# PNS SCHOOL OF ENGINEERING & TECHNOLOGY

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LECTURE NOTES ON

## *ARTIFICIAL INTELLIGENCE & MACHINE LEARNING*

**DEPARTMENT OF COMPUTER SCIENCE & ENGG.**

**6TH SEMESTER**

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# Detailed Course Content

| Unit No. | Unit Title | Sub-Topics |
|---|---|---|
| 1 | Introduction to Artificial Intelligence (AI) | 1.1 Definition of Artificial Intelligence and History of AI1.2 Goals and Applications of Artificial Intelligence1.3 Intelligent Agents: Concept and Characteristics1.4 Introduction to Computer Vision1.5 Introduction to Natural Language Processing (NLP)1.6 Turing Test1.7 Problem Solving in Games |
| 2 | Introduction to Search Algorithms | 2.1 Search, Search Space, and Search Tree2.2 Categories and Types of Search Algorithms2.3 Heuristic Algorithms versus Solution-Guaranteed Algorithms2.4 Local Search and Optimal Problem Solving Techniques: Hill Climbing, BFS, A*, AO* Algorithms2.5 Adversarial Search2.6 Artificial Intelligence and Game Playing |
| 3 | Knowledge Representation and Reasoning | 3.1 Knowledge and What to Represent3.2 Properties of Knowledge Representation Systems and Approaches3.3 Knowledge Representation Techniques3.4 Reasoning and Types of Reasoning |
| 4 | Machine Learning | 4.1 Introduction to Machine Learning4.2 Statistical / Unsupervised Learning4.3 Properties of Machine Learning4.4 Reinforcement Learning4.5 Decision Tree Algorithm |
| 5 | Pattern Recognition | 5.1 Introduction to Pattern Recognition5.2 Design Principles of Pattern Recognition Systems5.3 Statistical Pattern Recognition Systems5.4 Machine Perception5.5 Line Finding and Interception5.6 Object Identification |
| 6 | Expert Systems | 6.1 Introduction to Expert Systems6.2 Basic Architecture of Expert Systems6.3 Types of Problems Solved by Expert Systems6.4 Features of an Expert System6.5 Expert System Architectures6.6 Expert System Tools6.7 Existing Expert Systems6.8 Applications of Expert System Technology |

# CHAPTER-1

# 1. Introduction to AI

### 1.1 Definition of AI

Artificial intelligence (AI) refers to computer systems capable of performing complex tasks that historically only a human could do, such as reasoning, making decisions, or solving problems.

Artificial intelligence is the simulation of human intelligence processes by machines, especially computer systems. Specific applications of AI include expert systems, natural language processing, speech recognition and machine vision.

**How does AI work?**

As the hype around AI has accelerated, vendors have been scrambling to promote how their products and services use it. Often, what they refer to as AI is simply a component of the technology, such as machine learning. AI requires a foundation of specialized hardware and software for writing and training machine learning algorithms. No single programming language is synonymous with AI, but Python, R, Java, C++ and Julia have features popular with AI developers.

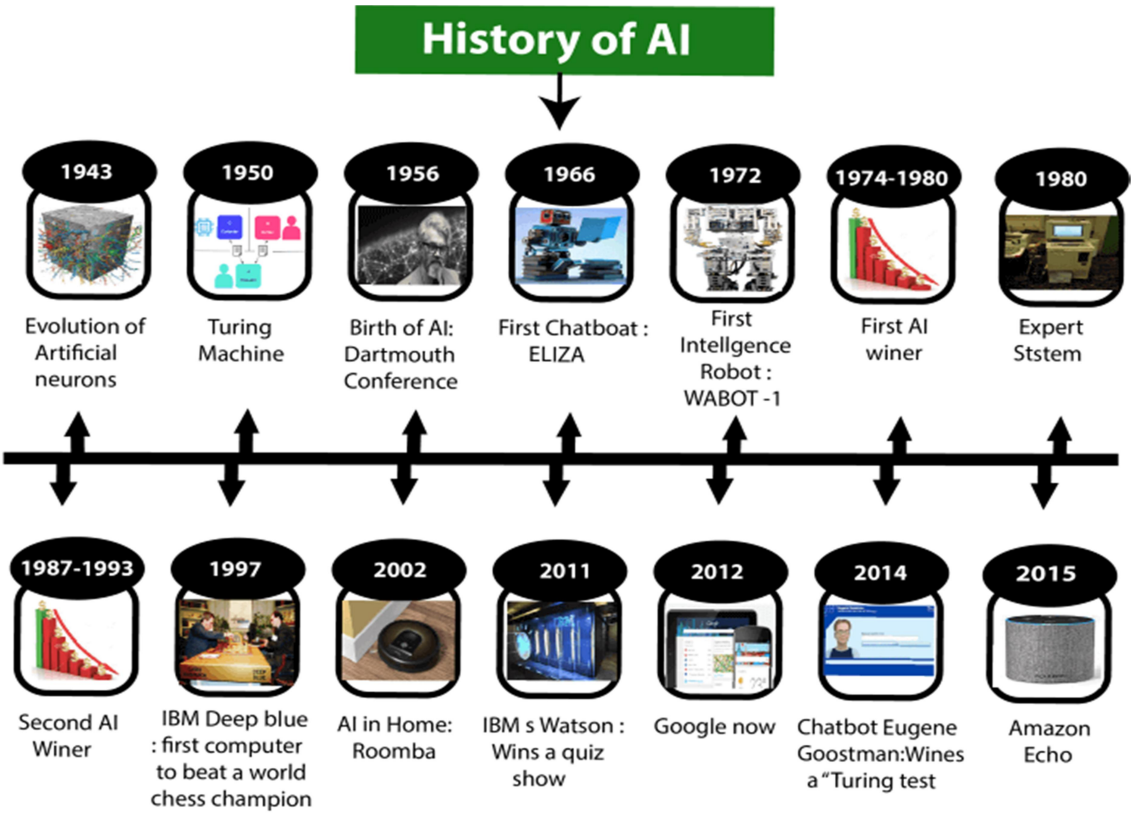
In general, AI systems work by ingesting large amounts of labeled training data, analyzing the data for correlations and patterns, and using these patterns to make predictions about future states. In this way, a chatbot that is fed examples of text can learn to generate lifelike exchanges with people, or an image recognition tool can learn to identify and describe objects in images by reviewing millions of examples. New, rapidly improving generative AI techniques can create realistic text, images, music and other media.

AI programming focuses on cognitive skills that include the following:

- **Learning.** This aspect of AI programming focuses on acquiring data and creating rules for how to turn it into actionable information. The rules, which are called *algorithms*, provide computing devices with step-by-step instructions for how to complete a specific task.
- **Reasoning.** This aspect of AI programming focuses on choosing the right algorithm to reach a desired outcome.
- **Self-correction.** This aspect of AI programming is designed to continually fine-tune algorithms and ensure they provide the most accurate results possible.
- **Creativity.** This aspect of AI uses neural networks, rules-based systems, statistical methods and other AI techniques to generate new images, new text, new music and new ideas.

**History of AI**

Artificial Intelligence is not a new word and not a new technology for researchers. This technology is much older than you would imagine. Even there are the myths of Mechanical men in Ancient Greek and Egyptian Myths. Following are some milestones in the history of AI which defines the journey from the AI generation to till date development.




Maturation of Artificial Intelligence (1943-1952)

- **Year 1943:** The first work which is now recognized as AI was done by Warren McCulloch and Walter pits in 1943. They proposed a model of **artificial neurons**.
- **Year 1949:** Donald Hebb demonstrated an updating rule for modifying the connection strength between neurons. His rule is now called **Hebbian learning**.
- **Year 1950:** The Alan Turing who was an English mathematician and pioneered Machine learning in 1950. Alan Turing publishes **"Computing Machinery and Intelligence"** in which he proposed a test. The test can check the machine's ability to exhibit intelligent behavior equivalent to human intelligence, called a **Turing test**.

The birth of Artificial Intelligence (1952-1956)

- **Year 1955:** An Allen Newell and Herbert A. Simon created the "first artificial intelligence program"Which was named as **"Logic Theorist"**. This program had proved 38 of 52 Mathematics theorems, and find new and more elegant proofs for some theorems.

- **Year 1956:** The word "Artificial Intelligence" first adopted by American Computer scientist John McCarthy at the Dartmouth Conference. For the first time, AI coined as an academic field.

At that time high-level computer languages such as FORTRAN, LISP, or COBOL were invented. And the enthusiasm for AI was very high at that time.

The golden years-Early enthusiasm (1956-1974)

- **Year 1966:** The researchers emphasized developing algorithms which can solve mathematical problems. Joseph Weizenbaum created the first chatbot in 1966, which was named as ELIZA.
- **Year 1972:** The first intelligent humanoid robot was built in Japan which was named as WABOT-1.

The first AI winter (1974-1980)

- The duration between years 1974 to 1980 was the first AI winter duration. AI winter refers to the time period where computer scientist dealt with a severe shortage of funding from government for AI researches.
- During AI winters, an interest of publicity on artificial intelligence was decreased.

A boom of AI (1980-1987)

- **Year 1980:** After AI winter duration, AI came back with "Expert System". Expert systems were programmed that emulate the decision-making ability of a human expert.
- In the Year 1980, the first national conference of the American Association of Artificial Intelligence **was held at Stanford University**.

The second AI winter (1987-1993)

- The duration between the years 1987 to 1993 was the second AI Winter duration.
- Again Investors and government stopped in funding for AI research as due to high cost but not efficient result. The expert system such as XCON was very cost effective.

The emergence of intelligent agents (1993-2011)

- **Year 1997:** In the year 1997, IBM Deep Blue beats world chess champion, Gary Kasparov, and became the first computer to beat a world chess champion.
- **Year 2002:** for the first time, AI entered the home in the form of Roomba, a vacuum cleaner.
- **Year 2006:** AI came in the Business world till the year 2006. Companies like Facebook, Twitter, and Netflix also started using AI.

Deep learning, big data and artificial general intelligence (2011-present)

- **Year 2011:** In the year 2011, IBM's Watson won jeopardy, a quiz show, where it had to solve the complex questions as well as riddles. Watson had proved that it could understand natural language and can solve tricky questions quickly.
- **Year 2012:** Google has launched an Android app feature "Google now", which was able to provide information to the user as a prediction.
- **Year 2014:** In the year 2014, Chatbot "Eugene Goostman" won a competition in the infamous "Turing test."
- **Year 2018:** The "Project Debater" from IBM debated on complex topics with two master debaters and also performed extremely well.
- Google has demonstrated an AI program "Duplex" which was a virtual assistant and which had taken hairdresser appointment on call, and lady on other side didn't notice that she was talking with the machine.

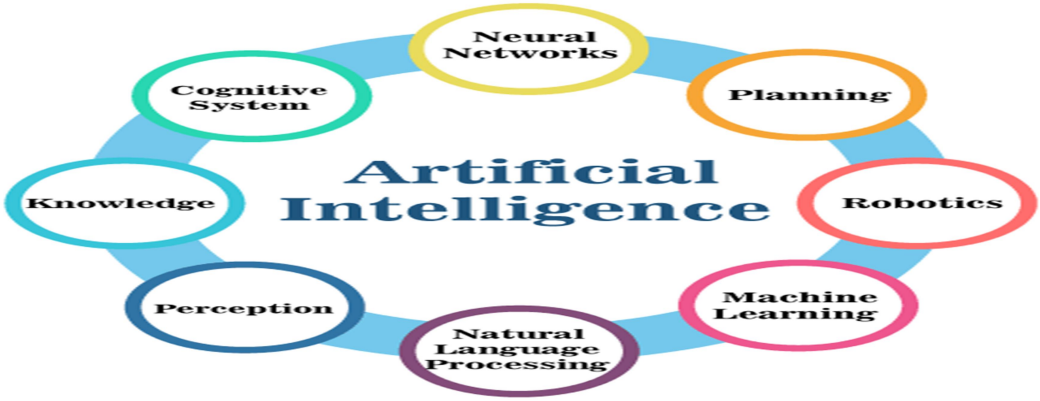
Now AI has developed to a remarkable level. The concept of Deep learning, big data, and data science are now trending like a boom. Nowadays companies like Google, Facebook, IBM, and Amazon are working with AI and creating amazing devices. The future of Artificial Intelligence is inspiring and will come with high intelligence.

**1.2 Goals and Applications of AI**

AI can be achieved by reading the behaviour of humans and using the results to develop intelligent systems. For example, they learn, make decisions and act in certain situations. Observing humans while problem-solving in simple tasks and using its results to develop intelligent systems.

The overall research goal of artificial intelligence is to create technology that allows computers and machines to work intelligently. The general problem of simulating (or creating) intelligence is broken down into sub-problems.

The symptoms described below receive the most attention. These include special traits or abilities that researchers expect an intelligent system to exhibit. Eric Sandwell emphasizes planning and learning that is relevant and applicable to the given situation.



