NUTAN MAHARASHTRA VIDYA PRASARAK MANDAL'S
NUTAN COLLEGE OF ENGINEERING & RESEARCH (NCER)
Department of Computer Science & Engineering

BTCOC701

Artificial Intelligence

Teaching Notes

Lecture Number	Topic to be covered
1	**Unit 1: Introduction (07Hrs)** □ Introduction, What Is AI?,
2	□ The Foundations of Artificial Intelligence
3	□ The History of Artificial Intelligence
4	□ Agents and Environments Good Behavior
5	□ The Concept of Rationality
6	□ The Nature of Environments The Structure of Agents.
7	□ The Structure of Agents.

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Unit 1: Introduction of AI

Artificial Intelligence:

- In today's world, technology is growing very fast, and we are getting in touch with different new technologies day by day Here, one of the booming technologies of computer science is Artificial Intelligence which is ready to create a new revolution in the world by making intelligent machines.
- The Artificial Intelligence is now all around us. It is currently working with a variety of subfields, ranging from general to specific, such as self-driving cars, playing chess, proving theorems, playing music, Painting, etc.
- One of the greatest innovators in the field of machine learning was **John McCarthy**, widely recognized as the **"Father of Artificial Intelligence".**
- In the mid 1950s, McCarthy coined the term "Artificial Intelligence" and defined it as "the science of making intelligent machines
- According to the father of Artificial Intelligence, **John McCarthy**, it is "**The science and engineering of making intelligent machines, especially intelligent computer programs".**
- Artificial Intelligence is a way of making a computer, **a computer-controlled robot, or a software think intelligently, in the similar manner the intelligent humans think**.
- AI is accomplished by studying how human brain thinks, and how humans learn, decide, and work while trying to solve a problem, and then using the outcomes of this study as a basis of developing intelligent software and systems.
- Artificial Intelligence suggest that machines can mimic humans in:

Talking

Thinking

Learning

Planning

Understanding

- Artificial Intelligence is composed of two words **Artificial** and **Intelligence**, where Artificial defines **"man-made,"** and intelligence defines **"thinking power",** hence AI means "a man-made thinking power."
- **"It is a branch of computer science by which we can create intelligent machines which can behave like a human, think like humans, and able to make decisions.**

Why Artificial Intelligence:

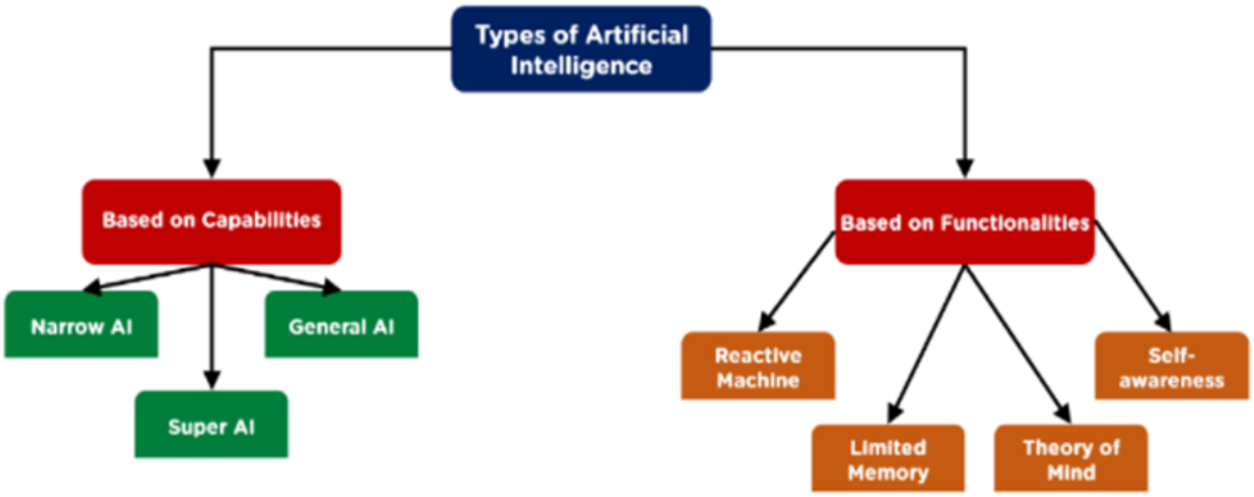
Before Learning about Artificial Intelligence, we should know that what is the importance of AI and why should we learn it. Following are some main reasons to learn about AI:

- With the help of AI, you can create such software or devices which can solve real-world problems very easily and with accuracy such as health issues, marketing, traffic issues, etc.
- With the help of AI, you can create your personal virtual Assistant, such as Cortana, Google Assistant, Siri, etc.
- With the help of AI, you can build such Robots which can work in an environment where survival of humans can be at risk.
- AI opens a path for other new technologies, new devices, and new Opportunities.

Goals of Artificial Intelligence

1. It helps you reduce the amount of time needed to perform specific tasks.
2. Making it easier for humans to interact with machines.
3. Facilitating human-computer interaction in a way that is more natural and efficient.
4. Improving the accuracy and speed of medical diagnoses.
5. Helping people learn new information more quickly.
6. Enhancing communication between humans and machines.

Types of Artificial Intelligence



1. **Artificial narrow intelligence (ANI),** which has a narrow range of abilities;

• Narrow AI is a type of AI which is able to perform a dedicated task with intelligence.The most common and currently available AI is Narrow AI in the world of Artificial Intelligence.

• Artificial narrow intelligence (ANI), also referred to as weak AI or narrow AI, is the only type of artificial intelligence we have successfully realized to date. Narrow AI is goal-oriented, designed to perform singular tasks - i.e. facial recognition, speech recognition/voice assistants, driving a car, or se •

While these machines may seem intelligent, they operate under a narrow set of constraints and limitations, which is why this type is commonly referred to as weak AI. Narrow AI doesn't mimic or replicate human intelligence, it merely simulates human behaviour based on a narrow range of parameters and contexts.

• Consider the speech and language recognition of the Siri virtual assistant on iPhones, vision recognition of self-driving cars, and recommendation engines that suggest products you make like based on your purchase history. These systems can only learn or be taught to complete specific tasks.

• Narrow AI's machine intelligence comes from the use of natural language processing (NLP) to

perform tasks. NLP is evident in chatbots and similar AI technologies. By understanding speech and text in natural language, AI is programmed to interact with humans in a natural, personalised manner.arching the internet - and is very intelligent at completing the specific task it is programmed to do.

Examples of narrow AI:

- Rankbrain by Google / Google Search
- Siri by Apple, Alexa by Amazon, Cortana by Microsoft and other virtual assistants
- IBM's Watson
- Image / facial recognition software
- Disease mapping and prediction tools
- Manufacturing and drone robots
- Email spam filters / social media monitoring tools for dangerous content
- Entertainment or marketing content recommendations based on watch/listen/purchase behaviour
- Self-driving cars

2. **Artificial General Intelligence (AGI) / Strong AI / Deep AI** : which is on par with human capabilities

•Artificial general intelligence (AGI), also referred to as strong AI or deep AI, is the concept of a machine with general intelligence that mimics human intelligence and/or behaviors, with the ability to learn and apply its intelligence to solve any problem. AGI can think, understand, and act in a way that is indistinguishable from that of a human in any given situation.

•The machines will not require humans to input programming to function. For all intents and purposes, this would be when machines act, feel, respond and think just like humans. We will be able to say strong AI has a mind of its own and will be able to accomplish any task it sets out to complete, just like any human.

•AI researchers and scientists have not yet achieved strong AI. To succeed, they would need to find a way to make machines conscious, programming a full set of cognitive abilities. Machines would have to take experiential learning to the next level, not just improving efficiency on singular tasks, but gaining the ability to apply experiential knowledge to a wider range of different problems.

•Currently, Most AI examples that you hear about- from **chess-playing computers, self-driving cars to understanding speech or text delivered in natural language rely on deep learning and natural language processing**

•Currently, there is no such system exist which could come under general AI and can perform any task as

perfect as a human.

•The worldwide researchers are now focused on developing machines with General AI.

•As systems with general AI are still under research, and it will take lots of efforts and time to develop such systems

3. **Artificial Superintelligence (ASI)** : which is more capable than a human

•Artificial super intelligence (ASI), is the hypothetical AI that doesn't just mimic or understand human intelligence and behaviour; ASI is where machines become self-aware and surpass the capacity of human intelligence and ability.

•In addition to replicating the multi-faceted intelligence of human beings, ASI would theoretically be exceedingly better at everything we do; math, science, sports, art, medicine, hobbies, emotional relationships, everything. ASI would have a greater memory and a faster ability to process and analyses data and stimuli. Consequently, the decision-making and problem solving capabilities of super intelligent beings would be far superior than those of human beings

Artificial Intelligence type-2: Based on functionality

1. Reactive Machines

- Purely reactive machines are the most basic types of Artificial Intelligence.
- This type of machine reacts depending on the present moment .
- Such AI systems do not store memories or past experiences for future actions.
- These machines only focus on current scenarios and react on it as per possible best action.
- IBM's Deep Blue system is an example of reactive machines.
- Google's AlphaGo is also an example of reactive machines
- Example: Chess Player Machine this type of machine greate with playing games has ability to recognize which move would be best

2. Limited Memory

- Limited memory machines can store past experiences or some data for a short period of time.
- These machines can use stored data for a limited time period only.
- Self-driving cars are one of the best examples of Limited Memory systems. These cars can store recent speed of nearby cars, the distance of other cars, speed limit, and other information to navigate the road. E.g Traffic light , chat Robots

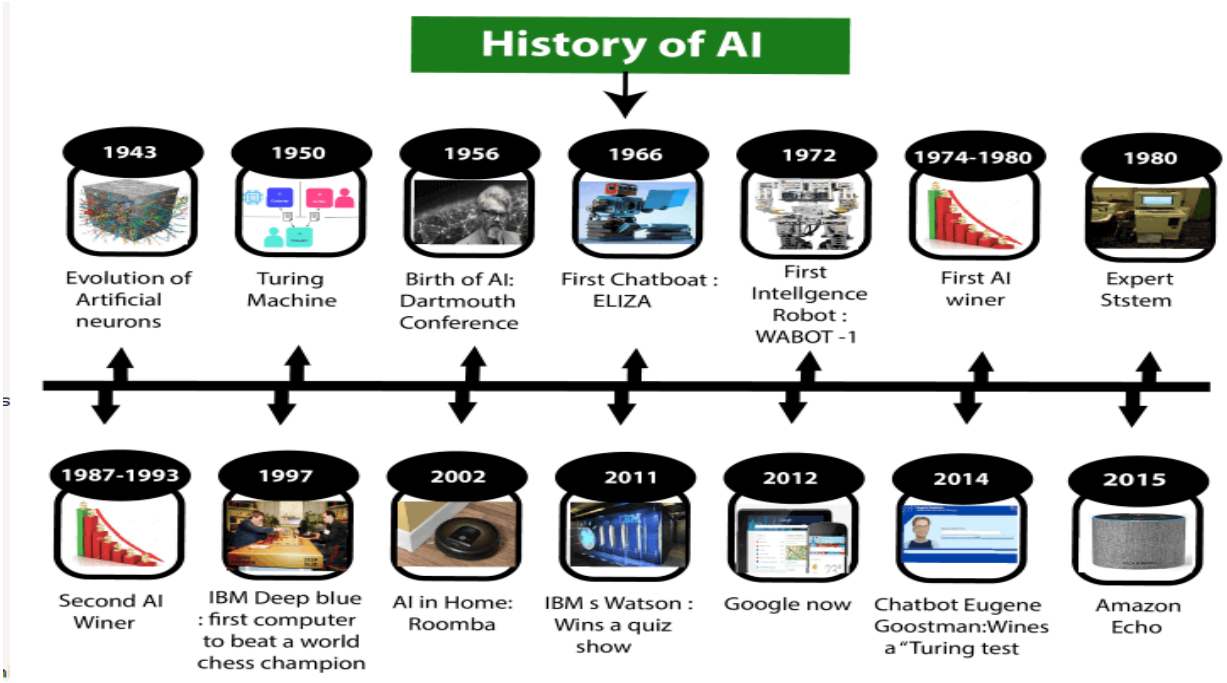
3. Theory of Mind

- Theory of Mind AI should understand the human emotions, people, beliefs, and be able to interact socially like humans.
- This type of AI machines is still not developed, but researchers are making lots of efforts and improvement for developing such AI machines.
- This type of AI Machine more intelligent as it reacts according to understood people thought & emotions, these machines can adjust with people around, build social interactions, predict how people expect to be Treats & thus behave according of these expectations.
- Example : **Robot Sofia** – Camera present in Sophia's eves combined with computer algorithms allow her to see , sustain eye contact , recognize individual & follow faces

4. Self-Awareness

- Self-awareness AI is the future of Artificial Intelligence. These machines will be super intelligent, and will have their own consciousness, sentiments, and self-awareness.
- These machines will be smarter than human mind. More aware of their needs and internal sense than human being
- Self-Awareness AI does not exist in reality still and it is a hypothetical concept. Such system understands their internal traits, states & conditions and perceives human emotion.
- This type of AI will not only be to understand and evoke emotions in those it interact with but also have emotions, needs and beliefs of it's own.

History of Artificial Intelligence



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.

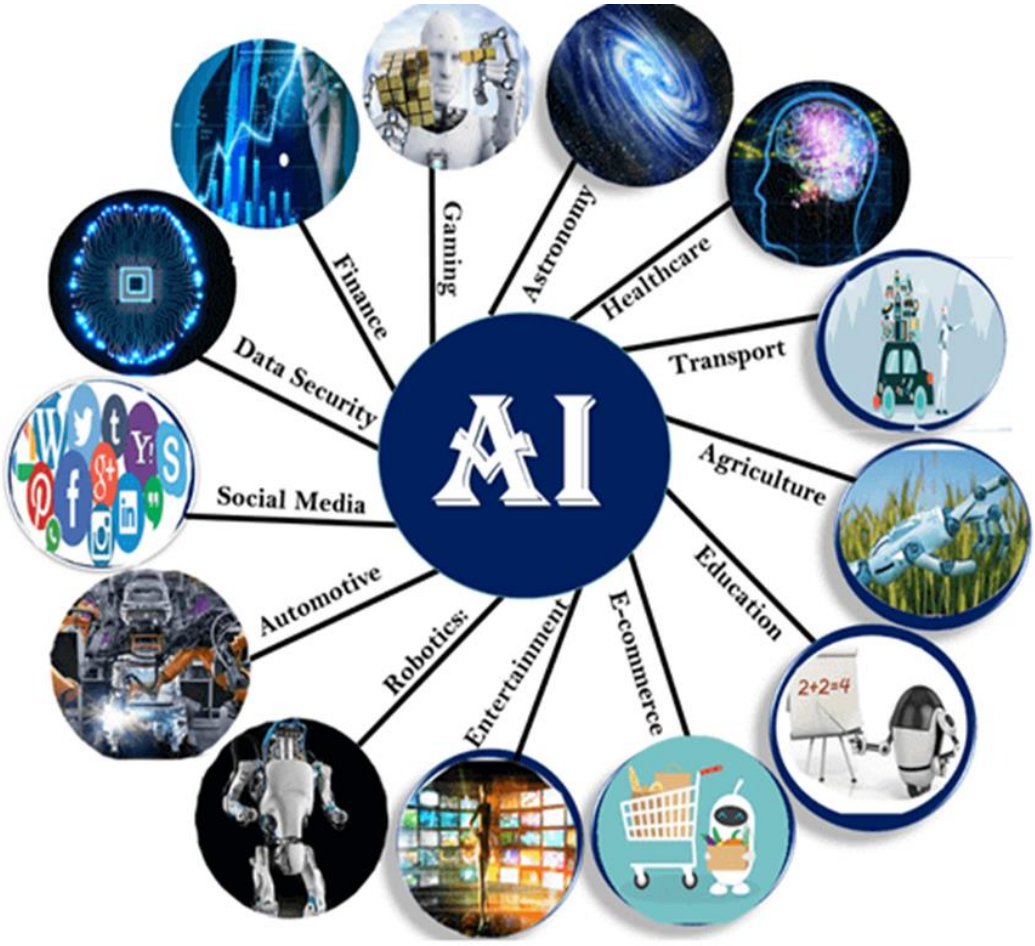
- **Year 2006:** AI came in the Business world till the year 2006. Companies like Facebook, Twitter, and Netflix also started using AI.

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.

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:



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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.

AI Examples

Artificial Intelligence Samples:

- Self Driving Cars
- E-Payment
- Google Maps
- Text Autocorrect
- Automated Translation
- Chatbots
- Social Media
- Face Detection
- Search Algorithms
- Robots
- Automated Investment
- NLP - Natural Language Processing
- Flying Drones
- Dr. Watson
- Apple Siri
- Microsoft Cortana
- Amazon Ale

Advantages of Artificial Intelligence

- **High Accuracy with less errors:** AI machines or systems are prone to less errors and high accuracy as it takes decisions as per pre-experience or information.
- **High-Speed:** AI systems can be of very high-speed and fast-decision making, because of that AI systems can beat a chess champion in the Chess game.
- **High reliability:** AI machines are highly reliable and can perform the same action multiple times with high accuracy.
- **Useful for risky areas:** AI machines can be helpful in situations such as defusing a bomb, exploring the ocean floor, where to employ a human can be risky.
- **Digital Assistant:** AI can be very useful to provide digital assistant to the users such as AI technology is currently used by various E-commerce websites to show the products as per customer requirement.
- **Useful as a public utility:** AI can be very useful for public utilities such as a self-driving car which can make our journey safer and hassle-free, facial recognition for security purpose, Natural language processing to communicate with the human in human-language, etc.

Disadvantages of Artificial Intelligence

- **High Cost:** The hardware and software requirement of AI is very costly as it requires lots of maintenance to meet current world requirements.
- **Can't think out of the box:** Even we are making smarter machines with AI, but still they cannot work out of the box, as the robot will only do that work for which they are trained, or programmed.
- **No feelings and emotions:** AI machines can be an outstanding performer, but still it does not have the feeling so it cannot make any kind of emotional attachment with human, and may sometime be harmful for users if the proper care is not taken.
- **Increase dependency on machines:** With the increment of technology, people are getting more dependent on devices and hence they are losing their mental capabilities.
- **No Original Creativity:** As humans are so creative and can imagine some new ideas but still AI machines cannot beat this power of human intelligence and cannot be creative and imaginative

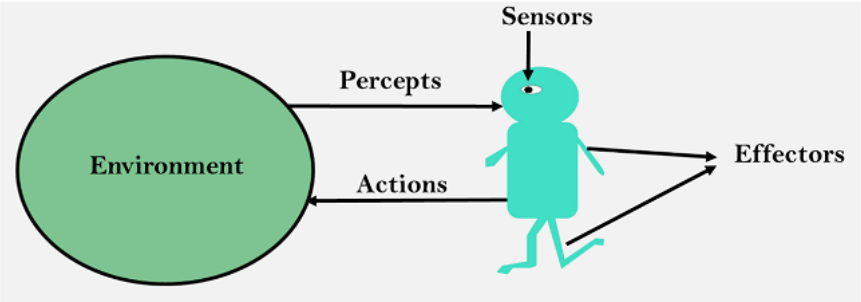
What are Agent and Environment?

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 perceive its 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: An agent is anything that can perceive its environment through sensors and acts upon that environment through effectors.

- **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. A software agent has encoded bit strings as its programs and actions.



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

Before moving forward, 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.

Agent Terminology

- **Performance Measure of Agent** − It is the criteria, which determines how successful an agent is.
- **Behavior of Agent** − It is the action that agent performs after any given sequence of percepts.
- **Percept** − It is agent's perceptual inputs at a given instance.
- **Percept Sequence** − It is the history of all that an agent has perceived till date.
- **Agent Function** − It is a map from the precept sequence to an action.

Intelligent Agents:

An intelligent agent is an autonomous entity which acts 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.

The Concept of Rationality:

Rationality is nothing but status of being reasonable, sensible, and having good sense of judgment.

Rationality is concerned with expected actions and results depending upon what the agent has perceived. Performing actions with the aim of obtaining useful information is an important part of 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.

Rational Agent:

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.

An ideal rational agent is the one, which is capable of doing expected actions to maximize its performance measure, on the basis of −

- Its percept sequence
- Its built-in knowledge base

Rationality of an agent depends on the following −

- The performance measures, which determine the degree of success.
- Agent's Percept Sequence till now.
- The agent's prior knowledge about the environment.
- The actions that the agent can carry out.

