Introduction to Artificial Intelligence

MODULE 01

Scope of AI

Department of Computer Science, YIASCM

Index:

What is Intelligence?

The ability to learn, understand, and make judgments or have opinions that are based on reason is known as intelligence.

What is AI?

- AI is the branch of computer science which deals with helping machines find solutions to complex problems in a more human-like fashion.
- AI is techniques that help machines mimic human behaviour.
- AI is the branch of computer science with which we can create intelligent machine which can think like human, able to take decision and behave like human.

- The term was coined by **John McCarthy** in 1956.

Examples

- Gmail's spam filter
- Smart assistant like Alexa, Siri…
- Recommendation Systems like Netflix, Spotify…
- Smartphone Features like face recognition, autocorrect, voice to text
- Navigation and Traffic Prediction
- Social Media
- Online Shopping
- Photo Organization
- Smart Home Devices

Activity 01

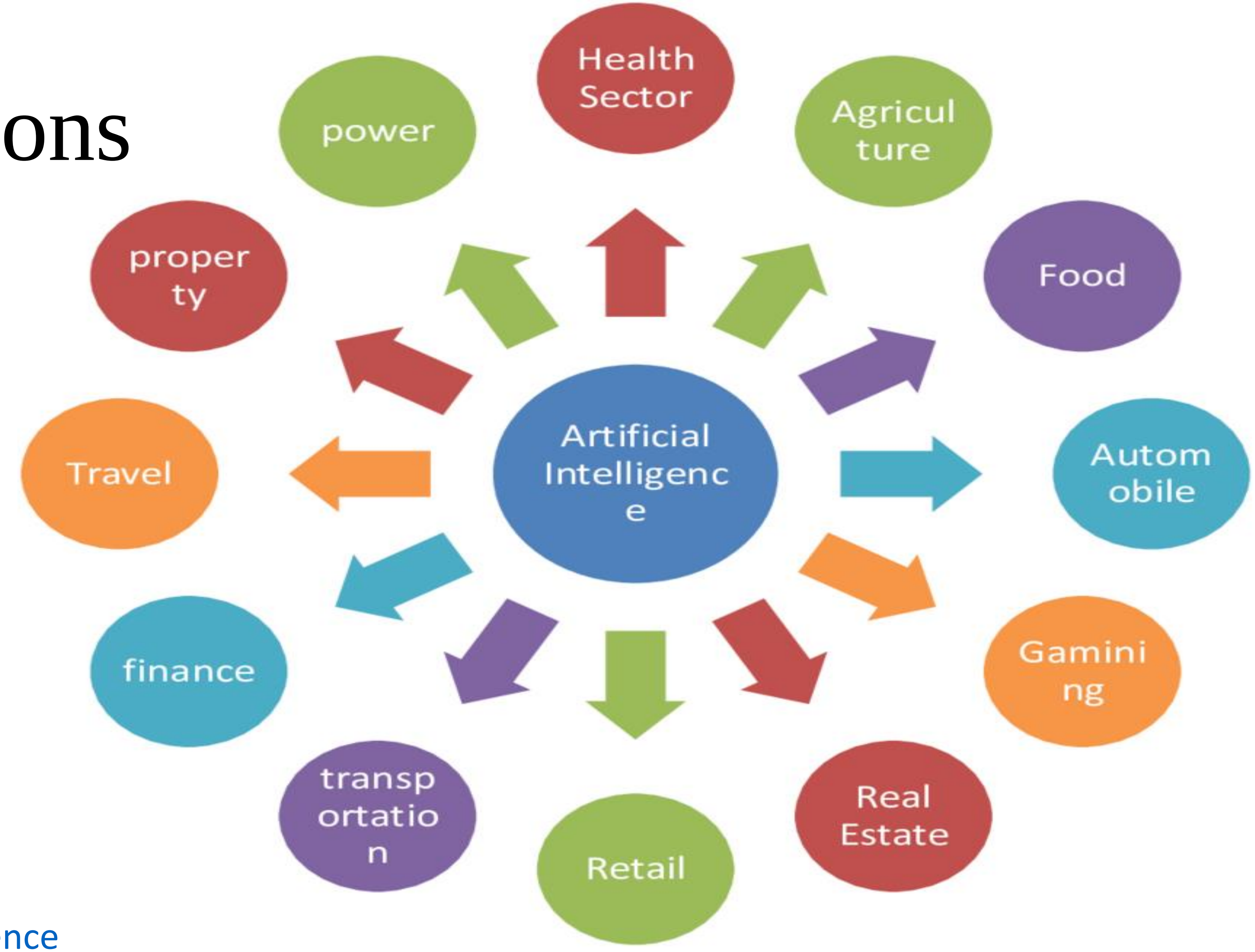
[A group of 3 students is to be formed. All the 3 members should discuss and select any 1 AI application each, document the explanation. Each member should be aware of all the 3 applications. Students should be able to explain it to the class if asked.]

Select three real-life examples of AI applications. Each example should come from different domains (e.g., healthcare, finance, transportation, entertainment, etc.).

For each example, provide:

- A detailed description of how AI is used in this context.
- The benefits and potential challenges or limitations of using AI in this example.
- The impact of this AI application on the industry or society.
- Each use case should be 300-500 words and include at least two references.

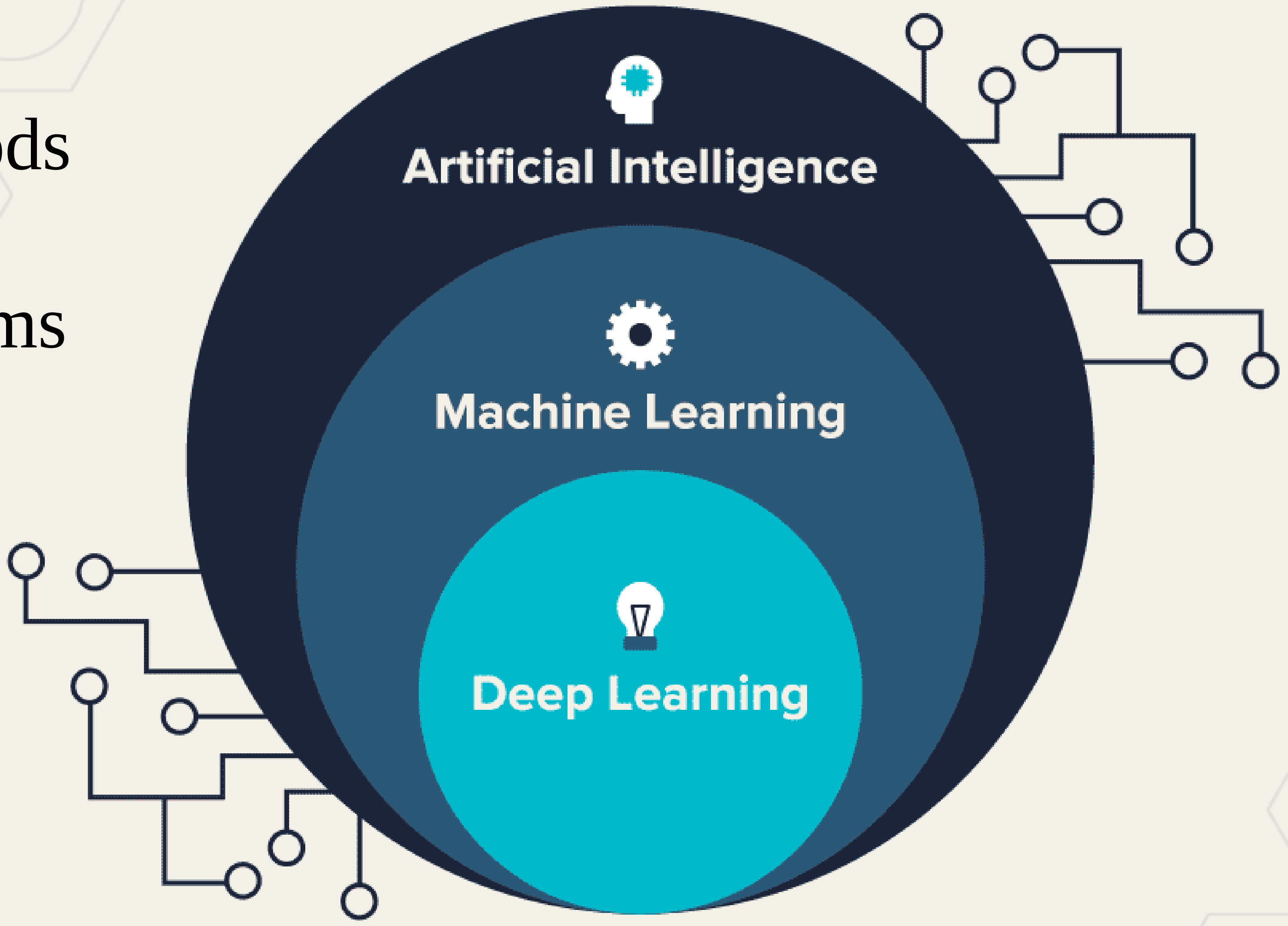
AI Applications



Click here for detailed reference

AI Techniques:

It refers to a set of methods and algorithms used to develop intelligent systems that can perform tasks requiring human-like intelligence.

