples is less than a specified tolerance, otherwise cycle through the training set again

Multilayer Perceptron, Back Propagation

- A multilayer perceptron (MLP) is a class of feedforward artificial neural network. An MLP consists of, at least, three layers of nodes: an input layer, a hidden layer and an output layer. Except for the input nodes, each node is a neuron that uses a nonlinear activation function.
- MLP utilizes a supervised learning technique called backpropagation for training. Its multiple layers and non-linear activation distinguish MLP from a linear perceptron. It can distinguish data that is not linearly separable

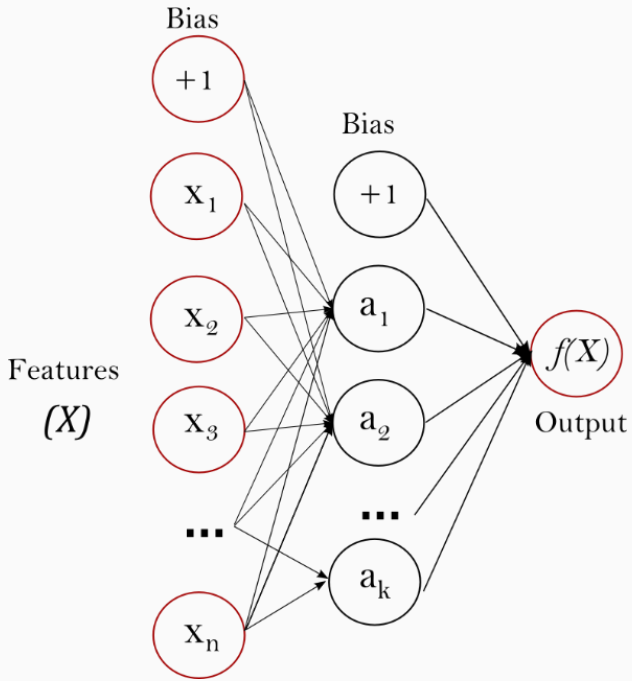


Fig. Multilayer Perceptron

Back Propagation Algorithm

- Backpropagation is an essential mechanism by which neural networks get trained. It is a mechanism used to fine-tune the weights of a neural network (otherwise referred to as a model in this article) in regards to the error rate produced in the previous iteration.
- It is similar to a messenger telling the model if the net made a mistake or not as soon as it predicted.
- Backpropagation in neural networks is about the transmission of information and relating this information to the error generated by the model when a guess was made.
- Applications:

✓ The neural network is trained to enunciate each letter of a word and a sentence

✓ It is used in the field of speech recognition

✓ It is used in the field of character and face recognition

Why We Need Backpropagation?

Some of the advantages of Backpropagation are

- It is simple, fast and easy to program
- Only numbers of the input are tuned and not any other parameter
- No need to have prior knowledge about the network
- It is flexible.
- A standard approach and works efficiently
- It does not require the user to learn special functions

Back Propagation Algorithm

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Back Propagation Algorithm

4. Iteration

- Increase iteration p by one, go back to Step 2 and repeat the process until convergence.

Disadvantages of backpropagation are:

- Backpropagation possibly be sensitive to noisy data and irregularity
- The performance of this is highly reliant on the input data
- Needs excessive time for training
- The need for a matrix-based method for backpropagation instead of mini-batch

Hopfield Network

- A Hopfield network is a form of recurrent artificial neural network popularized by John Hopfield in 1982, but described earlier by Little in 1974.
- The units in Hopfield nets are binary threshold units, i.e. the units only take on two different values for their states and the value is determined by whether or not the units' input exceeds their threshold. Hopfield nets normally have units that take on values of 1 or -1.
- Updating one unit (node in the graph simulating the artificial neuron) in the Hopfield network is performed using the following rule:

$$s_i \leftarrow \begin{cases} +1 & \text{if } \sum_j w_{ij} s_j \geq \theta_i, \\ -1 & \text{otherwise.} \end{cases}$$

Where

Si= is the state of unit j

Wij= is the strength of the connection weight from unit j to unit

θ_i =is the threshold of unit i.