A rational agent always performs right action, where the right action means the action that causes the agent to be most successful in the given percept sequence. The problem the agent solves is characterized by Performance Measure, Environment, Actuators, and Sensors (PEAS).

Agent Environment in AI

An environment is everything in the world which surrounds the agent, but it is not a part of an agent itself. An environment can be described as a situation in which an agent is present.

The environment is where agent lives, operate and provide the agent with something to sense and act upon it. An environment is mostly said to be non-feministic.

Type (Features) of Environment

An environment in artificial intelligence is the surrounding of the agent. The agent takes input from the environment through sensors and delivers the output to the environment through actuators. There are several types of environmentsStep-1: Select random K data points from the training set.

1. Fully observable vs Partially Observable
2. Static vs Dynamic
3. Discrete vs Continuous
4. Deterministic vs Stochastic
5. Single-agent vs Multi-agent
6. Episodic vs sequential
7. Known vs Unknown
8. Accessible vs Inaccessible

1. Fully observable vs Partially Observable:

- If an agent sensor can sense or access the complete state of an environment at each point of time then it is a fully observable environment, else it is partially observable.
- A fully observable environment is easy as there is no need to maintain the internal state to keep track history of the world.
- Maintaining a fully observable environment is easy as there is no need to keep track of the history of the surrounding.
- An environment is called unobservable when the agent has no sensors in all environments.

Examples:

Chess – the board is fully observable, so are the opponent's moves.

Driving – the environment is partially observable because what's around the corner is not known.

2. Deterministic vs Stochastic:

- If When a uniqueness an agent's current state and selected action can completely determine the next state of the environment, then such environment is called a **deterministic environment**.
- In a deterministic, fully observable environment, agent does not need to worry about uncertainty.
- **The stochastic environment** is random in nature which is not unique and cannot be completely determined by the agent.

Examples:

Chess – there would be only a few possible moves for a coin at the current state and these moves can be determined.

Self Driving Cars – the actions of a self-driving car are not unique, it varies time to time.

3. Episodic vs Sequential:

- In an episodic environment, there is a series of one-shot actions, and only the current percept is required for the action.
- In Episodic task environment, each of the agents action is divided into an atomic incidents or episodes. There is no dependency between current and previous incident. In each incident agent receives input from environment and then performs corresponding action.
- **Example:** Consider an example of **Pick and Place robot**, which is used to detect defective parts from conveyer belt. Here, every time robot(agent) will make decision on current part i.e. there is no dependency between current and previous decision.
- However, in Sequential environment, an agent requires memory of past actions to determine the next best actions.
- In Sequential environment, previous decision can affect all future decisions. The next action of agent depends on what action he has taken previously and what action he is supposed to take in future.

Example:

Checkers- Where previous move can affect all the following moves.

4. Single-agent vs Multi-agent

- If only one agent is involved in an environment, and operating by itself then such an environment is called single agent environment.
- However, if multiple agents are operating in an environment, then such an environment is called a multi-agent environment.
- The agent design problems in the multi-agent environment are different from single agent environment consisting of only one agent is said to be a single-agent environment.
- A person left alone in a **maze is an example of the single-agent system.**
- An environment involving more than one agent is a multi-agent environment.
- The game of **football** is multi-agent as it involves 11 players in each team.vironment.

5. Static vs Dynamic:

- If the environment can change itself while an agent is deliberating then such environment is called a dynamic environment else it is called a static environment.
- Static environments are easy to deal because an agent does not need to continue looking at the world while deciding for an action.
- However for dynamic environment, agents need to keep looking at the world at each action.
- **Taxi driving** is an example of a dynamic environment whereas **Crossword puzzles are an example of a static environment.**
- An environment that keeps constantly changing itself when the agent is up with some action is said to be dynamic.
- **A roller coaster** ride is **dynamic** as it is set in motion and the environment keeps changing every instant.
- An idle environment with no change in its state is called a static environment.
- An **empty house** is **static** as there's no change in the surroundings when an agent enters.

6. Discrete vs Continuous:

- If in an environment there are a finite number of percepts and actions that can be performed within it, then such an environment is called a discrete environment else it is called continuous environment.
- A chess game comes under discrete environment as there is a finite number of moves that can be performed.
- A self-driving car is an example of a continuous environment.

- If an environment consists of a finite number of actions that can be deliberated in the environment to obtain the output, it is said to be a discrete environment.
- The **game of chess** is **discrete** as it has only a finite number of moves. The number of moves might vary with every game, but still, it's finite.
- The environment in which the actions performed cannot be numbered i.e.. is not discrete, is said to be continuous.
- **Self-driving** cars are an example of **continuous environments** as their actions are driving, parking, etc. which cannot be numbered

7. Known vs Unknown

- Known and unknown are not actually a feature of an environment, but it is an agent's state of knowledge to perform an action.
- In a known environment, the results for all actions are known to the agent. While in unknown environment, agent needs to learn how it works in order to perform an action.
- It is quite possible that a known environment to be partially observable and an Unknown environment to be fully observable.

8. Accessible vs Inaccessible

- If an agent can obtain complete and accurate information about the state's environment, then such an environment is called an Accessible environment else it is called inaccessible.
- An empty room whose state can be defined by its temperature is an example of an accessible environment.
- Information about an event on earth is an example of Inaccessible environment.

The Structure of Intelligent Agents

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:

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.

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

Agent's structure can be viewed as −

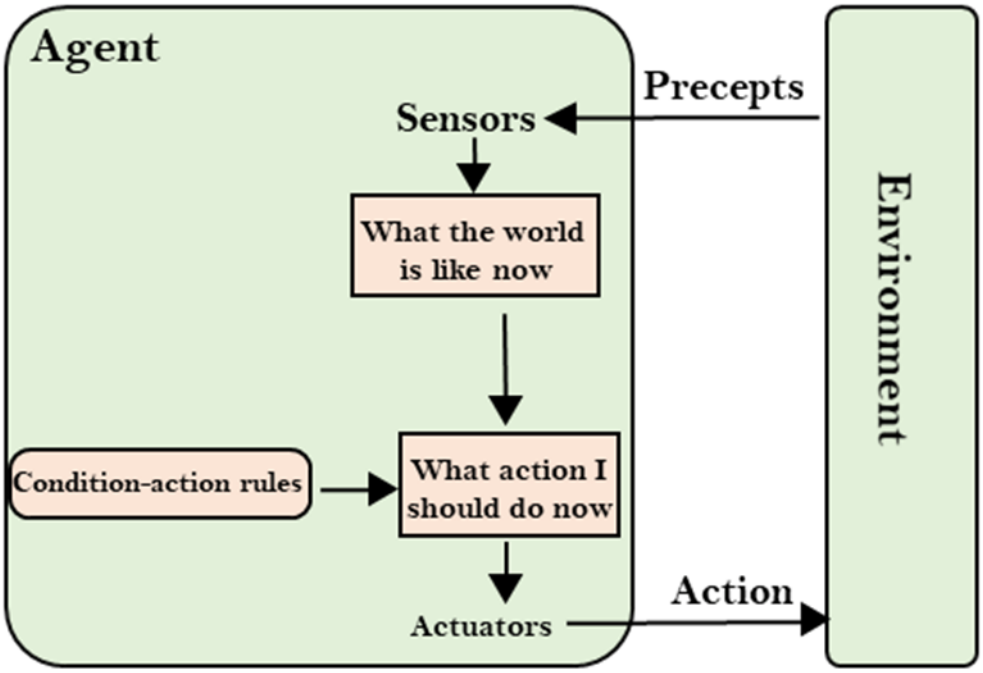
- **Agent** = Architecture + Agent Program
- **Architecture** = the machinery that an agent executes on.
- **Agent Program** = an implementation of an agent function.

Types of AI Agents

Agents can be grouped into five classes based on their degree of perceived intelligence and capability. All these agents can improve their performance and generate better action over the time. These are given below:

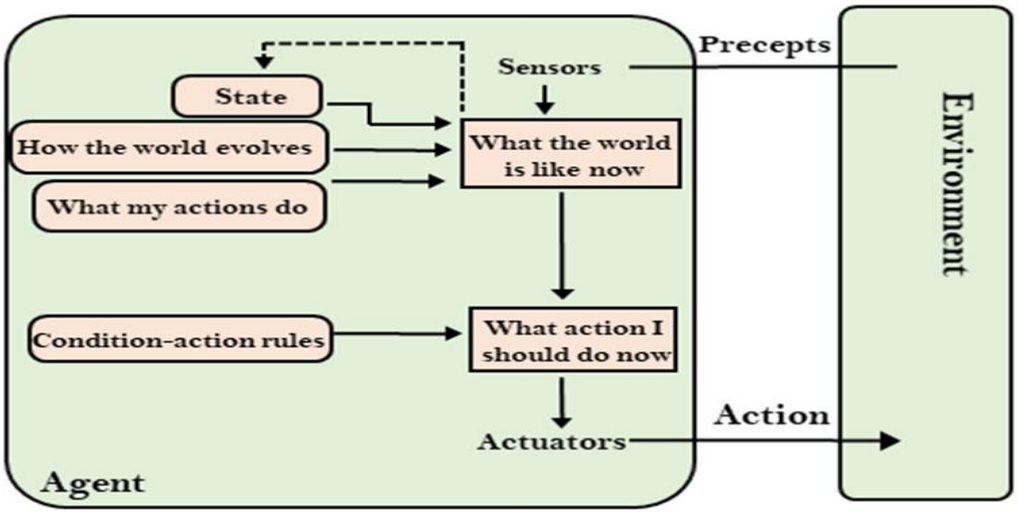
1. Simple Reflex Agent
2. Model-based reflex agent
3. Goal-based agents
4. Utility-based agent
5. Learning agent

1. Simple Reflex agent:



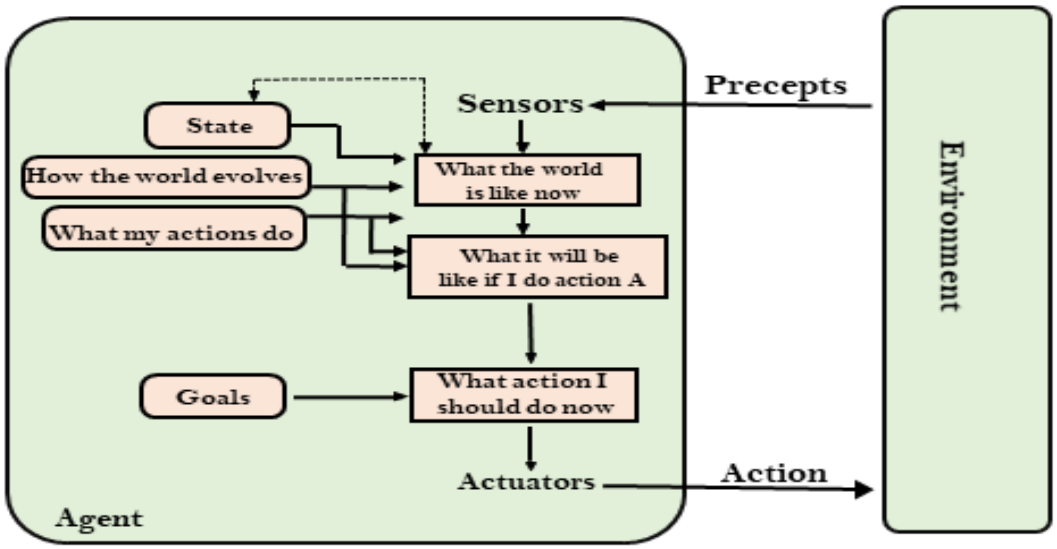
- The Simple reflex agents are the simplest agents. These agents take decisions on the basis of the current precepts and ignore the rest of the percept history.
- These agents only succeed in the fully observable environment.
- The Simple reflex agent does not consider any part of percepts history during their decision and action process.
- The Simple reflex agent works on Condition-action rule, which means it maps the current state to action. Such as a **Room Cleaner agent**, it works only **if there is dirt in the room**.
- Problems for the simple reflex agent design approach:
    - They have very limited intelligence
    - They do not have knowledge of non-perceptual parts of the current state
    - Mostly too big to generate and to store.
    - Not adaptive to changes in the environment.

2. Model-based reflex agent



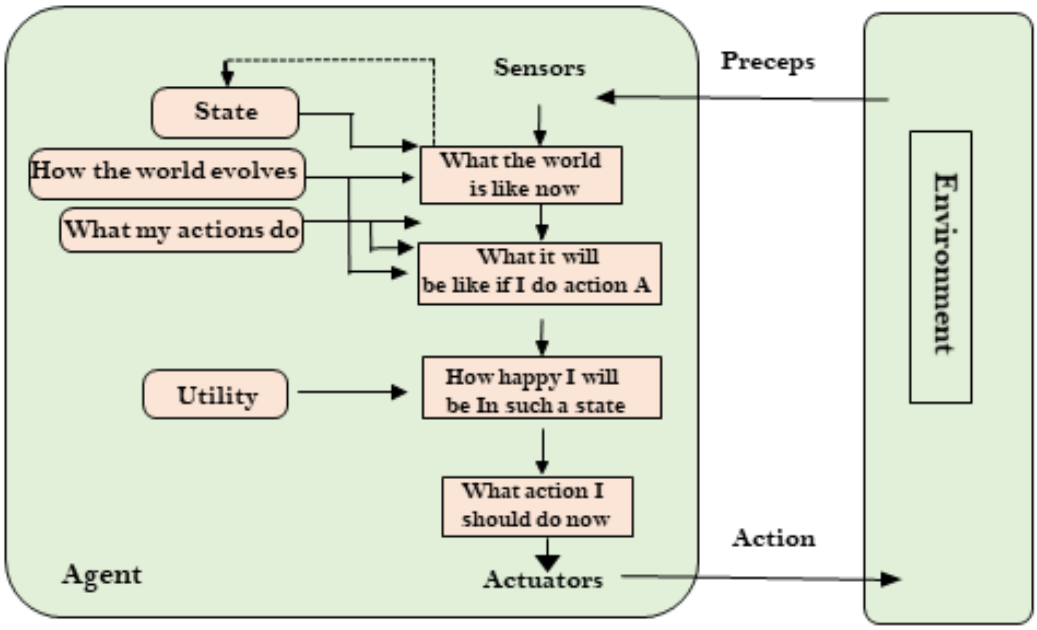
- The Model-based agent can work in a partially observable environment, and track the situation.
- A model-based agent has two important factors:
    - **Model:** It is knowledge about "how things happen in the world," so it is called a Model-based agent.
    - **Internal State:** It is a representation of the current state based on percept history.
- These agents have the model, "which is knowledge of the world" and based on the model they perform actions.
- Updating the agent state requires information about:
    - How the world evolves
    - How the agent's action affects the world.

3. Goal-based agents



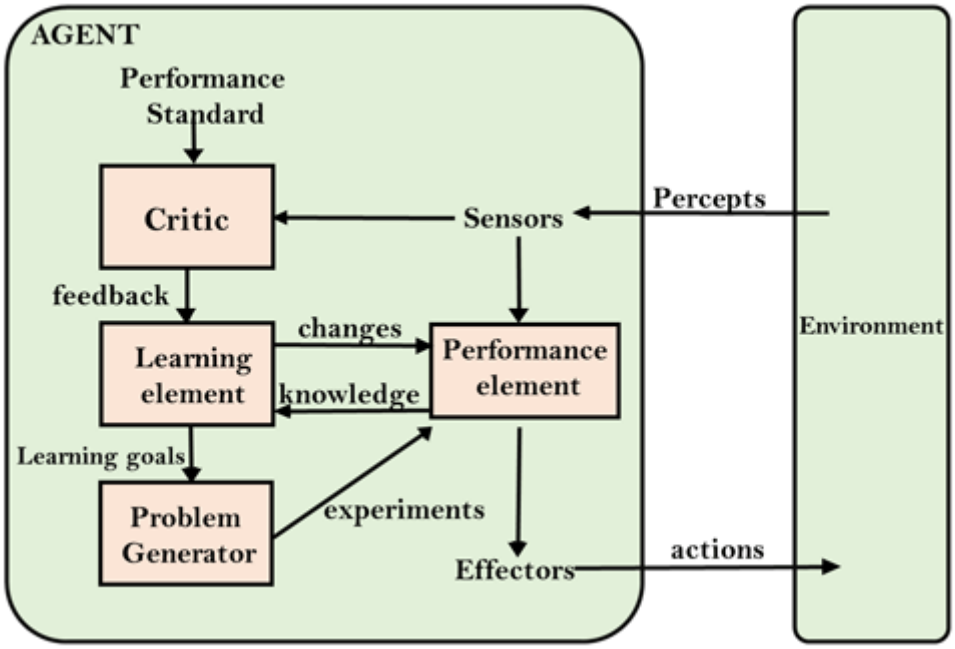
- The knowledge of the current state environment is not always sufficient to decide for an agent to what to do.
- The agent needs to know its goal which describes desirable situations.
- Goal-based agents expand the capabilities of the model-based agent by having the "goal" information.
- They choose an action, so that they can achieve the goal.
- These agents may have to consider a long sequence of possible actions before deciding whether the goal is achieved or not. Such considerations of different scenario are called searching and planning, which makes an agent proactive.

4. Utility-based agents



- These agents are similar to the goal-based agent but provide an extra component of utility measurement which makes them different by providing a measure of success at a given state.
- Utility-based agent act based not only goals but also the best way to achieve the goal.
- The Utility-based agent is useful when there are multiple possible alternatives, and an agent has to choose in order to perform the best action.
- The utility function maps each state to a real number to check how efficiently each action achieves the goals.

5. Learning Agents



- A learning agent in AI is the type of agent which can learn from its past experiences, or it has learning capabilities.
- It starts to act with basic knowledge and then able to act and adapt automatically through learning.
- A learning agent has mainly four conceptual components, which are:
    - **Learning element:** It is responsible for making improvements by learning from environment
    - **Critic:** Learning element takes feedback from critic which describes that how well the agent is doing with respect to a fixed performance standard.
    - **Performance element:** It is responsible for selecting external action
    - **Problem generator:** This component is responsible for suggesting actions that will lead to new and informative experiences.
- Hence, learning agents are able to learn, analyse performance, and look for new ways to improve the performance.

(Subject In-charge)

Prof.S.B.Mehta)

Unit 2: Problem Solving

Asst. Prof. S.B.Mehta

Computer Science and Engineer

Problem Solving

- In computer science, problem-solving refers to artificial intelligence techniques, including various techniques such as forming efficient algorithms, heuristics, and performing root cause analysis to find desirable solutions.
- In artificial intelligence, problems can be solved by using searching algorithms, evolutionary computations, knowledge representations, etc.
- The process of problem-solving using searching consists of the following steps.

    1. Define the problem
    2. Analyze the problem
    3. Identification of possible solutions
    4. Choosing the optimal solution
    5. Implementation

Problem Solving Agent

- The problem-solving agent preforms precisely by defining problems and its several solutions.
- “A problem-solving refers to a state where we wish to reach to a definite goal from a present state or condition.
- According to computer science, a problem-solving is a part of artificial intelligence which encompasses a number of techniques such as algorithms, heuristics to solve a problem.
- Therefore, a problem-solving agent is a goal-driven agent and focuses on satisfying the goal.

Problem Solving Agent

Steps performed by Problem-solving agent

- **Goal Formulation:** It is the first and simplest step in problem-solving. It organizes the steps/sequence required to formulate a target/goals which require some action to achieve the goal. Today the formulation of the goal is based on AI agents.

- **Problem Formulation:** It is the most important step of problem-solving which decides what actions should be taken to achieve the formulated goal. There are following five components involved in problem formulation

Problem Solving Agent

There are following five components involved in problem formulation

- **Initial State**: It is the starting state or initial step of the agent towards its goal.
- **Actions:** It is the description of the possible actions available to the agent.
- **Transition Model**: It describes what each action does.
- **Goal Test**: It determines if the given state is a goal state.
- **Path cost**: It assigns a numeric cost to each path that follows the goal. The problem-solving agent selects a cost function, which reflects its performance measure.