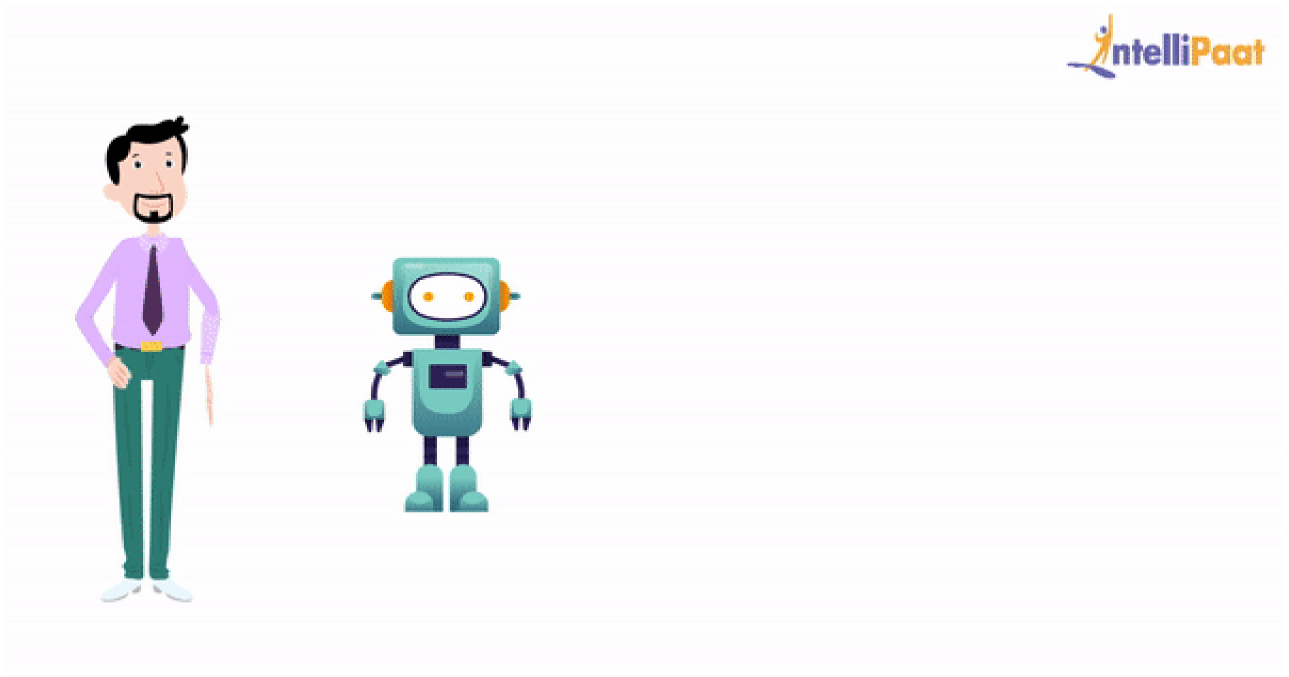


Machine Learning

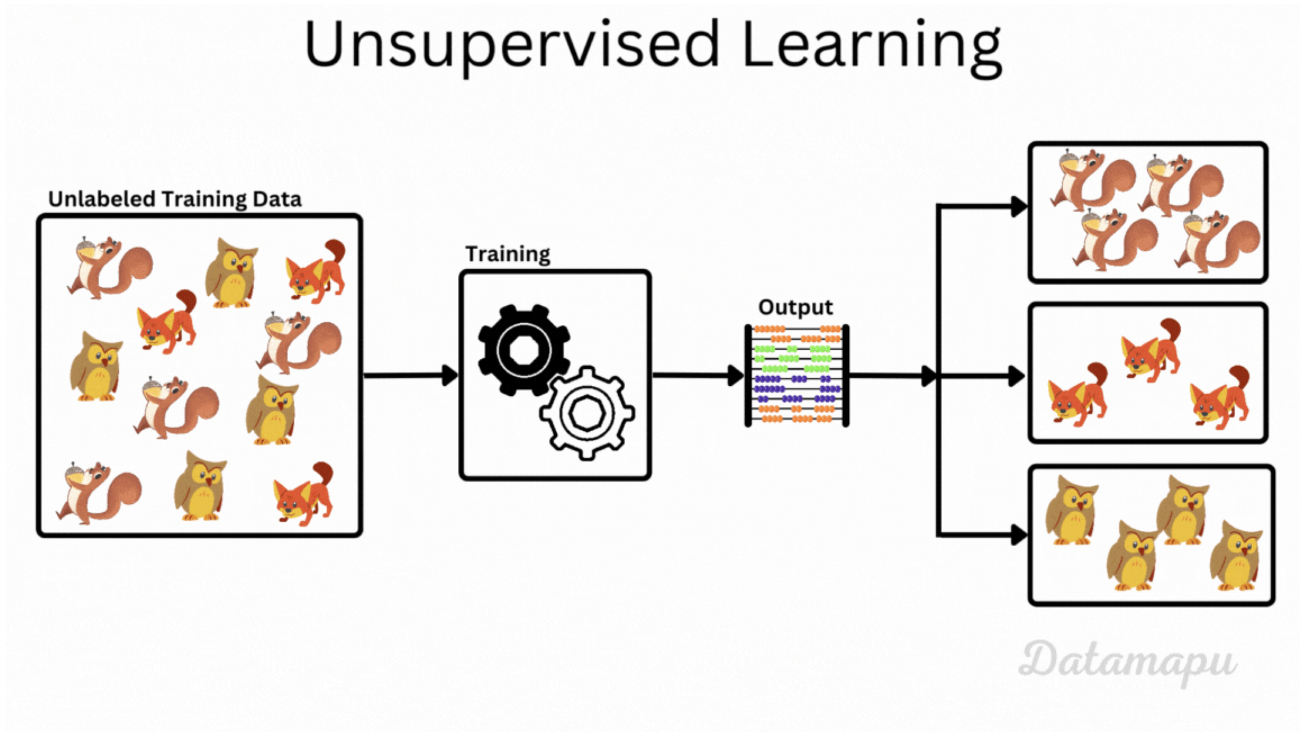
- It is a branch of artificial intelligence based on the idea that systems can learn from data, identify patterns and make decisions with minimal human intervention.
- This machine learning process starts with feeding them good quality data and then training the machines by building various machine learning models using the data and different algorithms.
- The choice of algorithms depends on what type of data we have and what kind of task we are trying to automate.
- This approach involves the building of algorithms to learn patterns in data and make predictions based on it.
- Ex: Personalized Recommendations

Types of Machine Learning

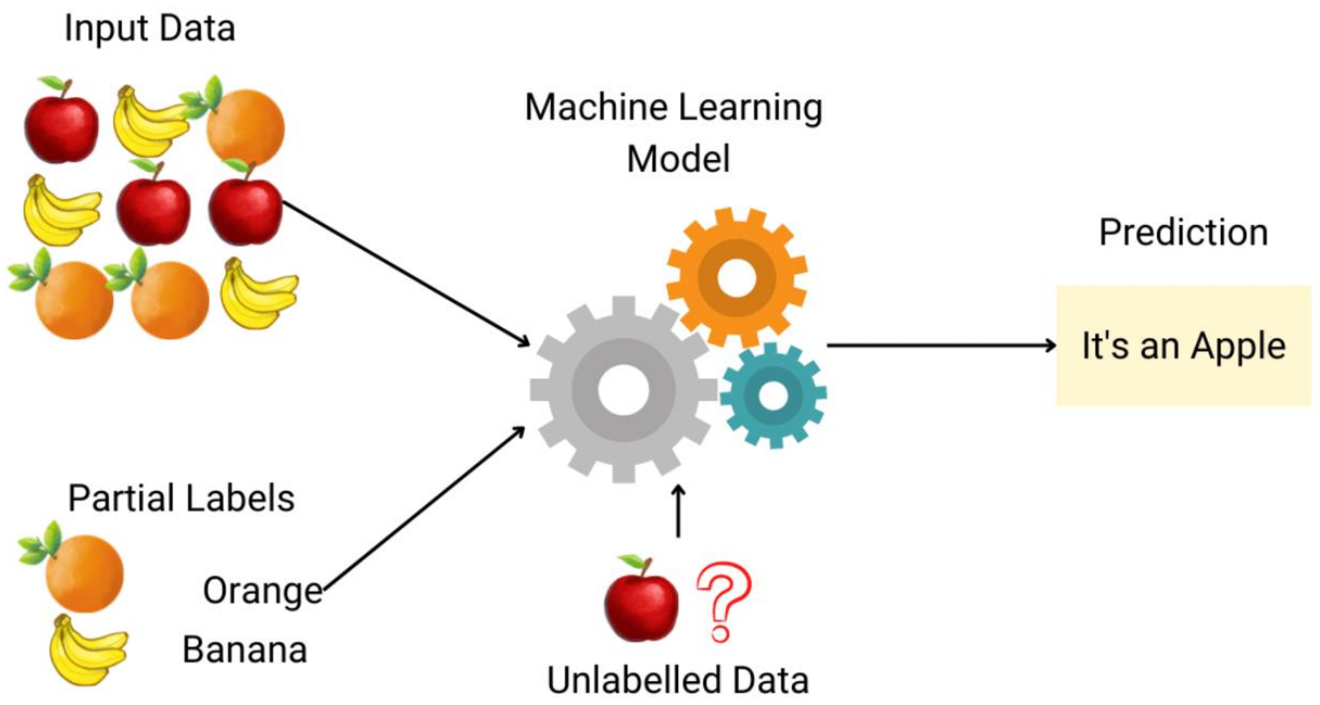
Supervised learning – A combination of an input data set and the intended output is inferred from the training data. AI systems learn from a labelled dataset, where each data point is associated with a known outcome. For instance, it enables email spam filters to distinguish between spam and legitimate emails based on learned patterns.



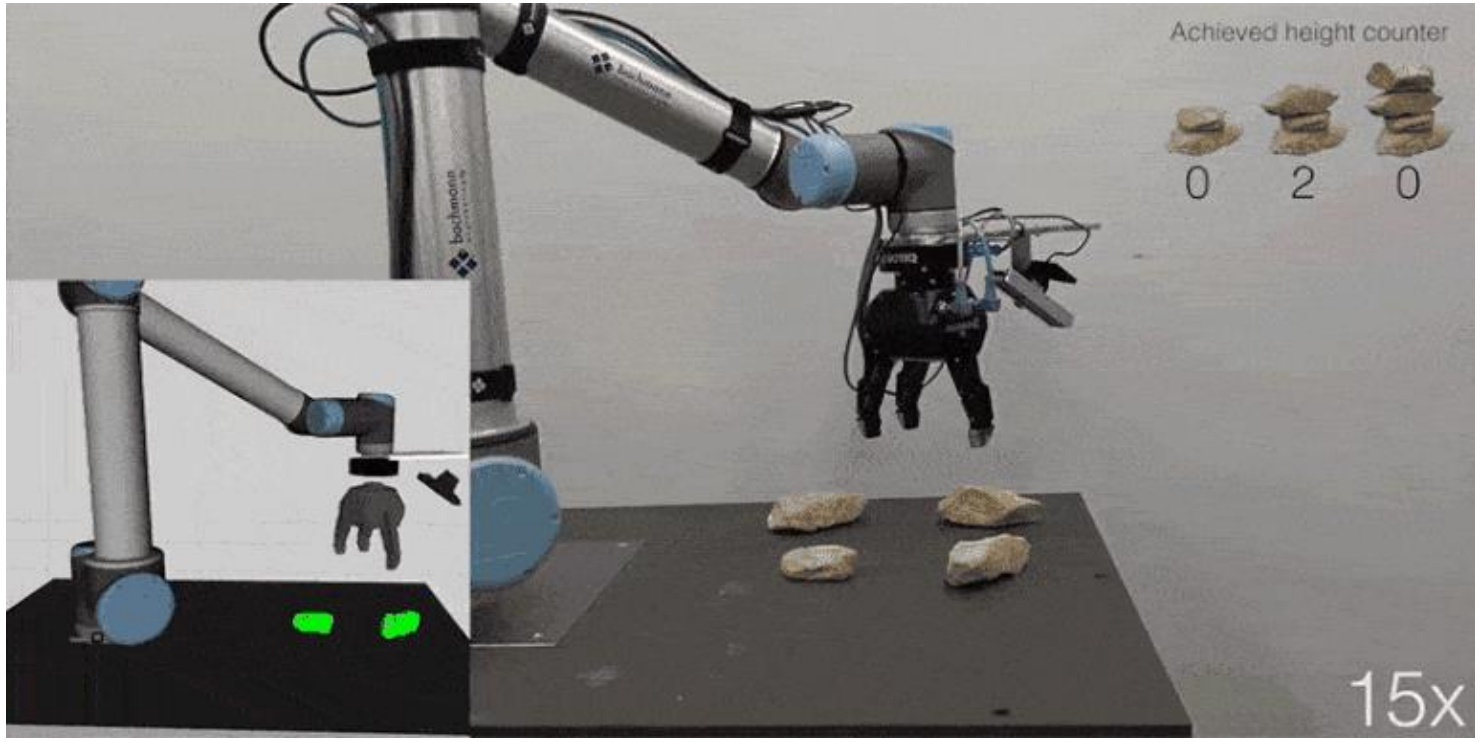
Unsupervised machine learning -AI systems analyse unlabelled data, where no predefined outcomes are provided. The objective is to uncover inherent structures or patterns within the data without any prior knowledge. For instance, it can group similar customer behaviour data to identify customer segments for targeted marketing strategies.



Semi-supervised learning – It is a method that uses a small amount of labelled data and a large amount of unlabelled data to train a model. The goal of semi-supervised learning is to learn a function that can accurately predict the output variable based on the input variables, similar to supervised learning. However, unlike supervised learning, the algorithm is trained on a dataset that contains both labelled and unlabelled data.