Hopfield Network

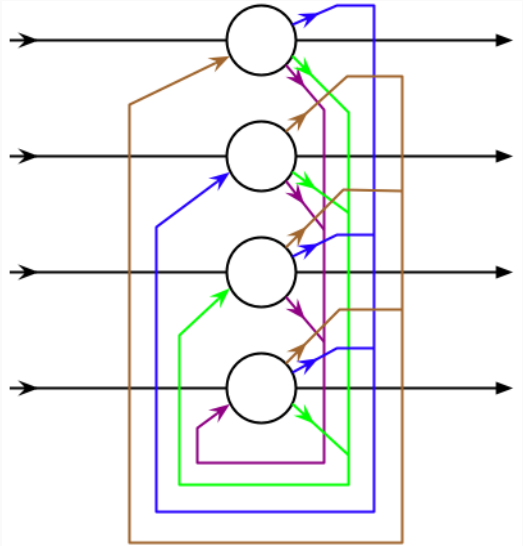


Fig. Hopfield Network

Kohonen Network

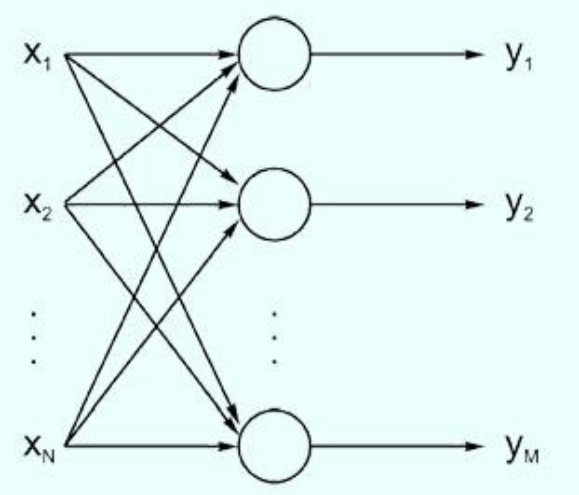
- Kohonen's networks are one of basic types of self-organizing neural networks.
- Kohonen’s network is a computational method for the visualization and analysis of high-dimensional data, especially experimentally acquired information.
- It seems to be the most natural way of learning, which is used in our brains, where no patterns are defined.
- The objective of a Kohonen network is to map input vectors (patterns) of arbitrary dimension N onto a discrete map with 1 or 2 dimensions.
- Patterns close to one another in the input space should be close to one another in the map: they should be topologically ordered.
- A Kohonen network is composed of a grid of output units and N input units. The input pattern is fed to each output unit. The input lines to each output unit are weighted. These weights are initialized to small random numbers.

Kohonen Network

- Functioning of self-organizing neural network is divided into three stages:

1. construction
2. learning
3. identification

- Organization of the net is better (neurons organization represents the distribution of input data in a better way) and the convergence of the algorithm is higher in Kohonen network.



Expert System

- **Expert system** is an artificial intelligence program that has expert-level knowledge about a particular domain and knows how to use its knowledge to respond properly.
- Domain refers to area within which the task is being performed. Ideally, the expert system should substitute a human expert.

Why Expert system?

Expert System is built because of two factors: either to replace or to help an expert.

- To enable the use of expertise after working hours or at different locations.
- To automate a routine task that requires human expertise all the time unattended, thus reducing operational costs.
- To replace a retiring or leaving employee who is an expert.
- To hire an expert is costly.
- To help Expert in their routine to improve productivity
- Effective Management of problems.

Comparisons between an Expert System and Human Expert

Factor	Human Expert	Expert System
Time (can be obtained)	Working days Only	Anytime
Geography	Local	Anywhere
Safety	Cannot be replaced	Can be replaced
Damages	Yes	No
Speed and Efficiency	Changes	Consistent
Cost	High	Intermediate

Characteristics of Expert System

1. **High Performance.** They should perform at the level of a human expert.
2. **Adequate response time.** They should have the ability to respond in a reasonable amount of time. Time is crucial for real time system
3. **Reliability.** They must be reliable and should not crash.
4. **Understandable:** They should not be a black box instead it should be able to explain the steps of reasoning process. It should justify its conclusions in the same way a human expert explains why he/she arrived at a particular conclusion.
5. Should be able to display the intelligent behavior.
6. Should be able to explain the reasoning.
7. Should be able to draw conclusion.
8. Should be able deal with the certainty
9. Does not possess the ability to deal with the mixed knowledge.
10. Limited to narrow problems.
11. Are very much difficult to maintain.