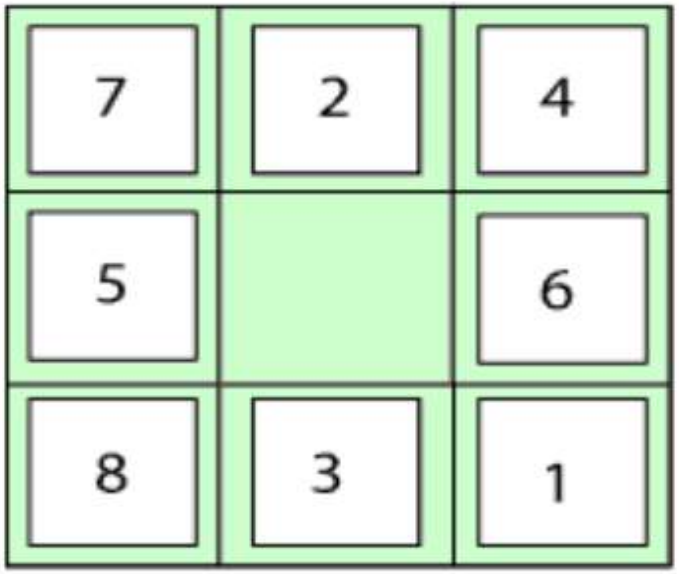
Example Problems

Basically, there are two types of problem approaches:

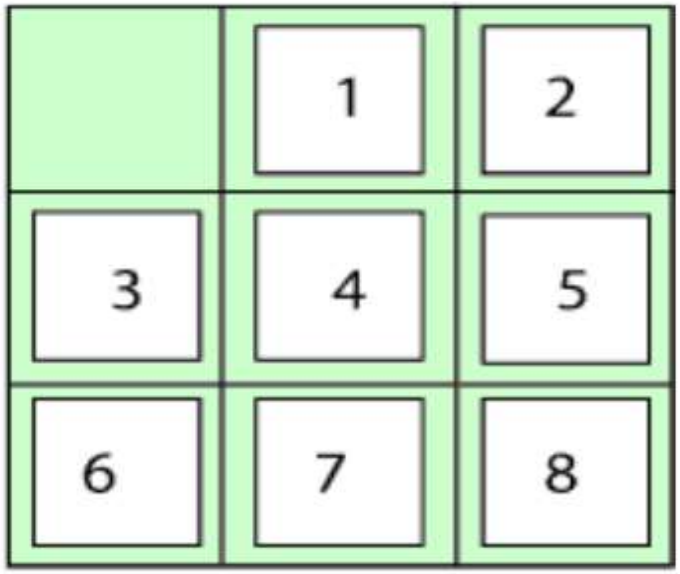
- **Toy Problem**: It is a concise and exact description of the problem which is used by the researchers to compare the performance of algorithms.
- **Real-world Problem:** It is real-world based problems which require solutions. Unlike a toy problem, it does not depend on descriptions, but we can have a general formulation of the problem.

Toy Problem

8 Puzzle Problem



Start State



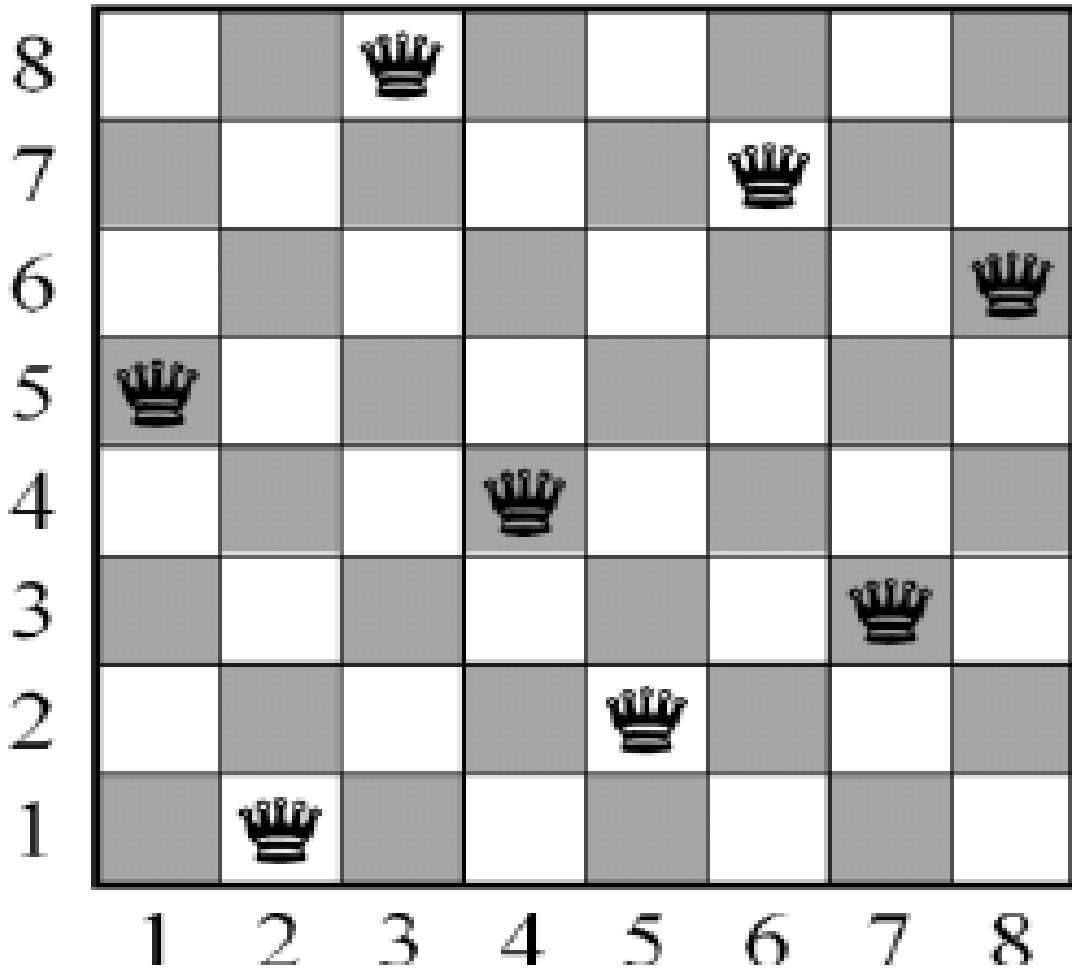
Goal State

The problem formulation is as follows:

- **States:** It describes the location of each numbered tiles and the blank tile.
- **Initial State**: We can start from any state as the initial state.
- **Actions:** Here, actions as movements of the blank space is defined, i.e., either left, right, up or down
- **Transition Model**: It returns the resulting state as per the given state and actions.
- **Goal test**: It identifies whether we have reached the correct goal-state.
- **Path cost:** The path cost is the number of steps in the path where the cost of each step is 1.

Toy Problem

8 Queen Problem



The problem formulation is as follows:

- **Incremental formulation:** It starts from an empty state where the operator augments a queen at each step.
    - **States:** Arrangement of any 0 to 8 queens on the chessboard.
    - **Initial State:** An empty chessboard
    - **Actions:** Add a queen to any empty box.
    - **Transition model:** Returns the chessboard with the queen added in a box.
    - **Goal test:** Checks whether 8-queens are placed on the chessboard without any attack.
    - **Path cost:** There is no need for path cost because only final states are counted.

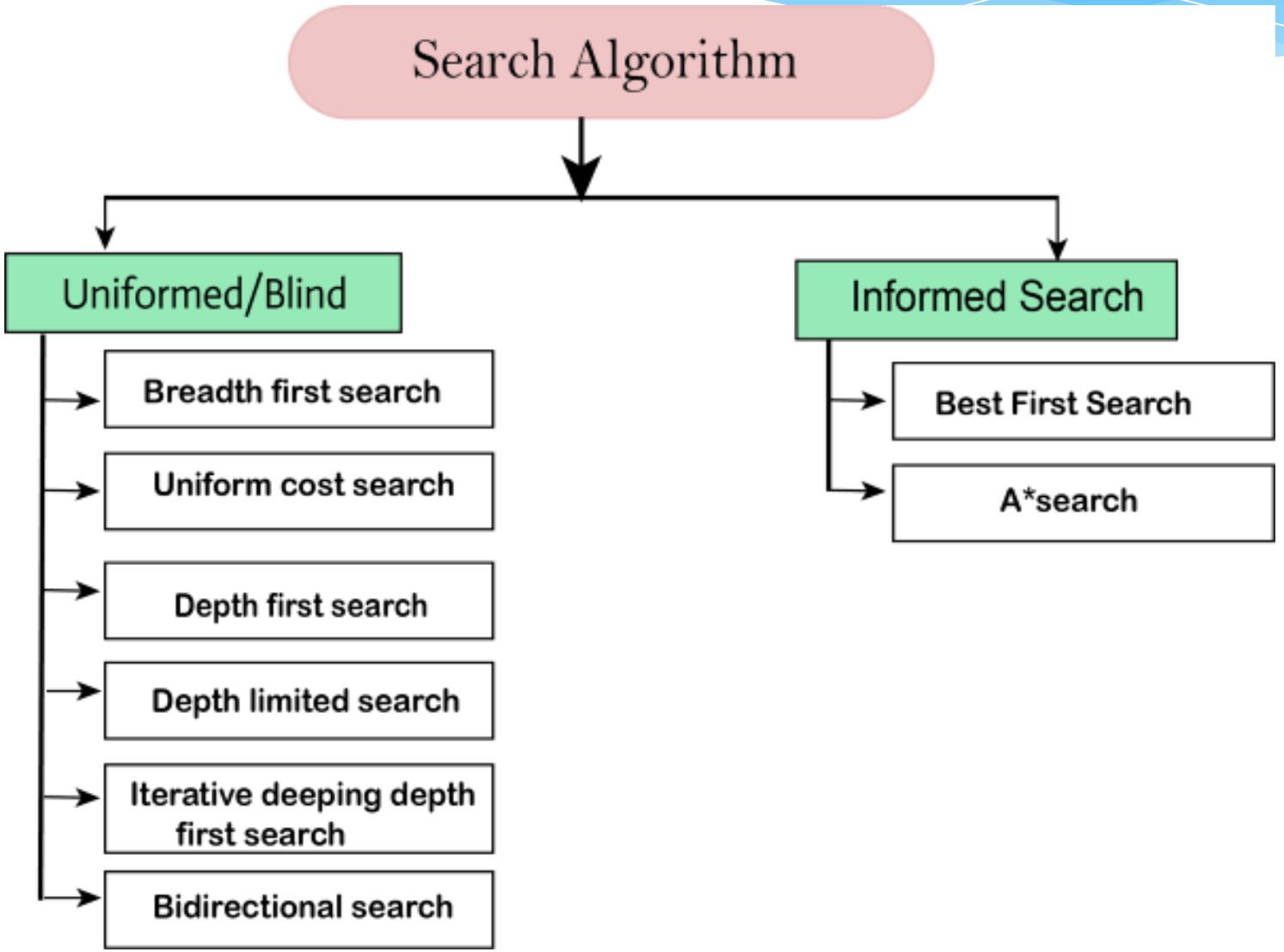
Search Algorithm Terminologies :

- **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:
  - **Search Space:** Search space represents a set of possible solutions, which a system may have.
  - **Start State:** It is a state from where agent begins **the search**.
  - **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:

- **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.

Types of 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 five main types:

- Depth-first search
- Breadth-first search
- Uniform cost search
- Iterative deepening depth-first search
- Bidirectional Search

Depth-first Search::

- Depth-first search is a 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 LIFO stack data structure for its implementation.

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).

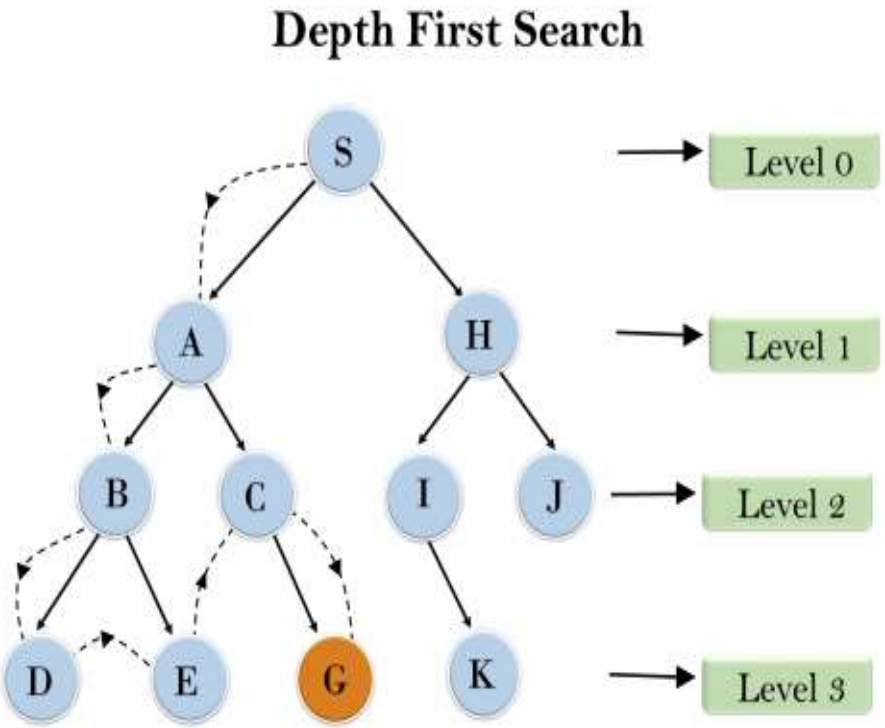
Disadvantage:

- 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 :Depth-first Search

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.



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.
- It starts from the root node, explores the neighboring nodes first and moves towards the next level neighbors. It generates one tree at a time until the solution is found.
- It can be implemented using FIFO queue data structure. This method provides shortest path to the solution.
- **Advantage:**
- 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.

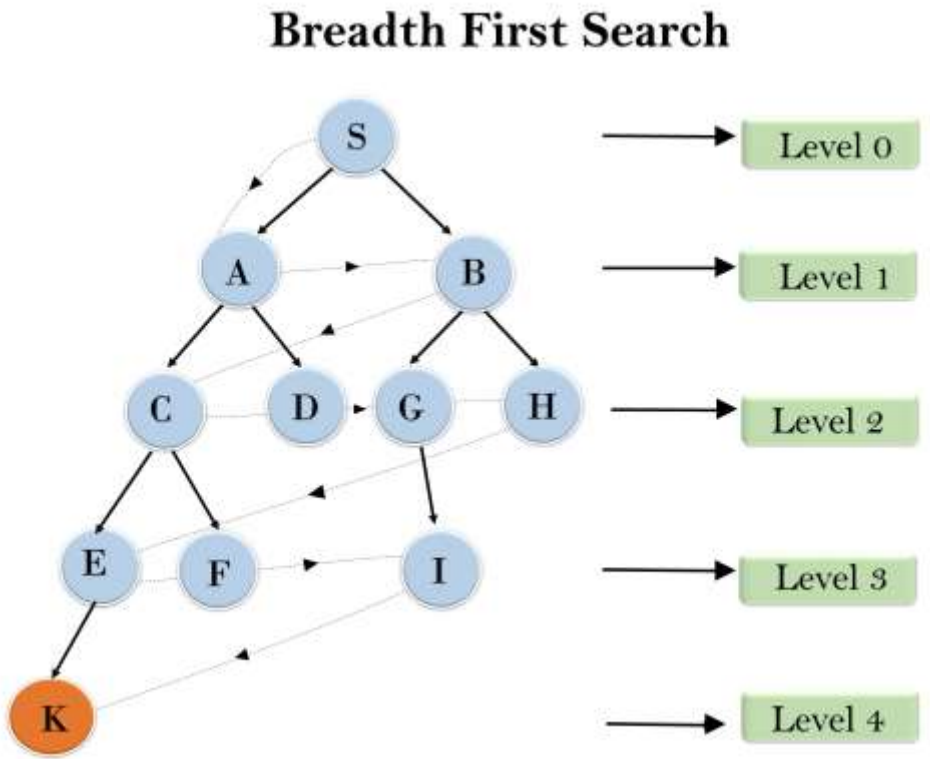
Disadvantage:

- 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 :Breadth-first Search

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



Informed Search (Heuristic Search)

- Informed search algorithms use domain knowledge. In an informed search, problem information is available which can guide the search.
- Informed search strategies can find a solution more efficiently than an uninformed search strategy. Informed search is also called a Heuristic search.
- This search maintains some sort of internal states via heuristic functions (which provides hints), so it is also called **heuristic search**.

There are following types of informed searches:

- Best first search (Greedy search)
- A* search

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**

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. I
- t 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.

f(n)= h(n).

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

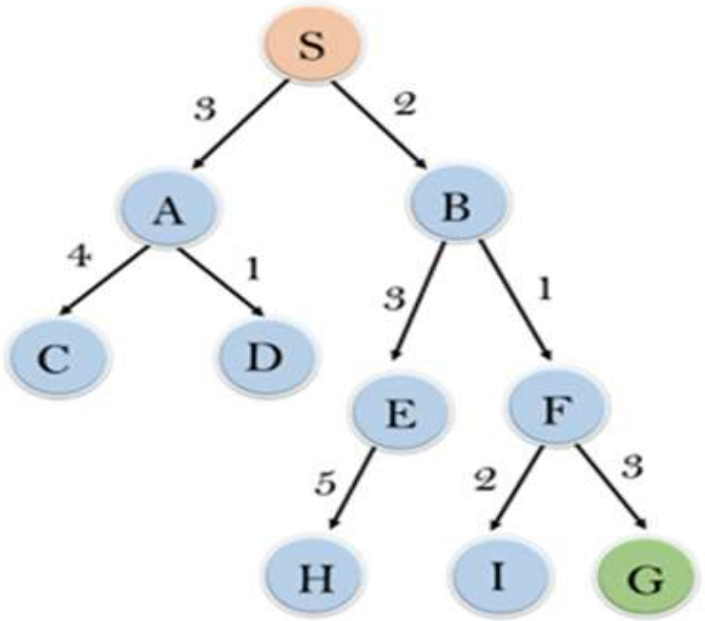
The greedy best first algorithm is implemented by the priority queue.

Best-first Search Algorithm (Greedy Search):

- **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.

Best-first Search Algorithm (Greedy Search):

- **Example:**Consider the below search problem, and we will traverse it using greedy best-first search. At each iteration, each node is expanded using evaluation function f(n)=h(n) , which is given in the below table.



node	H (n)
A	12
B	4
C	7
D	3
E	8
F	2
H	4
I	9
S	13
G	0

Best-first Search Algorithm (Greedy Search):

- **Example:** In this search example, we are using two lists which are OPEN and CLOSED Lists

Expand the nodes of S and put in the CLOSED list

Initialization: Open [A, B], Closed [S]

Iteration 1: Open [A], Closed [S, B]

Iteration 2: Open [E, F, A], Closed [S, B]

: Open [E, A], Closed [S, B, F]

Iteration 3: Open [I, G, E, A], Closed [S, B, F]

: Open [I, E, A], Closed [S, B, F, G]

Hence the final solution path will be: S----> B----->F----> G

Best-first Search Algorithm (Greedy Search):

Advantages:

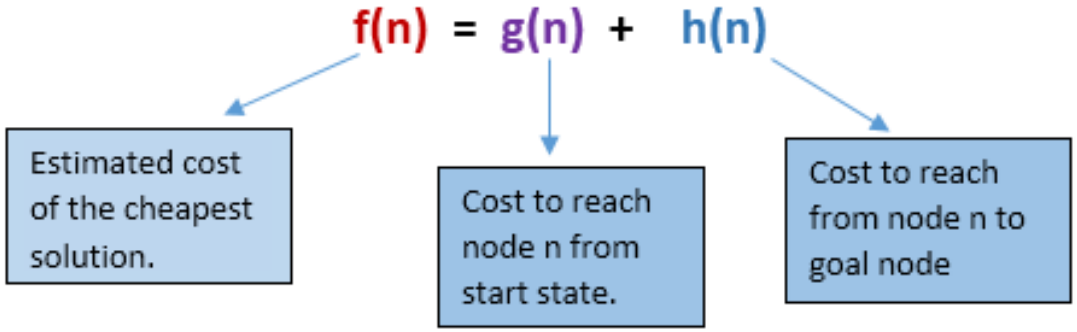
- Best first search can switch between BFS and DFS by gaining the advantages of both the algorithms.
- This algorithm is more efficient than BFS and DFS algorithms.

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.

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).
- 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.
- 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**.



Note: At each point in the search space, only those node is expanded which have the lowest value of f(n), and the algorithm terminates when the goal node is found.

A* Search Algorithm:

Advantages:

:

- A* search algorithm is the best algorithm than other search algorithms.
- A* search algorithm is optimal and complete.
- This algorithm can solve very complex problems.