- **Logic, problem-solving**: Early researchers developed algorithms that simulate humans' step-by-step reasoning when solving puzzles or making logical deductions. By the late 1980s and 1990s, AI research had developed methods for dealing with uncertain or incomplete information, employing concepts from probability and economics. For difficult problems, algorithms can require enormous computational resources-most experience a "**combinatorial explosion**": the amount of memory or computer time needed for problems of a certain size becomes astronomical. The search for more efficient problem-solving algorithms is a high priority.
- **Knowledge representation**: Knowledge representation and knowledge engineering are central to AI research. Many of the problems that machines are expected to solve will require extensive world knowledge. The things AI needs to represent are objects, properties, categories, and relationships between objects; situations, events, states, and times; Cause and Effect; Knowledge about knowledge (what other people know about what we know); and many other, less well-researched domains.
  A representation of "what exists" is an ontology: the set of **objects, relations**, concepts, and so on about which the machine knows. The most general is upper ontology, which attempts to provide a foundation for all other knowledge.
- **Planning**: Intelligent agents must be able to set goals and achieve them. They need a way to envision the future - a representation of the state of the world and make predictions about how their actions will change it - and be able to make choices that maximize the utility (or "**value**") of the options available.
  In classical planning problems, the agent can assume that it is the only system acting in the world, allowing the agent to be certain of the consequences of its actions. However, if the agent is not the only actor, it requires that the agent reason under uncertainty. It calls for an agent to assess its environment, make predictions, evaluate its predictions, and adapt based on its assessment.
- **Learning**: Machine learning, a fundamental concept of AI research since the field's inception, is the study of computer algorithms that automatically improve through experience. Unsupervised learning is the ability to find patterns in a stream of input. Supervised learning includes both classification and numerical regression. After seeing several examples of things from several categories, classification is used to determine which category something falls into. Regression attempts to construct a function that describes the relationship between inputs and outputs and predicts how the outputs should change as the inputs change.
- **Social Intelligence**: Effective computing is the study and development of systems that can detect, interpret, process, and simulate human It is an interdisciplinary field spanning computer science, psychology, and cognitive science. While the origins of the field can be traced to early philosophical inquiries into emotion, the more modern branch of computer science originated from Rosalind Picard's **1995** paper on "**effective computing**".
- **Creativity**: A sub-field of AI addresses creativity theoretically (philosophical, psychological perspective) and practically (the specific implementation of systems that produce novel and useful outputs). Some related areas of computational research include artificial intuition and artificial thinking.
- **General Intelligence**: Many researchers think that their work will eventually result in a machine with artificial general intelligence, combining all the skills described above and exceeding human capacity in most or all of these areas. Some believe that such a project may require anthropomorphic features such as artificial consciousness or an artificial brain.

**Application of AI**

Artificial Intelligence has various applications in today's society. It is becoming essential for today's time because it can solve complex problems with an efficient way in multiple industries, such as Healthcare, entertainment, finance, education, etc. AI is making our daily life more comfortable and fast.

Following are some sectors which have the application of Artificial Intelligence:


1. AI in Astronomy

   - Artificial Intelligence can be very useful to solve complex universe problems. AI technology can be helpful for understanding the universe such as how it works, origin, etc.

2. AI in Healthcare

   - In the last, five to ten years, AI becoming more advantageous for the healthcare industry and going to have a significant impact on this industry.
   - Healthcare Industries are applying AI to make a better and faster diagnosis than humans. AI can help doctors with diagnoses and can inform when patients are worsening so that medical help can reach to the patient before hospitalization.

3. AI in Gaming

   - AI can be used for gaming purpose. The AI machines can play strategic games like chess, where the machine needs to think of a large number of possible places.

4. AI in Finance

   - AI and finance industries are the best matches for each other. The finance industry is implementing automation, chatbot, adaptive intelligence, algorithm trading, and machine learning into financial processes.

5. AI in Data Security

- The security of data is crucial for every company and cyber-attacks are growing very rapidly in the digital world. AI can be used to make your data more safe and secure. Some examples such as AEG bot, AI2 Platform,are used to determine software bug and cyber-attacks in a better way.

6. AI in Social Media

- Social Media sites such as Facebook, Twitter, and Snapchat contain billions of user profiles, which need to be stored and managed in a very efficient way. AI can organize and manage massive amounts of data. AI can analyze lots of data to identify the latest trends, hashtag, and requirement of different users.

7. AI in Travel & Transport

- AI is becoming highly demanding for travel industries. AI is capable of doing various travel related works such as from making travel arrangement to suggesting the hotels, flights, and best routes to the customers. Travel industries are using AI-powered chatbots which can make human-like interaction with customers for better and fast response.

8. AI in Automotive Industry

- Some Automotive industries are using AI to provide virtual assistant to their user for better performance. Such as Tesla has introduced TeslaBot, an intelligent virtual assistant.
- Various Industries are currently working for developing self-driven cars which can make your journey more safe and secure.

9. AI in Robotics:

- Artificial Intelligence has a remarkable role in Robotics. Usually, general robots are programmed such that they can perform some repetitive task, but with the help of AI, we can create intelligent robots which can perform tasks with their own experiences without pre-programmed.
- Humanoid Robots are best examples for AI in robotics, recently the intelligent Humanoid robot named as Erica and Sophia has been developed which can talk and behave like humans.

10. AI in Entertainment

- We are currently using some AI based applications in our daily life with some entertainment services such as Netflix or Amazon. With the help of ML/AI algorithms, these services show the recommendations for programs or shows.

11. AI in Agriculture

- Agriculture is an area which requires various resources, labor, money, and time for best result. Now a day's agriculture is becoming digital, and AI is emerging in this field. Agriculture is applying AI as agriculture robotics, solid and crop monitoring, predictive analysis. AI in agriculture can be very helpful for farmers.

12. AI in E-commerce

- AI is providing a competitive edge to the e-commerce industry, and it is becoming more demanding in the e-commerce business. AI is helping shoppers to discover associated products with recommended size, color, or even brand.

13. AI in education:

- AI can automate grading so that the tutor can have more time to teach. AI chatbot can communicate with students as a teaching assistant.
- AI in the future can be work as a personal virtual tutor for students, which will be accessible easily at any time and any place.

1.3 Intelligent agent

**Agents in Artificial Intelligence**

An AI system can be defined as the study of the rational agent and its environment. The agents sense the environment through sensors and act on their environment through actuators. An AI agent can have mental properties such as knowledge, belief, intention, etc.

What is an Agent?

An agent can be anything that perceiveits environment through sensors and act upon that environment through actuators. An Agent runs in the cycle of **perceiving**, **thinking**, and **acting**. An agent can be:

- **Human-Agent:** A human agent has eyes, ears, and other organs which work for sensors and hand, legs, vocal tract work for actuators.
- **Robotic Agent:** A robotic agent can have cameras, infrared range finder, NLP for sensors and various motors for actuators.
- **Software Agent:** Software agent can have keystrokes, file contents as sensory input and act on those inputs and display output on the screen.

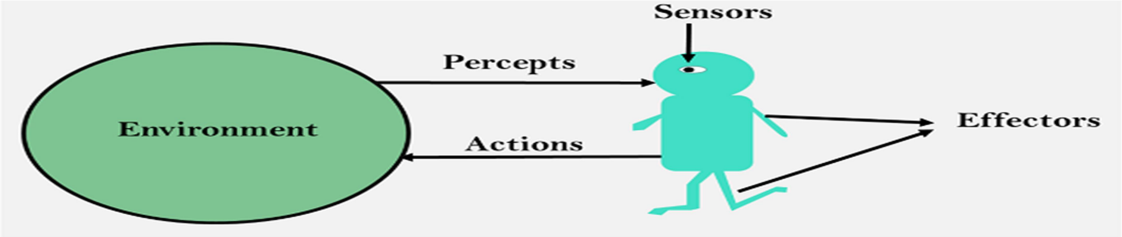
Hence the world around us is full of agents such as thermostat, cellphone, camera, and even we are also agents.

we should first know about sensors, effectors, and actuators.

**Sensor:** Sensor is a device which detects the change in the environment and sends the information to other electronic devices. An agent observes its environment through sensors.

**Actuators:** Actuators are the component of machines that converts energy into motion. The actuators are only responsible for moving and controlling a system. An actuator can be an electric motor, gears, rails, etc.

**Effectors:** Effectors are the devices which affect the environment. Effectors can be legs, wheels, arms, fingers, wings, fins, and display screen.




Intelligent Agents:

An intelligent agent is an autonomous entity which act upon an environment using sensors and actuators for achieving goals. An intelligent agent may learn from the environment to achieve their goals. A thermostat is an example of an intelligent agent.

Following are the main four rules for an AI agent:

- **Rule 1:** An AI agent must have the ability to perceive the environment.
- **Rule 2:** The observation must be used to make decisions.
- **Rule 3:** Decision should result in an action.
- **Rule 4:** The action taken by an AI agent must be a rational action.

Rational Agent:

A rational agent is an agent which has clear preference, models uncertainty, and acts in a way to maximize its performance measure with all possible actions.

A rational agent is said to perform the right things. AI is about creating rational agents to use for game theory and decision theory for various real-world scenarios.

For an AI agent, the rational action is most important because in AI reinforcement learning algorithm, for each best possible action, agent gets the positive reward and for each wrong action, an agent gets a negative reward.

Rationality:

The rationality of an agent is measured by its performance measure. Rationality can be judged on the basis of following points:

- Performance measure which defines the success criterion.
- Agent prior knowledge of its environment.
- Best possible actions that an agent can perform.
- The sequence of percepts.

Structure of an AI Agent

The task of AI is to design an agent program which implements the agent function. The structure of an intelligent agent is a combination of architecture and agent program. It can be viewed as:

1. Agent = Architecture + Agent program

Following are the main three terms involved in the structure of an AI agent:

**Architecture:** Architecture is machinery that an AI agent executes on.

**Agent Function:** Agent function is used to map a percept to an action.

1. $f:P^* \rightarrow A$

**Agent program:** Agent program is an implementation of agent function. An agent program executes on the physical architecture to produce function f.

PEAS Representation

PEAS is a type of model on which an AI agent works upon. When we define an AI agent or rational agent, then we can group its properties under PEAS representation model. It is made up of four words:

- **P:** Performance measure
- **E:** Environment
- **A:** Actuators
- **S:** Sensors

Here performance measure is the objective for the success of an agent's behaviour.

Let's suppose a self-driving car then PEAS representation will be:

**Performance:** Safety, time, legal drive, comfort

**Environment:** Roads, other vehicles, road signs, pedestrian

**Actuators:** Steering, accelerator, brake, signal, horn

**Sensors:** Camera, GPS, speedometer, odometer, accelerometer, sonar.

**1.4 Computer vision**

What is Computer Vision?

***Computer vision is one of the most important fields of artificial intelligence (AI) and computer science engineering that makes computer systems capable of extracting***

***meaningful information from visual data like videos and images.*** Further, it also helps to take appropriate actions and make recommendations based on the extracted information.

Further, Artificial intelligence is the branch of computer science that primarily deals with creating a smart and intelligent system that can behave and think like the human brain. So, we can say if artificial intelligence enables computer systems to think intelligently, computer vision makes them capable of seeing, analyzing, and understanding.

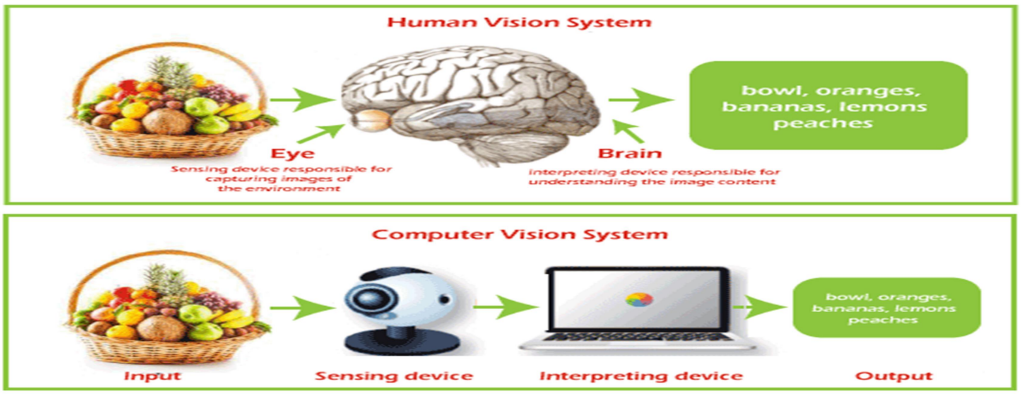
History of Computer Vision

Computer vision is not a new technology because scientists and experts have been trying to develop machines that can see and understand visual data for almost six decades. The evolution of computer vision is classified as follows:

- **1959:** The first experiment with computer vision was initiated in 1959, where they showed a cat as an array of images. Initially, they found that the system reacts first to hard edges or lines, and scientifically, this means that image processing begins with simple shapes such as straight edges.
- **1960:** In 1960, artificial intelligence was added as a field of academic study to solve human vision problems.
- **1963:** This was another great achievement for scientists when they developed computers that could transform 2D images into 3-D images.
- **1974:** This year, optical character recognition (OCR) and intelligent character recognition (ICR) technologies were successfully discovered. The OCR has solved the problem of recognizing text printed in any font or typeface, whereas ICR can decrypt handwritten text. These inventions are one of the greatest achievements in document and invoice processing, vehicle number plate recognition, mobile payments, machine translation, etc.
- **1982:** In this year, the algorithm was developed to detect edges, corners, curves, and other shapes. Further, scientists also developed a network of cells that could recognize patterns.
- **2000:** In this year, scientists worked on a study of object recognition.
- **2001:** The first real-time face recognition application was developed.
- **2010:** The ImageNet data set became available to use with millions of tagged images, which can be considered the foundation for recent Convolutional Neural Network (CNN) and deep learning models.
- **2012:** CNN has been used as an image recognition technology with a reduced error rate.
- **2014:** COCO has also been developed to offer a dataset for object detection and support future research.

How does Computer Vision Work?

Computer vision is a technique that extracts information from visual data, such as images and videos. Although computer vision works similarly to human eyes with brain work, this is probably one of the biggest open questions for IT professionals: How does the human brain operate and solve visual object recognition?