Components of Expert System/Architecture of ES

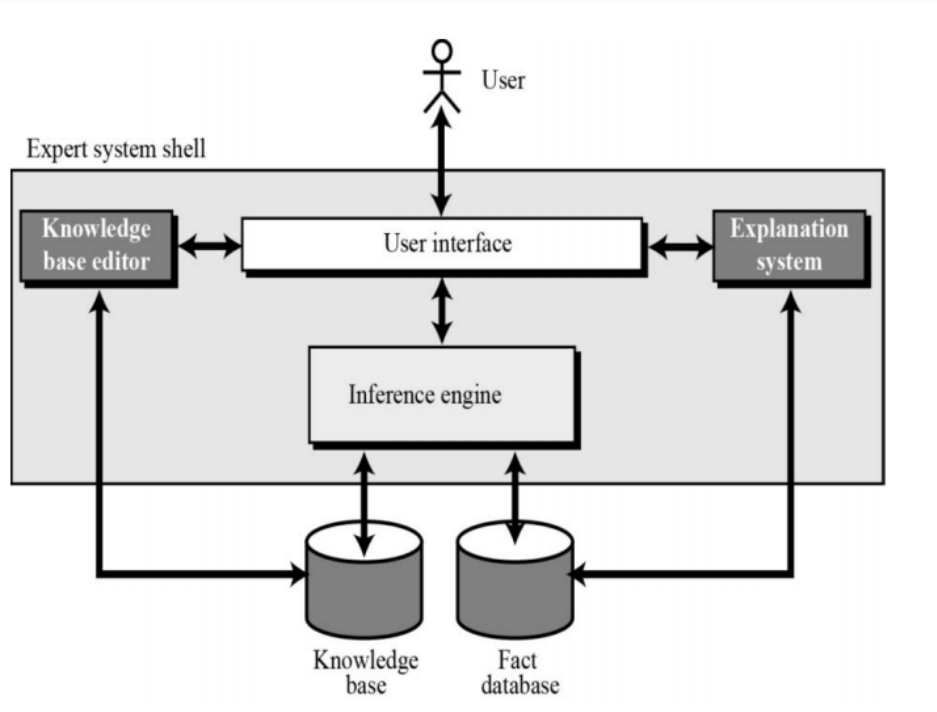


Fig. Architecture of Expert System

- **Knowledge Base**
- **Inference Engine**
- **User Interface**

Components of Expert System/Architecture of ES

Knowledge Base

- It contains domain specific and high quality knowledge, where knowledge is defined as the collection of data, information (data and facts) and past experience.
- Knowledge is required to exhibit intelligence.

Success of Expert System depends on collection of highly accurate and precise knowledge

Components of Knowledge

Knowledge base of Expert System stores factual and heuristic knowledge.

- **Factual Knowledge:** information widely accepted by the knowledge Engineers and scholars in the task domain.
- **Heuristic Knowledge:** It is about practice, accurate judgment , one's ability of evaluation and guessing.

Components of Expert System/Architecture of ES

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Components of Expert System/Architecture of ES

Knowledge Representation: Method used to organize and formalize the knowledge base.

It is the form of IF-THEN-ELSE rules.

Knowledge Acquisition: Expert System majority depends on the quality, completeness and accuracy of the information stored in the knowledge base.

- Knowledge base is formed by reading from various experts, scholars and the knowledge Engineers.
- Knowledge Engineer acquires information from subject expert by recording, interviewing and observing him at work. Etc.
- Knowledge Engineer then categorizes and organizes the information in a meaningful way, in the form of IF-THEN-ELSE rules, to be used by interference machine.
- Knowledge also monitors the development of ES.

2. Inference Engine

- Inference engine is essential in deducting a correct, flawless solution.
- In case of ***Knowledge-based ES***, Inference Engine acquires and manipulates the knowledge from the knowledge base to arrive at a particular solution.
- In case of ***rule based ES***, it-

✓ Applies rules repeatedly to the facts, which are obtained from earlier rule application
✓ Adds new knowledge in the knowledge base if required.
✓ Resolves rules conflict when multiple ruled are applicable to a particular case.