Disadvantages:

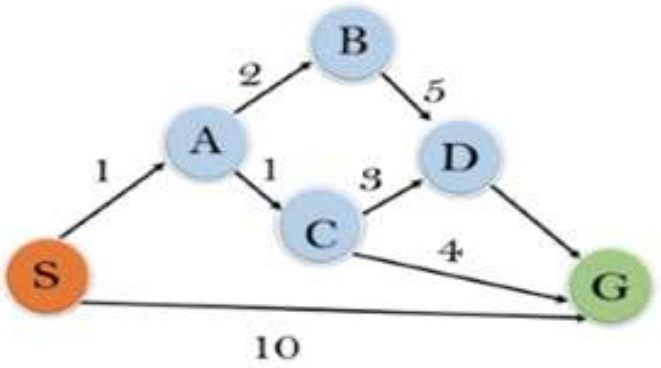
- It does not always produce the shortest path as it mostly based on heuristics and approximation.
- A* search algorithm has some complexity issues.
- The main drawback of A* is memory requirement as it keeps all generated nodes in the memory, so it is not practical for various large-scale problems.

A* Search Algorithm:

- **Step 1:** Place the starting node in the OPEN list.
- **Step 2:** Check if the OPEN list is empty or not, if the list is empty then return failure and stops.
- **Step 3:** Select the node from the OPEN list which has the smallest value of evaluation function (g+h), if node n is goal node then return success and stop, otherwise
- **Step 4:** Expand node n and generate all of its successors, and put n into the closed list. For each successor n', check whether n' is already in the OPEN or CLOSED list, if not then compute evaluation function for n' and place into Open list.
- **Step 5:** Else if node n' is already in OPEN and CLOSED, then it should be attached to the back pointer which reflects the lowest g(n') value.
- **Step 6:** Return to **Step 2**.

A* Search Algorithm:

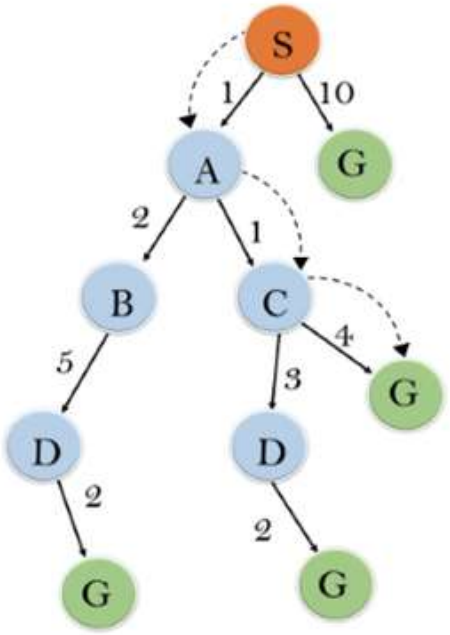
- **Example:**In this example, we will traverse the given graph using the A* algorithm. The heuristic value of all states is given in the below table so we will calculate the f(n) of each state using the formula f(n)= g(n) + h(n), where g(n) is the cost to reach any node from start state.
- Here we will use OPEN and CLOSED list.



State	h(n)
S	5
A	3
B	4
C	2
D	6
G	0

A* Search Algorithm:

- **Solution:**



Initialization: {(S, 5)}

Iteration1: {(S--> A, 4), (S-->G, 10)}

Iteration2: {(S--> A-->C, 4), (S--> A-->B, 7), (S-->G, 10)}

Iteration3: {(S--> A-->C--->G, 6), (S--> A-->C--->D, 11), (S--> A-->B, 7), (S-->G, 10)}

Iteration 4 will give the final result, as **S--->A--->C--->G** it provides the optimal path with cost 6.

A* Search Algorithm:

Points to remember:

- A* algorithm returns the path which occurred first, and it does not search for all remaining paths.
- The efficiency of A* algorithm depends on the quality of heuristic.
- A* algorithm expands all nodes which satisfy the condition f(n)

Complete: A* algorithm is complete as long as:

- Branching factor is finite.
- Cost at every action is fixed.

Time Complexity: The time complexity of A* search algorithm depends on heuristic function, and the number of nodes expanded is exponential to the depth of solution d. So the time complexity is O(b^d), where b is the branching factor.

Space Complexity: The space complexity of A* search algorithm is **O(b^d)**

BTCOC701

Artificial Intelligence

Teaching Notes

Lecture Number	Topic to be covered
1	**Unit 3: Knowledge and Reasoning (07Hrs)** ➢ Knowledge representation issues, Representation & mapping
2	➢ Approaches to knowledge representation, Issues in knowledge representation
3	➢ Using predicate logic: Representing simple fact in logic
4	➢ Representing instant & ISA relationship, Computable functions & predicates
5	➢ Computable functions & predicates Representing knowledge using rules:
6	➢ Procedural verses declarative knowledge Logic programming
7	➢ Forward Chaining, Backward Chaining, Resolution

:Submitted by:
Prof. S. B. Mehta

Unit 3: Knowledge & Reasoning

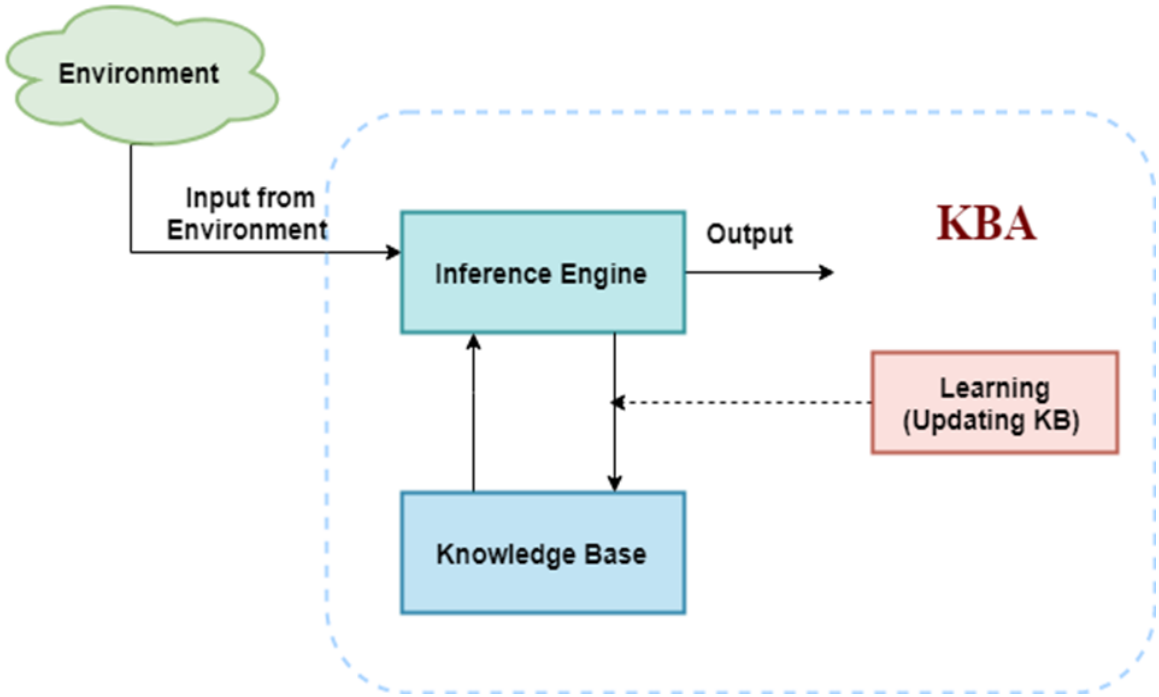
Knowledge-Based Agent:

- An intelligent agent needs **knowledge** about the real world for taking decisions and **reasoning** to act efficiently.
- Knowledge-based agents are those agents who have the capability of **maintaining an internal state of knowledge, reason over that knowledge, update their knowledge after observations and take actions. These agents can represent the world with some formal representation and act intelligently**.
- Knowledge-based agents are composed of two main parts:
  - **Knowledge-base and**
  - **Inference system**.

A knowledge-based agent must able to do the following:

- An agent should be able to represent states, actions, etc.
- An agent Should be able to incorporate new percepts
- An agent can update the internal representation of the world
- An agent can deduce the internal representation of the world
- An agent can deduce appropriate actions.

The architecture of knowledge-based agent:



The above diagram is representing a generalized architecture for a knowledge-based agent. The knowledge-based agent (KBA) take input from the environment by perceiving the environment. The input is taken by the inference engine of the agent and which also communicate with KB to decide as per the knowledge store in KB. The learning element of KBA regularly updates the KB by learning new knowledge.

Knowledge base: Knowledge-base is a central component of a knowledge-based agent, it is also known as KB. It is a collection of sentences (here 'sentence' is a technical term and it is not identical to sentence in English). These sentences are expressed in a language which is called a knowledge representation language. The Knowledge-base of KBA stores fact about the world.

Why use a knowledge base?

Knowledge-base is required for updating knowledge for an agent to learn with experiences and take action as per the knowledge.

Inference system

Inference means deriving new sentences from old. Inference system allows us to add a new sentence to the knowledge base. A sentence is a proposition about the world. Inference system applies logical rules to the KB to deduce new information.

Inference system generates new facts so that an agent can update the KB. An inference system works mainly in two rules which are given as:

- **Forward chaining**
- **Backward chaining**

Operations Performed by KBA

Following are three operations which are performed by KBA in order to show the intelligent

behavior:

1. **TELL:** This operation tells the knowledge base what it perceives from the environment.
2. **ASK:** This operation asks the knowledge base what action it should perform.
3. **Perform:** It performs the selected action.

Various levels of knowledge-based agent:

A knowledge-based agent can be viewed at different levels which are given below:

1. Knowledge level

Knowledge level is the first level of knowledge-based agent, and in this level, we need to specify what the agent knows, and what the agent goals are. With these specifications, we can fix its behavior. For example, suppose an automated taxi agent needs to go from a station A to station B, and he knows the way from A to B, so this comes at the knowledge level.

2. Logical level:

At this level, we understand that how the knowledge representation of knowledge is stored. At this level, sentences are encoded into different logics. At the logical level, an encoding of knowledge into logical sentences occurs. At the logical level we can expect to the automated taxi agent to reach to the destination B.

3. Implementation level:

This is the physical representation of logic and knowledge. At the implementation level agent perform actions as per logical and knowledge level. At this level, an automated taxi agent actually implement his knowledge and logic so that he can reach to the destination.

What is knowledge representation?

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

Following are the various 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 declarative sentences.
- 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.

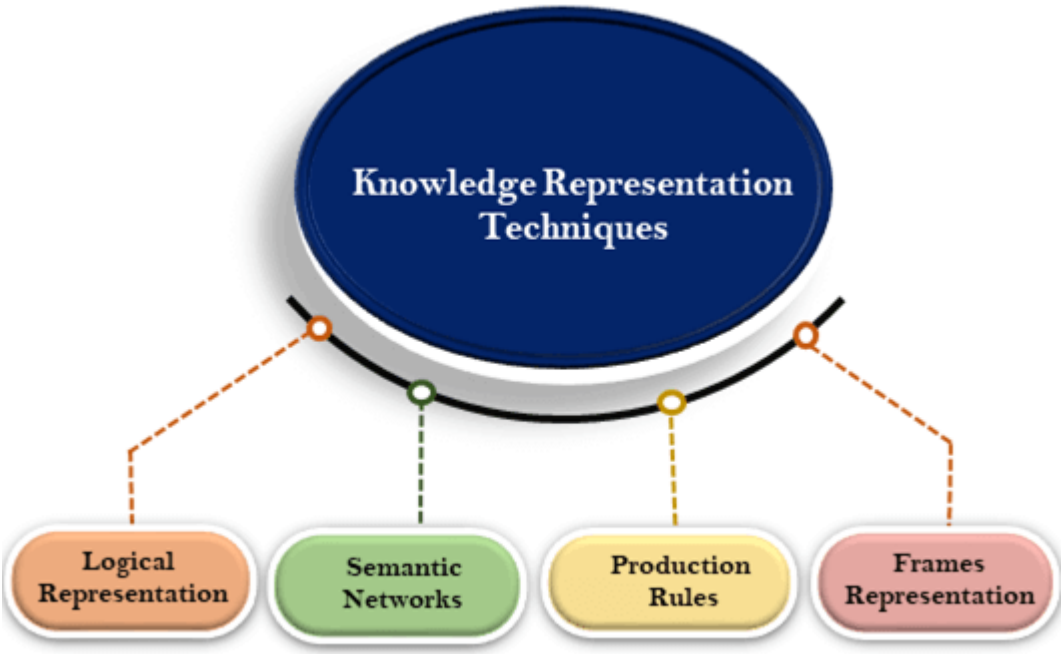
5. Structural knowledge:

- 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.

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

Logical representation is a language with some concrete rules which deals with propositions and has no ambiguity in representation. Logical representation means drawing a conclusion based on various conditions. This representation lays down some important communication rules. It consists of precisely

defined syntax and semantics which supports the sound inference. Each sentence can be translated into logics using syntax and semantics.

Syntax:

- Syntaxes are the rules which decide how we can construct legal sentences in the logic.
- It determines which symbol we can use in knowledge representation.
- How to write those symbols.

Semantics:

- Semantics are the rules by which we can interpret the sentence in the logic.
- Semantic also involves assigning a meaning to each sentence.

Logical representation can be categorised into mainly two logics:

a. Propositional Logics
b. Predicate logics

Advantages of logical representation:

1. Logical representation enables us to do logical reasoning.
2. Logical representation is the basis for the programming languages.

Disadvantages of logical Representation:

1. Logical representations have some restrictions and are challenging to work with.
2. Logical representation technique may not be very natural, and inference may not be so efficient.

2. Semantic Network Representation

Semantic networks are alternative of predicate logic for knowledge representation. In Semantic networks, we can represent our knowledge in the form of graphical networks. This network consists of nodes representing objects and arcs which describe the relationship between those objects. Semantic networks can categorize the object in different forms and can also link those objects. Semantic networks are easy to understand and can be easily extended.

This representation consist of mainly two types of relations:

a. IS-A relation (Inheritance)
b. Kind-of-relation

Example: Following are some statements which we need to represent in the form of nodes and arcs.

Statements:

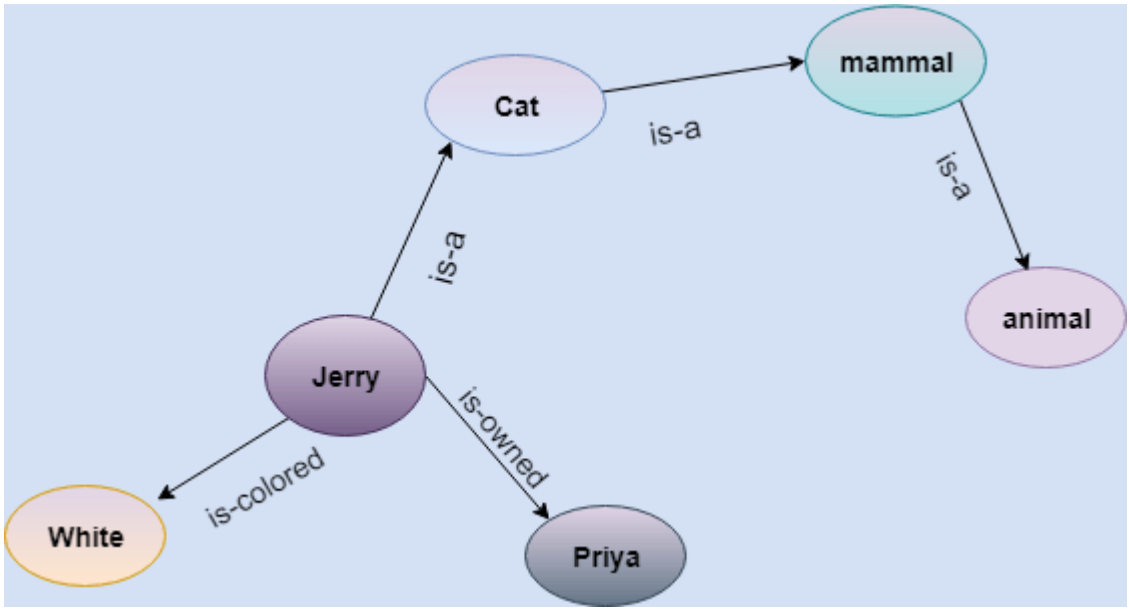
a. Jerry is a cat.

b. Jerry is a mammal

c. Jerry is owned by Priya.

d. Jerry is brown colored.

e. All Mammals are animal.



In the above diagram, we have represented the different type of knowledge in the form of nodes and arcs. Each object is connected with another object by some relation.

Drawbacks in Semantic representation:

1. Semantic networks take more computational time at runtime as we need to traverse the complete network tree to answer some questions. It might be possible in the worst case scenario that after traversing the entire tree, we find that the solution does not exist in this network.
2. Semantic networks try to model human-like memory (Which has 1015 neurons and links) to store the information, but in practice, it is not possible to build such a vast semantic network.
3. These types of representations are inadequate as they do not have any equivalent quantifier, e.g., for all, for some, none, etc.
4. Semantic networks do not have any standard definition for the link names.
5. These networks are not intelligent and depend on the creator of the system.

Advantages of Semantic network:

1. Semantic networks are a natural representation of knowledge.
2. Semantic networks convey meaning in a transparent manner.
3. These networks are simple and easily understandable.

3. Frame Representation

A frame is a record like structure which consists of a collection of attributes and its values to describe an entity in the world. Frames are the AI data structure which divides knowledge into substructures by representing stereotypes situations. It consists of a collection of slots and slot values. These slots may be of any type and sizes. Slots have names and values which are called facets.

Facets: The various aspects of a slot is known as **Facets**. Facets are features of frames which enable us to put constraints on the frames. Example: IF-NEEDED facts are called when data of any particular slot is needed. A frame may consist of any number of slots, and a slot may include any number of facets and facets may have any number of values. A frame is also known as **slot-filter knowledge representation** in artificial intelligence.

Frames are derived from semantic networks and later evolved into our modern-day classes and objects. A single frame is not much useful. Frames system consist of a collection of frames which are connected. In the frame, knowledge about an object or event can be stored together in the knowledge base. The frame is a type of technology which is widely used in various applications including Natural language processing and machine visions.

Example: 1

Let's take an example of a frame for a book

Slots	Filters
Title	Artificial Intelligence
Genre	Computer Science
Author	Peter Norvig
Edition	Third Edition
Year	1996
Page	1152

Example 2:

Let's suppose we are taking an entity, Peter. Peter is an engineer as a profession, and his age is 25, he lives in city London, and the country is England. So following is the frame representation for this:

Slots	Filter
Name	Peter
Profession	Doctor
Age	25
Marital status	Single
Weight	78

Advantages of frame representation:

1. The frame knowledge representation makes the programming easier by grouping the related data.
2. The frame representation is comparably flexible and used by many applications in AI.
3. It is very easy to add slots for new attribute and relations.
4. It is easy to include default data and to search for missing values.
5. Frame representation is easy to understand and visualize.

Disadvantages of frame representation:

1. In frame system inference mechanism is not be easily processed.
2. Inference mechanism cannot be smoothly proceeded by frame representation.
3. Frame representation has a much generalized approach.

4. Production Rules

Production rules system consist of (**condition, action**) pairs which mean, "If condition then action". It has mainly three parts:

- The set of production rules
- Working Memory
- The recognize-act-cycle

In production rules agent checks for the condition and if the condition exists then production rule fires and corresponding action is carried out. The condition part of the rule determines which rule may be applied to a problem. And the action part carries out the associated problem-solving steps. This complete process is called a recognize-act cycle.

The working memory contains the description of the current state of problems-solving and rule can write knowledge to the working memory. This knowledge match and may fire other rules.

If there is a new situation (state) generates, then multiple production rules will be fired together, this is called conflict set. In this situation, the agent needs to select a rule from these sets, and it is called a conflict resolution.

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 expressed in natural language.
2. The production rules are highly modular, so we can easily remove, add or modify an individual rule.

Disadvantages of Production rule:

1. Production rule system does not exhibit any learning capabilities, as it does not store the result of the problem for the future uses.
2. During the execution of the program, many rules may be active hence rule-based production systems are inefficient.

Propositional logic in Artificial intelligence

Propositional logic (PL) is the simplest form of logic where all the statements are made by propositions. A proposition is a declarative statement which is either true or false. It is a technique of knowledge representation in logical and mathematical form.

Example:

a) It is Sunday.

b) The Sun rises from West (False proposition)

c) 3+3= 7(False proposition)

d) 5 is a prime number.