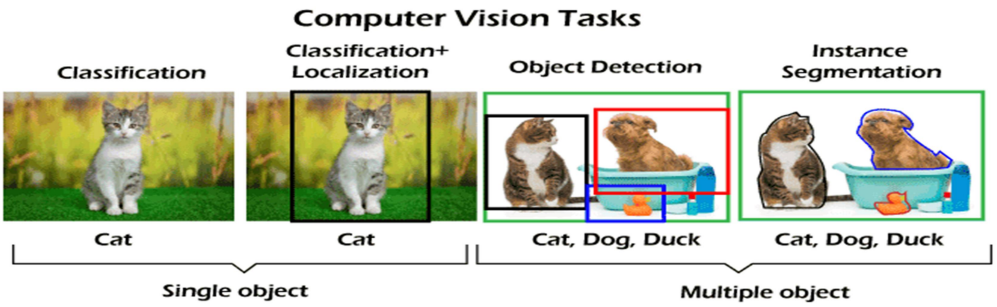



On a certain level, computer vision is all about pattern recognition which includes the training process of machine systems for understanding the visual data such as images and videos, etc.

Firstly, a vast amount of visual labeled data is provided to machines to train it. This labeled data enables the machine to analyze different patterns in all the data points and can relate to those labels. E.g., suppose we provide visual data of millions of dog images. In that case, the computer learns from this data, analyzes each photo, shape, the distance between each shape, color, etc., and hence identifies patterns similar to dogs and generates a model. As a result, this computer vision model can now accurately detect whether the image contains a dog or not for each input image.

Task Associated with Computer Vision

Although computer vision has been utilized in so many fields, there are a few common tasks for computer vision systems. These tasks are given below:




- **Object classification: Object classification is a** computer vision technique/task used to classify an image, such as whether an image contains a dog, a person's face, or a banana. It analyzes the visual content (videos & images) and classifies the object into the defined category. It means that we can accurately **predict the class of an object present in an image with image classification.**
- **Object Identification/detection:** Object identification or detection uses image classification to identify and locate the objects in an image or video. With such detection and identification technique, the system can count objects in a given image or scene and determine their accurate location and labeling. For example, in a given

image, one dog, one cat, and one duck can be easily detected and classified using the object detection technique.

- **Object Verification:** The system processes videos, finds the objects based on search criteria, and tracks their movement.
- **Object Landmark Detection:** The system defines the key points for the given object in the image data.
- **Image Segmentation:** Image segmentation not only detects the classes in an image as image classification; instead, it classifies each pixel of an image to specify what objects it has. It tries to determine the role of each pixel in the image.
- **Object Recognition:** In this, the system recognizes the object's location with respect to the image.

### 1.5 Natural Language Processing

It is a field of Artificial Intelligence (AI) and Computer Science that is concerned with the interactions between computers and humans in natural language. The goal of NLP is to develop algorithms and models that enable computers to understand, interpret, generate, and manipulate human languages.

**Common Natural Language Processing (NLP) Task:**

- **Text and speech processing:** This includes Speech recognition, text-&-speech processing, encoding(i.e converting speech or text to machine-readable language), etc.
- **Text classification:** This includes Sentiment Analysis in which the machine can analyze the qualities, emotions, and sarcasm from text and also classify it accordingly.
- **Language generation:** This includes tasks such as machine translation, summary writing, essay writing, etc. which aim to produce coherent and fluent text.
- **Language interaction:** This includes tasks such as dialogue systems, voice assistants, and chatbots, which aim to enable natural communication between humans and computers.

NLP techniques are widely used in a variety of applications such as search engines, machine translation, sentiment analysis, text summarization, question answering, and many more. NLP research is an active field and recent advancements in deep learning have led to significant improvements in NLP performance.

Components of NLP

There are two components of NLP as given −

Natural Language Understanding (NLU)

Understanding involves the following tasks −

- Mapping the given input in natural language into useful representations.

- 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.

It involves −

- **Text planning** − It includes retrieving the relevant content from knowledge base.
- **Sentence planning** − It includes choosing required words, forming meaningful phrases, setting tone of the sentence.
- **Text Realization** − It is mapping sentence plan into sentence structure.

The NLU is harder than NLG.

Difficulties in NLU

NL has an extremely rich form and structure.

It is very ambiguous. There can be different levels of ambiguity −

- **Lexical ambiguity** − It is at very primitive level such as word-level.
- For example, treating the word “board” as noun or verb?
- **Syntax Level ambiguity** − A sentence can be parsed in different ways.
- For example, “He lifted the beetle with red cap.” − Did he use cap to lift the beetle or he lifted a beetle that had red cap?
- **Referential ambiguity** − Referring to something using pronouns. For example, Rima went to Gauri. She said, “I am tired.” − Exactly who is tired?
- One input can mean different meanings.
- Many inputs can mean the same thing.

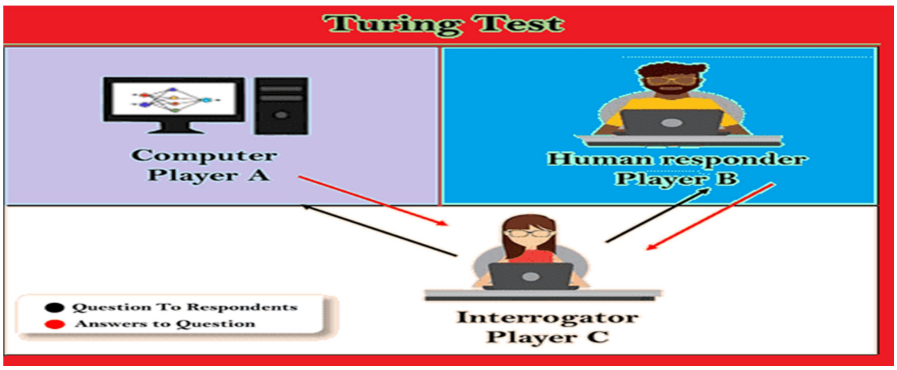
1.6 Turing test

In 1950, Alan Turing introduced a test to check whether a machine can think like a human or not, this test is known as the Turing Test. In this test, Turing proposed that the computer can be said to be an intelligent if it can mimic human response under specific conditions.

Turing Test was introduced by Turing in his 1950 paper, "Computing Machinery and Intelligence," which considered the question, "Can Machine think?"

The basic idea of the Turing Test is simple: a human judge engages in a text-based conversation with both a human and a machine, and then decides which of the two they believe to be a human. If the judge is unable to distinguish between the human and the machine based on the conversation, then the machine is said to have passed the Turing Test.

The Turing Test is widely used as a benchmark for evaluating the progress of artificial intelligence research, and has inspired numerous studies and experiments aimed at developing machines that can pass the test.




A modified version of the party game "Imitation game" serves as the basis for the Turing test. There are three players in this game: one is a computer, another is a human responder, and the third is a human interrogator who is separated from the other two players and whose task is to determine which of the two is a machine.

Because all players communicate via keyboard and screen, the outcome is unaffected by the machine's capacity to transform words into speech.

The exam result is determined not by the number of correct answers, but by how closely the responses resemble those of a human. The computer is allowed to do whatever it can to force the interrogator to make a false identification.

The questions and answers can be like:

**Interrogator:** Are you a computer?

**Player A (Computer):** No

**Interrogator:** Multiply two large numbers such as (256896489*456725896)

**Player A:** Long pause and give the wrong answer.

If an interrogator is unable to distinguish between a machine and a human in this game, the computer passes the test, and the machine is said to be intelligent and capable of thinking like a human.

**1.7 Problem solving in Games**

- **Problem Solving in games such as "Sudoku" can be an example. It can be done by building an artificially intelligent system to solve that particular problem. To do this, one needs to define the problem statements first and then generating the solution by keeping the conditions in mind.**
- **Some of the most popularly used problem solving with the help of artificial intelligence are:**
    1. **Chess.**
    2. **Travelling Salesman Problem.**

3. **Tower of Hanoi Problem.**
4. **Water-Jug Problem.**
5. **N-Queen Problem.**

**Problem Searching**

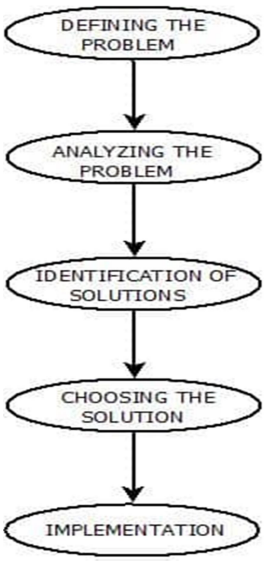
- **In general, searching refers to as finding information one needs.**
- **Searching is the most commonly used technique of problem solving in artificial intelligence.**
- **The searching algorithm helps us to search for solution of particular problem.**

**Problem**

- **Problems are the issues which comes across any system. A solution is needed to solve that particular problem.**

**Steps : Solve Problem Using Artificial Intelligence**

- **The process of solving a problem consists of five steps. These are:**




Problem Solving in Artificial Intelligence

1. Defining The Problem: The definition of the problem must be included precisely. It should contain the possible initial as well as final situations which should result in acceptable solution.
2. Analyzing The Problem: Analyzing the problem and its requirement must be done as few features can have immense impact on the resulting solution.
3. Identification Of Solutions: This phase generates reasonable amount of solutions to the given problem in a particular range.

4. Choosing a Solution: From all the identified solutions, the best solution is chosen basis on the results produced by respective solutions.
5. Implementation: After choosing the best solution, its implementation is done.

# 2. Introduction to Search Algorithm

### 2.1 Search, Search space, Search Tree

Searching is the universal technique of problem solving in AI. There are some single-player games such as tile games, Sudoku, crossword, etc. The search algorithms help you to search for a particular position in such games.

Problem-solving agents:

In Artificial Intelligence, Search techniques are universal problem-solving methods. **Rational agents** or **Problem-solving agents** in AI mostly used these search strategies or algorithms to solve a specific problem and provide the best result. Problem-solving agents are the goal-based agents and use atomic representation. In this topic, we will learn various problem-solving search algorithms.

Search Algorithm Terminologies:

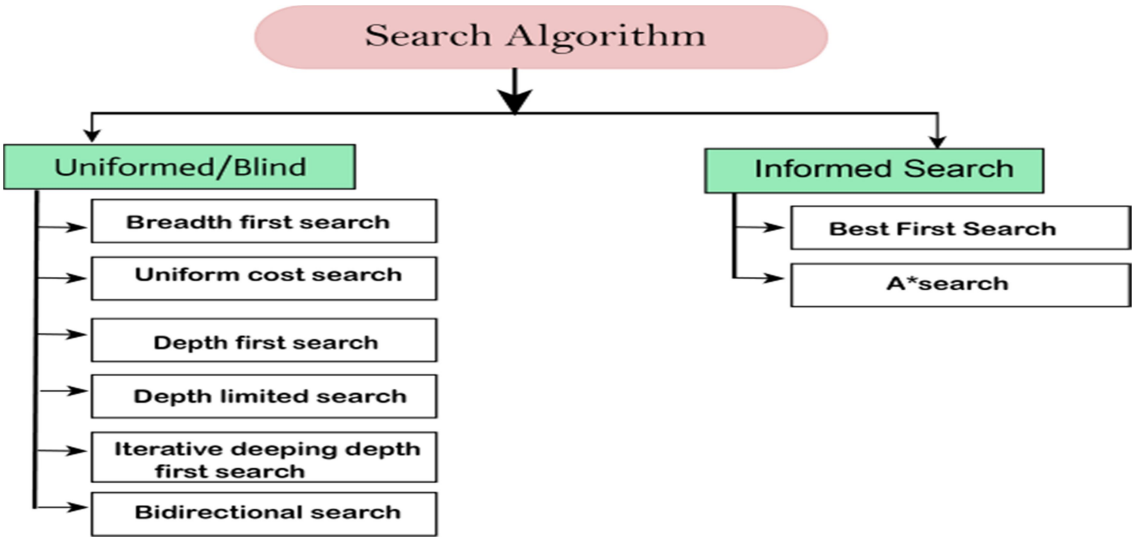
- **Search:** Searchingis a step by step procedure to solve a search-problem in a given search space. A search problem can have three main factors:
    a. **Search Space:** Search space represents a set of possible solutions, which a system may have.
    b. **Start State:** It is a state from where agent begins **the search**.
    c. **Goal test:** It is a function which observe the current state and returns whether the goal state is achieved or not.
- **Search tree:** A tree representation of search problem is called Search tree. The root of the search tree is the root node which is corresponding to the initial state.
- **Actions:** It gives the description of all the available actions to the agent.
- **Transition model:** A description of what each action do, can be represented as a transition model.
- **Path Cost:** It is a function which assigns a numeric cost to each path.
- **Solution:** It is an action sequence which leads from the start node to the goal node.
- **Optimal Solution:** If a solution has the lowest cost among all solutions.

- Properties of Search Algorithms:

- Following are the four essential properties of search algorithms to compare the efficiency of these algorithms:
- **Completeness:** A search algorithm is said to be complete if it guarantees to return a solution if at least any solution exists for any random input.
- **Optimality:** If a solution found for an algorithm is guaranteed to be the best solution (lowest path cost) among all other solutions, then such a solution for is said to be an optimal solution.
- **Time Complexity:** Time complexity is a measure of time for an algorithm to complete its task.
- **Space Complexity:** It is the maximum storage space required at any point during the search, as the complexity of the problem.

**2.2 Categories and Types of Search**

**Based on the search problems we can classify the search algorithms into uninformed (Blind search) search and informed search (Heuristic search) algorithms.**




**Uninformed/Blind Search:**

The uninformed search does not contain any domain knowledge such as closeness, the location of the goal. It operates in a brute-force way as it only includes information about how to traverse the tree and how to identify leaf and goal nodes. Uninformed search applies a way in which search tree is searched without any information about the search space like initial state operators and test for the goal, so it is also called blind search.It examines each node of the tree until it achieves the goal node.