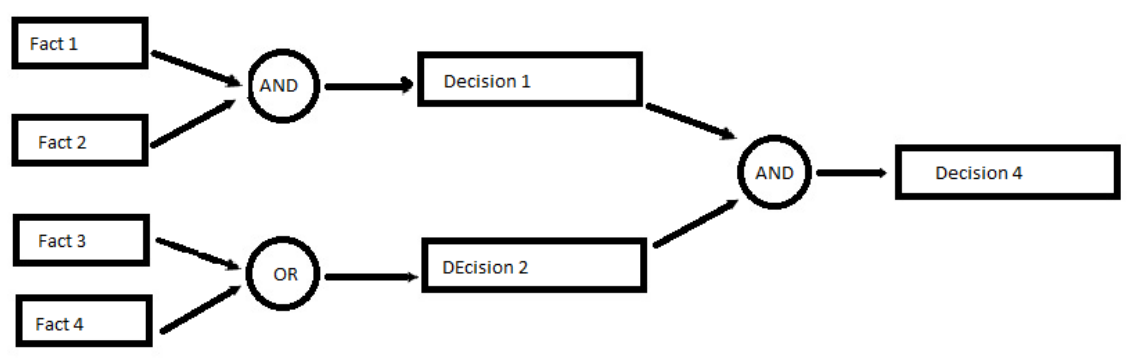
To recommend the solution, the Inference engine uses the following strategies:

✓ Forward Chaining
✓ Backward Chaining

2. Inference Engine

✓ Forward Chaining: It is a strategy to explain the question, “What can happen next?”

This strategy is followed for working on conclusion, result or effect.

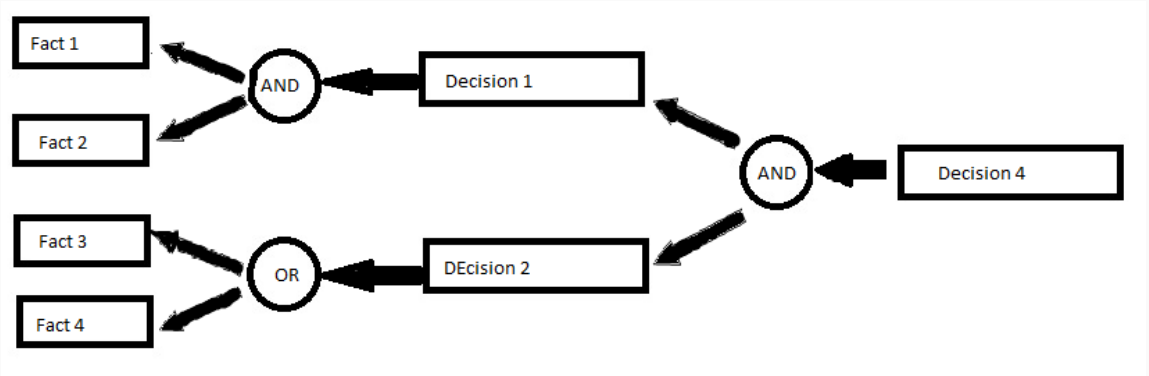


2. Inference Engine

Backward Chaining: It can finds the answer “Why this happened?”

This strategy is used for finding out cause or reason.

For example, diagnosis of blood cancer in humans.



3. User Interface

- It provides interaction between user of ES and ES itself.
- It uses Natural Language Processing
- User need not to be necessarily an expert to use this system
- It explains how an ES has arrived at a particular recommendation.

Development of ES

Step 1: Identify Problem Domain

- Problem must be suitable for an expert system to solve it
- Find the expert in task domain for the ES project.
- Establish cost-effectiveness of the system

Step 2: Design The system

- Identify the ES Technology
- Know and establish the degree if integration with the other systems and databases
- Realize how the concepts can represent the domain knowledge best.

Step 3: Develop the prototype

From Knowledge Base, The Knowledge engineer works to:

- Acquire domain knowledge from the expert.
- Represent it in the form of IF-THEN-ELSE rules

Step 4: Test and Refine the prototype

- The knowledge engineer uses samples cases to test the prototype for any deficiencies in performance.
- End users test the prototypes of ES

Development of ES

Step 5: Develop and Complete the ES

- Test and ensure the interaction of the ES with all elements of its environment, including end users, database, and other information systems
- Document the ES project well
- Train the user to use ES

Step 6: Maintain the ES

- Keep the knowledge base up-to-date regular review and update
- Cater for new interfaces with other information systems, as those systems evolve.