Following are some basic facts about propositional logic:

- Propositional logic is also called Boolean logic as it works on 0 and 1.
- In propositional logic, we use symbolic variables to represent the logic, and we can use any symbol for a representing a proposition, such A, B, C, P, Q, R, etc.
- Propositions can be either true or false, but it cannot be both.
- Propositional logic consists of an object, relations or function, and logical connectives.
- These connectives are also called logical operators.
- The propositions and connectives are the basic elements of the propositional logic.
- Connectives can be said as a logical operator which connects two sentences.
- A proposition formula which is always true is called tautology, and it is also called a valid sentence.
- A proposition formula which is always false is called Contradiction.
- A proposition formula which has both true and false values is called
- Statements which are questions, commands, or opinions are not propositions such as "Where is Rohini", "How are you", "What is your name", are not propositions.

Syntax of propositional logic:

The syntax of propositional logic defines the allowable sentences for the knowledge representation. There are two types of Propositions:

a. Atomic Propositions

b. Compound propositions

- **Atomic Proposition:**

  Atomic propositions are the simple propositions. It consists of a single proposition symbol. These are the sentences which must be either true or false.

Example:

a) 2+2 is 4, it is an atomic proposition as it is a true fact.

b) "The Sun is cold" is also a proposition as it is a false fact.

- **Compound proposition:**

  Compound propositions are constructed by combining simpler or atomic propositions, using parenthesis and logical connectives.

Example:

a) "It is raining today, and street is wet."

b) "Ankit is a doctor, and his clinic is in Mumbai."

Logical Connectives:

Logical connectives are used to connect two simpler propositions or representing a sentence logically. We can create compound propositions with the help of logical connectives. There are mainly five connectives, which are given as follows:

1. **Negation:** A sentence such as ¬ P is called negation of P. A literal can be either Positive literal or negative literal.

2. **Conjunction:** A sentence which has ∧ connective such as, **P ∧ Q** is called a conjunction.
   Example: Rohan is intelligent and hardworking. It can be written as,
   P= Rohan is intelligent,
   Q= Rohan is hardworking. → P∧ Q.

3. **Disjunction:** A sentence which has ∨ connective, such as **P ∨ Q**. is called disjunction, where P and Q are the propositions.
   Example: "Ritika is a doctor or Engineer",
   Here P= Ritika is Doctor. Q= Ritika is Doctor, so we can write it as **P ∨ Q**.

4. **Implication:** A sentence such as P → Q, is called an implication. Implications are also known as if-then rules. It can be represented as
   If it is raining, then the street is wet.
   Let P= It is raining, and Q= Street is wet, so it is represented as P → Q

5. **Biconditional:** A sentence such as **P⇔ Q is a Biconditional sentence, example If I am breathing, then I am alive**
   P= I am breathing, Q= I am alive, it can be represented as P ⇔ Q.

Following is the summarized table for Propositional Logic Connectives:

Connective symbols	Word	Technical term	Example
∧	AND	Conjunction	A ∧ B
∨	OR	Disjunction	A ∨ B
→	Implies	Implication	A → B
⇔	If and only if	Biconditional	A⇔ B
¬ or ~	Not	Negation	¬ A or ¬ B

Truth Table:

In propositional logic, we need to know the truth values of propositions in all possible scenarios. We can combine all the possible combination with logical connectives, and the representation of these combinations in a tabular format is called **Truth table**. Following are the truth table for all logical connectives:

For Negation:

P	¬ P
True	**False**
False	**True**

For Conjunction:

P	Q	P∧ Q
True	True	**True**
True	False	**False**
False	True	**False**
False	False	**False**

For disjunction:

P	Q	P ∨ Q.
True	True	**True**
False	True	**True**
True	False	**True**
False	False	**False**

For Implication:

P	Q	P→ Q
True	True	**True**
True	False	**False**
False	True	**True**
False	False	**True**

For Biconditional:

P	Q	P⇔ Q
True	True	**True**
True	False	**False**
False	True	**False**
False	False	**True**

Truth table with three propositions:

We can build a proposition composing three propositions P, Q, and R. This truth table is made-up of 8n Tuples as we have taken three proposition symbols.

P	Q	R	¬R	Pv Q	PvQ→¬R
True	True	True	False	True	False
True	True	False	True	True	True
True	False	True	False	True	False
True	False	False	True	True	True
False	True	True	False	True	False
False	True	False	True	True	True
False	False	True	False	False	True
False	False	False	True	False	True

Precedence of connectives:

Just like arithmetic operators, there is a precedence order for propositional connectors or logical operators. This order should be followed while evaluating a propositional problem. Following is the list of the precedence order for operators:4

Precedence	Operators
First Precedence	Parenthesis
Second Precedence	Negation
Third Precedence	Conjunction(AND)
Fourth Precedence	Disjunction(OR)
Fifth Precedence	Implication
Six Precedence	Biconditional

Note: For better understanding use parenthesis to make sure of the correct interpretations. Such as ¬R∨ Q, It can be interpreted as (¬R) ∨ Q.

Logical equivalence:

Logical equivalence is one of the features of propositional logic. Two propositions are said to be logically equivalent if and only if the columns in the truth table are identical to each other.

Let's take two propositions A and B, so for logical equivalence, we can write it as A⇔B. In below truth table we can see that column for ¬A∨ B and A→B, are identical hence A is Equivalent to B

A	B	¬A	¬A∨ B	A→B
T	T	F	**T**	**T**
T	F	F	**F**	**F**
F	T	T	**T**	**T**
F	F	T	**T**	**T**

Properties of Operators:

- **Commutativity:**
  - P∧ Q= Q ∧ P, or
  - P ∨ Q = Q ∨ P.
- **Associativity:**
  - (P ∧ Q) ∧ R= P ∧ (Q ∧ R),
  - (P ∨ Q) ∨ R= P ∨ (Q ∨ R)
- **Identity element:**
  - P ∧ True = P,
  - P ∨ True= True.
- **Distributive:**
  - P∧ (Q ∨ R) = (P ∧ Q) ∨ (P ∧ R).
  - P ∨ (Q ∧ R) = (P ∨ Q) ∧ (P ∨ R).
- **DE Morgan's Law:**
  - ¬ (P ∧ Q) = (¬P) ∨ (¬Q)
  - ¬ (P ∨ Q) = (¬ P) ∧ (¬Q).
- **Double-negation elimination:**
  - ¬ (¬P) = P.

Limitations of Propositional logic:

- We cannot represent relations like ALL, some, or none with propositional logic. Example:

a. **All the girls are intelligent.**

b. **Some apples are sweet.**

- Propositional logic has limited expressive power.
- In propositional logic, we cannot describe statements in terms of their properties or logical relationships.

First-Order Logic in Artificial intelligence

In the topic of Propositional logic, we have seen that how to represent statements using propositional logic. But unfortunately, in propositional logic, we can only represent the facts, which are either true or false. PL is not sufficient to represent the complex sentences or natural language statements. The propositional logic has very limited expressive power. Consider the following sentence, which we cannot represent using PL logic.

- **"Some humans are intelligent", or**
- **"Sachin likes cricket."**

To represent the above statements, PL logic is not sufficient, so we required some more powerful logic, such as first-order logic.

First-Order logic:

- First-order logic is another way of knowledge representation in artificial intelligence. It is an extension to propositional logic.
- FOL is sufficiently expressive to represent the natural language statements in a concise way.
- First-order logic is also known as **Predicate logic or First-order predicate logic**. First-order logic is a powerful language that develops information about the objects in a more easy way and can also express the relationship between those objects.
- First-order logic (like natural language) does not only assume that the world contains facts like propositional logic but also assumes the following things in the world:
  - **Objects:** A, B, people, numbers, colors, wars, theories, squares, pits, wumpus, ...
  - **Relations: It can be unary relation such as:** red, round, is adjacent, **or n-any relation such as:** the sister of, brother of, has color, comes between
  - **Function:** Father of, best friend, third inning of, end of, ...
- As a natural language, first-order logic also has two main parts:

a. **Syntax**

b. **Semantics**

Syntax of First-Order logic:

The syntax of FOL determines which collection of symbols is a logical expression in first-order logic. The basic syntactic elements of first-order logic are symbols. We write statements in short-hand notation in FOL.

Basic Elements of First-order logic:

Following are the basic elements of FOL syntax:

Constant	1, 2, A, John, Mumbai, cat,....
Variables	x, y, z, a, b,....
Predicates	Brother, Father, >,....
Function	sqrt, LeftLegOf, ...
Connectives	∧, ∨, ¬, ⇒, ⇔
Equality	==
Quantifier	∀, ∃

Atomic sentences:

- Atomic sentences are the most basic sentences of first-order logic. These sentences are formed from a predicate symbol followed by a parenthesis with a sequence of terms.
- We can represent atomic sentences as **Predicate (term1, term2, ..., term n)**.

Example: Ravi and Ajay are brothers: => Brothers(Ravi, Ajay). Chinky is a cat: => cat (Chinky).

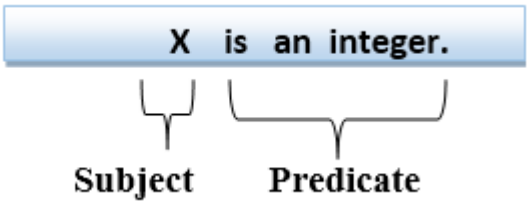
Complex Sentences:

- Complex sentences are made by combining atomic sentences using connectives.

First-order logic statements can be divided into two parts:

- **Subject:** Subject is the main part of the statement.
- **Predicate:** A predicate can be defined as a relation, which binds two atoms together in a statement.

Consider the statement: "x is an integer.", it consists of two parts, the first part x is the subject of the statement and second part "is an integer," is known as a predicate.



Quantifiers in First-order logic:

- A quantifier is a language element which generates quantification, and quantification specifies the quantity of specimen in the universe of discourse.
- These are the symbols that permit to determine or identify the range and scope of the variable in the logical expression. There are two types of quantifier:

a. **Universal Quantifier, (for all, everyone, everything)**

b. **Existential quantifier, (for some, at least one).**

Universal Quantifier:

Universal quantifier is a symbol of logical representation, which specifies that the statement within its range is true for everything or every instance of a particular thing.

The Universal quantifier is represented by a symbol ∀, which resembles an inverted A.

Note: In universal quantifier we use implication "→".

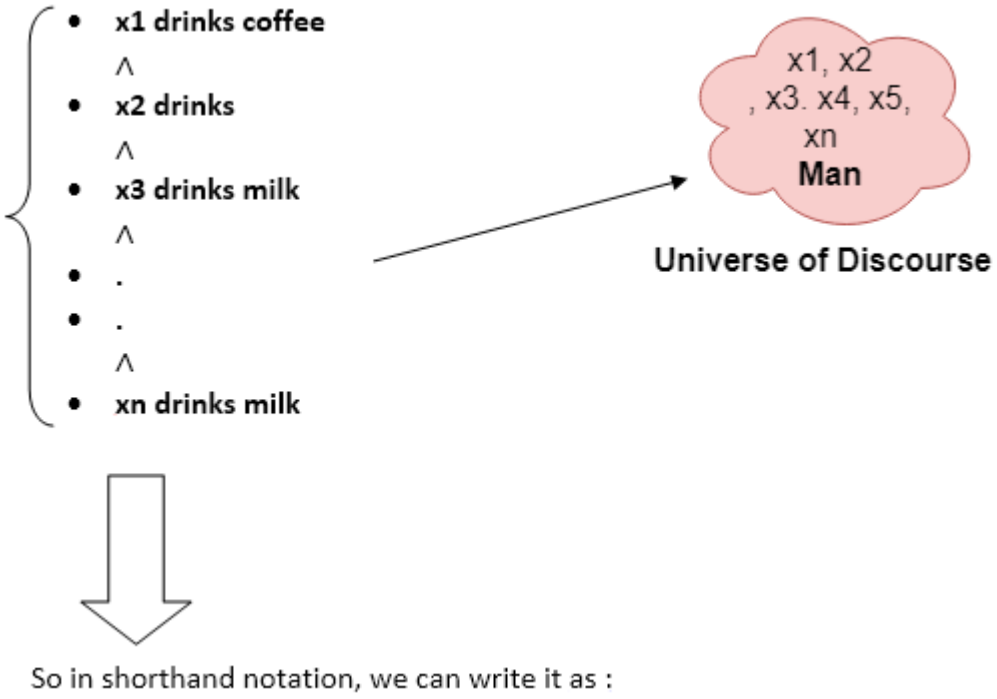
If x is a variable, then ∀x is read as:

- **For all x**
- **For each x**
- **For every x.**

Example:

All man drink coffee.

Let a variable x which refers to a cat so all x can be represented in UOD as below:



∀x man(x) → drink (x, coffee).

It will be read as: There are all x where x is a man who drink coffee.

Existential Quantifier:

Existential quantifiers are the type of quantifiers, which express that the statement within its scope is true for at least one instance of something.

It is denoted by the logical operator **∃,** which resembles as inverted **E.** When it is used with a predicate variable then it is called as an **existential quantifier**.

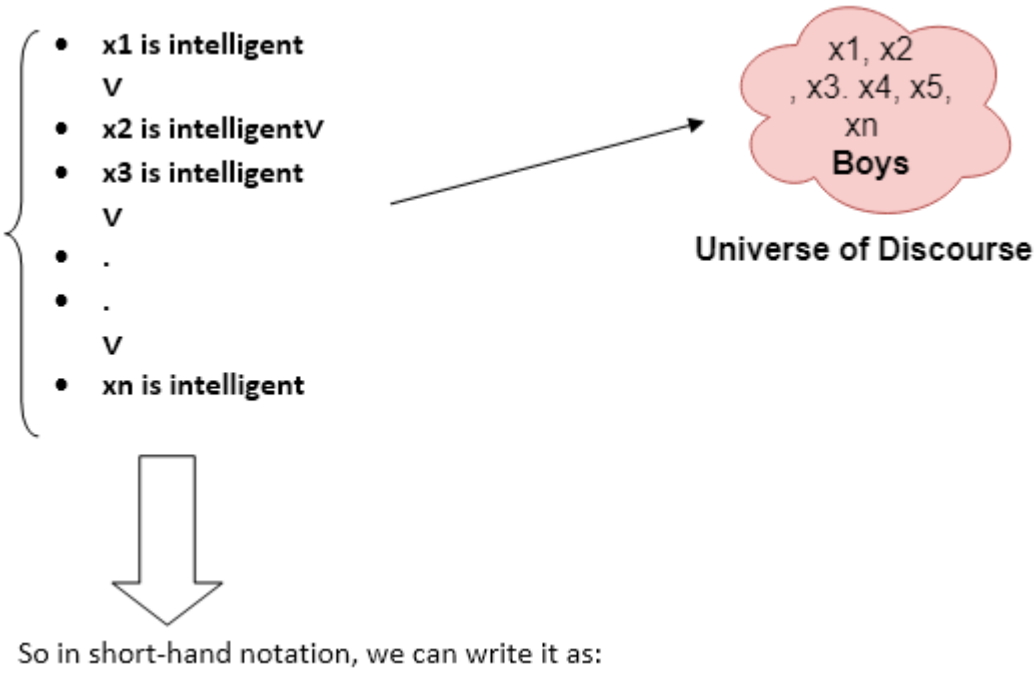
Note: In Existential quantifier we always use AND or Conjunction symbol (∧).

If x is a variable, then existential quantifier will be ∃x or ∃(x). And it will be read as:

- **There exists a 'x.'**
- **For some 'x.'**
- **For at least one 'x.'**

Example:

Some boys are intelligent.



∃x: boys(x) ∧ intelligent(x)

It will be read as: There are some x where x is a boy who is intelligent.

Points to remember:

- The main connective for universal quantifier ∀ is implication →.
- The main connective for existential quantifier ∃ is and ∧.

Properties of Quantifiers:

- In universal quantifier, ∀x∀y is similar to ∀y∀x.
- In Existential quantifier, ∃x∃y is similar to ∃y∃x.
- ∃x∀y is not similar to ∀y∃x.

Some Examples of FOL using quantifier:

1. All birds fly.

In this question the predicate is "fly(bird)."

And since there are all birds who fly so it will be represented as follows.

∀x bird(x) →fly(x).

2. Every man respects his parent.

In this question, the predicate is "respect(x, y)," where x=man, and y= parent.

Since there is every man so will use ∀, and it will be represented as follows:

∀x man(x) → respects (x, parent).

3. Some boys play cricket.

In this question, the predicate is "play(x, y)," where x= boys, and y= game. Since there are some boys so we will use ∃, and it will be represented as:

∃x boys(x) → play(x, cricket).

4. Not all students like both Mathematics and Science.

In this question, the predicate is "like(x, y)," where x= student, and y= subject.

Since there are not all students, so we will use ∀ with negation, so following representation for this:

¬∀ (x) [student(x) → like(x, Mathematics) ∧ like(x, Science)].

5. Only one student failed in Mathematics.

In this question, the predicate is "failed(x, y)," where x= student, and y= subject.

Since there is only one student who failed in Mathematics, so we will use following representation for this:

∃(x) [student(x) → failed (x, Mathematics) ∧∀ (y) [¬(x==y) ∧ student(y) → ¬failed (x, Mathematics)].

Knowledge Engineering in First-order logic

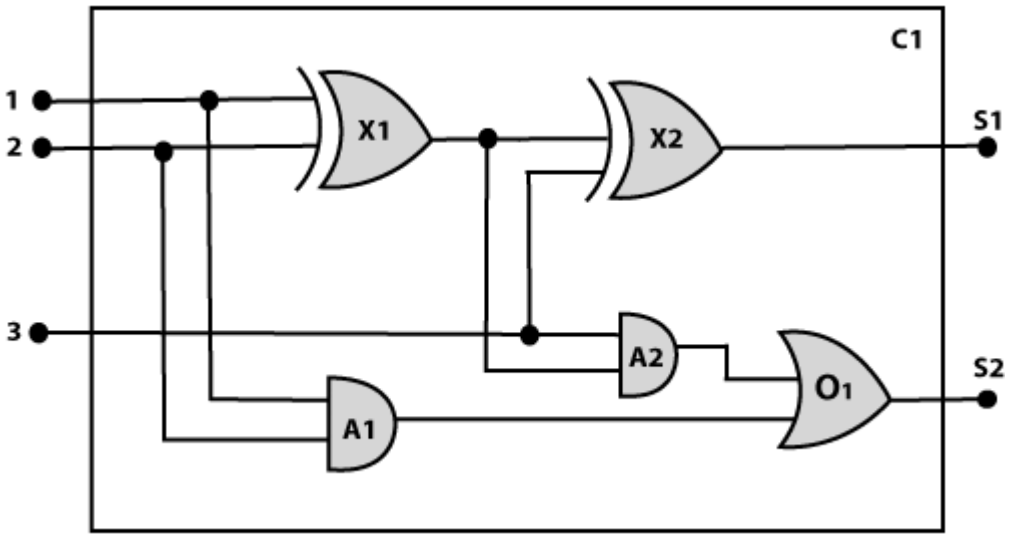
What is knowledge-engineering?

The process of constructing a knowledge-base in first-order logic is called as knowledge- engineering. In knowledge-engineering, someone who investigates a particular domain, learns important concept of that domain, and generates a formal representation of the objects, is known as knowledge engineer.

In this topic, we will understand the Knowledge engineering process in an electronic circuit domain, which is already familiar. This approach is mainly suitable for creating special-purpose knowledge base.

The knowledge-engineering process:

Following are some main steps of the knowledge-engineering process. Using these steps, we will develop a knowledge base which will allow us to reason about digital circuit (One-bit full adder) which is given below



1. Identify the task:

The first step of the process is to identify the task, and for the digital circuit, there are various reasoning tasks.

At the first level or highest level, we will examine the functionality of the circuit:

- **Does the circuit add properly?**
- **What will be the output of gate A2, if all the inputs are high?**

At the second level, we will examine the circuit structure details such as:

- **Which gate is connected to the first input terminal?**
- **Does the circuit have feedback loops?**

2. Assemble the relevant knowledge:

In the second step, we will assemble the relevant knowledge which is required for digital circuits. So for digital circuits, we have the following required knowledge:

- Logic circuits are made up of wires and gates.
- Signal flows through wires to the input terminal of the gate, and each gate produces the corresponding output which flows further.
- In this logic circuit, there are four types of gates used: **AND, OR, XOR, and NOT**.
- All these gates have one output terminal and two input terminals (except NOT gate, it has one input terminal).

3. Decide on vocabulary:

The next step of the process is to select functions, predicate, and constants to represent the circuits, terminals, signals, and gates. Firstly we will distinguish the gates from each other and from other objects. Each gate is represented as an object which is named by a constant, such as, **Gate(X1)**. The functionality of each gate is determined by its type, which is taken as constants such as **AND, OR, XOR, or NOT**. Circuits will be identified by a predicate: **Circuit (C1)**.