**It can be divided into 6 main types:**

1. **Breadth-first Search**
2. **Depth-first Search**
3. **Depth-limited Search**

4. **Iterative deepening depth-first search**
5. **Uniform cost search**
6. **Bidirectional Search**

1. Breadth-first Search:

- Breadth-first search is the most common search strategy for traversing a tree or graph. This algorithm searches breadthwise in a tree or graph, so it is called breadth-first search.
- BFS algorithm starts searching from the root node of the tree and expands all successor node at the current level before moving to nodes of next level.
- The breadth-first search algorithm is an example of a general-graph search algorithm.
- Breadth-first search implemented using FIFO queue data structure.

**Advantages:**

- BFS will provide a solution if any solution exists.
- If there are more than one solutions for a given problem, then BFS will provide the minimal solution which requires the least number of steps.

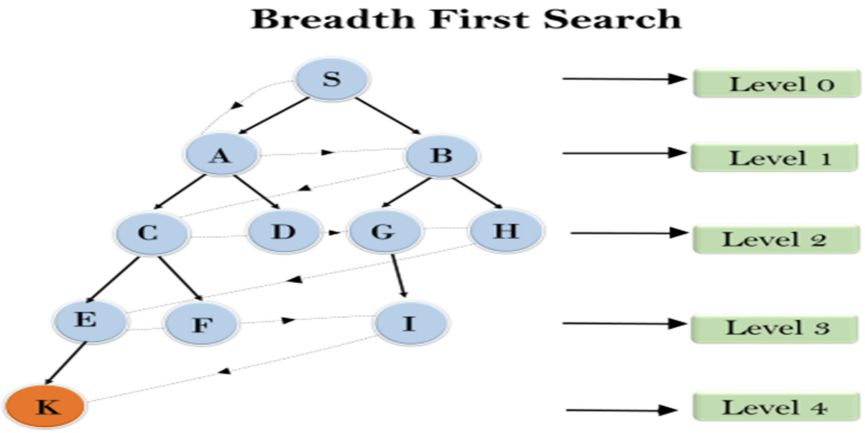
Disadvantages:

- It requires lots of memory since each level of the tree must be saved into memory to expand the next level.
- BFS needs lots of time if the solution is far away from the root node.

Example:

In the below tree structure, we have shown the traversing of the tree using BFS algorithm from the root node S to goal node K. BFS search algorithm traverse in layers, so it will follow the path which is shown by the dotted arrow, and the traversed path will be:

1. S---> A--->B---->C--->D----->G--->H--->E----->F----->I----->K




**Time Complexity:** Time Complexity of BFS algorithm can be obtained by the number of nodes traversed in BFS until the shallowest Node. Where the d= depth of shallowest solution and b is a node at every state.

**$T(b) = 1+b^2+b^3+.....+ b^d = O(b^d)$**

**Space Complexity:** Space complexity of BFS algorithm is given by the Memory size of frontier which is $O(b^d)$.

**Completeness:** BFS is complete, which means if the shallowest goal node is at some finite depth, then BFS will find a solution.

**Optimality:** BFS is optimal if path cost is a non-decreasing function of the depth of the node.

2. Depth-first Search

- Depth-first search isa recursive algorithm for traversing a tree or graph data structure.
- It is called the depth-first search because it starts from the root node and follows each path to its greatest depth node before moving to the next path.
- DFS uses a stack data structure for its implementation.
- The process of the DFS algorithm is similar to the BFS algorithm.

***Note: Backtracking is an algorithm technique for finding all possible solutions using recursion.***

**Advantage:**

- DFS requires very less memory as it only needs to store a stack of the nodes on the path from root node to the current node.
- It takes less time to reach to the goal node than BFS algorithm (if it traverses in the right path).

**Disadvantage:**

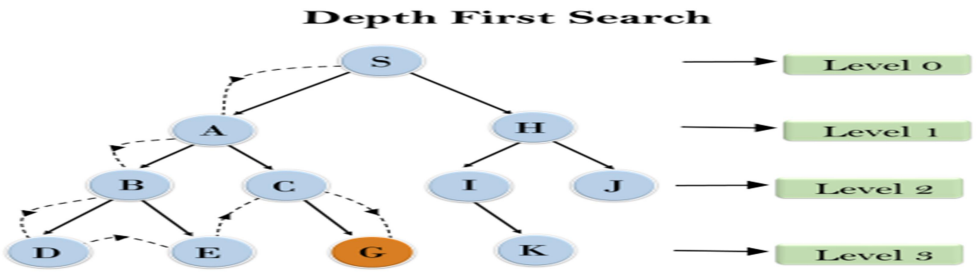
- There is the possibility that many states keep re-occurring, and there is no guarantee of finding the solution.
- DFS algorithm goes for deep down searching and sometime it may go to the infinite loop.

Example:

In the below search tree, we have shown the flow of depth-first search, and it will follow the order as:

Root node--->Left node ----> right node.

It will start searching from root node S, and traverse A, then B, then D and E, after traversing E, it will backtrack the tree as E has no other successor and still goal node is not found. After backtracking it will traverse node C and then G, and here it will terminate as it found goal node.




**Completeness:** DFS search algorithm is complete within finite state space as it will expand every node within a limited search tree.

**Time Complexity:** Time complexity of DFS will be equivalent to the node traversed by the algorithm. It is given by:

**$T(n)= 1+ n^2+ n^3 +.....+ n^m=O(n^m)$**

**Where, m= maximum depth of any node and this can be much larger than d (Shallowest solution depth)**

**Space Complexity:** DFS algorithm needs to store only single path from the root node, hence space complexity of DFS is equivalent to the size of the fringe set, which is **O(bm)**.

**Optimal:** DFS search algorithm is non-optimal, as it may generate a large number of steps or high cost to reach to the goal node.

3. Depth-Limited Search Algorithm:

A depth-limited search algorithm is similar to depth-first search with a predetermined limit. Depth-limited search can solve the drawback of the infinite path in the Depth-first search. In this algorithm, the node at the depth limit will treat as it has no successor nodes further.

Depth-limited search can be terminated with two Conditions of failure:

- Standard failure value: It indicates that problem does not have any solution.
- Cutoff failure value: It defines no solution for the problem within a given depth limit.

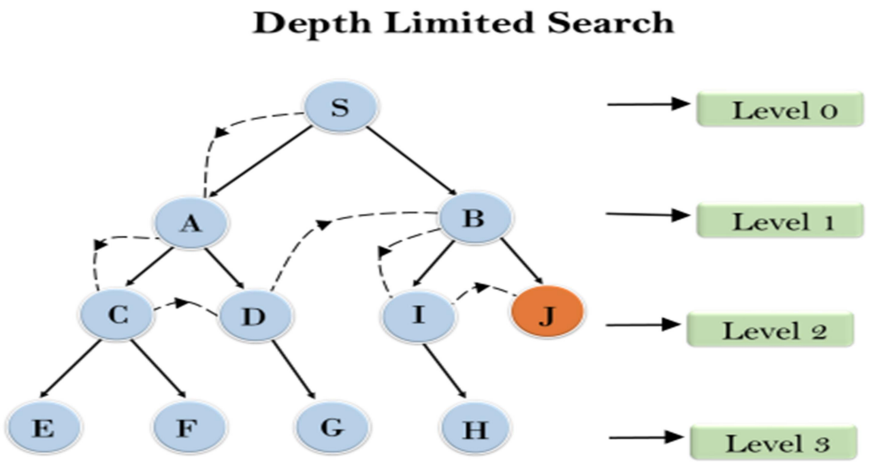
**Advantages:**

Depth-limited search is Memory efficient.

**Disadvantages:**

- Depth-limited search also has a disadvantage of incompleteness.
- It may not be optimal if the problem has more than one solution.

Example:




**Completeness:** DLS search algorithm is complete if the solution is above the depth-limit.

**Time Complexity:** Time complexity of DLS algorithm is **O($b^{\ell}$)**.



**Space Complexity:** Space complexity of DLS algorithm is O**($b \times \ell$)**.

**Optimal:** Depth-limited search can be viewed as a special case of DFS, and it is also not optimal even if $\ell > d$.

4. Uniform-cost Search Algorithm:

Uniform-cost search is a searching algorithm used for traversing a weighted tree or graph. This algorithm comes into play when a different cost is available for each edge. The primary goal of the uniform-cost search is to find a path to the goal node which has the lowest cumulative cost. Uniform-cost search expands nodes according to their path costs form the root node. It can be used to solve any graph/tree where the optimal cost is in demand. A uniform-cost search algorithm is implemented by the priority queue. It gives maximum priority to the lowest cumulative cost. Uniform cost search is equivalent to BFS algorithm if the path cost of all edges is the same.

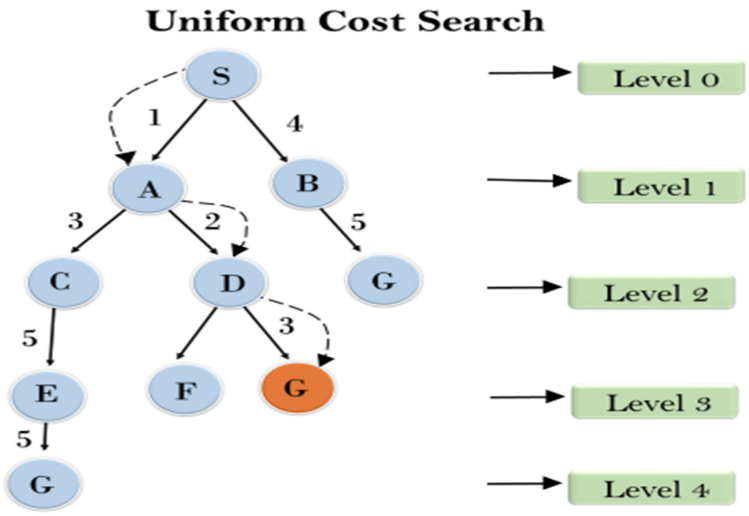
**Advantages:**

- Uniform cost search is optimal because at every state the path with the least cost is chosen.

**Disadvantages:**

- It does not care about the number of steps involve in searching and only concerned about path cost. Due to which this algorithm may be stuck in an infinite loop.

Example:




**Completeness:**

Uniform-cost search is complete, such as if there is a solution, UCS will find it.

**Time Complexity:**

Let C* **is Cost of the optimal solution**, and **ε** is each step to get closer to the goal node. Then the number of steps is = C*/ε+1. Here we have taken +1, as we start from state 0 and end to C*/ε.

Hence, the worst-case time complexity of Uniform-cost search is$\mathbf{O(b^{1 + [C^*/\varepsilon]})}$/.

**Space Complexity:**

The same logic is for space complexity so, the worst-case space complexity of Uniform-cost search is $\mathbf{O(b^{1 + [C^*/\varepsilon]})}$.

**Optimal:**

Uniform-cost search is always optimal as it only selects a path with the lowest path cost.

**5. Iterative deepeningdepth-first Search:**

The iterative deepening algorithm is a combination of DFS and BFS algorithms. This search algorithm finds out the best depth limit and does it by gradually increasing the limit until a goal is found.

This algorithm performs depth-first search up to a certain "depth limit", and it keeps increasing the depth limit after each iteration until the goal node is found.

This Search algorithm combines the benefits of Breadth-first search's fast search and depth-first search's memory efficiency.

The iterative search algorithm is useful uninformed search when search space is large, and depth of goal node is unknown.

**Advantages:**

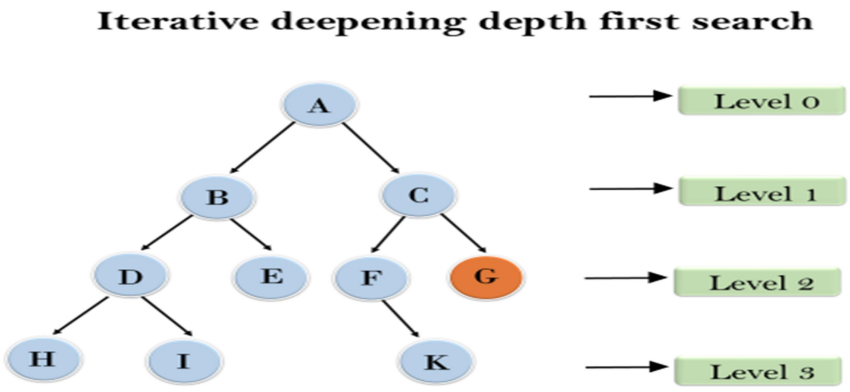
- Itcombines the benefits of BFS and DFS search algorithm in terms of fast search and memory efficiency.

**Disadvantages:**

- The main drawback of IDDFS is that it repeats all the work of the previous phase.

Example:

Following tree structure is showing the iterative deepening depth-first search. IDDFS algorithm performs various iterations until it does not find the goal node. The iteration performed by the algorithm is given as:




1'st Iteration-----> A
2'nd Iteration----> A, B, C
3'rd Iteration------>A, B, D, E, C, F, G
4'th Iteration------>A, B, D, H, I, E, C, F, K, G
In the fourth iteration, the algorithm will find the goal node.

**Completeness:**

This algorithm is complete is if the branching factor is finite.

**Time Complexity:**

Let's suppose b is the branching factor and depth is d then the worst-case time complexity is **$O(b^d)$**.

**Space Complexity:**

The space complexity of IDDFS will be **O(bd)**.

**Optimal:**

IDDFS algorithm is optimal if path cost is a non- decreasing function of the depth of the node.