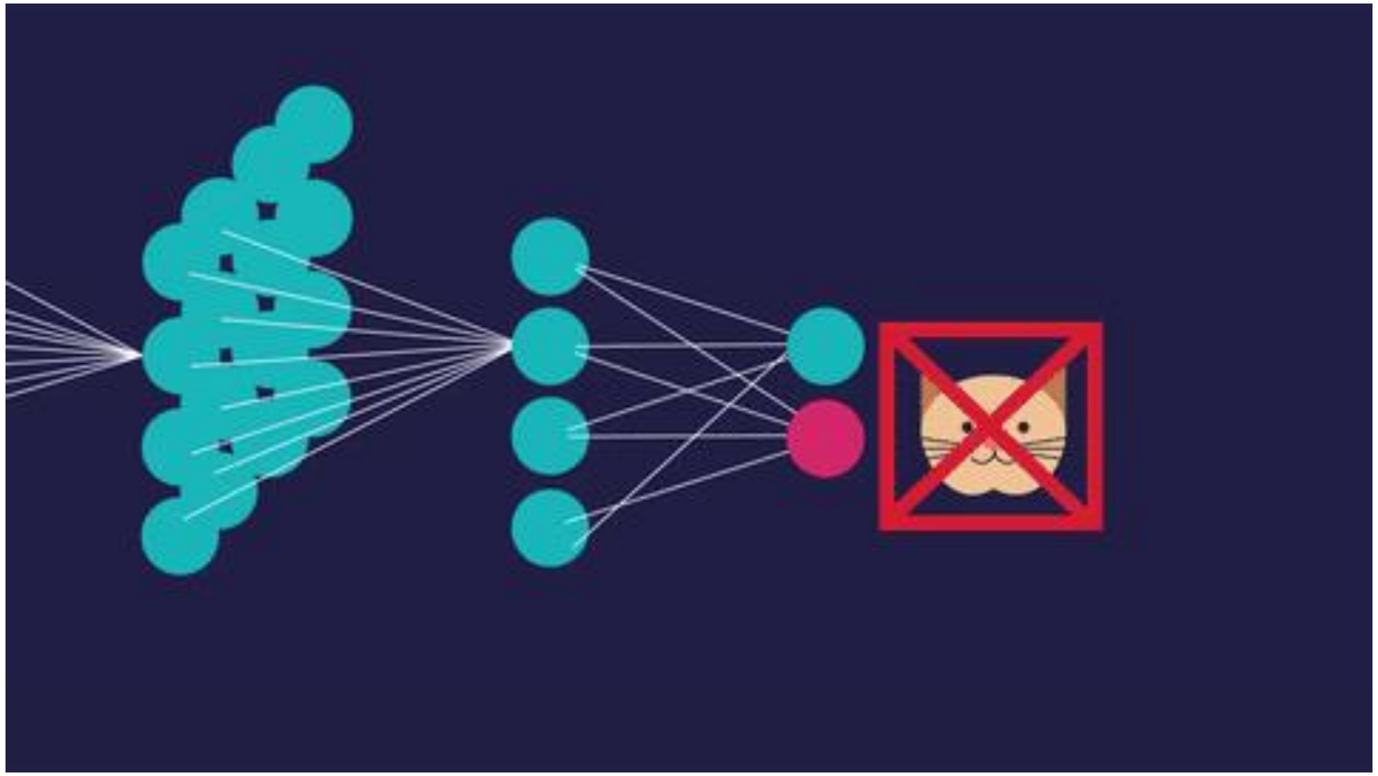


Reinforcement learning – In RL, the data is accumulated from ML systems that use a trial-and-error method to learn from outcomes and decide which action to take next. After each action, the algorithm receives feedback that helps it determine whether the choice it made was correct, neutral or incorrect. It performs actions with the aim of maximizing rewards, or in other words, it is learning by doing in order to achieve the best outcomes.



Deep learning

- It is a method in AI that teaches computers to process data in a way that is inspired by the human brain.
- Deep learning models can recognize complex patterns in pictures, text, sounds, and other data to produce accurate insights and predictions
- This field has led to major advances in areas like computer vision, natural language processing to healthcare diagnostics and autonomous driving.
- Ex: Image classification

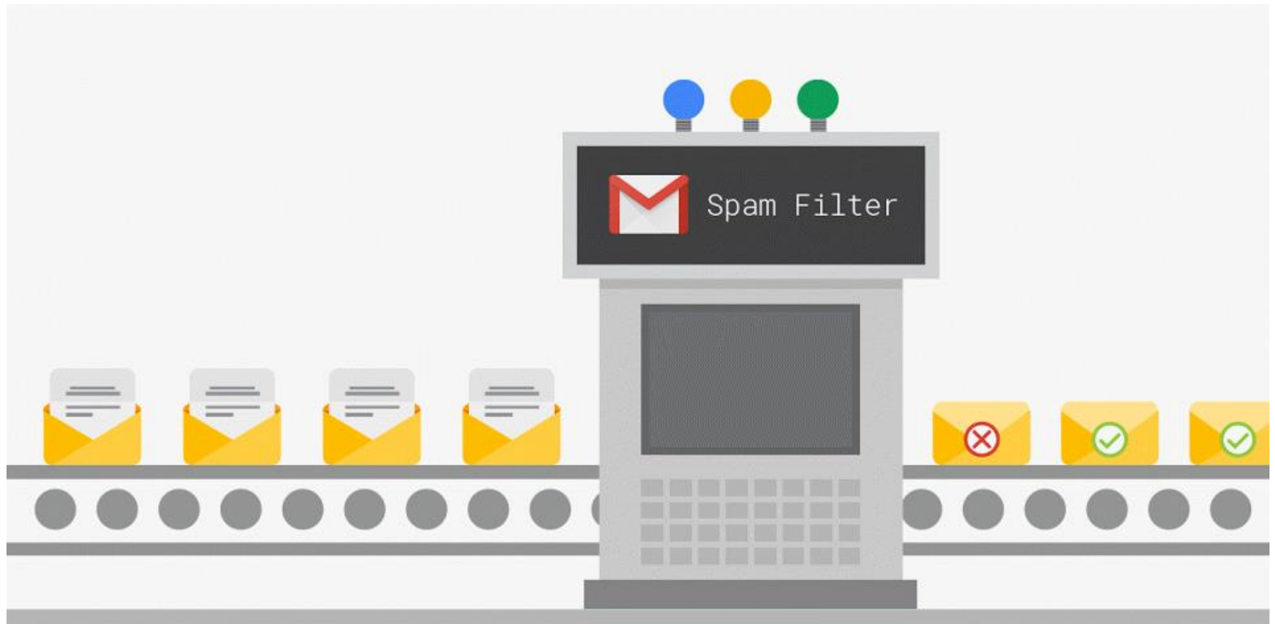


Natural language processing

- NLP is a machine learning technology that gives computers the ability to interpret, manipulate, and comprehend human language.
- NLP is the ability of a computer program to understand human language as it's spoken and written referred to as natural language.
- NLP is widely used in Text classification, text extraction, machine translation, NL generation.

Natural language processing

- **Text Classification**: This involves categorizing text into predefined groups. Common applications include spam detection, sentiment analysis, and topic categorization. For instance, NLP can analyze movie reviews to determine if they are positive, negative, or neutral.

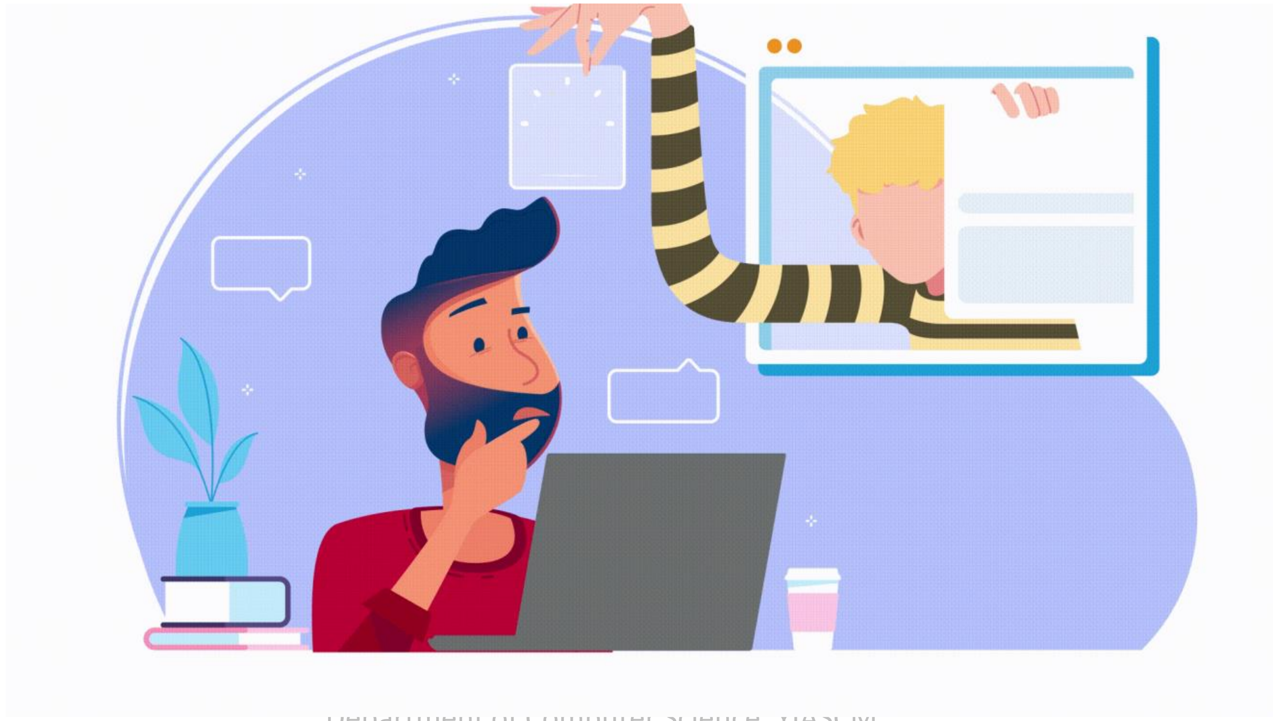


Natural language processing

- **Text Extraction**: This is the process of automatically extracting structured information from unstructured text. Applications include keyword extraction. Businesses use text extraction to identify key terms and entities from large volumes of data for further analysis.
- **Machine Translation**: This involves using computational techniques to translate text or speech from one language to another. Modern machine translation systems, such as Google Translate, leverage deep learning models to provide more accurate translations by understanding the context.
- **Natural Language Generation (NLG)**: NLG is used in applications such as automated report writing, chatbots, and content creation. It enables systems to produce human-like text, making interactions with machines more natural.