For the terminal, we will use predicate: **Terminal(x)**.

For gate input, we will use the function **In(1, X1)** for denoting the first input terminal of the gate, and for output terminal we will use **Out (1, X1)**.

The function **Arity(c, i, j)** is used to denote that circuit c has i input, j output.

The connectivity between gates can be represented by predicate **Connect(Out(1, X1), In(1, X1))**.

We use a unary predicate **On (t)**, which is true if the signal at a terminal is on.

4. Encode general knowledge about the domain:

To encode the general knowledge about the logic circuit, we need some following rules:

- If two terminals are connected then they have the same input signal, it can be represented as:

  ∀ t1, t2 Terminal (t1) ∧ Terminal (t2) ∧ Connect (t1, t2) → Signal (t1) = Signal (2).

- Signal at every terminal will have either value 0 or 1, it will be represented as:

  ∀ t Terminal (t) →Signal (t) = 1 ∨Signal (t) = 0.

5. Encode a description of the problem instance:

Now we encode problem of circuit C1, firstly we categorize the circuit and its gate components. This step is easy if ontology about the problem is already thought. This step involves the writing simple atomics sentences of instances of concepts, which is known as ontology.

For the given circuit C1, we can encode the problem instance in atomic sentences as below:

1. Since in the circuit there are two XOR, two AND, and one OR gate so atomic sentences for the For XOR gate: Type(x1)= XOR, Type(X2) = XOR
2. For AND gate: Type(A1) = AND, Type(A2)= AND
3. For OR gate: Type (O1) = OR.

And then represent the connections between all the gates.

Note: Ontology defines a particular theory of the nature of existence

6. Pose queries to the inference procedure and get answers:

In this step, we will find all the possible set of values of all the terminal for the adder circuit. The first query will be:

What should be the combination of input which would generate the first output of circuit C1, as 0 and a second output to be 1?

1. ∃ i1, i2, i3 Signal (In(1, C1))=i1 ∧ Signal (In(2, C1))=i2 ∧ Signal (In(3, C1))= i3
2. ∧ Signal (Out(1, C1)) =0 ∧ Signal (Out(2, C1))=1

7. Debug the knowledge base:

Now we will debug the knowledge base, and this is the last step of the complete process. In this step, we will try to debug the issues of knowledge base.

In the knowledge base, we may have omitted assertions like $1 \neq 0$.

Inference in First-Order Logic

Inference in First-Order Logic is used to deduce new facts or sentences from existing sentences. Before understanding the FOL inference rule, let's understand some basic terminologies used in FOL.

Substitution:

Substitution is a fundamental operation performed on terms and formulas. It occurs in all inference systems in first-order logic. The substitution is complex in the presence of quantifiers in FOL. If we write **F[a/x]**, so it refers to substitute a constant "**a**" in place of variable "**x**".

Note: First-order logic is capable of expressing facts about some or all objects in the universe

Equality:

First-Order logic does not only use predicate and terms for making atomic sentences but also uses another way, which is equality in FOL. For this, we can use **equality symbols** which specify that the two terms refer to the same object.

Example: Brother (John) = Smith.

As in the above example, the object referred by the **Brother (John)** is similar to the object referred by **Smith**. The equality symbol can also be used with negation to represent that two terms are not the same objects.

Example: ¬(x=y) which is equivalent to x ≠y.

FOL inference rules for quantifier:

As propositional logic we also have inference rules in first-order logic, so following are some basic inference rules in FOL:

- **Universal Generalization**
- **Universal Instantiation**
- **Existential Instantiation**
- **Existential introduction**

1. Universal Generalization:

- Universal generalization is a valid inference rule which states that if premise P(c) is true for any arbitrary element c in the universe of discourse, then we can have a conclusion as ∀ x P(x).
- It can be represented as: $\frac{P(c)}{\forall x\, P(x)}$.
- This rule can be used if we want to show that every element has a similar property.
- In this rule, x must not appear as a free variable.

Example: Let's represent, P(c): "**A byte contains 8 bits**", so for **∀ x P(x)** "**All bytes contain 8 bits**.", it will also be true.

2. Universal Instantiation:

- Universal instantiation is also called as universal elimination or UI is a valid inference rule. It can be applied multiple times to add new sentences.
- The new KB is logically equivalent to the previous KB.
- As per UI, **we can infer any sentence obtained by substituting a ground term for the variable**.
- The UI rule state that we can infer any sentence P(c) by substituting a ground term c (a constant within domain x) from **∀ x P(x) for any object in the universe of discourse**.
- It can be represented as: $\frac{\forall x\, P(x)}{P(c)}$.

Example:1.

IF "Every person like ice-cream"=> ∀x P(x) so we can infer that "John likes ice-cream" => P(c)

Example: 2.

Let's take a famous example,

"All kings who are greedy are Evil." So let our knowledge base contains this detail as in the form of FOL:

∀x king(x) ∧ greedy (x) → Evil (x),

So from this information, we can infer any of the following statements using Universal Instantiation:

- **King(John) ∧ Greedy (John) → Evil (John),**

- **King(Richard) ∧ Greedy (Richard) → Evil (Richard),**
- **King(Father(John)) ∧ Greedy (Father(John)) → Evil (Father(John)),**

3. Existential Instantiation:

- Existential instantiation is also called as Existential Elimination, which is a valid inference rule in first-order logic.
- It can be applied only once to replace the existential sentence.
- The new KB is not logically equivalent to old KB, but it will be satisfiable if old KB was satisfiable.
- This rule states that one can infer P(c) from the formula given in the form of ∃x P(x) for a new constant symbol c.
- The restriction with this rule is that c used in the rule must be a new term for which P(c) is true.
- It can be represented as: $\frac{\exists x\, P(x)}{P(c)}$

Example:

From the given sentence: **∃x Crown(x) ∧ OnHead(x, John),**

So we can infer: **Crown(K) ∧ OnHead(K, John),** as long as K does not appear in the knowledge base.

- The above used K is a constant symbol, which is called **Skolem constant**.
- The Existential instantiation is a special case of **Skolemization process**.

4. Existential introduction

- An existential introduction is also known as an existential generalization, which is a valid inference rule in first-order logic.
- This rule states that if there is some element c in the universe of discourse which has a property P, then we can infer that there exists something in the universe which has the property P.
- It can be represented as: $\frac{P(c)}{\exists x P(x)}$
- **Example: Let's say that,**
  "Priyanka got good marks in English."
  "Therefore, someone got good marks in English."

(Subject In-charge)

Prof.S.B.Mehta)

Unit 4: Probabilistic Reasoning

Probabilistic reasoning:

Uncertainty:

Till now, we have learned knowledge representation using first-order logic and propositional logic with certainty, which means we were sure about the predicates. With this knowledge representation, we might write A→B, which means if A is true then B is true, but consider a situation where we are not sure about whether A is true or not then we cannot express this statement, this situation is called uncertainty.

So to represent uncertain knowledge, where we are not sure about the predicates, we need uncertain reasoning or probabilistic reasoning.

Causes of uncertainty:

Following are some leading causes of uncertainty to occur in the real world.

1. Information occurred from unreliable sources.
2. Experimental Errors
3. Equipment fault
4. Temperature variation
5. Climate change.

Probabilistic reasoning:

Probabilistic reasoning is a way of knowledge representation where we apply the concept of probability to indicate the uncertainty in knowledge. In probabilistic reasoning, we combine probability theory with logic to handle the uncertainty.

We use probability in probabilistic reasoning because it provides a way to handle the uncertainty that is the result of someone's laziness and ignorance.

In the real world, there are lots of scenarios, where the certainty of something is not confirmed, such as "It will rain today," "behavior of someone for some situations," "A match between two teams or two

players." These are probable sentences for which we can assume that it will happen but not sure about it, so here we use probabilistic reasoning.

Need of probabilistic reasoning in AI:

- When there are unpredictable outcomes.
- When specifications or possibilities of predicates becomes too large to handle.
- When an unknown error occurs during an experiment.

In probabilistic reasoning, there are two ways to solve problems with uncertain knowledge:

- **Bayes' rule**
- **Bayesian Statistics**

As probabilistic reasoning uses probability and related terms, so before understanding probabilistic reasoning, let's understand some common terms:

Probability: Probability can be defined as a chance that an uncertain event will occur. It is the numerical measure of the likelihood that an event will occur. The value of probability always remains between 0 and 1 that represent ideal uncertainties.

1. $\leq P(A) \leq 1$, where P(A) is the probability of an event A.
1. P(A) = 0, indicates total uncertainty in an event A.
1. P(A) =1, indicates total certainty in an event A.

We can find the probability of an uncertain event by using the below formula.

$$\text{Probability of occurrence} = \frac{\text{Number of desired outcomes}}{\text{Total number of outcomes}}$$

- P(¬A) = probability of a not happening event.
- P(¬A) + P(A) = 1.

Event: Each possible outcome of a variable is called an event.

Sample space: The collection of all possible events is called sample space.

Random variables: Random variables are used to represent the events and objects in the real world.

Prior probability: The prior probability of an event is probability computed before observing new information.

Posterior Probability: The probability that is calculated after all evidence or information has taken into account. It is a combination of prior probability and new information.

Conditional probability:

Conditional probability is a probability of occurring an event when another event has already happened.

Let's suppose, we want to calculate the event A when event B has already occurred, "the probability of A under the conditions of B", it can be written as:

$$P(A|B) = \frac{P(A \wedge B)}{P(B)}$$

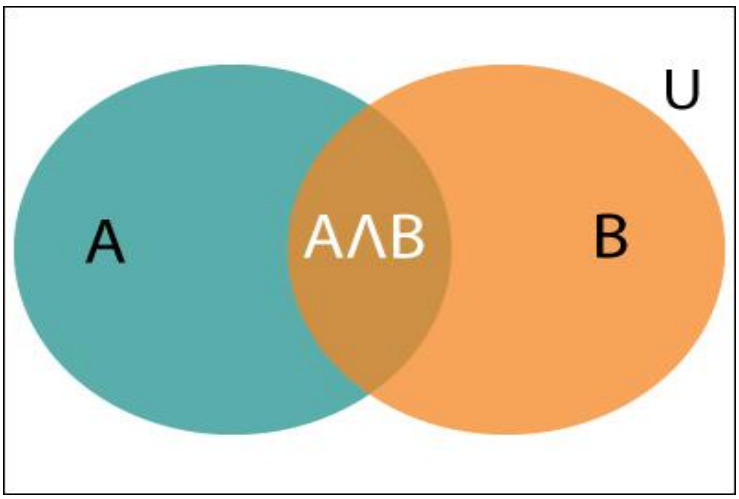
Where P($A \wedge B$)= Joint probability of a and B

P(B)= Marginal probability of B.

If the probability of A is given and we need to find the probability of B, then it will be given as:

$$P(B|A) = \frac{P(A \wedge B)}{P(A)}$$

It can be explained by using the below Venn diagram, where B is occurred event, so sample space will be reduced to set B, and now we can only calculate event A when event B is already occurred by dividing the probability of **P($A \wedge B$) by P(B)**.



Example:

In a class, there are 70% of the students who like English and 40% of the students who likes English and mathematics, and then what is the percent of students those who like English also like mathematics?

Solution:

Let, A is an event that a student likes Mathematics

B is an event that a student likes English.

$$P(A|B) = \frac{P(A \wedge B)}{P(B)} = \frac{0.4}{0.7} = 57\%$$

Hence, 57% are the students who like English also like Mathematics.

Bayes' theorem:

Bayes' theorem is also known as **Bayes' rule, Bayes' law**, or **Bayesian reasoning**, which determines the probability of an event with uncertain knowledge.

In probability theory, it relates the conditional probability and marginal probabilities of two random events.

Bayes' theorem was named after the British mathematician **Thomas Bayes**. The **Bayesian inference** is an application of Bayes' theorem, which is fundamental to Bayesian statistics.

It is a way to calculate the value of P(B|A) with the knowledge of P(A|B).

ayes' theorem allows updating the probability prediction of an event by observing new information of the real world.

Example: If cancer corresponds to one's age then by using Bayes' theorem, we can determine the probability of cancer more accurately with the help of age.

Bayes' theorem can be derived using product rule and conditional probability of event A with known event B:

As from product rule we can write:

1. $P(A \wedge B) = P(A|B)\, P(B)$ or

Similarly, the probability of event B with known event A:

1. $P(A \wedge B) = P(B|A)\, P(A)$

Equating right hand side of both the equations, we will get:

$$P(A|B) = \frac{P(B|A)\, P(A)}{P(B)} \quad \text{....(a)}$$

The above equation (a) is called as **Bayes' rule** or **Bayes' theorem**. This equation is basic of most modern AI systems for **probabilistic inference**.

It shows the simple relationship between joint and conditional probabilities. Here,

P(A|B) is known as **posterior**, which we need to calculate, and it will be read as Probability of hypothesis A when we have occurred an evidence B.

P(B|A) is called the likelihood, in which we consider that hypothesis is true, then we calculate the probability of evidence.

P(A) is called the **prior probability**, probability of hypothesis before considering the evidence

P(B) is called **marginal probability**, pure probability of an evidence.

In the equation (a), in general, we can write P (B) = P(A)*P(B|Ai), hence the Bayes' rule can be written as:

$$P(A_i|B) = \frac{P(A_i)*P(B|A_i)}{\sum_{i=1}^{k} P(A_i)*P(B|A_i)}$$

Where A_1, A_2, A_3,....., A_n is a set of mutually exclusive and exhaustive events.

Example-2:

Question: From a standard deck of playing cards, a single card is drawn. The probability that the card is king is 4/52, then calculate posterior probability P(King|Face), which means the drawn face card is a king card.

Solution:

$$P(king|face) = \frac{P(Face|king)*P(King)}{P(Face)} \quad .....(i)$$

P(king): probability that the card is King= 4/52= 1/13

P(face): probability that a card is a face card= 3/13

P(Face|King): probability of face card when we assume it is a king = 1

Putting all values in equation (i) we will get:

$$P(king|face) = \frac{1*(\frac{1}{13})}{(\frac{3}{13})} = 1/3,$$ **it is a probability that a face card is a king card.**

Application of Bayes' theorem in Artificial intelligence:

Following are some applications of Bayes' theorem:

- It is used to calculate the next step of the robot when the already executed step is given.
- Bayes' theorem is helpful in weather forecasting.
- It can solve the Monty Hall problem.

Bayesian Belief Network in artificial intelligence

Bayesian belief network is key computer technology for dealing with probabilistic events and to solve a problem which has uncertainty. We can define a Bayesian network as:

"A Bayesian network is a probabilistic graphical model which represents a set of variables and their conditional dependencies using a directed acyclic graph."

It is also called a **Bayes network, belief network, decision network**, or **Bayesian model**.

Bayesian networks are probabilistic, because these networks are built from a **probability distribution**, and also use probability theory for prediction and anomaly detection.

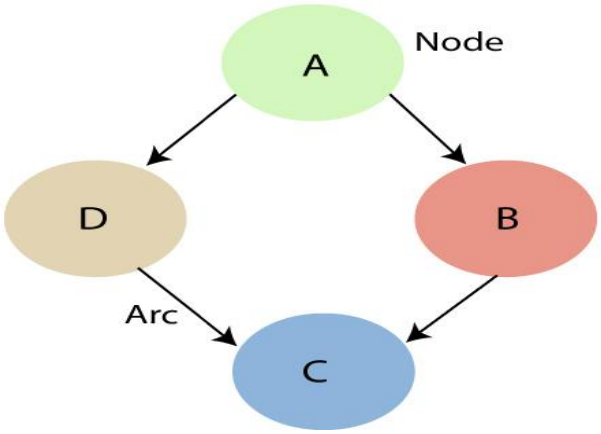
Real world applications are probabilistic in nature, and to represent the relationship between multiple events, we need a Bayesian network. It can also be used in various tasks including **prediction, anomaly detection, diagnostics, automated insight, reasoning, time series prediction**, and **decision making under uncertainty**.

Bayesian Network can be used for building models from data and experts opinions, and it consists of two parts:

- **Directed Acyclic Graph**
- **Table of conditional probabilities.**

The generalized form of Bayesian network that represents and solve decision problems under uncertain knowledge is known as an **Influence diagram**.

A Bayesian network graph is made up of nodes and Arcs (directed links), where:



- Each **node** corresponds to the random variables, and a variable can be **continuous** or **discrete**.
- **Arc or directed arrows** represent the causal relationship or conditional probabilities between random variables. These directed links or arrows connect the pair of nodes in the graph. These links represent that one node directly influence the other node, and if there is no directed link that means that nodes are independent with each other
    - **In the above diagram, A, B, C, and D are random variables represented by the nodes of the network graph.**
    - **If we are considering node B, which is connected with node A by a directed arrow, then node A is called the parent of Node B.**
    - **Node C is independent of node A.**

Note: The Bayesian network graph does not contain any cyclic graph. Hence, it is known as a **directed acyclic graph or DAG**.

The Bayesian network has mainly two components:

- **Causal Component**
- **Actual numbers**

Each node in the Bayesian network has condition probability distribution **$P(X_i | Parent(X_i))$**, which determines the effect of the parent on that node.

Bayesian network is based on Joint probability distribution and conditional probability. So let's first understand the joint probability distribution:

Joint probability distribution:

If we have variables x1, x2, x3,....., xn, then the probabilities of a different combination of x1, x2, x3.. xn, are known as Joint probability distribution.

$P[x_1, x_2, x_3,....., x_n]$, it can be written as the following way in terms of the joint probability distribution.

$= P[x_1 | x_2, x_3,....., x_n]P[x_2, x_3,....., x_n]$

$= P[x_1 | x_2, x_3,....., x_n]P[x_2|x_3,....., x_n]....P[x_{n-1}|x_n]P[x_n].$

In general for each variable Xi, we can write the equation as:

$$P(X_i|X_{i-1},....., X_1) = P(X_i | Parents(X_i))$$

Explanation of Bayesian network:

Let's understand the Bayesian network through an example by creating a directed acyclic graph:

Example: Harry installed a new burglar alarm at his home to detect burglary. The alarm reliably responds at detecting a burglary but also responds for minor earthquakes. Harry has two neighbors David and Sophia, who have taken a responsibility to inform Harry at work when they hear the alarm. David always calls Harry when he hears the alarm, but sometimes he got confused with the phone ringing and calls at that time too. On the other hand, Sophia likes to listen to high music, so sometimes she misses to hear the alarm. Here we would like to compute the probability of Burglary Alarm.

Problem:

Calculate the probability that alarm has sounded, but there is neither a burglary, nor an earthquake occurred, and David and Sophia both called the Harry.