6. Bidirectional Search Algorithm:

**Bidirectional search algorithm runs two simultaneous searches, one form initial state called as forward-search and other from goal node called as backward-search, to find the goal node. Bidirectional search replaces one single search graph with two small subgraphs in which one starts the search from an initial vertex and other starts from goal vertex. The search stops when these two graphs intersect each other.**

**Bidirectional search can use search techniques such as BFS, DFS, DLS, etc.**

**Advantages:**

- Bidirectional search is fast.
- Bidirectional search requires less memory

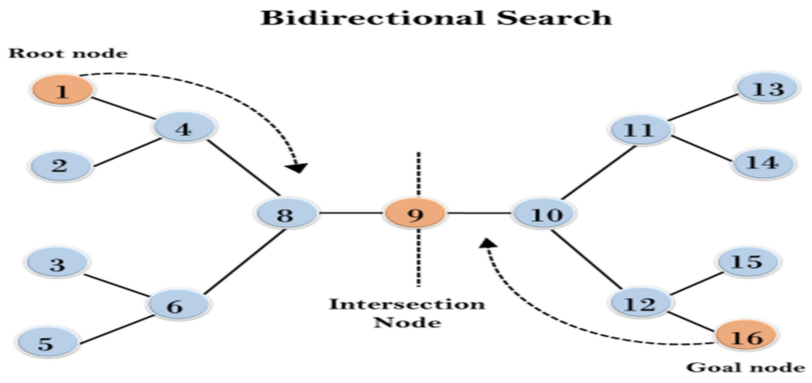
**Disadvantages:**

- Implementation of the bidirectional search tree is difficult.
- **In bidirectional search, one should know the goal state in advance.**

Example:

In the below search tree, bidirectional search algorithm is applied. This algorithm divides one graph/tree into two sub-graphs. It starts traversing from node 1 in the forward direction and starts from goal node 16 in the backward direction.

The algorithm terminates at node 9 where two searches meet.




**Completeness:** Bidirectional Search is complete if we use BFS in both searches.

**Time Complexity:** Time complexity of bidirectional search using BFS is **$O(b^d)$**.

**Space Complexity:** Space complexity of bidirectional search is **$O(b^d)$**.

**Optimal:** Bidirectional search is Optimal.

### 2.3 Heuristic Algorithm vrs Solution Guaranteed Algorithm

The informed search algorithm is more useful for large search space. Informed search algorithm uses the idea of heuristic, so it is also called Heuristic search.

**Heuristics function:** Heuristic is a function which is used in Informed Search, and it finds the most promising path. It takes the current state of the agent as its input and produces the

estimation of how close agent is from the goal. The heuristic method, however, might not always give the best solution, but it guaranteed to find a good solution in reasonable time. Heuristic function estimates how close a state is to the goal. It is represented by h(n), and it calculates the cost of an optimal path between the pair of states. The value of the heuristic function is always positive.

**Admissibility of the heuristic function is given as:**

1. $h(n) <= h^*(n)$

**Here h(n) is heuristic cost, and h*(n) is the estimated cost. Hence heuristic cost should be less than or equal to the estimated cost.**

Pure Heuristic Search:

Pure heuristic search is the simplest form of heuristic search algorithms. It expands nodes based on their heuristic value h(n). It maintains two lists, OPEN and CLOSED list. In the CLOSED list, it places those nodes which have already expanded and in the OPEN list, it places nodes which have yet not been expanded.

On each iteration, each node n with the lowest heuristic value is expanded and generates all its successors and n is placed to the closed list. The algorithm continues unit a goal state is found.

In the informed search we will discuss two main algorithms which are given below:

- **Best First Search Algorithm(Greedy search)**
- **A* Search Algorithm**

1.) Best-first Search Algorithm (Greedy Search):

Greedy best-first search algorithm always selects the path which appears best at that moment. It is the combination of depth-first search and breadth-first search algorithms. It uses the heuristic function and search. Best-first search allows us to take the advantages of both algorithms. With the help of best-first search, at each step, we can choose the most promising node. In the best first search algorithm, we expand the node which is closest to the goal node and the closest cost is estimated by heuristic function, i.e.

1. $f(n)= g(n)$.

Were, h(n)= estimated cost from node n to the goal.

The greedy best first algorithm is implemented by the priority queue.

Best first search algorithm:

- **Step 1:** Place the starting node into the OPEN list.

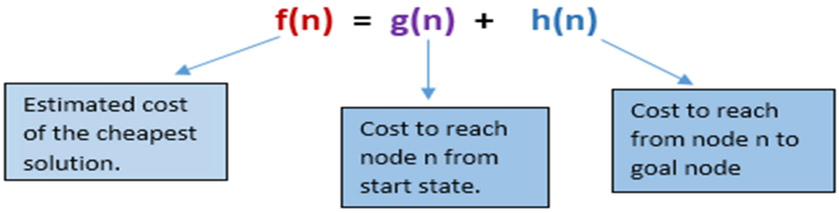
- **Step 2:** If the OPEN list is empty, Stop and return failure.
- **Step 3:** Remove the node n, from the OPEN list which has the lowest value of h(n), and places it in the CLOSED list.
- **Step 4:** Expand the node n, and generate the successors of node n.
- **Step 5:** Check each successor of node n, and find whether any node is a goal node or not. If any successor node is goal node, then return success and terminate the search, else proceed to Step 6.
- **Step 6:** For each successor node, algorithm checks for evaluation function f(n), and then check if the node has been in either OPEN or CLOSED list. If the node has not been in both list, then add it to the OPEN list.
- **Step 7:** Return to Step 2.

Advantages:

- Best first search can switch between BFS and DFS by gaining the advantages of both the algorithms.
- This algorithm is more efficient than BFS and DFS algorithms.

Disadvantages:

- It can behave as an unguided depth-first search in the worst case scenario.
- It can get stuck in a loop as DFS.
- This algorithm is not optimal.
- 2.) A* Search Algorithm:
- A* search is the most commonly known form of best-first search. It uses heuristic function h(n), and cost to reach the node n from the start state g(n). It has combined features of UCS and greedy best-first search, by which it solve the problem efficiently. A* search algorithm finds the shortest path through the search space using the heuristic function. This search algorithm expands less search tree and provides optimal result faster. A* algorithm is similar to UCS except that it uses g(n)+h(n) instead of g(n).
- In A* search algorithm, we use search heuristic as well as the cost to reach the node. Hence we can combine both costs as following, and this sum is called as a **fitness number**.




**2.4 Local search and Optimal problem (Hill climbing, BFS,A*,AO*)**

Local search is a type of Artificial Intelligence (AI) algorithm used to solve optimisation problems. It is also known as simulated annealing or hill-climbing and involves searching for the best solution in each region using greedy search techniques.

**Hill Climbing Algorithm**

- Hill climbing algorithm is a local search algorithm which continuously moves in the direction of increasing elevation/value to find the peak of the mountain or best solution to the problem. It terminates when it reaches a peak value where no neighbor has a higher value.
- Hill climbing algorithm is a technique which is used for optimizing the mathematical problems. One of the widely discussed examples of Hill climbing algorithm is Traveling-salesman Problem in which we need to minimize the distance traveled by the salesman.
- It is also called greedy local search as it only looks to its good immediate neighbor state and not beyond that.
- A node of hill climbing algorithm has two components which are state and value.
- Hill Climbing is mostly used when a good heuristic is available.
- In this algorithm, we don't need to maintain and handle the search tree or graph as it only keeps a single current state.

Features of Hill Climbing:

Following are some main features of Hill Climbing Algorithm:

- **Generate and Test variant:** Hill Climbing is the variant of Generate and Test method. The Generate and Test method produce feedback which helps to decide which direction to move in the search space.
- **Greedy approach:** Hill-climbing algorithm search moves in the direction which optimizes the cost.
- **No backtracking:** It does not backtrack the search space, as it does not remember the previous states.

## Breadth First Search Algorithm

Breadth first search algorithm is an algorithm used to find the shortest path from one node to another in a graph. It begins by searching through the nodes closest to the starting node, and then expands outward to the more distant nodes. The algorithm is often used in tree traversal and network routing algorithms.

## Working of Breadth First Search Algorithm

The breadth first search algorithm is a method used to traverse a tree or graph. In this algorithm, the nodes are visited in the order of their distance from the root node. The root node is expanded first, then the immediate child nodes of the root node are expanded, and so on. This process continues until all the nodes in the tree or graph have been visited.

The main advantage of the breadth first search algorithm is that it is simple to implement and can be easily understood. Moreover, this algorithm can be used to find the shortest path between two nodes in a graph.

## Advantages of Breadth First Search Algorithm

There are many advantages to using the Breadth First Search algorithm:

- The main advantage is that it is very simple to implement and understand.
- It is guaranteed to find the shortest path from the starting point to the goal.
- Breadth First Search tends to find paths with fewer steps than other algorithms, such as Depth First Search.
- Breadth First Search can be easily parallelized, which means that it can take advantage of multiple processors to speed up the search.

## Disadvantages of Breadth First Search Algorithm

There are a few disadvantages to the Breadth First Search algorithm:

- It can be very memory intensive since it needs to keep track of all the nodes in the search tree.
- It can be slow since it expands all the nodes at each level before moving on to the next level.
- It can sometimes find sub-optimal solutions since it doesn’t explore all possible paths through the search tree.

## Applications of Breadth First Search Algorithm

The breadth first search algorithm is a powerful tool that can be used to solve various problems. In this article, we will explore some of the potential applications of this algorithm.

1. Graph traversal: Breadth first search can be used to traverse a graph. This can be useful for tasks such as finding the shortest path between two nodes or determining if a graph is connected.

2. Network routing: Breadth first search can be used to find the shortest path between two nodes in a network. This can be useful for tasks such as routing traffic or finding the quickest route between two points.

3. Pattern matching: Breadth first search can be used to match patterns in data. This can be useful for tasks such as searching for a specific string in a text file or finding all instances of a particular word in a document.

**A* Algorithm**

Let's briefly understand what the A* algorithm is:

- A* is a widely used path-finding algorithm in computer science and is particularly useful for applications like route planning in maps, robotics, and games.
- It is an informed search algorithm meaning it uses a heuristic to estimate the cost of reaching the goal from any given node.
- A* algorithm is like a GPS for computers. It is widely used in many areas of computer science, especially in things like video games where characters need to find the best path to a destination.
- A* is efficient and clever because it doesn't waste time exploring unnecessary routes.
- It uses a clever trick called a heuristic which is like a smart guess to estimate how far it is from any point to the goal. This helps it find the quickest path without having to look at every single option.

**AO* Algorithm**

Let's briefly understand what the AO* algorithm is:

- AO* is a variant of the A* algorithm. It is designed to be more flexible and capable of adapting to changing environments.
- AO* can repair its solution whenever it encounters a change in the environment without having to start the search from scratch.
- AO* is like a supercharged version of A*. It is designed to handle situations where things might change like a dynamic environment.
- For example, imagine a robot moving around a busy room. If furniture gets rearranged AO* can quickly adjust its plan without starting from scratch.
- One of the cool things about AO* is that it uses a combination of OR and AND operations. This means it can consider multiple paths simultaneously making it really good at adapting to new information.
- It's like being able to plan a route while also keeping an eye on alternative options. This makes AO* a powerful tool for tasks that involve uncertainty and change.

**2.5 Adversarial Search**

**Adversarial search is a search, where we examine the problem which arises when we try to plan ahead of the world and other agents are planning against us.**

- In previous topics, we have studied the search strategies which are only associated with a single agent that aims to find the solution which often expressed in the form of a sequence of actions.
- But, there might be some situations where more than one agent is searching for the solution in the same search space, and this situation usually occurs in game playing.
- The environment with more than one agent is termed as **multi-agent environment**, in which each agent is an opponent of other agent and playing against each other. Each agent needs to consider the action of other agent and effect of that action on their performance.
- So, Searches in which two or more players with conflicting goals are trying to explore the same search space for the solution, are called adversarial searches, often known as Games.
- Games are modeled as a Search problem and heuristic evaluation function, and these are the two main factors which help to model and solve games in AI.

### 2.6 AI and Game Playing

Game playing in artificial intelligence refers to the development and application of algorithms that enable computers to engage in strategic decision-making within the context of games. These algorithms, often termed game playing algorithms in AI, empower machines to mimic human-like gameplay by evaluating potential moves, predicting opponent responses, and making informed choices that lead to favorable outcomes. This concept extends the capabilities of AI systems beyond mere computation and calculation, enabling them to participate in interactive scenarios and make choices based on strategic thinking.

### Types of Game Playing in Artificial Intelligence

Game playing in artificial intelligence encompasses a diverse array of strategies, each aimed at enabling AI systems to excel in games and strategic decision-making scenarios. These strategies, often referred to as game playing algorithms in AI, can be broadly classified into two main categories: rule-based systems and machine learning-based systems.

1. **Rule-Based Systems**

Rule-based systems, a cornerstone of game playing in AI, rely on predefined sets of rules to govern the behavior of AI agents during gameplay. These rules encapsulate strategies, tactics, and heuristics designed by human experts. These experts analyze the game, anticipate possible moves, and formulate guidelines that the AI adheres to.

In rule-based systems, decisions are based on a deterministic process where each move is evaluated against the predefined rules. These rules dictate how the AI should react to various game states, opponent moves, and potential outcomes. Rule-based approaches are particularly

effective in games with well-defined rules and relatively simple decision trees, such as Tic-Tac-Toe.

2. **Machine Learning-Based Systems**

Machine learning-based systems, on the other hand, represent a paradigm shift in game playing in AI. Instead of relying on fixed rules, these systems utilize algorithms to learn from experience and adapt their strategies accordingly. These algorithms process vast amounts of data generated through gameplay, identifying patterns, correlations, and optimal moves.

Reinforcement learning is a prominent example of machine learning-based systems in game playing algorithms in AI. Here, AI agents play games repeatedly, receiving rewards for favorable moves and penalties for unfavorable ones. Over time, the AI learns to maximize rewards by exploring different strategies and refining its decision-making processes. This approach has propelled AI achievements in complex games like Go and chess, showcasing the capacity to tackle intricate decision trees.

**Mini-Max Algorithm in Artificial Intelligence**

The Mini-Max algorithm is a cornerstone of game playing in artificial intelligence, allowing AI agents to make strategic decisions in competitive games. It operates on the principle that in a two-player, zero-sum game, one player's gain is balanced by the other player's loss. This powerful algorithm enables AI players to assess different moves and select the one that maximizes their advantage while considering their opponent's optimal response.