Natural language processing

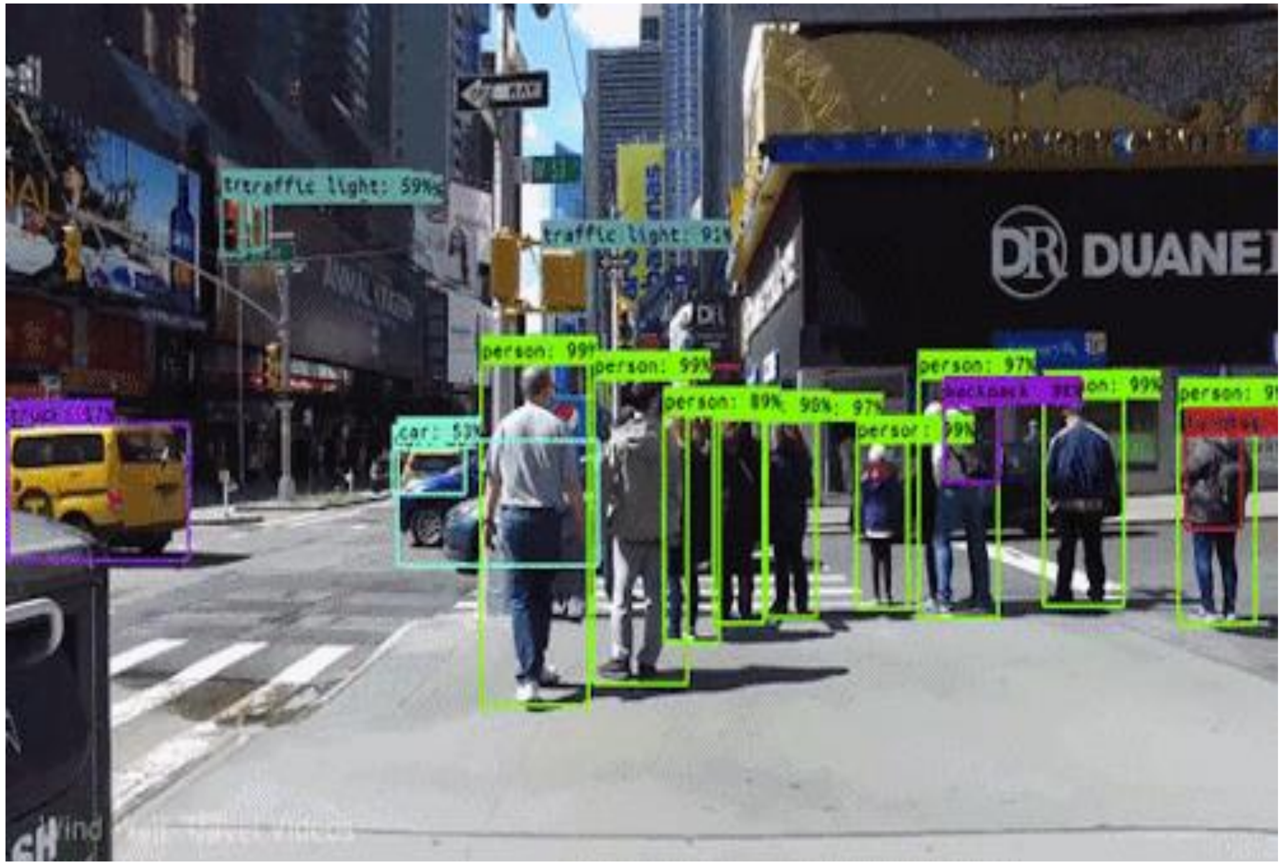
- Real world examples are, Customer feedback analysis, customer service automation, automatic translation, academic research and analysis, categorization of healthcare record, plagiarism detection etc..



Computer vision

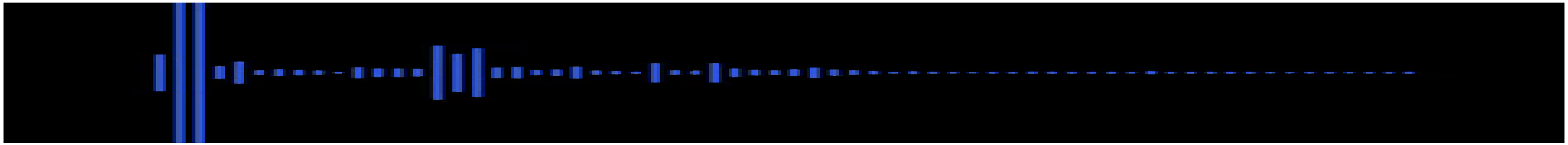
- A field of AI that deals with the processing and analysis of visual information using computer algorithms.
- It is a field of AI that trains computers to capture and interpret information from image and video data.

- By applying ML models to images, computers can classify objects and respond—like unlocking your smartphone when it recognizes your face.
- If AI enables computers to think, computer vision enables them to see, observe and understand.

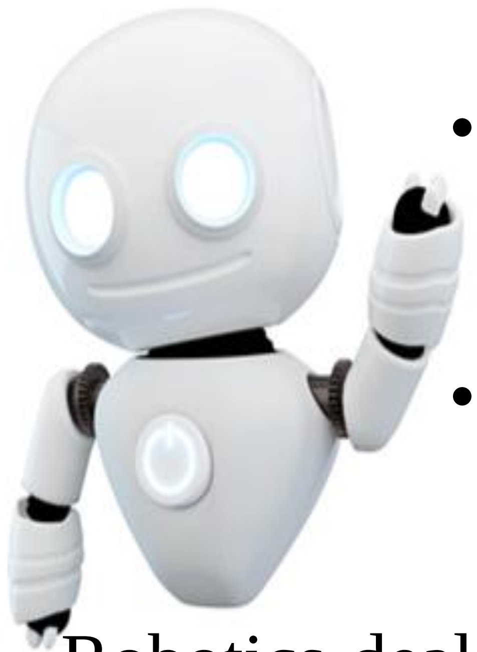


Speech recognition

- It enables computers and software applications to “understand” what people are saying, allows them to process information faster and with high accuracy.
- This software can translate spoken words into text using closed captions to enable a person with hearing loss to understand what others are saying.
- It can also enable those with limited use of their hands to work with computers, using voice commands instead of typing.
- Use cases include Virtual assistants, accessibility tools, automotive systems(google maps), healthcare, customer service, security and authentication.



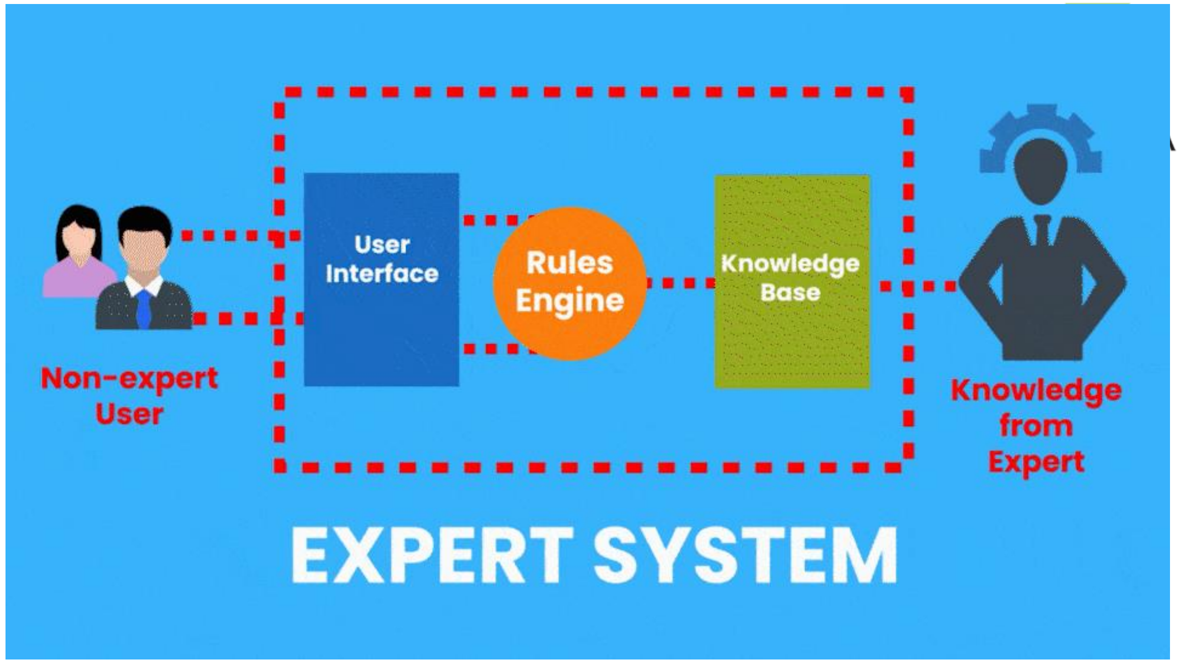
Robotics



- It involves integrating AI technologies into robotic systems to enhance their capabilities and enable them to perform more complex tasks.
- AI in robotics allows robots to learn from experience, adapt to new situations, and make decisions based on data from sensors.

- Robotics deals with the design, construction, operation, and use of robots and computer systems for their control, sensory feedback, and information processing.
- A robot is a unit that implements this interaction with the physical world based on sensors, actuators, and information processing.
- Robotics is used in defence sector, medical sector, industrial sector, entertainment, mining industry and so on.

Expert system



- It is a computer program that is designed to solve complex problems and to provide decision-making ability like a human expert.
- An expert system's job is to resolve the trickiest problems in a specific field.
- It performs this by extracting knowledge from its knowledge base using the reasoning and inference rules according to the user queries.
- Popular examples are,

DENDRAL: It was an artificial intelligence project that was made as a chemical analysis expert system. It was used in organic chemistry to detect unknown organic molecules with the help of their mass spectra and knowledge base of chemistry.

MYCIN: It was one of the earliest backward chaining expert systems that was designed to find the bacteria causing infections like bacteraemia and meningitis. It was also used for the recommendation of antibiotics and the diagnosis of blood clotting diseases.

Activity 02

[Form group of 3 – 5 students and do as directed,

- *Choose a diverse set of sentences that convey different emotions (positive, negative, neutral).*

Example: "I love this product!" (Tool: Positive, Score: 0.9)
"This is the worst service ever." (Tool: Negative, Score: -0.8)
"The weather is fine today." (Tool: Neutral, Score: 0.0)

1. *Input each sentence into an online sentiment analysis tool (such as Monkey Learn, Google Cloud Natural Language, IBM Watson, or a similar service).*
2. *Note down the sentiment score and category (positive, negative, neutral) provided by the tool for each sentence.*
3. *Compare the tool's analysis with your own understanding of the sentiment conveyed by each sentence.*
4. *Observe any inconsistencies or errors in the tool's analysis and understand the possible reasons (e.g., sarcasm, context, complex sentences).]*

Analyze the sentiment of a given set of sentences using an online sentiment analysis tool, record the results, and reflect on the tool's accuracy and limitations.

AI Agents

An agent can be some independent program or entity that perceive environment through sensor and act upon that environment through actuators.

An AI agent can be defined as a program that makes decisions and takes action based on the decisions.

In AI, an intelligent agent (IA) is an independent entity which observes and operates upon an environment and directs its activity towards accomplishing goals.

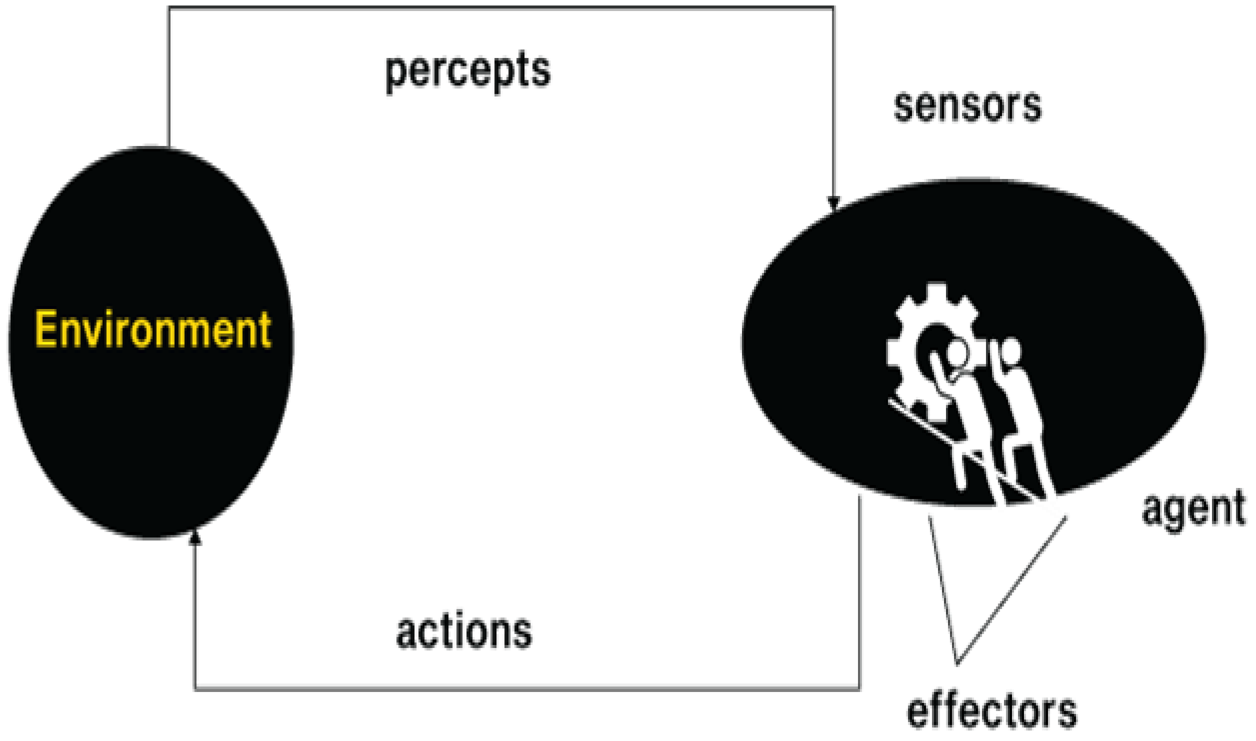
In short, an intelligent agent is an entity that interacts with its surroundings via:

- perception through sensors.
- actions through effectors or actuators(which operate).