Solution:

- The Bayesian network for the above problem is given below. The network structure is showing that burglary and earthquake is the parent node of the alarm and directly affecting the probability of alarm's going off, but David and Sophia's calls depend on alarm probability.
- The network is representing that our assumptions do not directly perceive the burglary and also do not notice the minor earthquake, and they also not confer before calling.
- The conditional distributions for each node are given as conditional probabilities table or CPT.
- Each row in the CPT must be sum to 1 because all the entries in the table represent an exhaustive set of cases for the variable.
- In CPT, a boolean variable with k boolean parents contains 2^K probabilities. Hence, if there are two parents, then CPT will contain 4 probability values

List of all events occurring in this network:

- **Burglary (B)**
- **Earthquake(E)**
- **Alarm(A)**
- **David Calls(D)**
- **Sophia calls(S)**

We can write the events of problem statement in the form of probability: **P[D, S, A, B, E]**, can rewrite the above probability statement using joint probability distribution:

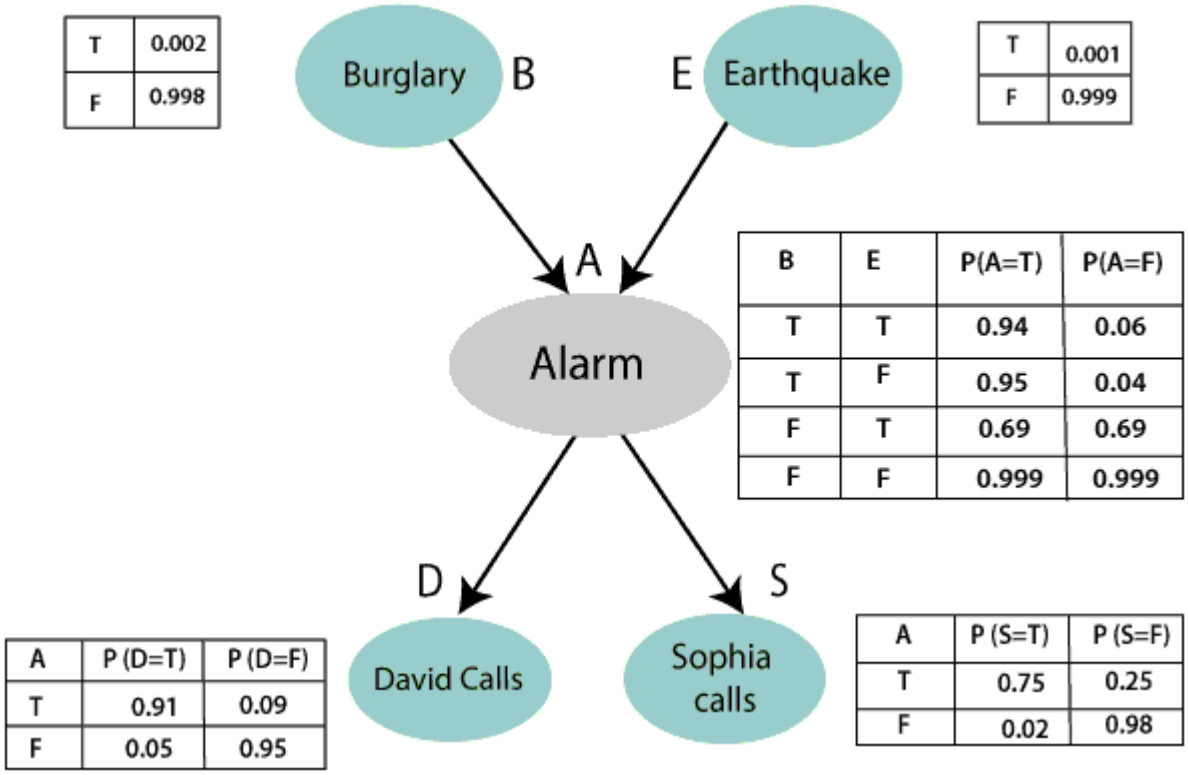
P[D, S, A, B, E]= P[D | S, A, B, E]. P[S, A, B, E]

=P[D | S, A, B, E]. P[S | A, B, E]. P[A, B, E]

= P [D| A]. P [S| A, B, E]. P[A, B, E]

= P[D | A]. P[S | A]. P[A| B, E]. P[B, E]

= P[D | A]. P[S | A]. P[A| B, E]. P[B |E]. P[E]



T	0.002
F	0.998

T	0.001
F	0.999

B	E	P(A=T)	P(A=F)
T	T	0.94	0.06
T	F	0.95	0.04
F	T	0.69	0.69
F	F	0.999	0.999

A	P (D=T)	P (D=F)
T	0.91	0.09
F	0.05	0.95

A	P (S=T)	P (S=F)
T	0.75	0.25
F	0.02	0.98

Let's take the observed probability for the Burglary and earthquake component:

P(B= True) = 0.002, which is the probability of burglary.

P(B= False)= 0.998, which is the probability of no burglary.

P(E= True)= 0.001, which is the probability of a minor earthquake

P(E= False)= 0.999, Which is the probability that an earthquake not occurred.

We can provide the conditional probabilities as per the below tables:

Conditional probability table for Alarm A:

The Conditional probability of Alarm A depends on Burglar and earthquake:

B	E	P(A= True)	P(A= False)
True	True	0.94	0.06
True	False	0.95	0.04
False	True	0.31	0.69
False	False	0.001	0.999

Conditional probability table for David Calls:

The Conditional probability of David that he will call depends on the probability of Alarm.

A	P(D= True)	P(D= False)
True	0.91	0.09
False	0.05	0.95

Conditional probability table for Sophia Calls:

The Conditional probability of Sophia that she calls is depending on its Parent Node "Alarm."

A	P(S= True)	P(S= False)
True	0.75	0.25
False	0.02	0.98

From the formula of joint distribution, we can write the problem statement in the form of probability distribution:

P(S, D, A, ¬B, ¬E) = P (S|A) *P (D|A)*P (A|¬B ^ ¬E) *P (¬B) *P (¬E).

= 0.75* 0.91* 0.001* 0.998*0.999

= 0.00068045.

Hence, a Bayesian network can answer any query about the domain by using Joint distribution.

The semantics of Bayesian Network:

There are two ways to understand the semantics of the Bayesian network, which is given below:

1. To understand the network as the representation of the Joint probability distribution.

It is helpful to understand how to construct the network.

2. To understand the network as an encoding of a collection of conditional independence statements.

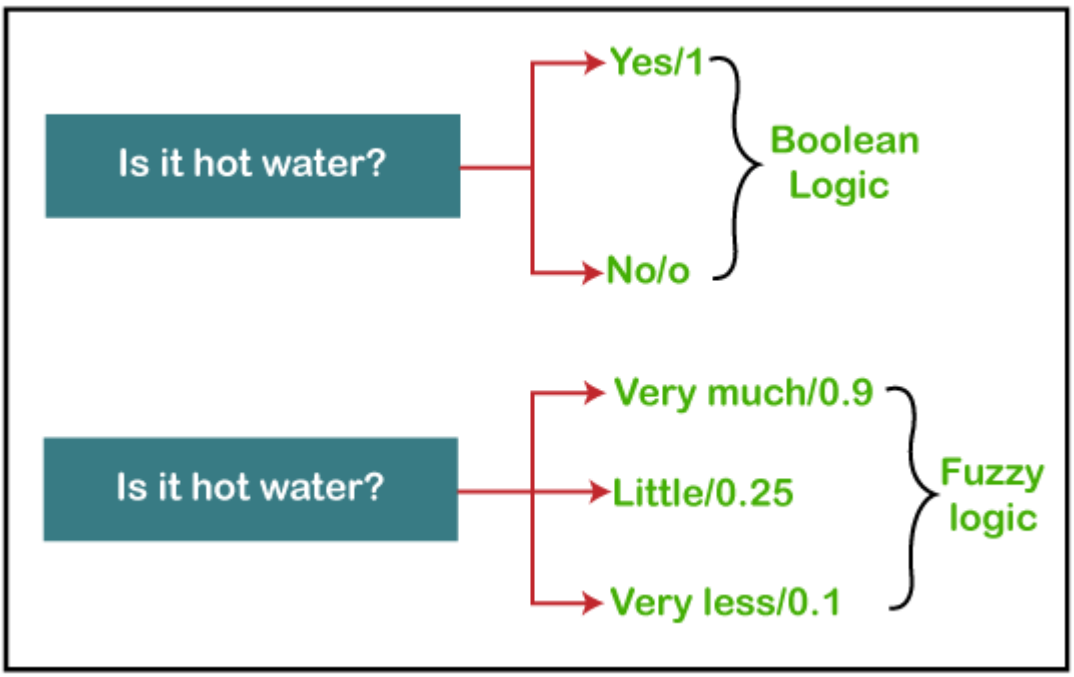
It is helpful in designing inference procedure.

Fuzzy Logic | Introduction

What is Fuzzy Logic?

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

Example of Fuzzy Logic as comparing to Boolean Logic



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

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

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

Characteristics of Fuzzy Logic

Following are the characteristics of fuzzy logic:

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

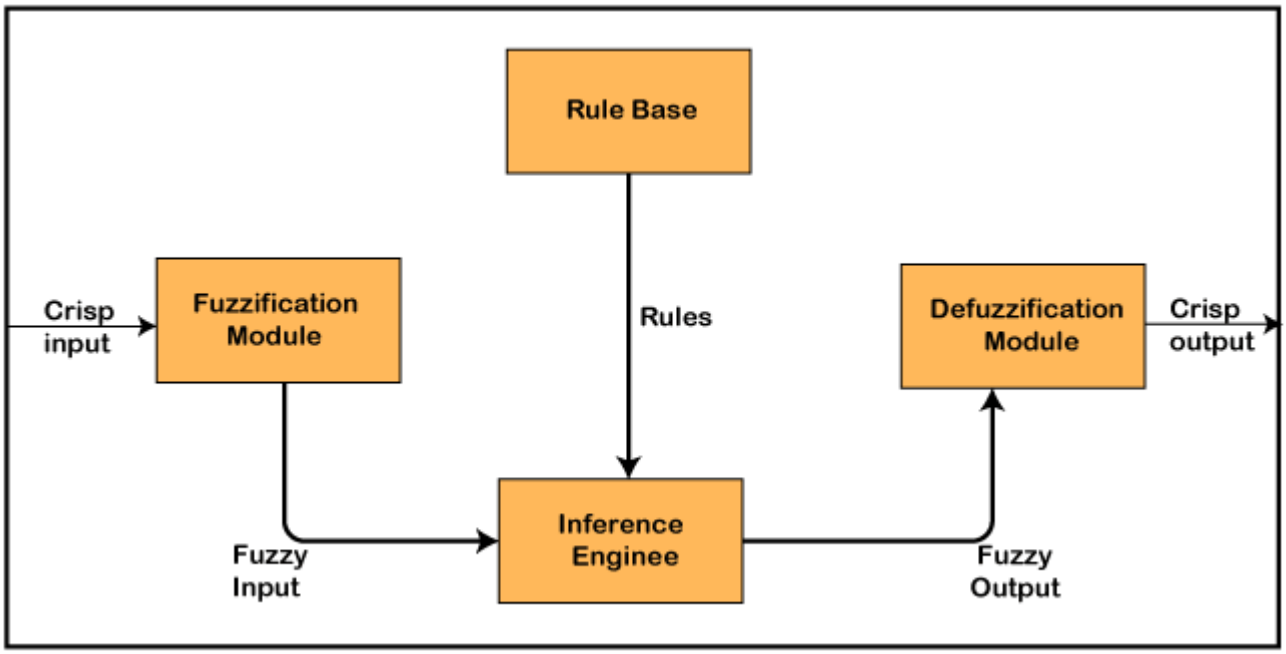
9. It is also used by the quantitative analysts for improving their algorithm's execution.
10. It also allows users to integrate with the programming.

Architecture of a Fuzzy Logic System

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

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

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



1. Rule Base

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

2. Fuzzification

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

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

3. Inference Engine

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

4. Defuzzification

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

Classical and Fuzzy Set Theory

To learn about classical and Fuzzy set theory, firstly you have to know about what is set.

Set

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

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

Types of Set:

There are following various categories of set:

1. Finite
2. Empty
3. Infinite
4. Proper
5. Universal
6. Subset

7. Singleton
8. Equivalent Set
9. Disjoint Set

Applications of Fuzzy Logic

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

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

Advantages of Fuzzy Logic

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

1. The methodology of this concept works similarly as the human reasoning.
2. Any user can easily understand the structure of Fuzzy Logic.
3. It does not need a large memory, because the algorithms can be easily described with fewer data.

4. It is widely used in all fields of life and easily provides effective solutions to the problems which have high complexity.
5. This concept is based on the set theory of mathematics, so that's why it is simple.
6. It allows users for controlling the control machines and consumer products.
7. The development time of fuzzy logic is short as compared to conventional methods.
8. Due to its flexibility, any user can easily add and delete rules in the FLS system.

Disadvantages of Fuzzy Logic

Fuzzy Logic has various disadvantages or limitations. Some of them are as follows:

1. The run time of fuzzy logic systems is slow and takes a long time to produce outputs.
2. Users can understand it easily if they are simple.
3. The possibilities produced by the fuzzy logic system are not always accurate.
4. Many researchers give various ways for solving a given statement using this technique which leads to ambiguity.
5. Fuzzy logics are not suitable for those problems that require high accuracy.
6. The systems of a Fuzzy logic need a lot of testing for verification and validation.

Classical Set

It is a type of set which collects the distinct objects in a group. The sets with the crisp boundaries are classical sets. In any set, each single entity is called an element or member of that set.

Mathematical Representation of Sets

Any set can be easily denoted in the following two different ways:

1. Roaster Form: This is also called as a tabular form. In this form, the set is represented in the following way:

```
Set_name = { element1, element2, element3, ....., element N}
```

The elements in the set are enclosed within the brackets and separated by the commas.

Following are the two examples which describes the set in Roaster or Tabular form:

Example 1:

```
Set of Natural Numbers: N={1, 2, 3, 4, 5, 6, 7, .....,n).
```

Example 2:

```
Set of Prime Numbers less than 50: X={2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37, 41, 43, 47}.
```

2. Set Builder Form: Set Builder form defines a set with the common properties of an element in a set. In this form, the set is represented in the following way:

$A = \{x:p(x)\}$

The following example describes the set in the builder form:

The set {2, 4, 6, 8, 10, 12, 14, 16, 18} is written as:
$B = \{x:2 \leq x < 20 \text{ and } (x\%2) = 0\}$

Operations on Classical Set

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

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

1. Union:

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

It can be described as:

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

Example:

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

2. Intersection

This operation is denoted by (A ∩ B). A ∩ B is the set of those elements which are common in both set A and B. It is also called a Logical OR operation.

It can be described as:

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

Example:

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

3. Difference Operation

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

It can be described as:

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

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

It can be described as:

$$A' = \{x | x \notin A\}.$$

Fuzzy Set

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

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

1. Fuzzy set is a set having degrees of membership between 1 and 0. Fuzzy sets are represented with tilde character(~). For example, Number of cars following traffic signals at a particular time out of all cars present will have membership value between [0,1].

2. Partial membership exists when member of one fuzzy set can also be a part of other fuzzy sets in the same universe.

3. The degree of membership or truth is not same as probability, fuzzy truth represents membership in vaguely defined sets

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

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

Membership function

Definition: A graph that defines how each point in the input space is mapped to membership value between 0 and 1. Input space is often referred to as the universe of discourse or universal set (u), which contains all the possible elements of concern in each particular application

Operations on Fuzzy Set

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

The operations of Fuzzy set are as follows:

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

$\mu A \cup B(x) = \max(\mu A(x), \mu B(x))$

Example:

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

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

And, B is a set which contains following elements:

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

then,

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

Because, according to this operation

For X1

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

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

$\mu A \cup B(X1) = 0.6$

For X2

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

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

$\mu A \cup B(X2) = 0.8$

For X3

μA∪B(X3) = max (μA(X3), μB(X3))

μA∪B(X3) = max (1, 0)

μA∪B(X3) = 1

For X4

μA∪B(X4) = max (μA(X4), μB(X4))

μA∪B(X4) = max (0.4, 0.9)

μA∪B(X4) = 0.9

2. Intersection Operation:The intersection operation of fuzzy set is defined by:

μA∩B(x) = min (μA(x), μB(x))

Example:

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

A = {(X1, 0.3), (X2, 0.7), (X3, 0.5), (X4, 0.1)}

And, B is a set which contains following elements:

B = {(X1, 0.8), (X2, 0.2), (X3, 0.4), (X4, 0.9)}

then,

A∩B = {(X1, 0.3), (X2, 0.2), (X3, 0.4), (X4, 0.1)}

Because, according to this operation

For X1

μA∩B(X1) = min (μA(X1), μB(X1))

μA∩B(X1) = min (0.3, 0.8)

μA∩B(X1) = 0.3

For X2

μA∩B(X2) = min (μA(X2), μB(X2))

μA∩B(X2) = min (0.7, 0.2)

μA∩B(X2) = 0.2

For X3

$\mu A \cap B(X3) = \min (\mu A(X3), \mu B(X3))$

$\mu A \cap B(X3) = \min (0.5, 0.4)$

$\mu A \cap B(X3) = 0.4$

For X4

$\mu A \cap B(X4) = \min (\mu A(X4), \mu B(X4))$

$\mu A \cap B(X4) = \min (0.1, 0.9)$

$\mu A \cap B(X4) = 0.1$

3. **Complement Operation:** The complement operation of fuzzy set is defined by:

$$\mu \bar{A}(x) = 1-\mu A(x),$$

Example:

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

A = {(X1, 0.3), (X2, 0.8), (X3, 0.5), (X4, 0.1)}

then,

$\bar{A}$= {(X1, 0.7), (X2, 0.2), (X3, 0.5), (X4, 0.9)}

Because, according to this operation

For X1

$\mu \bar{A}(X1) = 1-\mu A(X1)$

$\mu \bar{A}(X1) = 1 - 0.3$

$\mu \bar{A}(X1) = 0.7$

For X2

$\mu \bar{A}(X2) = 1-\mu A(X2)$

$\mu \bar{A}(X2) = 1 - 0.8$

$\mu \bar{A}(X2) = 0.2$

For X3

$\mu \bar{A}(X3) = 1-\mu A(X3)$

$\mu\bar{A}(X3) = 1 - 0.5$

$\mu\bar{A}(X3) = 0.5$

For X4

$\mu\bar{A}(X4) = 1-\mu A(X4)$

$\mu\bar{A}(X4) = 1 - 0.1$

$\mu\bar{A}(X4) = 0.9$

Classical Set Theory	Fuzzy Set Theory
1. This theory is a class of those sets having sharp boundaries.	1. This theory is a class of those sets having un-sharp boundaries.
2. This set theory is defined by exact boundaries only 0 and 1.	2. This set theory is defined by ambiguous boundaries.
3. In this theory, there is no uncertainty about the boundary's location of a set.	3. In this theory, there always exists uncertainty about the boundary's location of a set.
4. This theory is widely used in the design of digital systems.	4. It is mainly used for fuzzy controllers.

Advantages of Fuzzy Logic System

- This system can work with any type of inputs whether it is imprecise, distorted or noisy input information.
- The construction of Fuzzy Logic Systems is easy and understandable.
- Fuzzy logic comes with mathematical concepts of set theory and the reasoning of that is quite simple.
- It provides a very efficient solution to complex problems in all fields of life as it resembles human reasoning and decision-making.
- The algorithms can be described with little data, so little memory is required.

Disadvantages of Fuzzy Logic Systems

- Many researchers proposed different ways to solve a given problem through fuzzy logic which leads to ambiguity. There is no systematic approach to solve a given problem through fuzzy logic.
- Proof of its characteristics is difficult or impossible in most cases because every time we do not get a mathematical description of our approach.
- As fuzzy logic works on precise as well as imprecise data so most of the time accuracy is compromised.

Application

- It is used in the aerospace field for altitude control of spacecraft and satellites.
- It has been used in the automotive system for speed control, traffic control.
- It is used for decision-making support systems and personal evaluation in the large company business.
- It has application in the chemical industry for controlling the pH, drying, chemical distillation process.
- Fuzzy logic is used in Natural language processing and various intensive applications in Artificial Intelligence.
- Fuzzy logic is extensively used in modern control systems such as expert systems.

Fuzzy Logic is used with Neural Networks as it mimics how a person would make decisions, only much faster. It is done by Aggregation of data and changing it into more meaningful data by forming partial truths as Fuzzy

Fuzzy Logic - Applications

Aerospace

In aerospace, fuzzy logic is used in the following areas −

- Altitude control of spacecraft
- Satellite altitude control
- Flow and mixture regulation in aircraft deicing vehicles

Automotive

In automotive, fuzzy logic is used in the following areas −

- Trainable fuzzy systems for idle speed control
- Shift scheduling method for automatic transmission
- Intelligent highway systems
- Traffic control
- Improving efficiency of automatic transmissions

Business

In business, fuzzy logic is used in the following areas −

- Decision-making support systems
- Personnel evaluation in a large company

Defense

In defense, fuzzy logic is used in the following areas −

- Underwater target recognition
- Automatic target recognition of thermal infrared images
- Naval decision support aids
- Control of a hypervelocity interceptor
- Fuzzy set modeling of NATO decision making

Electronics

In electronics, fuzzy logic is used in the following areas −

- Control of automatic exposure in video cameras
- Humidity in a clean room
- Air conditioning systems
- Washing machine timing
- Microwave ovens
- Vacuum cleaners

Finance

In the finance field, fuzzy logic is used in the following areas −

- Banknote transfer control
- Fund management
- Stock market predictions

Industrial Sector

In industrial, fuzzy logic is used in following areas −

- Cement kiln controls heat exchanger control
- Activated sludge wastewater treatment process control
- Water purification plant control
- Quantitative pattern analysis for industrial quality assurance
- Control of constraint satisfaction problems in structural design
- Control of water purification plants

Manufacturing

In the manufacturing industry, fuzzy logic is used in following areas −

- Optimization of cheese production
- Optimization of milk production

Marine

In the marine field, fuzzy logic is used in the following areas −

- Autopilot for ships
- Optimal route selection
- Control of autonomous underwater vehicles
- Ship steering

Medical

In the medical field, fuzzy logic is used in the following areas −

- Medical diagnostic support system
- Control of arterial pressure during anesthesia

- Multivariable control of anesthesia
- Modeling of neuropathological findings in Alzheimer's patients
- Radiology diagnoses
- Fuzzy inference diagnosis of diabetes and prostate cancer

Securities

In securities, fuzzy logic is used in following areas −

- Decision systems for securities trading
- Various security appliances

Transportation

In transportation, fuzzy logic is used in the following areas −

- Automatic underground train operation
- Train schedule control
- Railway acceleration
- Braking and stopping

Pattern Recognition and Classification

In Pattern Recognition and Classification, fuzzy logic is used in the following areas −

- Fuzzy logic based speech recognition
- Fuzzy logic based
- Handwriting recognition
- Fuzzy logic based facial characteristic analysis
- Command analysis
- Fuzzy image search

Psychology

In Psychology, fuzzy logic is used in following areas −

- Fuzzy logic based analysis of human behavior
- Criminal investigation and prevention based on fuzzy logic reasoning

Planning

- Artificial intelligence is an important technology in the future. Whether it is intelligent robots, self-driving cars, or smart cities, they will all use different aspects of artificial intelligence!!! But Planning is very important to make any such AI project.
- Even Planning is an important part of Artificial Intelligence which deals with the tasks and domains of a particular problem. Planning is considered the logical side of acting.
- Everything we humans do is with a definite goal in mind, and all our actions are oriented towards achieving our goal. Similarly, Planning is also done for Artificial Intelligence.