**Advantages of Game Playing in Artificial Intelligence**

- **Enhanced Strategic Thinking:** Game-playing algorithms empower AI to strategize and make optimal choices, improving decision-making in various scenarios.
- **Adaptive Learning:** Machine learning-driven approaches enable AI to learn and refine strategies, adapting over time for better performance.
- **Real-world Relevance:** Strategies developed in games find applications in diverse fields, enhancing decision-making in practical situations.
- **Efficient Decision-making:** Algorithms like Alpha-Beta Pruning optimize computation, enabling AI to efficiently explore complex game scenarios.
- **Benchmarking AI Progress:** AI's success in games serves as a marker of advancement, showcasing the growth of AI's strategic capabilities.

**Disadvantages of Game Playing in Artificial Intelligence**

- **Computational Complexity:** Game-playing algorithms can be computationally intensive, limiting their real-time application in complex scenarios.
- **Limited Generalization:** Strategies developed for specific games might not readily apply to broader real-world decision-making contexts.
- **Lack of Creativity:** AI's decisions are based on algorithms and past experiences, lacking the creativity and intuition that humans possess.
- **Complexity of Game Rules:** Adapting game-playing algorithms to diverse games with intricate rules can be challenging and time-consuming.

- **Overfitting:** In machine learning-based approaches, there's a risk of overfitting to limited training data, leading to suboptimal decisions in novel situations.

# 3.Knowledge Representation and Reasoning

- **3.1 What to represent, Knowledge**
- Humans are best at understanding, reasoning, and interpreting knowledge. Human knows things, which is knowledge and as per their knowledge they perform various actions in the real world. **But how machines do all these things comes under knowledge representation and reasoning**. Hence we can describe Knowledge representation as following:

  - Knowledge representation and reasoning (KR, KRR) is the part of Artificial intelligence which concerned with AI agents thinking and how thinking contributes to intelligent behavior of agents.
  - It is responsible for representing information about the real world so that a computer can understand and can utilize this knowledge to solve the complex real world problems such as diagnosis a medical condition or communicating with humans in natural language.
  - It is also a way which describes how we can represent knowledge in artificial intelligence. Knowledge representation is not just storing data into some database, but it also enables an intelligent machine to learn from that knowledge and experiences so that it can behave intelligently like a human.

What to Represent:

Following are the kind of knowledge which needs to be represented in AI systems:

- **Object:** All the facts about objects in our world domain. E.g., Guitars contains strings, trumpets are brass instruments.
- **Events:** Events are the actions which occur in our world.
- **Performance:** It describe behavior which involves knowledge about how to do things.
- **Meta-knowledge:** It is knowledge about what we know.
- **Facts:** Facts are the truths about the real world and what we represent.
- **Knowledge-Base:** The central component of the knowledge-based agents is the knowledge base. It is represented as KB. The Knowledgebase is a group of the

Sentences (Here, sentences are used as a technical term and not identical with the English language).

**Knowledge:** Knowledge is awareness or familiarity gained by experiences of facts, data, and situations. Following are the types of knowledge in artificial intelligence:

Types of knowledge


**1. Declarative Knowledge:**

- Declarative knowledge is to know about something.
- It includes concepts, facts, and objects.
- It is also called descriptive knowledge and expressed in declarativesentences.
- It is simpler than procedural language.

**2. Procedural Knowledge**

- It is also known as imperative knowledge.
- Procedural knowledge is a type of knowledge which is responsible for knowing how to do something.
- It can be directly applied to any task.
- It includes rules, strategies, procedures, agendas, etc.
- Procedural knowledge depends on the task on which it can be applied.

**3. Meta-knowledge:**

- Knowledge about the other types of knowledge is called Meta-knowledge.

**4. Heuristic knowledge:**

- Heuristic knowledge is representing knowledge of some experts in a filed or subject.
- Heuristic knowledge is rules of thumb based on previous experiences, awareness of approaches, and which are good to work but not guaranteed.

**5. Structural knowledge:**

- Structural knowledge is basic knowledge to problem-solving.
- It describes relationships between various concepts such as kind of, part of, and grouping of something.
- It describes the relationship that exists between concepts or objects.

- **3.2 Properties of Knowledge Representation System, Approaches**
  A good knowledge representation system must possess the following properties.

1. **1.Representational Accuracy:**
   KR system should have the ability to represent all kind of required knowledge.
2. **2.Inferential Adequacy:**
   KR system should have ability to manipulate the representational structures to produce new knowledge corresponding to existing structure.
3. **3.Inferential Efficiency:**
   The ability to direct the inferential knowledge mechanism into the most productive directions by storing appropriate guides.
4. **4. Acquisitional efficiency-** The ability to acquire the new knowledge easily using automatic methods.

Approaches to knowledge representation:

There are mainly four approaches to knowledge representation, which are givenbelow:

1. Simple relational knowledge:

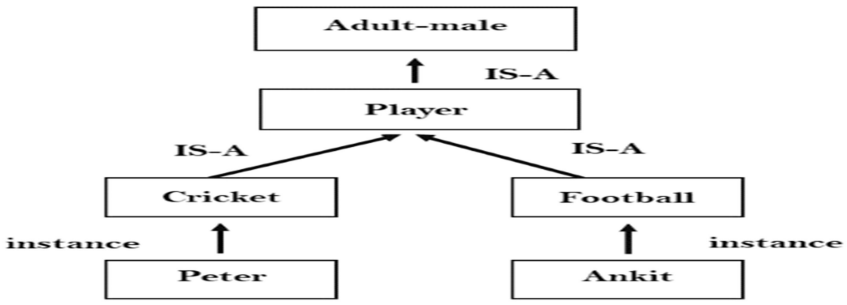
- It is the simplest way of storing facts which uses the relational method, and each fact about a set of the object is set out systematically in columns.
- This approach of knowledge representation is famous in database systems where the relationship between different entities is represented.
- This approach has little opportunity for inference.

**Example: The following is the simple relational knowledge representation.**

| Player | Weight | Age |
|---|---|---|
| Player1 | 65 | 23 |
| Player2 | 58 | 18 |
| Player3 | 75 | 24 |

2. Inheritable knowledge:

- In the inheritable knowledge approach, all data must be stored into a hierarchy of classes.
- All classes should be arranged in a generalized form or a hierarchal manner.
- In this approach, we apply inheritance property.
- Elements inherit values from other members of a class.
- This approach contains inheritable knowledge which shows a relation between instance and class, and it is called instance relation.
- Every individual frame can represent the collection of attributes and its value.
- In this approach, objects and values are represented in Boxed nodes.
- We use Arrows which point from objects to their values.
- **Example:**




3. Inferential knowledge:

- Inferential knowledge approach represents knowledge in the form of formal logics.
- This approach can be used to derive more facts.
- It guaranteed correctness.
- **Example:** Let's suppose there are two statements:
    a. Marcus is a man

b. All men are mortal
Then it can represent as;

**man(Marcus)**
**∀x = man (x) ----------> mortal (x)s**

4. Procedural knowledge:

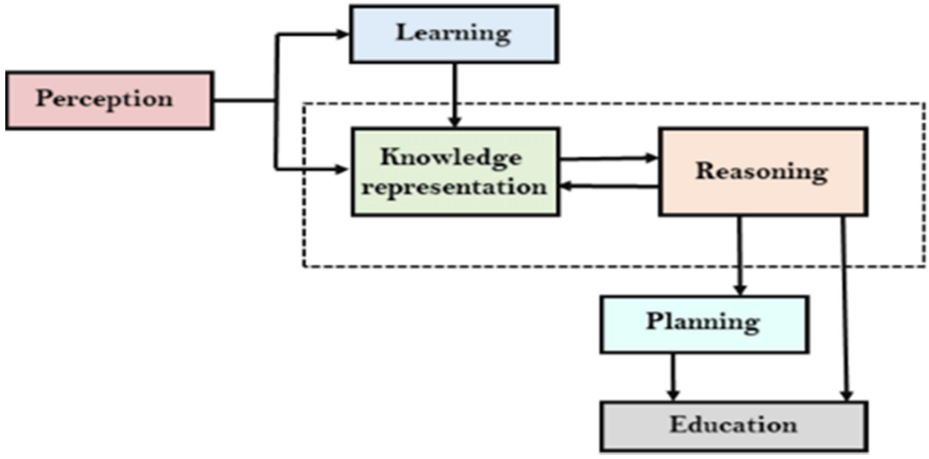
- Procedural knowledge approach uses small programs and codes which describes how to do specific things, and how to proceed.
- In this approach, one important rule is used which is **If-Then rule**.
- In this knowledge, we can use various coding languages such as **LISP language** and **Prolog language**.
- We can easily represent heuristic or domain-specific knowledge using this approach.
- But it is not necessary that we can represent all cases in this approach.

- **3.3 Knowledge Representation**

AI knowledge cycle:

An Artificial intelligence system has the following components for displaying intelligent behaviour:

- Perception
- Learning
- Knowledge Representation and Reasoning
- Planning
- Execution




**Perception**

Perception is the process of acquiring information from the environment through sensors. This information is then processed and interpreted to generate knowledge.

**Learning**

Learning is the process of acquiring new knowledge from experience. This can be achieved through supervised learning, unsupervised learning, or reinforcement learning.

**Knowledge Representation & Reasoning**

Knowledge representation and reasoning is the stage where acquired knowledge is transformed into a form that can be processed by machines. This involves choosing an appropriate KR technique and representing knowledge using that technique. Reasoning involves using the knowledge represented to draw inferences and make decisions.

**Planning**

Planning is the stage where the system uses the acquired knowledge and reasoning to generate a sequence of actions to achieve a particular goal. This involves selecting the most appropriate actions to achieve the goal while considering any constraints or limitations.

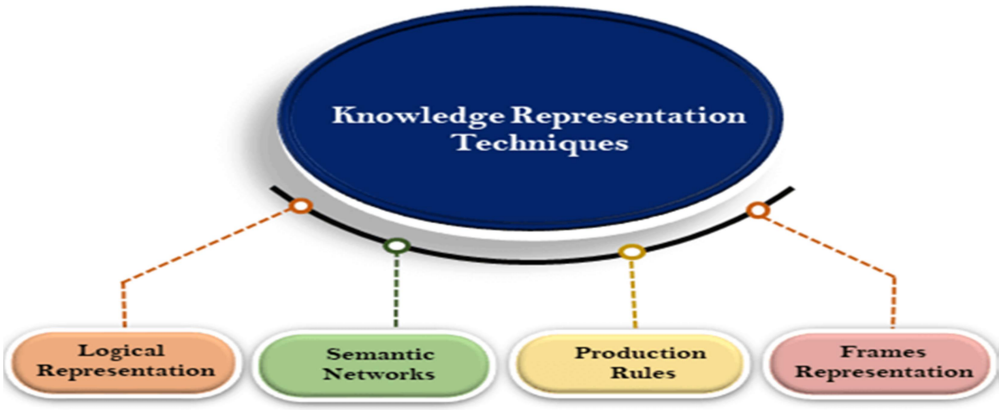
**Execution**

Execution is the final stage where the system performs the planned actions. The success of the execution depends on the accuracy and completeness of the knowledge representation, reasoning, and planning.

**Techniques of knowledge representation**

There are mainly four ways of knowledge representation which are given as follows:

1. Logical Representation
2. Semantic Network Representation
3. Frame Representation
4. Production Rules




1.Logical Representation

A language with certain concrete principles that deals with propositions and has no ambiguity in representation is referred to as logical representation. Drawing a conclusion based on numerous criteria is referred to as logical representation. Some important communication guidelines are laid out in this diagram. It's made up of well-defined syntax and semantics that facilitate sound inference. Each sentence could be translated into logics using the syntax and semantics.

Syntax:

- Syntaxes are the principles that govern how legal sentences are constructed in logic.
- It determines the symbol we can use to express knowledge.
- What is the best way to write those symbols?

Semantics:

- The rules by which we can comprehend a phrase in logic are known as semantics.
- Semantic also entails giving each statement a meaning.
- There are primarily two logics that can be used to represent logic:
    - Propositional Logics
    - Predicate logics

Advantages of logical representation:

- We can do logical reasoning with the help of logical representation.
- Programming languages are built on the foundation of logical representation.

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- Programming languages are built on the foundation of logical representation.

Disadvantages of logical Representation:

The various types of knowledge are as follows:

- Logical representations have some limitations and are difficult to use.
- It's possible that the logical representation technique isn't very natural, and inference isn't particularly efficient.

**Note: That logical representation and logical reasoning are not the same thing; logical representation is a representation language, and reasoning is a logical thinking process.**

2. Semantic Network Representation

For knowledge representation, semantic networks are an alternative to predicate logic. We can express our knowledge in Semantic Networks as graphical networks. This network is made up of nodes that represent things and arcs that describe their relationships. Semantic networks may classify objects in a variety of ways and link them together.

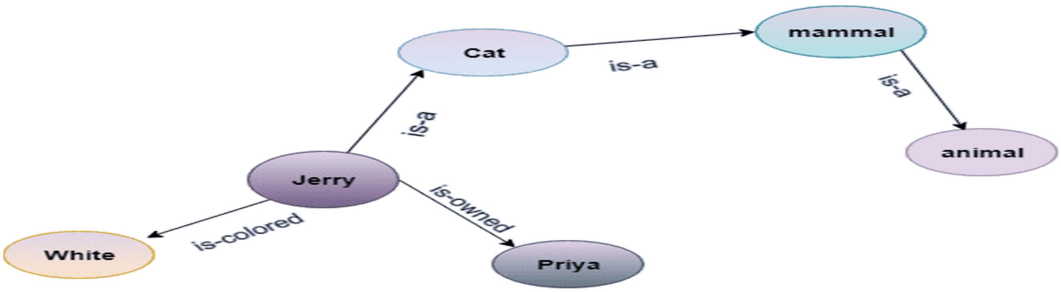
This representation consists of basically two types of relations:

1. IS-A relation (Inheritance)
2. Kind-of-relation

Example: Some statements which we have to represent in the form of nodes and arcs are as follows.