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.

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



Agents can of be 3 types

Human agent

Humans contain sensors like their eyes, ears and other organs, as well as actuators like their hands, legs, mouth and other bodily parts.

Robot agent

These agents feature a variety of high quality motors, grippers, wheels, lights, speakers etc that serve as actuators, as well as cameras, infrared range finders, bumper etc that serve as sensors.

Software agent

This agent acts on sensory inputs(Data given as input to functions in the structure of encoded bit strings or symbols) such as file contents and network packets it has received, by acting on those inputs and with the result on the screen.

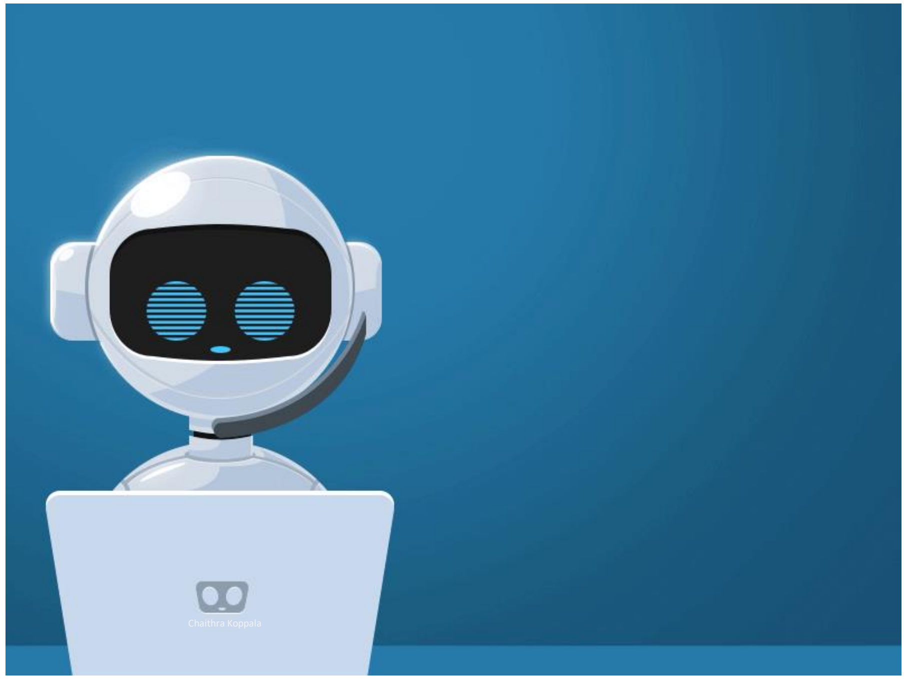
Rules for AI agents

Rule 01: An AI agent needs to have an environment perception.

Rule 02: Decisions must be based on observations of the environment.

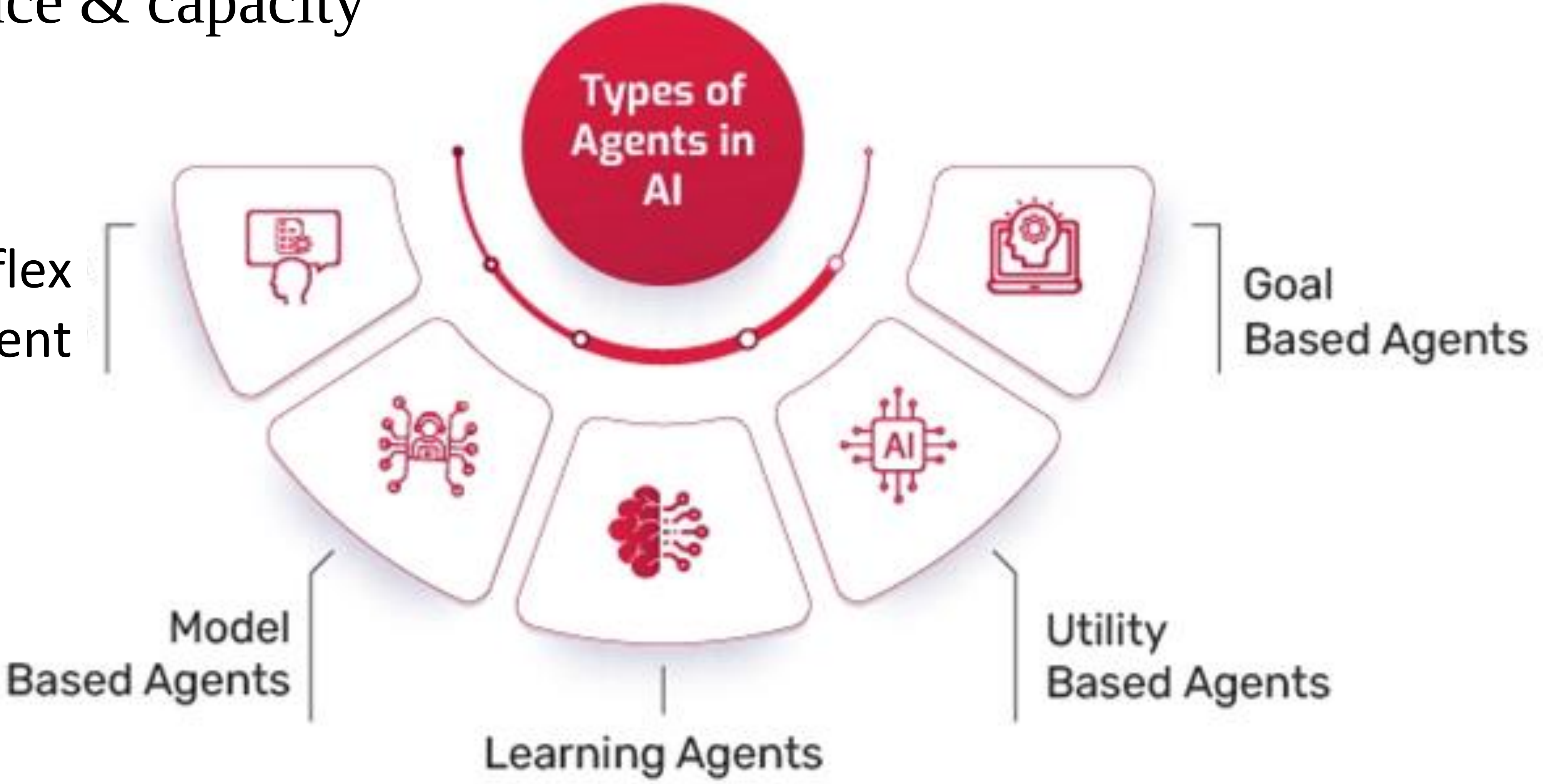
Rule 3: All the action should be based on decisions.

Rule 4: The AI agent’s actions have to be logical.



Types of Agents based on their degree of perceived intelligence & capacity

Simple Reflex agent



Simple reflex agents

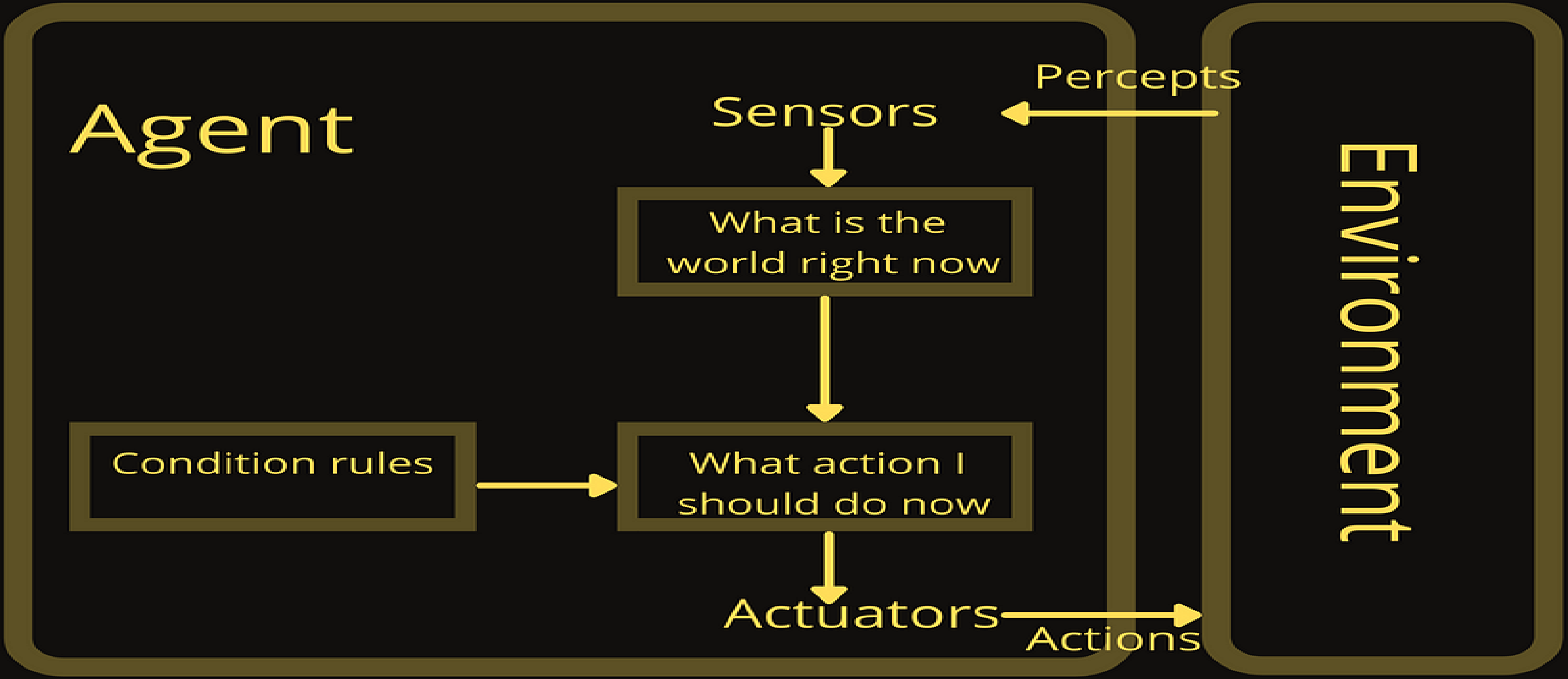
- These are the simplest agents.
- These agents take decisions on the basis of the current percepts and ignore the rest of the percepts history.
- This type is agent is based upon the condition action rule
  If the condition is true
  Action is action,
  Else NOT

Problems for the simple reflex agent design approach:

- They have very limited intelligence.
- They make decisions based only on what they currently sense, ignoring other relevant information.