Limitations of Expert System

- Not adopted in highly sophisticated sensory inputs
- Mainly function in the domain of the extracted, cognitive, logical thinking process.
- Multi-dimensional problems from multiple users cannot be faced by ES
- Lack of common-sense knowledge and broad –ranging contextual information
- Very narrow range of knowledge is incorporated in the Expert Systems
- Could not respond to the outside range of the expertise
- Human’s self-awareness is lacking in Expert System.

Applications of Expert System

Application	Description
Design Domain	Camera lens design, automobile design.
Medical Domain	Diagnosis Systems to deduce cause of disease from observed data, conduction medical operations on humans.
Monitoring Systems	Comparing data continuously with observed system or with prescribed behavior such as leakage monitoring in long petroleum pipeline.
Process Control Systems	Controlling a physical process based on monitoring.
Knowledge Domain	Finding out faults in vehicles, computers.
Finance/Commerce	Detection of possible fraud, suspicious transactions, stock market trading, Airline scheduling, cargo scheduling.

Natural Language Processing (NLP)

- Natural Language Processing (NLP) refers to AI method of communicating with an intelligent systems using a natural language such as English.
- The field of NLP involves making computers to perform useful tasks with the natural languages humans use. The input and output of an NLP system can be *speech and written text.*
- Components of NLP = NLU + NLG, where

  NLU: speech/text to meaning

  NLG: meaning to text/speech

Natural Language Understanding (NLU):

Understanding involves the following tasks:

1. Mapping the given input in natural language into useful representations.
2. Analyzing different aspects of the language.

Natural Language Generation (NLG): It is the process of producing meaningful phrases and sentences in the form of natural language from some internal representation.

- Problems in NLP

1. Multiple meaning of words in different places of world. For example: Flat = House (for English man) and Flat = Puncture (for American man).
2. One sentence may have multiple meaning. For example: “I saw Pashupatinath flying over Kathmandu”. This has two meaning that whether Pashupatinath or person is flying.
3. Single word may have multiple meaning. For example: Copy = Notebook or Copy = Transfer data in computer.
4. Language phrases will give separate meaning in combined way and in segmented way. For example: get-rid-off = Release, get = obtain.

NLP Terminology:

Phonology − It is study of organizing sound systematically.

Morphology − It is a study of construction of words from primitive meaningful units.

Morpheme − It is primitive unit of meaning in a language.

Syntax − It refers to arranging words to make a sentence. It also involves determining the structural role of words in the sentence and in phrases.

Semantics − It is concerned with the meaning of words and how to combine words into meaningful phrases and sentences.

Pragmatics − It deals with using and understanding sentences in different situations and how the interpretation of the sentence is affected.

Discourse − It deals with how the immediately preceding sentence can affect the interpretation of the next sentence.

World Knowledge − It includes the general knowledge about the world.

- Phases of NLP

  Speech recognition: including word-spotting, speech separation, sound classification

  Speech coding: Encoding sound wave to binary code

  Speech synthesis: Production of speech by the computer

Natural Language Processing (NLP): Process/ Steps

1. **Lexical Analysis** − It involves identifying and analyzing the structure of words. Lexicon of a language means the collection of words and phrases in a language. Lexical analysis is dividing the whole chunk of txt into paragraphs, sentences, and words.
2. **Syntactic Analysis (Parsing)** − It involves analysis of words in the sentence for grammar and arranging words in a manner that shows the relationship among the words. The sentence such as “The school goes to boy” is rejected by English syntactic analyzer.

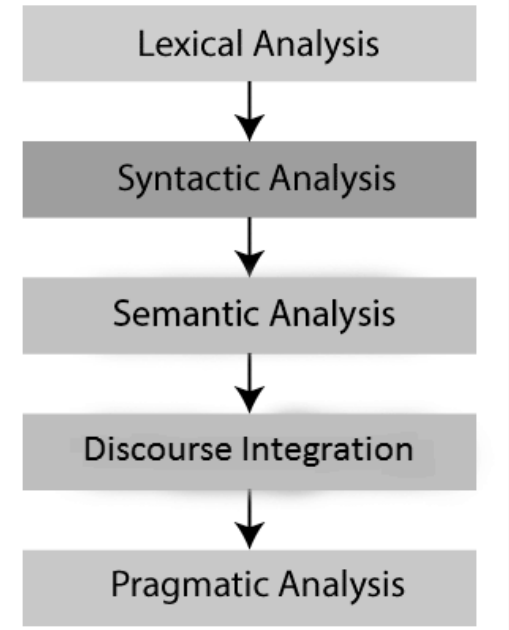


Fig. Steps in NLP

Natural Language Processing (NLP): Process/ Steps

3. **Semantic Analysis** − It draws the exact meaning or the dictionary meaning from the text. The text is checked for meaningfulness. It is done by mapping syntactic structures and objects in the task domain. The semantic analyzer disregards sentence such as “hot ice-cream”.