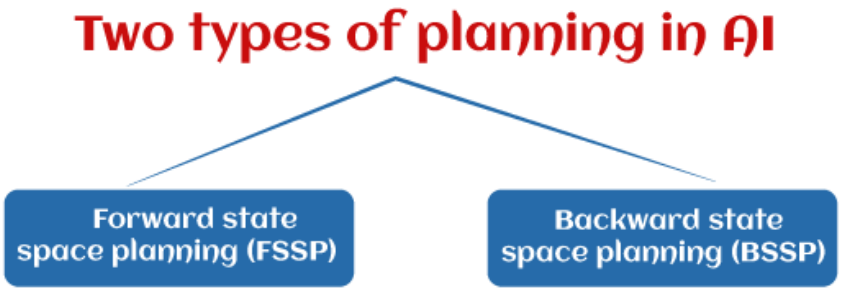
For example, Planning is required to reach a particular destination. It is necessary to find the best route in Planning, but the tasks to be done at a particular time and why they are done are also very important.

That is why Planning is considered the logical side of acting. In other words, Planning is about deciding the tasks to be performed by the artificial intelligence system and the system's functioning under domain-independent conditions.

What is a Plan?

We require domain description, task specification, and goal description for any planning system. A plan is considered a sequence of actions, and each action has its preconditions that must be satisfied before it can act and some effects that can be positive or negative.

So, we have Forward State Space Planning (FSSP) and Backward State Space Planning (BSSP) at the basic level.



What is planning in AI?

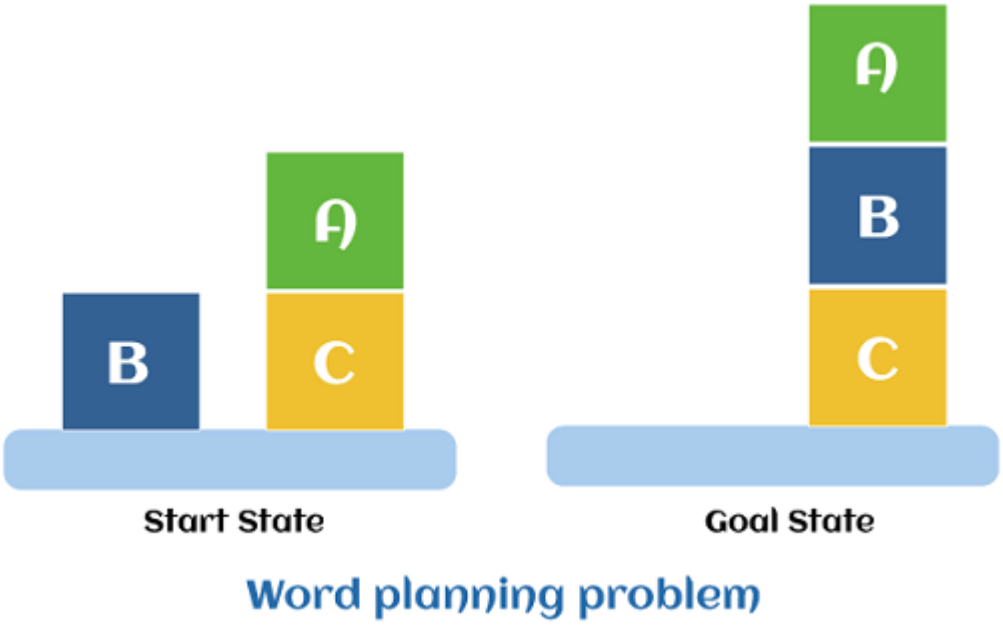
Planning in artificial intelligence is about decision-making actions performed by robots or computer programs to achieve a specific goal.

Execution of the plan is about choosing a sequence of tasks with a high probability of accomplishing a specific task.

Block-world planning problem

- The block-world problem is known as the Sussmann anomaly.
- The non-interlaced planners of the early 1970s were unable to solve this problem. Therefore it is considered odd.
- When two sub-goals, G1 and G2, are given, a non-interleaved planner either produces a plan for G1 that is combined with a plan for **G2** or vice versa.
- In the block-world problem, three blocks labeled 'A', 'B', and 'C' are allowed to rest on a flat surface. The given condition is that only one block can be moved at a time to achieve the target.

The start position and target position are shown in the following diagram.



Word planning problem

Components of the planning system

The plan includes the following important steps:

- Choose the best rule to apply the next rule based on the best available guess.
- Apply the chosen rule to calculate the new problem condition.
- Find out when a solution has been found.
- Detect dead ends so they can be discarded and direct system effort in more useful directions.
- Find out when a near-perfect solution is found.

Target stack plan

- It is one of the most important planning algorithms used by STRIPS.
- Stacks are used in algorithms to capture the action and complete the target. A knowledge base is used to hold the current situation and actions.
- A target stack is similar to a node in a search tree, where branches are created with a choice of action.

The important steps of the algorithm are mentioned below:

1. Start by pushing the original target onto the stack. Repeat this until the pile is empty. If the stack top is a mixed target, push its unsatisfied sub-targets onto the stack.
2. If the stack top is a single unsatisfied target, replace it with action and push the action precondition to the stack to satisfy the condition.

Non-linear Planning

This Planning is used to set a goal stack and is included in the search space of all possible sub-goal orderings. It handles the goal interactions by the interleaving method.

Advantages of non-Linear Planning

Non-linear Planning may be an optimal solution concerning planning length (depending on the search strategy used).

Disadvantages of Nonlinear Planning

It takes a larger search space since all possible goal orderings are considered.

Complex algorithm to understand.

Algorithm

1. Choose a goal 'g' from the goal set
2. If 'g' does not match the state, then
    - Choose an operator 'o' whose add-list matches goal g
    - Push 'o' on the OpStack
    - Add the preconditions of 'o' to the goal set
3. While all preconditions of the operator on top of OpenStack are met in a state
    - Pop operator o from top of opstack
    - state = apply(o, state)
    - plan = [plan; o]

Goal Stack Planning:

Goal Stack Planning is one of the earliest methods in artificial intelligence in which we work backwards from the goal state to the initial state.

We start at the goal state and we try fulfilling the preconditions required to achieve the initial state. These preconditions in turn have their own set of preconditions, which are required to be satisfied first. We keep solving these “goals” and “sub-goals” until we finally arrive at the Initial State. We make use of a stack to hold these goals that need to be fulfilled as well the actions that we need to perform for the same.

Apart from the “Initial State” and the “Goal State”, we maintain a “World State” configuration as well. Goal Stack uses this world state to work its way from Goal State to Initial State. World State on the other hand starts off as the Initial State and ends up being transformed into the Goal state.

At the end of this algorithm we are left with an empty stack and a set of actions which helps us navigate from the Initial State to the World State.

Goal Stack Planning Algorithm:

Step-1: Push the original goal on the stack. Repeat until the stack is empty.

Step-2: If the stack top is a compound goal, push its unsatisfied subgoals on the stack.

Step-3: If the stack top is a single unsatisfied goal. It replaces it with an action that makes it satisfied and push the action’s precondition on the stack.

Step-4: If stack top is an action, pop it from the stack, execute it and change the knowledge base by the action’s effects.

Step-5: If stack top is a satisfying goal, pop it from the stack.

Representing the configurations as a list of "predicates"

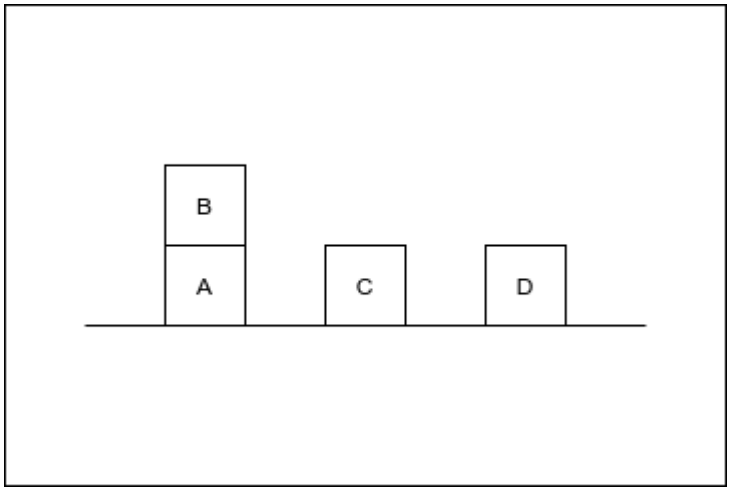
Predicates can be thought of as a statement which helps us convey the information about a configuration in Blocks World.

Given below are the list of predicates as well as their intended meaning

1. ON(A,B) : Block A is on B
2. ONTABLE(A) : A is on table
3. CLEAR(A) : Nothing is on top of A
4. HOLDING(A) : Arm is holding A.
5. ARMEMPTY : Arm is holding nothing

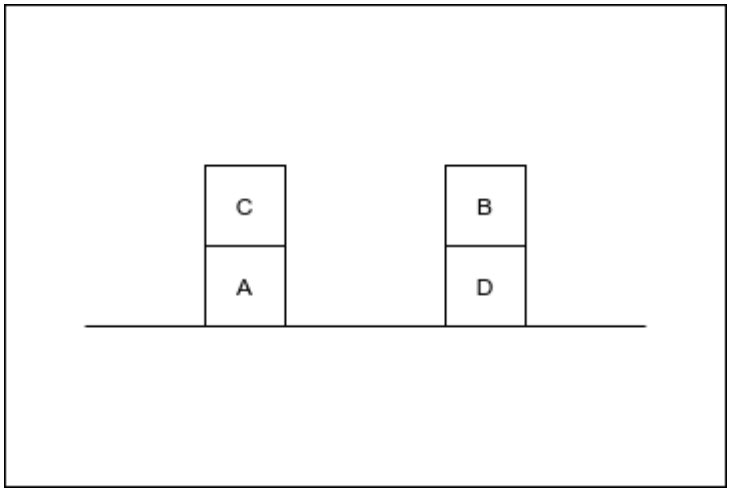
Using these predicates, we represent the Initial State and the Goal State in our example like this:

Initial State — ON(B,A) ∧ ONTABLE(A) ∧ ONTABLE(C) ∧ ONTABLE(D) ∧ CLEAR(B) ∧ CLEAR(C) ∧ CLEAR(D) ∧ ARMEMPTY



Initial State

Goal State — ON(C,A) ∧ ON(B,D) ∧ ONTABLE(A) ∧ ONTABLE(D) ∧ CLEAR(B) ∧ CLEAR(C) ∧ ARMEMPTY



Goal State

Thus a configuration can be thought of as a list of predicates describing the current scenario.

"Operations" performed by the robot arm

The Robot Arm can perform 4 operations:

1. STACK(X,Y) : Stacking Block X on Block Y
2. UNSTACK(X,Y) : Picking up Block X which is on top of Block Y
3. PICKUP(X) : Picking up Block X which is on top of the table
4. PUTDOWN(X) : Put Block X on the table

All the four operations have certain preconditions which need to be satisfied to perform the same. These preconditions are represented in the form of predicates.

Hierarchical Planning:

Hierarchical Planning is a method used in Artificial Intelligence (AI) that breaks down complex problems into smaller, more manageable sub-problems. This approach allows AI systems to efficiently plan and execute actions to achieve their goals.

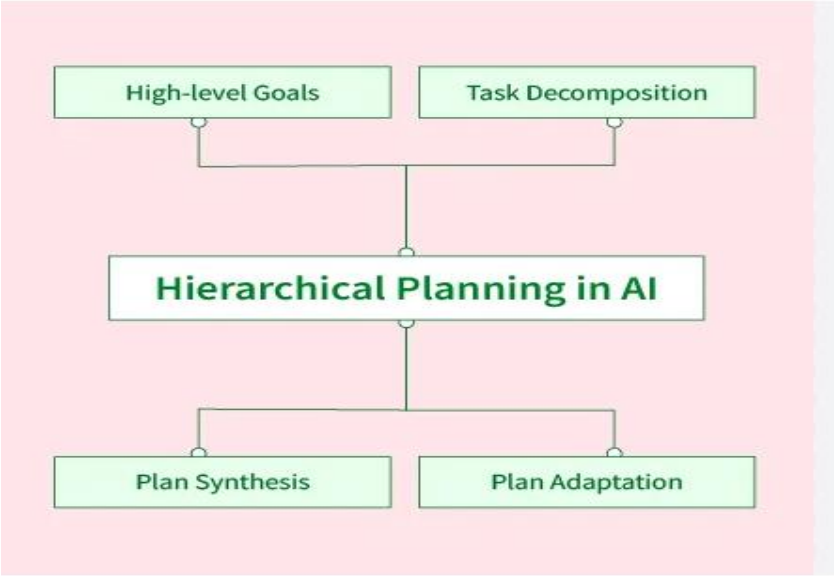
At its core, Hierarchical Planning involves two main levels: the high-level planner and the low-level planner. The high-level planner is responsible for setting the overall goal and breaking it down into smaller sub-goals. It then passes these sub-goals to the low-level planner, which generates a sequence of actions to achieve each sub-goal.

This process continues until all sub-goals have been accomplished, and the overall goal has been achieved. The high-level planner may also monitor the progress of the low-level planner and make adjustments as necessary.

For complicated projects with several subtasks, hierarchical planning is especially helpful since it enables the AI system to divide the issue into more manageable chunks. It is also helpful in scenarios when the activities required to accomplish a goal may alter depending on the setting or circumstances.

Overall, Hierarchical Planning is an essential technique in the field of AI, as it allows AI systems to efficiently plan and execute actions to achieve their goals.

For example, in autonomous robots, hierarchical planning can be used to plan high-level goals, such as navigating to a specific location, and decompose them into lower-level tasks, such as obstacle avoidance, path planning, and motion control.



Components of Hierarchical Planning

Hierarchical planning in artificial intelligence (AI) typically involves several key components, including:

- **High-level goals:** The overall objectives or tasks that the AI system aims to achieve.
- **Task decomposition:** Breaking down high-level goals into lower-level tasks or subgoals.
- **Planning hierarchy:** The organization of tasks or subgoals into a hierarchical structure, such as a tree or a directed acyclic graph (DAG).
- **Plan generation at different levels:** Reasoning and planning at different levels of the hierarchy, with plans generated for achieving subgoals or actions.
- **Plan synthesis:** Combining the plans for achieving subgoals or actions into a cohesive plan for execution.
- **Plan execution:** Carrying out the actions or subgoals in the plan in the correct order.
- **Plan adaptation:** Revising plans at different levels of abstraction to accommodate changes in the environment or goals.

Advantages of Hierarchical Planning

Hierarchical planning offers several advantages, including:

- **Scalability:** Hierarchical planning allows for reasoning and planning at different levels of abstraction, enabling efficient handling of complex tasks and environments.
- **Flexibility:** Hierarchical planning provides the flexibility to adapt plans to changes in the environment or goals, making them more robust and adaptable.
- **Abstraction and reuse:** The use of a hierarchy of tasks or subgoals allows for the abstraction and reuse of plans, making planning more efficient and reducing the need for redundant planning.

- **Higher-level reasoning:** Hierarchical planning allows for higher-level reasoning and decision-making, enabling AI systems to make strategic choices and coordinate actions at a higher level of abstraction.
- **Task organization:** Hierarchical planning helps in organizing tasks or subgoals into a coherent structure, providing a clear overview of the planning process and facilitating better coordination and management of tasks.

Techniques Used in Hierarchical Planning

Hierarchical planning in artificial intelligence (AI) involves the use of various techniques to effectively decompose tasks, abstract them at different levels, allocate tasks to appropriate agents or resources, and integrate execution plans. Here's a brief overview of these techniques:

- **Decomposition techniques:** Decomposition techniques involve breaking down high-level goals or tasks into lower-level tasks or subgoals. This can be done using methods such as goal decomposition, task network decomposition, or state-based decomposition. Goal decomposition involves breaking down high-level goals into smaller subgoals that can be achieved independently. Task network decomposition involves representing tasks and their dependencies as a directed graph and decomposing it into smaller subgraphs. State-based decomposition involves dividing the planning problem into smaller subproblems based on different states of the environment.
- **Abstraction techniques:** Abstraction techniques involve representing tasks or actions at different levels of abstraction. This can be done using methods such as state abstraction, action abstraction, or temporal abstraction. State abstraction involves representing the state of the environment at a higher level of abstraction, reducing the complexity of the planning problem. Action abstraction involves representing actions at a higher level of abstraction, allowing for more generalizable plans. Temporal abstraction involves representing actions or plans at a higher level of time granularity, such as abstracting a sequence of actions into a single abstract action.
- **Task allocation techniques:** Task allocation techniques involve assigning tasks or subgoals to appropriate agents or resources in a hierarchical planning system. This can be done using methods such as centralized allocation, decentralized allocation, or market-based allocation. Centralized allocation involves a central planner assigning tasks to agents or resources. Decentralized allocation involves agents or resources autonomously selecting tasks based on local information. Market-based allocation involves agents or resources bidding for tasks in a market-like mechanism.
- **Plan integration techniques:** Plan integration techniques involve combining plans generated at different levels of abstraction into a cohesive plan for execution. This can be done using methods such as plan merging, plan refinement, or plan composition. Plan merging involves combining plans for achieving different subgoals into a single plan. Plan refinement involves refining a high-level plan by generating detailed plans for achieving lower-level subgoals. Plan composition involves combining plans for achieving different tasks or actions into a coherent and executable plan.

Applications of Hierarchical Planning in AI

Hierarchical planning has been widely used in various applications of artificial intelligence (AI), including:

- **Robotics:** Hierarchical planning is commonly used in robotics to plan and execute complex tasks involving multiple levels of abstraction. For example, in autonomous robots, hierarchical planning can be used to plan high-level goals, such as navigating to a specific location, and decompose them into lower-level tasks, such as obstacle avoidance, path planning, and motion control. Hierarchical planning can also be used in robot task planning, where high-level goals, such as

picking and placing objects, can be decomposed into subgoals, such as perception, grasping, and manipulation, to be executed by the robot.

- **Autonomous Systems:** Hierarchical planning is used in various autonomous systems, such as autonomous vehicles, drones, and unmanned aerial vehicles (UAVs). Hierarchical planning can be used to plan and coordinate actions at different levels of abstraction, such as high-level goals like reaching a destination or following a mission plan, and low-level tasks like obstacle avoidance, navigation, and communication. Hierarchical planning allows autonomous systems to efficiently plan and execute complex tasks in dynamic and uncertain environments.
- **Manufacturing:** Hierarchical planning is employed in manufacturing systems to plan and optimize production processes. High-level goals, such as production scheduling, resource allocation, and task coordination, can be decomposed into lower-level tasks, such as machine scheduling, material handling, and quality control, which can be planned and executed hierarchically. Hierarchical planning enables efficient coordination and management of manufacturing processes to improve productivity and resource utilization.
- **Transportation:** Hierarchical planning is utilized in transportation systems for tasks such as route planning, traffic management, and logistics. High-level goals, such as finding optimal routes, coordinating multiple vehicles, and managing traffic flow, can be decomposed into lower-level tasks, such as path planning, traffic control, and fleet coordination. Hierarchical planning can help transportation systems make informed decisions, optimize resource utilization, and improve overall efficiency.

(Subject In-charge)

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