SIMPLE REFLEX AGENT

Simple Reflex Agent ignore the rest of the percept history and act only on the basis of the current percept



Model-based agent

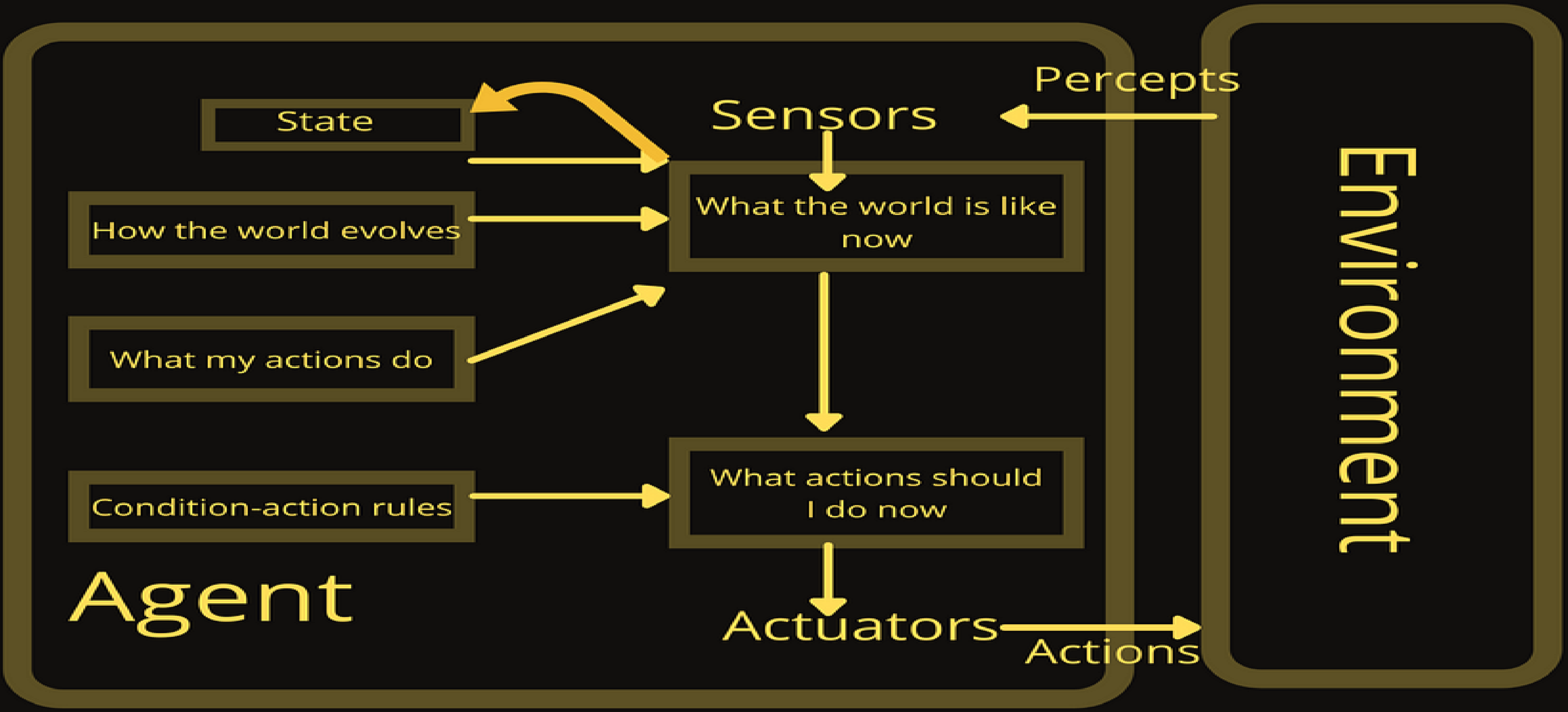
A model-based agent has two important factors:

- **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.

- It works by finding a rule whose condition matches the current situation
- It can handle partially observable environment
- Updating the state requires information about
  - How the world evolves
  - How the agent's action affects the world.

MODEL-BASED REFLEX AGENT

It works by finding a rule whose condition matches the current situation

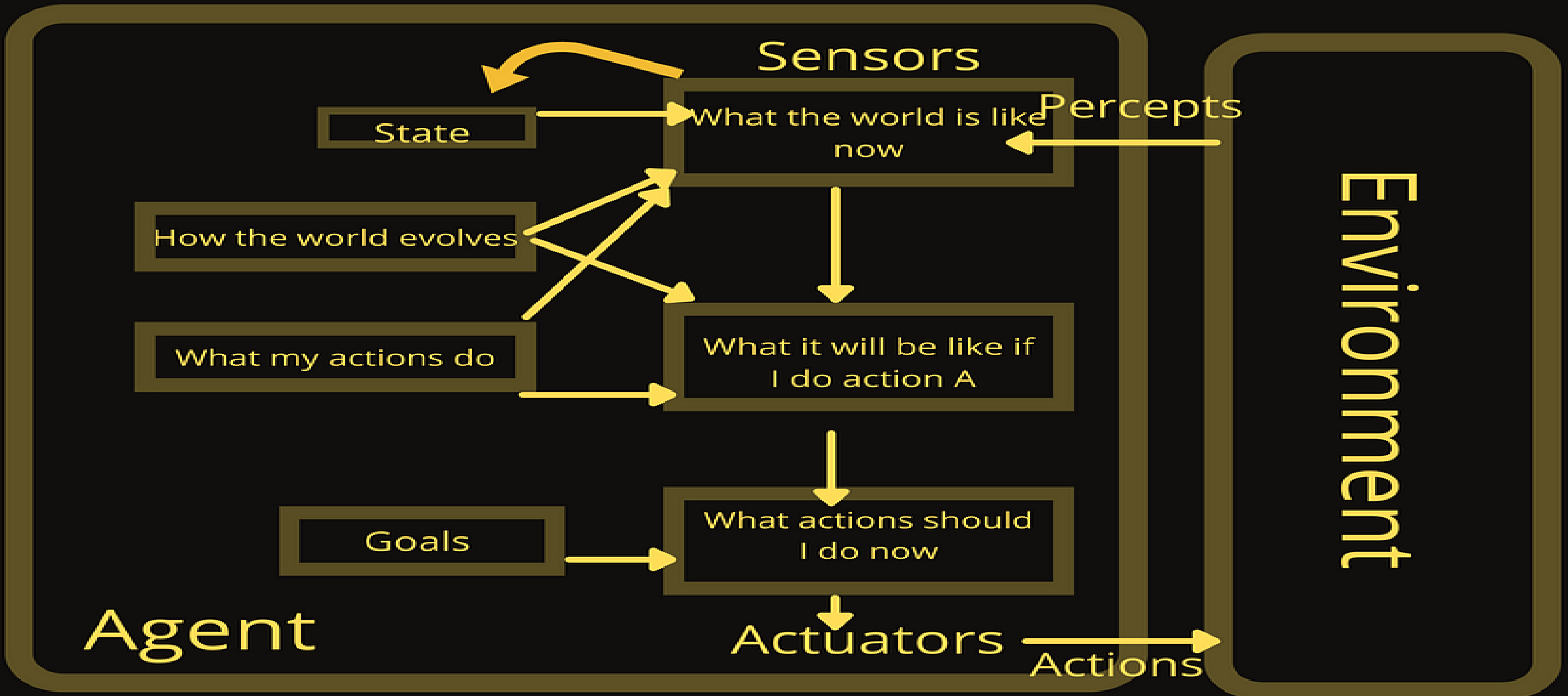


Goal-based agents

- 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.
- The goal based agent focuses only on reaching the goal set.
- Their every action is intended to minimise their distance from the goal
- This agent is more flexible and the agent develop the decision making skill by choosing the right.

GOAL-BASED AGENTS

These kind of agents take decision based on how far they are currently from their goal

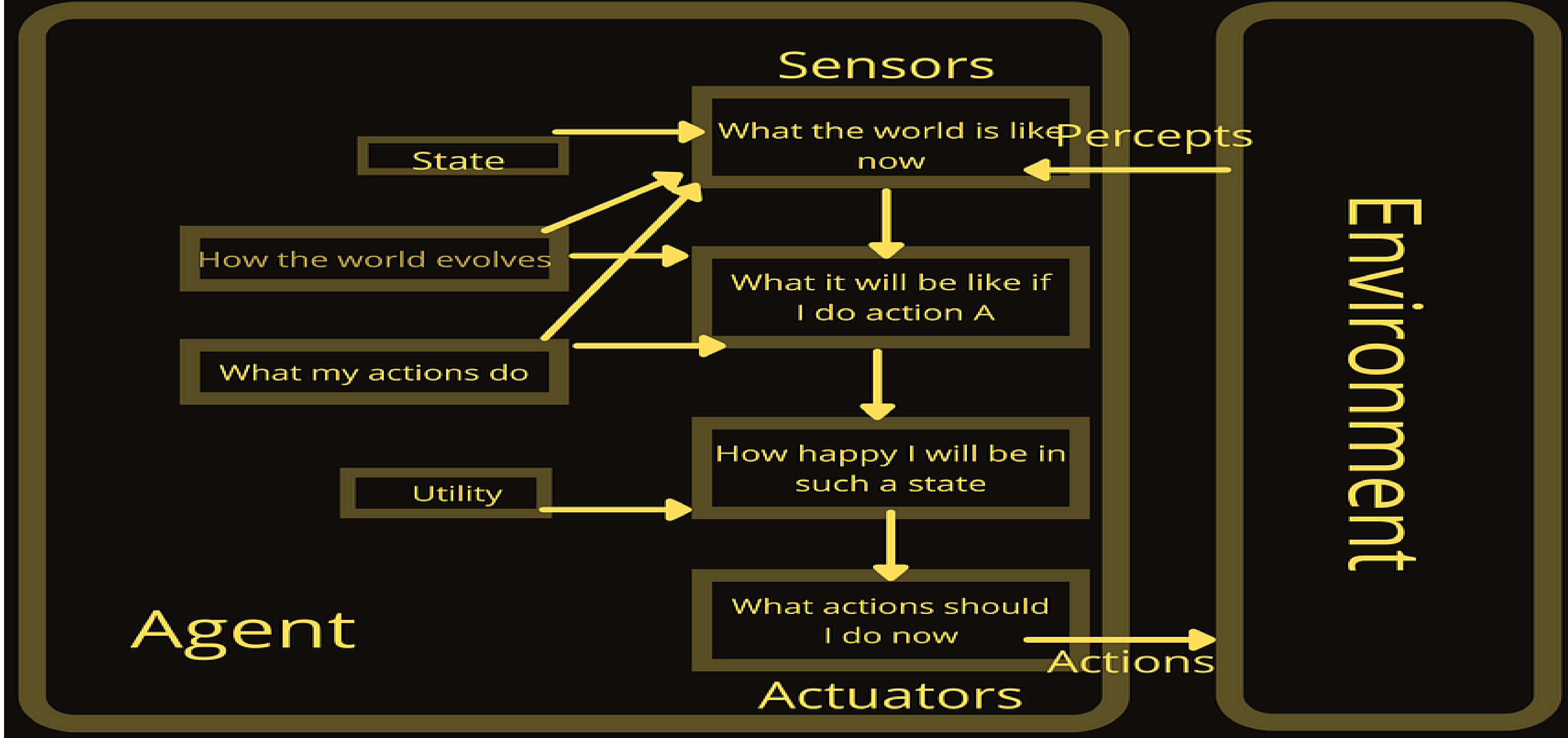


Utility-based agent

- Utility-based agents used the optimal path which lead to their goal. They choose the best path which leads to their goal among multiple paths.
- 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 not only based on 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.