Statements:

- Jerry is a cat.
- Jerry is a mammal.
- Jerry is owned by Priya.
- Jerry is brown colored.
- All Mammals are animal.




We've used nodes and arcs to represent different types of knowledge in the diagram above. Each object has some sort of relationship with another object.

Disadvantage in Semantic representation:

- Because we need to traverse the entire network tree to answer some questions, semantic networks take longer to compute at runtime. In the worst-case situation, we may discover that the answer does not exist in this network after traversing the entire tree.
- Semantic networks attempt to replicate human-like memory (which has 1015 neurons and linkages) in order to store information, however in actuality, such a large semantic network is impossible to construct.
- These types of representations are insufficient since they lack an equivalent quantifier, such as all, some, none, and so on.
- The link names in semantic networks are not defined in any way.
- These networks aren't intelligent and rely on the system's inventor.

Advantages of Semantic network:

- Semantic networks are a natural way to represent information.
- Semantic networks are a transparent way of conveying meaning.
- These networks are straightforward and simple to comprehend.

3. Frame Representation

A frame is a record-like structure that contains a set of properties and their values to describe a physical thing. Frames are a sort of artificial intelligence data structure that splits knowledge into substructures by depicting stereotyped situations. It is made up of a set of slots and slot values. These slots can come in any shape or size. Facets are the names and values assigned to slots.

**Facets:** Facets are the numerous aspects of a slot machine. Facets are characteristics of frames that allow us to constrain them. Example: When data from a specific slot is required, IF-NEEDED facts are used. A frame can have any number of slots, each of which can contain any number of facets, each of which can have any number of values.

Semantic networks gave rise to frames, which later evolved into our modern-day classes and objects. A single frame is of limited utility. A frames system is made up of a group of

interconnected frames. Knowledge about an object or event can be kept in the knowledge base in the frame. The frame is a form of technology that can be used in a wide range of applications.

Example: 1Let's take an example of a frame for a book

| **Slots** | **Filter** |
|---|---|
| **Title** | Artificial Intelligence |
| **Genre** | Computer Science |
| **Author** | Peter Norvig |
| **Edition** | PThird Edition |
| **Year** | 1996 |
| **Page** | 1152 |

Example: 2

Let's pretend we're dealing with an entity, Peter. Peter is a professional engineer, and he is 25 years old. He lives in the city of London, in the country of England. The frame representation for this is as follows:

| **Slots** | **Filter** |
|---|---|
| **Name** | Peter |
| **Profession** | Doctor |
| **Age** | 25 |
| **Marital Status** | Single |
| **Year** | 1996 |
| **Weight** | 78 |

Advantages of frame representation:

- By grouping related facts, the frame knowledge representation makes programming easier.
- Many AI applications employ the frame representation because it is rather flexible.
- Adding slots for additional attributes and relations is a breeze.
- It's simple to add default data and look for missing variables.
- The frame representation is simple to grasp and visualize.

Disadvantages of frame representation:

- The inference mechanism in a frame system is difficult to process.
- Frame representation does not allow for a smooth progression of the inference procedure.
- The approach to frame representation is rather broad

4. Production Rules

Production rules system consists of (condition, action) pairs which means, "If condition then action". It has basically three parts:

- The set of production rules

- Working Memory
- The recognize-act-cycled

The agent in production rules checks for the condition, and if it exists, the production rule fires and the appropriate action is taken. The rule's condition component determines which rule can be used to solve an issue. The action portion, on the other hand, is responsible for carrying out the corresponding problem-solving actions. A recognize-act cycle is the name given to the entire procedure.

Working memory stores a description of the present state of problem-solving, and rules can be used to write knowledge to it. Other rules may be triggered by this knowledge.

If a new scenario (state) arises, numerous production rules will be fired at the same time, which is known as a conflict set. In this case, the agent must choose a rule from among these sets, and it is called a recognize-act cycle.

**Example:**
**IF (at bus stop AND bus arrives) THEN action (get into the bus)**
**IF (on the bus AND paid AND empty seat) THEN action (sit down).**
**IF (on bus AND unpaid) THEN action (pay charges).**
**IF (bus arrives at destination) THEN action (get down from the bus.**

Advantages of Production rule:

1. The production rules are written in plain English.
2. We can quickly delete, add, or modify an individual rule because the production rules are relatively modular

Disadvantages of Production rule:

1. The production rule system has no learning capabilities because it does not save the solution to the problem for future use.
2. Many rules may be active during the execution of the program, making rule-based production systems inefficient.

### 3.4 Reasoning and Types of reasoning

Reasoning:

The reasoning is the mental process of deriving logical conclusion and making predictions from available knowledge, facts, and beliefs. Or we can say, "**Reasoning is a way to infer facts from existing data**." It is a general process of thinking rationally, to find valid conclusions.

In artificial intelligence, the reasoning is essential so that the machine can also think rationally as a human brain, and can perform like a human.

Types of Reasoning

In artificial intelligence, reasoning can be divided into the following categories:

- Deductive reasoning
- Inductive reasoning
- Abductive reasoning
- Common Sense Reasoning
- Monotonic Reasoning
- Non-monotonic Reasoning
- **Deductive Reasoning:** Deductive Reasoning is the strategic approach that uses available facts, information or knowledge to draw valid conclusions. It basically beliefs in the facts and ideas before drawing any result. Deductive reasoning uses a top-down approach. In deductive reasoning, the arguments can be valid or invalid based on the value of the premises. If the value of the premises is true, then the conclusion is also true. Deductive reasoning helps in scanning the generalized statement into a valid conclusion. Some of the examples are
  - People who are aged 20 or above are active users of the internet.
  - Out of the total number of students present in the class, the ratio of boys is more than the girls.
- **Inductive Reasoning:** Inductive reasoning is completely different from the deductive reasoning approach because Inductive reasoning is associated with the hypothesis-generating approach rather than drawing any particular conclusion to the facts at the beginning of the process. Inductive reasoning help in making generalization from specific facts and knowledge. Inductive reasoning is the bottom-up process. In inductive Reasoning even if the premises are true there is no chance that the conclusion will also be true because it depends upon the inductive argument which can be either strong or weak. Some of the examples are:
  - All the students present in the classroom are from London.
  - Always the hottest temperature is recorded in Death Valley.
- **Common Sense Reasoning:** Common sense reasoning is the most occurred type of reasoning in daily life events. It is the type of reasoning which comes from experiences. When a human face a different situation in life it gains some knowledge. So whenever in the next point of time it faces a similar type of situation then it uses its previous experiences to draw a conclusion to do situation. Some of the examples are:
  - when a bike crosses the traffic signal when it is red then it learns from its mistakes and next time the bike is aware of the signal and actions.
  - While overtaking someone on the road what all ideas should be kept in mind.
- **Monotonic Reasoning:** It is the type of reasoning which follows a different approach towards the thinking process it uses facts, information, and knowledge to draw a conclusion about the problem but the major point is its conclusion remain fixed permanently once it is decided because even if we add new information or facts to the existing one the conclusion remains the same it doesn't change. Monotonic reasoning is used mainly in conventional reasoning systems and logic-based systems. Some Examples of monotonic are:
  - The Sahara Desert of the world is one of the most spectacular deserts.
  - One of the longest rivers in the world is the Nile River.

- **Abductive Reasoning:** Abductive Reasoning is a type of reasoning which acts differently from all the above reasoning strategies. It begins with an incomplete set of facts, information and knowledge and then proceeds to find the most deserving explanation and conclusion. It draws conclusions based on what facts you know at present rather than collecting some outdated facts and information. It mostly plays a great role in the daily life decision-making process. Some of the examples are:
    - Doctor drawing conclusions regarding your health based on test reports.
    - A bowl of soup is kept and vapour evaporating from it which draws the conclusion that the bowl is hot in nature.

**Non-monotonic Reasoning**

**In Non-monotonic reasoning, some conclusions may be invalidated if we add some more information to our knowledge base.**

Logic will be said as non-monotonic if some conclusions can be invalidated by adding more knowledge into our knowledge base.

Non-monotonic reasoning deals with incomplete and uncertain models.

Human perceptions for various things in daily life, "is a general example of non-monotonic reasoning.

**Example:** Let suppose the knowledge base contains the following knowledge:

- **Birds can fly**
- **Penguins cannot fly**
- **Pitty is a bird**

So from the above sentences, we can conclude that **Pitty can fly**.

However, if we add one another sentence into knowledge base "**Pitty is a penguin**", which concludes "**Pitty cannot fly**", so it invalidates the above conclusion.

# 4. Machine Learning



## Chapter 4

Machine Learning**

Machine Learning (ML) is a core area of Artificial Intelligence that focuses on building systems capable of learning from data and improving their performance without explicit programming. Instead of relying on fixed rules, machine learning algorithms identify patterns, trends, and relationships within data and use this knowledge to make predictions or decisions. Machine learning has become essential in modern applications such as recommendation systems, medical diagnosis, fraud detection, speech recognition, and autonomous systems.

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# 4.1 Machine Learning

Machine Learning can be defined as the process by which a computer system learns from experience (data) and improves its performance on a specific task over time. The learning process involves feeding data into an algorithm, training a model, evaluating its performance, and then using the trained model for prediction or decision-making.

The general workflow of machine learning includes data collection, preprocessing, model training, testing, and deployment. The quality of data and the choice of algorithm play a significant role in determining the accuracy and reliability of the system.

**Example:**
An email spam filter learns from previously classified emails and gradually improves its ability to detect spam messages.

---

## 4.2 Statistical or Unsupervised Learning

Statistical or Unsupervised Learning is a type of machine learning in which the model is trained using **unlabeled data**. Since no target output is provided, the algorithm attempts to discover hidden patterns, structures, or relationships in the data using statistical methods.

Unsupervised learning is commonly used for **clustering**, **association**, and **dimensionality reduction**. Clustering groups similar data points together based on similarity measures, while dimensionality reduction reduces the number of features while preserving important information.

**Example:**
Grouping customers into different segments based on shopping behavior without predefined labels.

---

## 4.3 Properties of Machine Learning (ML Properties)

Machine learning systems possess several distinguishing properties that make them suitable for intelligent applications.

One important property is **learning capability**, where the system improves performance with more data. **Adaptability** allows the system to adjust to new data and changing environments. **Generalization** enables the model to perform well on unseen data rather than memorizing training data. **Automation** reduces the need for manual programming, and **data-driven behavior** ensures decisions are based on evidence rather than assumptions.

**Example:**
A music recommendation system adapts its suggestions as user preferences change over time.

---

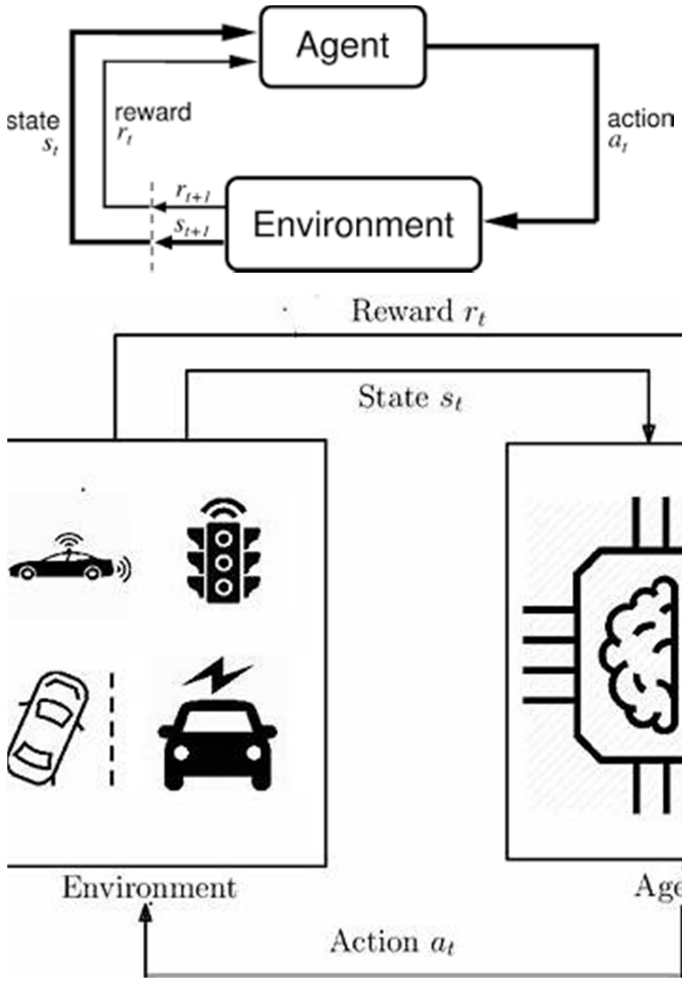
# 4.4 Reinforcement Learning

Reinforcement Learning (RL) is a learning paradigm in which an **agent** learns by interacting with an **environment**. The agent performs actions and receives feedback in the form of rewards or penalties. The objective is to learn an optimal policy that maximizes cumulative rewards over time.

Unlike supervised learning, reinforcement learning does not require labeled data. Learning occurs through trial and error. Reinforcement learning is widely used in robotics, gaming, autonomous driving, and control systems.

Key components of reinforcement learning include the agent, environment, actions, rewards, and policy.