4. **Discourse Integration** −The meaning of any sentence depends upon the meaning of the sentence just before it. In addition, it also brings about the meaning of immediately succeeding sentence.

5. **Pragmatic Analysis** −During this, what was said is re-interpreted on what it actually meant. It involves deriving those aspects of language which require real world knowledge.

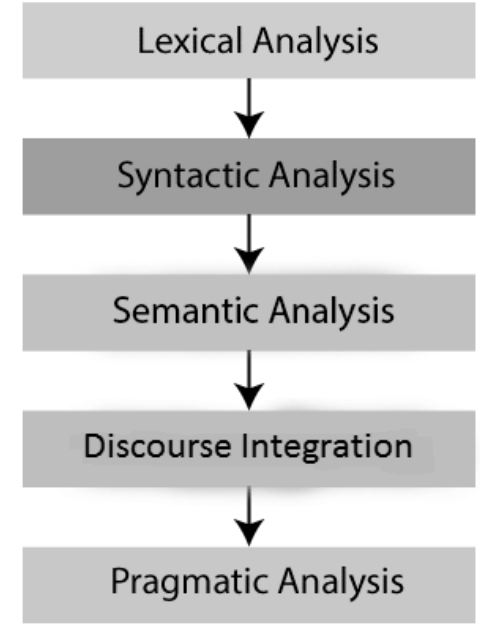


Fig. Steps in NLP

Computer Vision: Machine Vision

- Computer vision is the technology concerned with computational understanding and use of the information present in visual images.
- Computer vision is an interdisciplinary scientific field that deals with how computers can be made to gain high-level understanding from digital images or videos. From the perspective of engineering, it seeks to automate tasks that the human visual system can do.
- Computer vision tasks include methods for acquiring, processing, analyzing and understanding digital images, and extraction of high-dimensional data from the real world in order to produce numerical or symbolic information, e.g., in the forms of decisions.

Machine Vision : Computer Vision

- Image processing is one part of computer vision. Computer vision system uses the image processing algorithms.
- The input image is composed of large numbers of array of pixels and each contains very little information. The individual pixel is meaningless but when we combine similar type of pixel, it will show certain meaningful things. This type of pixel organization for meaningful information is the goal of machine vision.
- In manufacturing, vision based sensing and interpretation system help in automatic inspection such as identification of cracks, holes, and surface roughness, counting of objects, and alignment of parts. The most applicable area of computer vision is the car manufacturing company, X-ray image analysis, satellite image analysis, movement of weather patterns analysis etc.

Machine Vision : Computer Vision

The process of computer vision can be pointed as:

a. Image acquisition: Convert the analog image signal into digital image signal.

b. Image processing: Reduce noise; enhance image, color and gray level adjustment etc.

c. Image analysis: Classify the different objects contained in an image.

d. Image understanding: Recognition of different classified object of an image with their description and relation to other. The object is described according to the predefined information.

Current trends & the future: **Google Assistant**

- Google Assistant was unveiled during Google's developer conference on May 18, 2016.
- Google Assistant is one of the application of natural language processing (NLP).
- Google Assistant is an artificial intelligence-powered virtual assistant developed by Google that is primarily available on mobile and smart home devices. Unlike the company's previous virtual assistant, Google Now, Google Assistant can engage in two-way conversations.
- Users primarily interact with Google Assistant through natural voice, though keyboard input is also supported.

Current trends & the future: **Google Assistant**

- In the same nature and manner as Google Now, the Assistant is able to search the Internet, schedule events and alarms, adjust hardware settings on the user's device, and show information from the user's Google account.
- Google has also announced that the Assistant will be able to identify objects and gather visual information through the device's camera, and support purchasing products and sending money, as well as identifying songs.
- In May 2018, Google revealed Duplex, an extension of Google Assistant that allows it to carry out natural conversations by mimicking human voice.

THANK YOU

Any Queries ?

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