UTILITY-BASED AGENTS

An agent that acts not only what is the goal, but the best way to reach the goal


Sensors
What the world is like now
Percepts
State
How the world evolves
What it will be like if I do action A
What my actions do
How happy I will be in such a state
Utility
What actions should I do now
Actions
Agent
Actuators
Environment

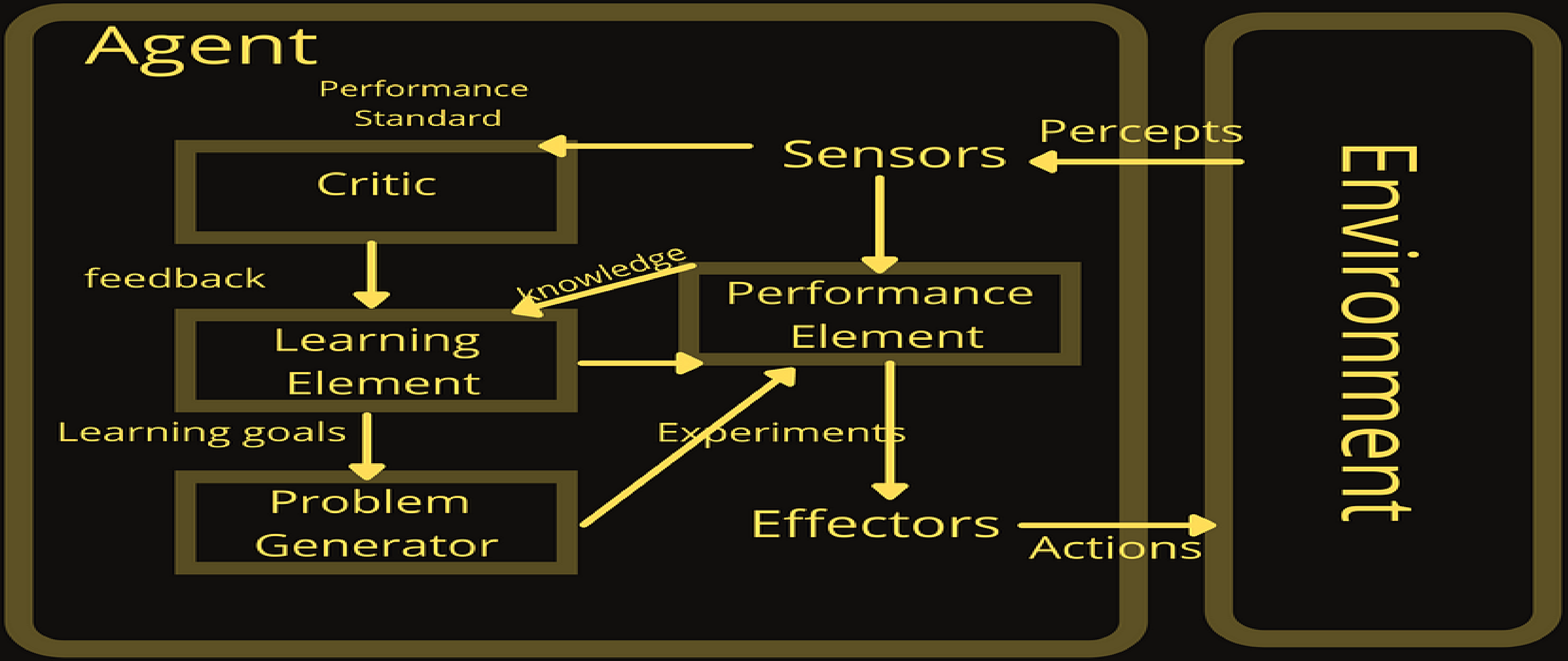
Learning agent

- 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, analyze performance, and look for new ways to improve the performance.

LEARNING AGENTS

A learning agent in AI is a type of agent which can learn from its past experience or it has learning capabilities

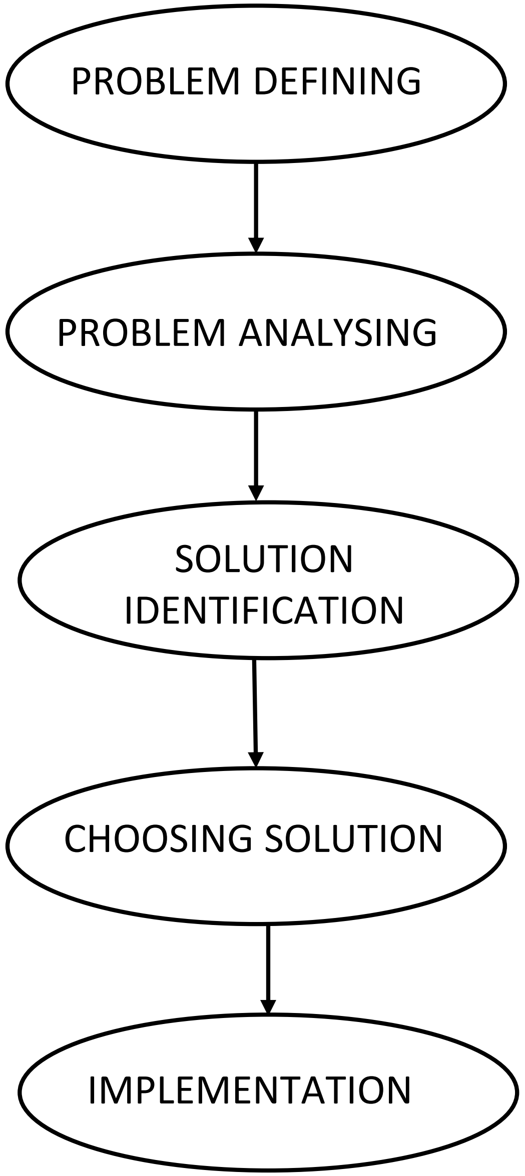


Example : Robotic Vacuum Cleaner

1. **Simple Reflex Agent**: Changes direction upon bumping into a wall.
2. **Model-Based Reflex Agent**: Uses an internal map to navigate the house.
3. **Goal-Based Agent**: Plans its path to clean the entire floor.
4. **Utility-Based Agent**: Balances cleaning efficiency with battery usage.
5. **Learning Agent**: Learns the layout and high-traffic areas over time.

Problem solving in AI

- Problem-solving is commonly known as the method to reach the desired goal or find a solution to a given situation.
- In computer science, problem-solving refers to various techniques such as forming efficient algorithms, heuristics, and performing root cause analysis to find desirable solutions.
- Problem-solving in AI usually refers to researching a solution to a problem by performing logical algorithms, utilizing polynomial and differential equations, and executing them using modeling paradigms.
- There can be various solutions to a single problem, which are achieved by different heuristics.
- Also, some problems have unique solutions. It all rests on the nature of the given problem.

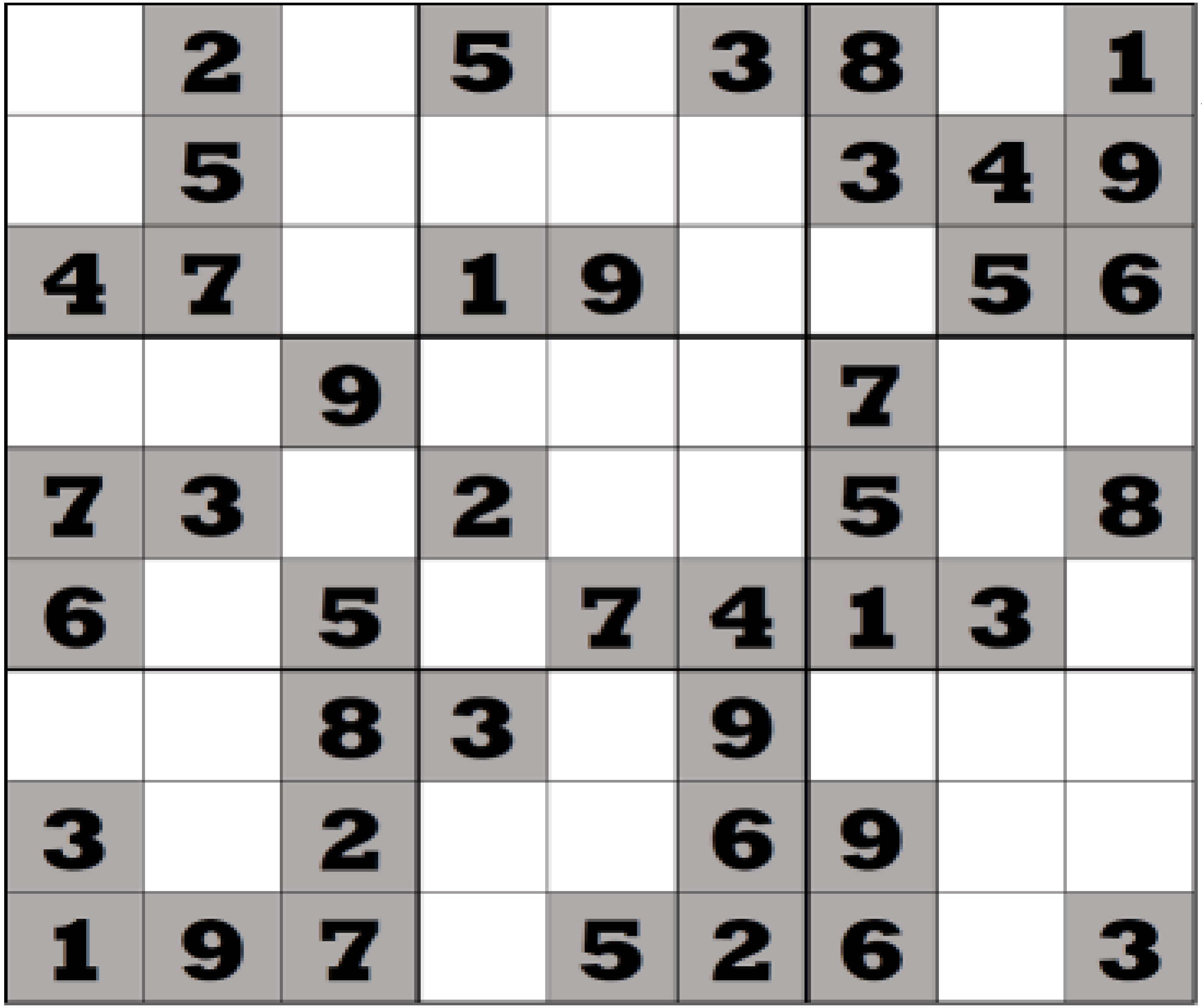


Steps involved to solve the problem

1. **Defining The Problem:** The definition of the problem must be included precisely. It should contain the possible initial as well as final situations which should result in acceptable solution.
2. **Analyzing The Problem:** Analyzing the problem and its requirement must be done as few features can have immense impact on the resulting solution.
3. **Identification Of Solutions:** This phase generates reasonable amount of solutions to the given problem in a particular range.
4. **Choosing a Solution:** From all the identified solutions, the best solution is chosen basis on the results produced by respective solutions.
5. **Implementation:** After choosing the best solution, its implementation is done.