**Example:**
A robot learning to walk by receiving positive rewards for stable movements and penalties for falling.

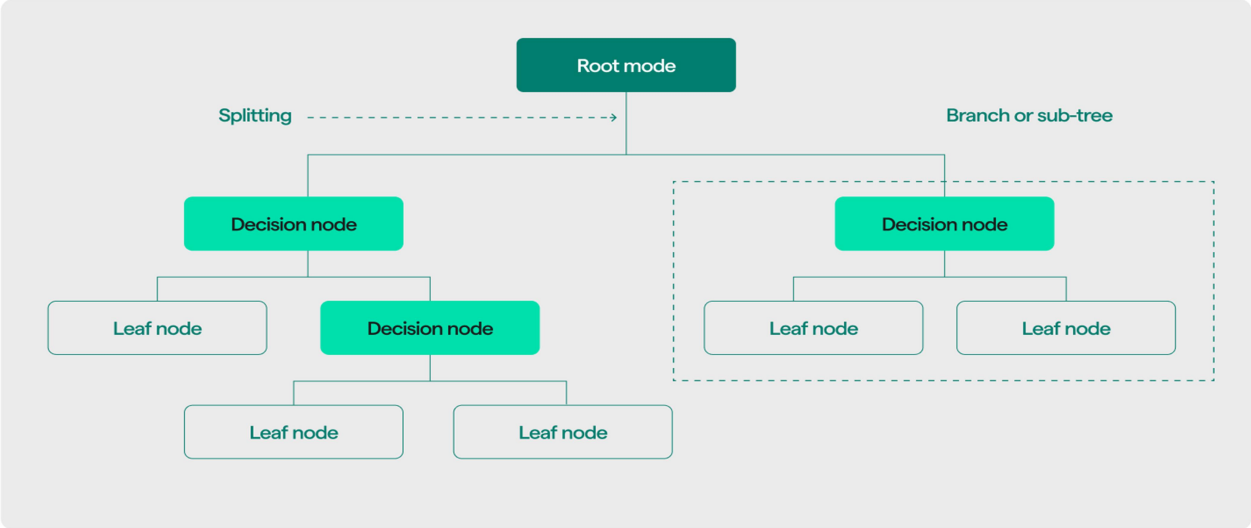


# 4.5 Decision Tree

A Decision Tree is a supervised machine learning algorithm used for **classification** and **regression**. It represents decisions in a tree-like structure where each internal node tests an attribute, each branch represents an outcome, and each leaf node represents a final decision or class label.

Decision trees are easy to understand and interpret. They are built using measures such as **Information Gain**, **Entropy**, or **Gini Index** to decide the best feature for splitting data.

**Example:**
Predicting whether a student will pass or fail based on attendance and study hours.



# Chapter 5

# Pattern Recognition

Pattern Recognition is a fundamental area of Artificial Intelligence and Machine Learning that focuses on the automatic recognition, classification, and interpretation of patterns in data. A pattern may be a fingerprint, handwritten character, face, speech signal, image, or any observable structure. Pattern recognition systems aim to emulate human perception by identifying regularities and meaningful structures in complex data. These systems form the backbone of applications such as image processing, speech recognition, biometric authentication, medical diagnosis, and computer vision.

---

## 5.1 Introduction to Pattern Recognition

Pattern Recognition can be defined as the process of identifying patterns and regularities in data and assigning them to appropriate categories or classes. The data used in pattern recognition can be numerical, symbolic, or visual. The goal is to make decisions based on similarities and differences among data patterns.

A pattern recognition system typically involves sensing the data, extracting meaningful features, and classifying the pattern into a predefined category. Humans perform pattern recognition naturally, such as recognizing faces or reading handwritten text, whereas machines require mathematical models and algorithms to perform similar tasks.

**Example:**
Recognizing handwritten digits (0–9) from scanned images is a classic pattern recognition problem.

### Pictorial Diagram: Basic Pattern Recognition Concept

```
Input Pattern
   (Image / Signal)
          |
     Feature Extraction
          |
      Pattern Classifier
          |
     Recognized Class
```

---

## 5.2 Design Principles of Pattern Recognition System

The design of a pattern recognition system follows a structured approach to ensure accuracy, efficiency, and robustness. The system must be able to handle noise, variations, and incomplete data.

The major design stages include **data acquisition**, **preprocessing**, **feature extraction**, **feature selection**, and **classification**. Preprocessing improves data quality by removing noise and normalizing input. Feature extraction transforms raw data into a set of informative features that best represent the pattern. Feature selection reduces dimensionality by selecting only the most relevant features. Finally, a classifier assigns the pattern to a class.

**Example:**
In face recognition, preprocessing includes image resizing and noise removal, while features may include facial landmarks such as eyes and nose.

### Pictorial Diagram: Pattern Recognition System Design

```
Sensor / Input
      |
Preprocessing
      |
Feature Extraction
      |
Feature Selection
      |
Classifier
      |
Decision / Output
```

---

# 5.3 Statistical Pattern Recognition System

Statistical Pattern Recognition is based on probability theory and statistical decision-making. In this approach, patterns are represented as feature vectors, and classification decisions are made using statistical models such as probability density functions and Bayesian decision theory.

Statistical classifiers assume that data follows certain probability distributions. Popular statistical techniques include **Bayes classifier**, **Minimum Distance classifier**, **k-Nearest Neighbors (k-NN)**, and **Maximum Likelihood estimation**. These methods are effective when sufficient training data is available.

**Example:**
Email spam detection using probability of words occurring in spam versus non-spam emails.

### Pictorial Diagram: Statistical Pattern Recognition

```
Feature Vector
      |
Statistical Model
(Probability Estimation)
      |
Decision Rule
      |
Class Label
```

---

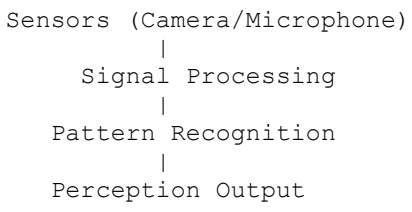
# 5.4 Machine Perception

Machine Perception refers to the ability of machines to interpret sensory information such as images, sound, and signals in a manner similar to human perception. It combines pattern recognition, signal processing, and artificial intelligence to understand the environment.

Machine perception is widely used in computer vision, speech recognition, and robotics. It involves detecting objects, understanding scenes, recognizing speech, and interpreting sensory inputs.

**Example:**
A self-driving car perceiving pedestrians, traffic signs, and road lanes using cameras and sensors.

### Pictorial Diagram: Machine Perception System

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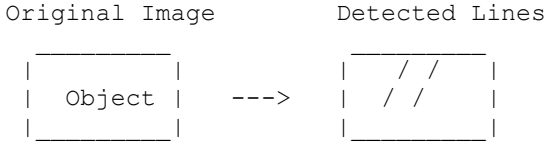
# 5.5 Line Finding and Interception

Line finding is an important problem in image processing and pattern recognition, used to detect straight lines in images. It plays a key role in object detection, road lane detection, and industrial inspection. One of the most widely used techniques for line detection is the **Hough Transform**.

Line interception refers to identifying the intersection points of detected lines, which helps in recognizing shapes and structures such as rectangles, buildings, or road crossings.

**Example:**
Detecting road lane markings in autonomous driving systems.

### Pictorial Diagram: Line Detection in Image

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# 5.6 Object Identification

Object Identification is the process of detecting and recognizing objects in images or scenes. It involves locating objects and classifying them into predefined categories. Object identification is a higher-level task that builds upon feature extraction, pattern recognition, and machine perception.

Modern object identification systems use machine learning and deep learning techniques to recognize objects under varying conditions such as lighting, scale, and orientation.

**Example:**
Identifying cars, pedestrians, and bicycles in traffic surveillance footage.

### Pictorial Diagram: Object Identification Process

```
Input Image
     |
Feature Extraction
     |
Pattern Matching / Classifier
     |
Identified Object
```

# Chapter 6

# Expert System

---

## 6.1 Introduction to Expert System

An **Expert System** is a branch of **Artificial Intelligence (AI)** that emulates the **decision-making ability of a human expert** in a specific domain. It uses **stored knowledge and reasoning techniques** to solve complex problems that normally require human expertise.

Expert systems do not replace human experts completely; instead, they **assist users** by providing **advice, diagnosis, decision support, or explanations**.

### Definition

An Expert System is a computer-based system that uses **knowledge**, **facts**, and **reasoning rules** to solve problems at a level comparable to a human expert.

### Example

- A **medical expert system** that diagnoses diseases based on symptoms.
- A **troubleshooting system** that identifies faults in computer hardware.

---

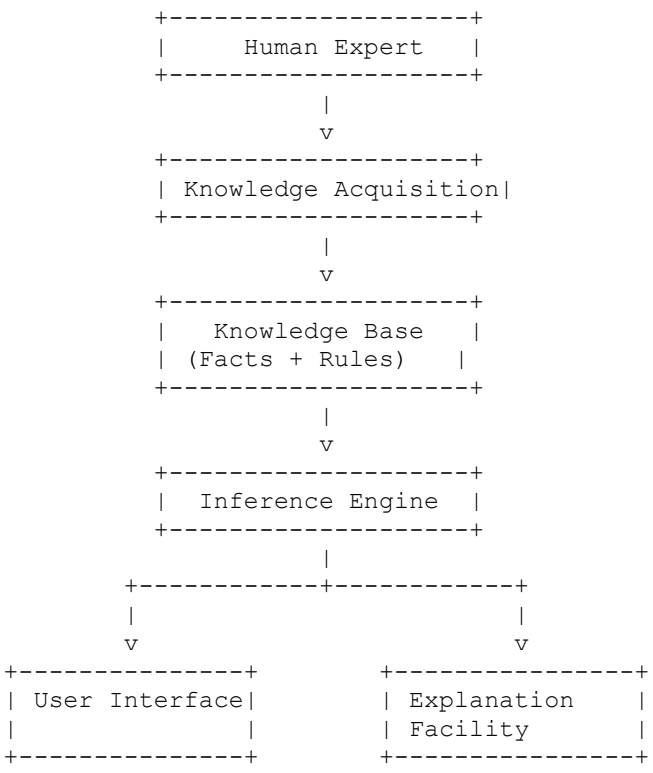
# 6.2 Basic Architecture of an Expert System

An expert system consists of several interconnected components that work together to simulate expert reasoning.

## Main Components

1. **Knowledge Base**
2. **Inference Engine**
3. **User Interface**
4. **Explanation Facility**
5. **Knowledge Acquisition Module**

## Pictorial Diagram: Basic Architecture




## Explanation

- **Knowledge Base** stores expert knowledge.
- **Inference Engine** applies logical rules.
- **User Interface** allows interaction.
- **Explanation Facility** explains reasoning steps.
- **Knowledge Acquisition** captures expert knowledge.

---

# 6.3 Types of Problems Solved by Expert Systems

Expert systems are suitable for **complex, knowledge-intensive problems**.

### Problem Types

1. **Diagnosis Problems**
   - Identify cause of faults or diseases
     *Example:* Medical diagnosis systems
2. **Decision-Making Problems**
   - Choose best alternative
     *Example:* Loan approval systems
3. **Planning Problems**
   - Generate action sequences
     *Example:* Production planning systems
4. **Prediction Problems**
   - Forecast future outcomes
     *Example:* Weather prediction systems
5. **Monitoring Problems**
   - Observe systems and detect abnormalities
     *Example:* Nuclear plant monitoring

---

# 6.4 Features of an Expert System

An expert system has the following key features:

1. **High Performance**
   - Provides accurate and reliable solutions.
2. **Domain-Specific Knowledge**
   - Focuses on a narrow problem area.
3. **Explanation Capability**
   - Justifies conclusions logically.
4. **Consistency**
   - Produces uniform decisions without fatigue.
5. **Heuristic Reasoning**
   - Uses rule-of-thumb approaches like humans.
6. **User-Friendly Interface**
   - Easy interaction with non-experts.

---

# 6.5 Expert System Architectures

### 1. Rule-Based Architecture

- Knowledge represented using **IF–THEN rules**.

**Example Rule**

```
IF fever AND cough
THEN diagnosis = flu
```

**Diagram**

```
Facts → Rules → Conclusion
```

---

### 2. Frame-Based Architecture

- Knowledge represented using **frames (structured objects)**.

**Example Frame**

```
Frame: Patient
- Age
- Symptoms
- Diagnosis
```

---

### 3. Hybrid Architecture

- Combines **rule-based and frame-based** systems.

**Diagram**

```
Rules + Frames → Inference Engine → Decision
```

---

# 6.6 Expert System Tools

Expert system tools simplify development and deployment.

### Common Tools and Languages

| Tool / Language | Description |
|---|---|
| **CLIPS** | Rule-based expert system tool |
| **PROLOG** | Logic programming language |
| **Jess** | Java-based expert system shell |
| **EMYCIN** | Medical expert system shell |
| **Drools** | Business rule management system |

### Example

- **CLIPS** used in NASA applications for fault diagnosis.

---

# 6.7 Existing Expert Systems

Several expert systems are successfully used in real-world applications.

### Examples

1. **MYCIN**
   - Medical diagnosis of bacterial infections.
2. **DENDRAL**
   - Chemical structure analysis.
3. **XCON (R1)**
   - Computer system configuration at DEC.
4. **PROSPECTOR**
   - Mineral exploration.
5. **PUFF**
   - Diagnosis of lung diseases.

---

# 6.8 Applications of Expert System Technology

Expert systems are widely used across various domains.

### Major Applications

1. **Healthcare**
   - Disease diagnosis, treatment recommendation.
2. **Engineering**
   - Fault detection, system maintenance.
3. **Finance**
   - Credit evaluation, investment advice.
4. **Education**
   - Intelligent tutoring systems.
5. **Manufacturing**
   - Quality control, process optimization.
6. **Agriculture**
   - Crop disease diagnosis, fertilizer recommendation.

### Pictorial Diagram: Application Areas