Example for problem solving

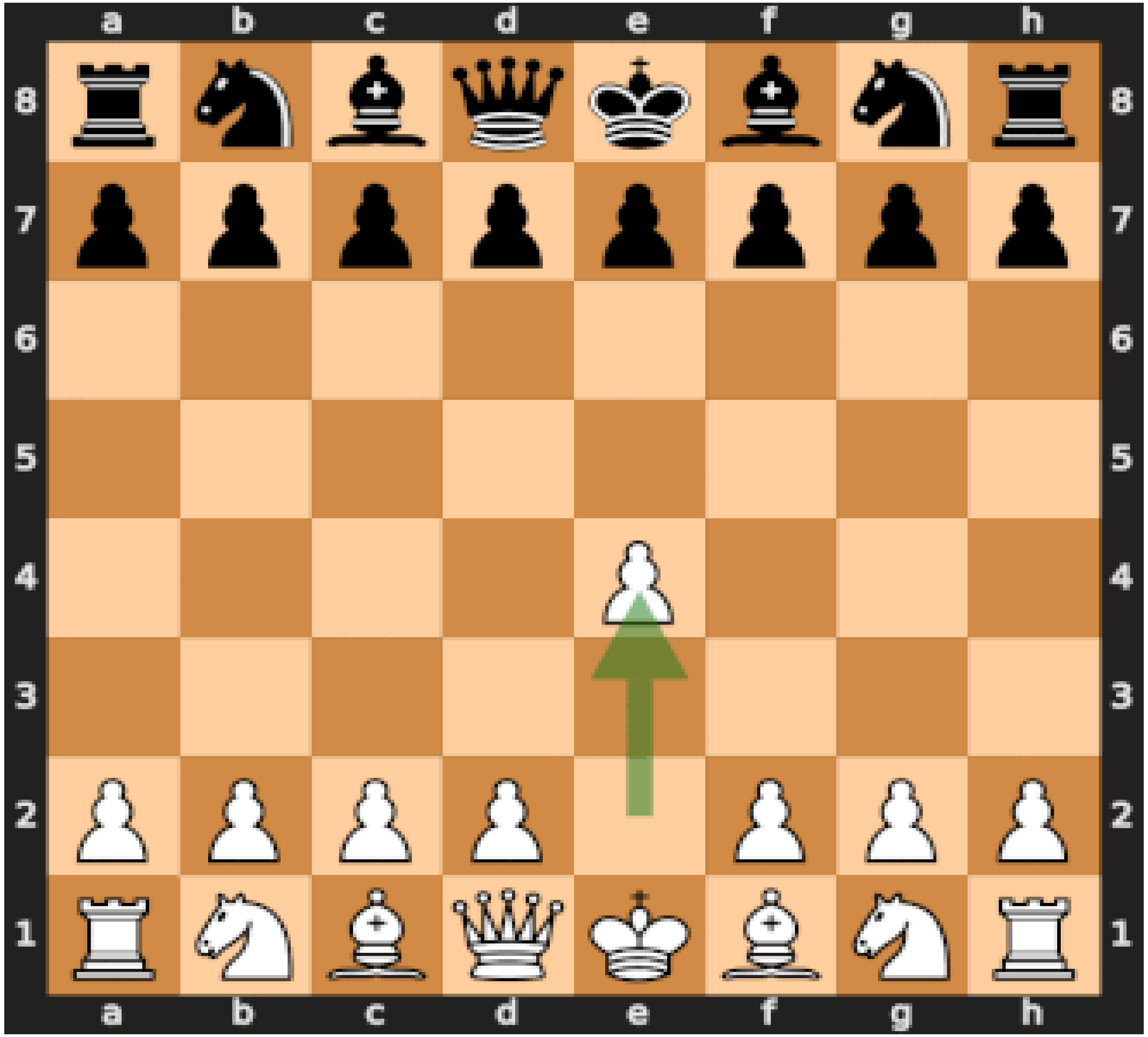
SUDOKU



	2		5		3	8		1
	5					3	4	9
4	7		1	9			5	6
		9				7		
7	3		2			5		8
6		5		7	4	1	3	
		8	3		9			
3		2			6	9		
1	9	7		5	2	6		3

Example for problem solving

CHESS

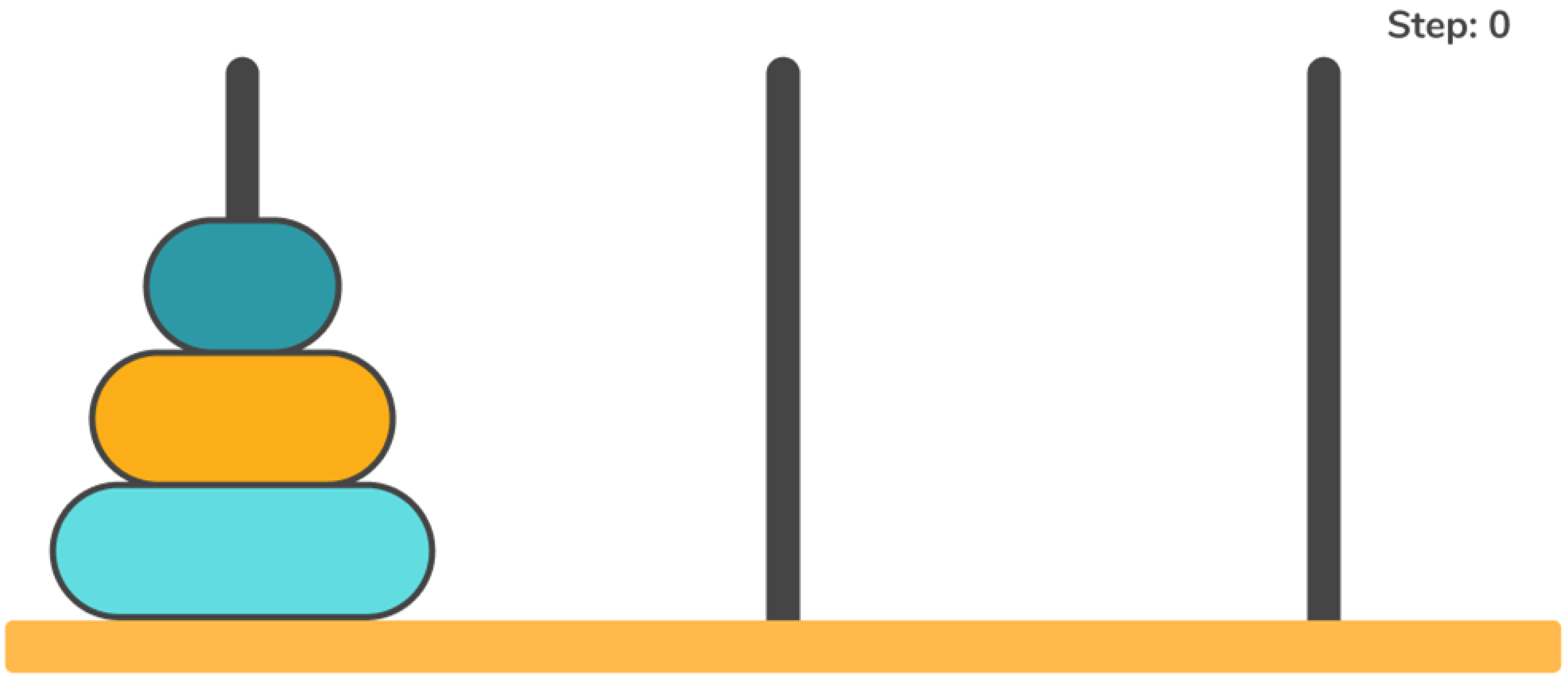


Example for problem solving

N-QUEENS PROBLEM

Example for problem solving

TOWER OF HANOI



Problem solving techniques

Heuristics

- The heuristic method helps comprehend a problem and devises a solution based purely on experiments and trial and error methods.
- However, these heuristics do not often provide the best optimal solution to a specific problem.
- Instead, these undoubtedly offer efficient solutions to attain immediate goals.
- Therefore, the developers utilize these when classic methods do not provide an efficient solution for the problem.
- Since heuristics only provide time-efficient solutions and compromise accuracy, these are combined with optimization algorithms to improve efficiency.

- Ex: Traveling salesman problem

Searching Algorithms

- Searching is one of the primary methods of solving any problem in AI.
- These problem-solving agents are often goal-based.
- Moreover, these searching algorithms possess completeness, optimality, time complexity, and space complexity properties based on the quality of the solution provided by them.
- 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 state: It is a function which observe the current state and returns whether the goal state is achieved or not.

Search tree:

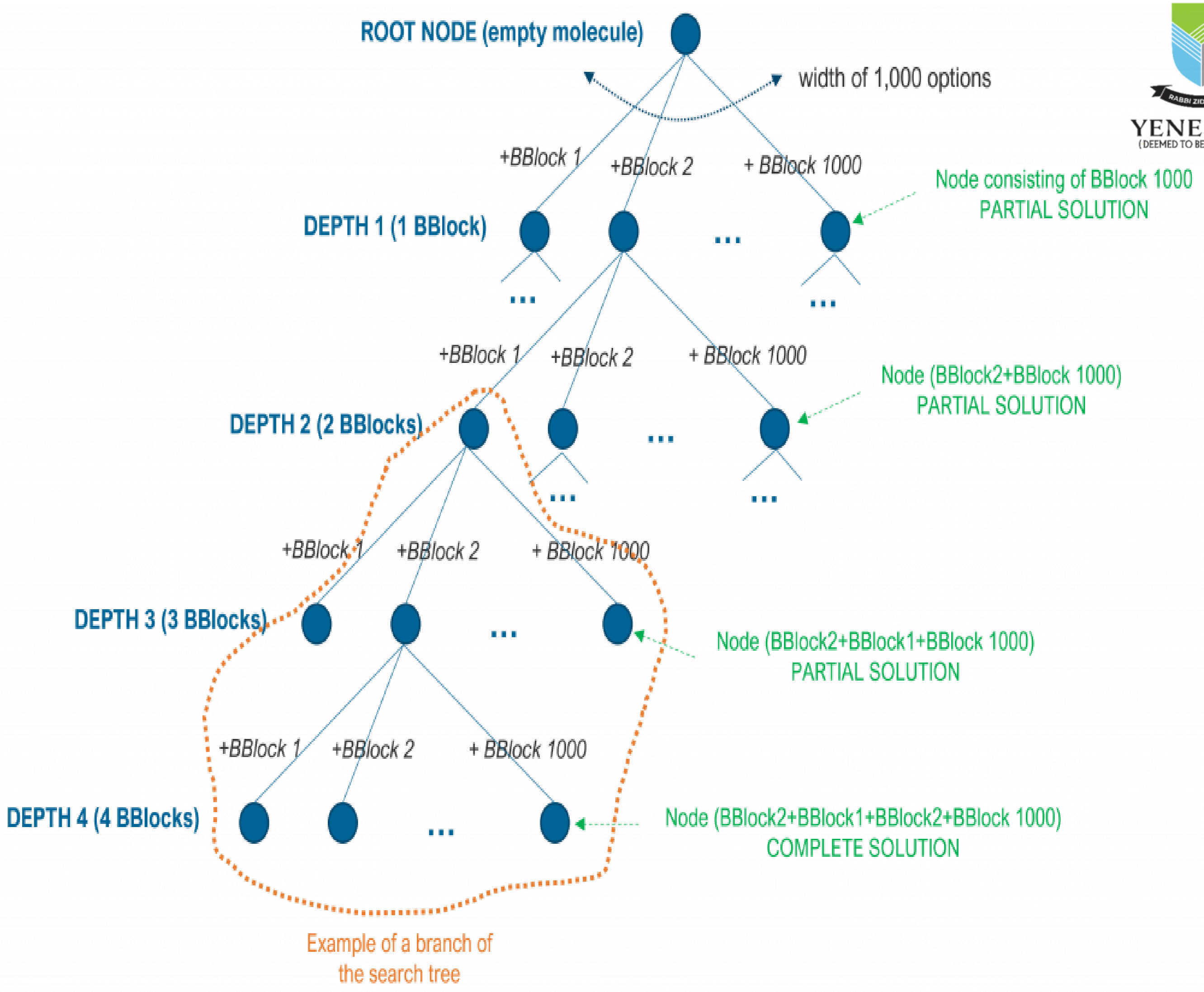
A tree representation of search problem is called Search tree. The root of the search tree is the root node which is corresponding to the initial state.

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.


ROOT NODE (empty molecule)
width of 1,000 options
+BBlock 1
+BBlock 2
+ BBlock 1000
Node consisting of BBlock 1000
PARTIAL SOLUTION
DEPTH 1 (1 BBlock)
...
DEPTH 2 (2 BBlocks)
Node (BBlock2+BBlock 1000)
PARTIAL SOLUTION
DEPTH 3 (3 BBlocks)
Node (BBlock2+BBlock1+BBlock 1000)
PARTIAL SOLUTION
DEPTH 4 (4 BBlocks)
Node (BBlock2+BBlock1+BBlock2+BBlock 1000)
COMPLETE SOLUTION
Example of a branch of the search tree

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

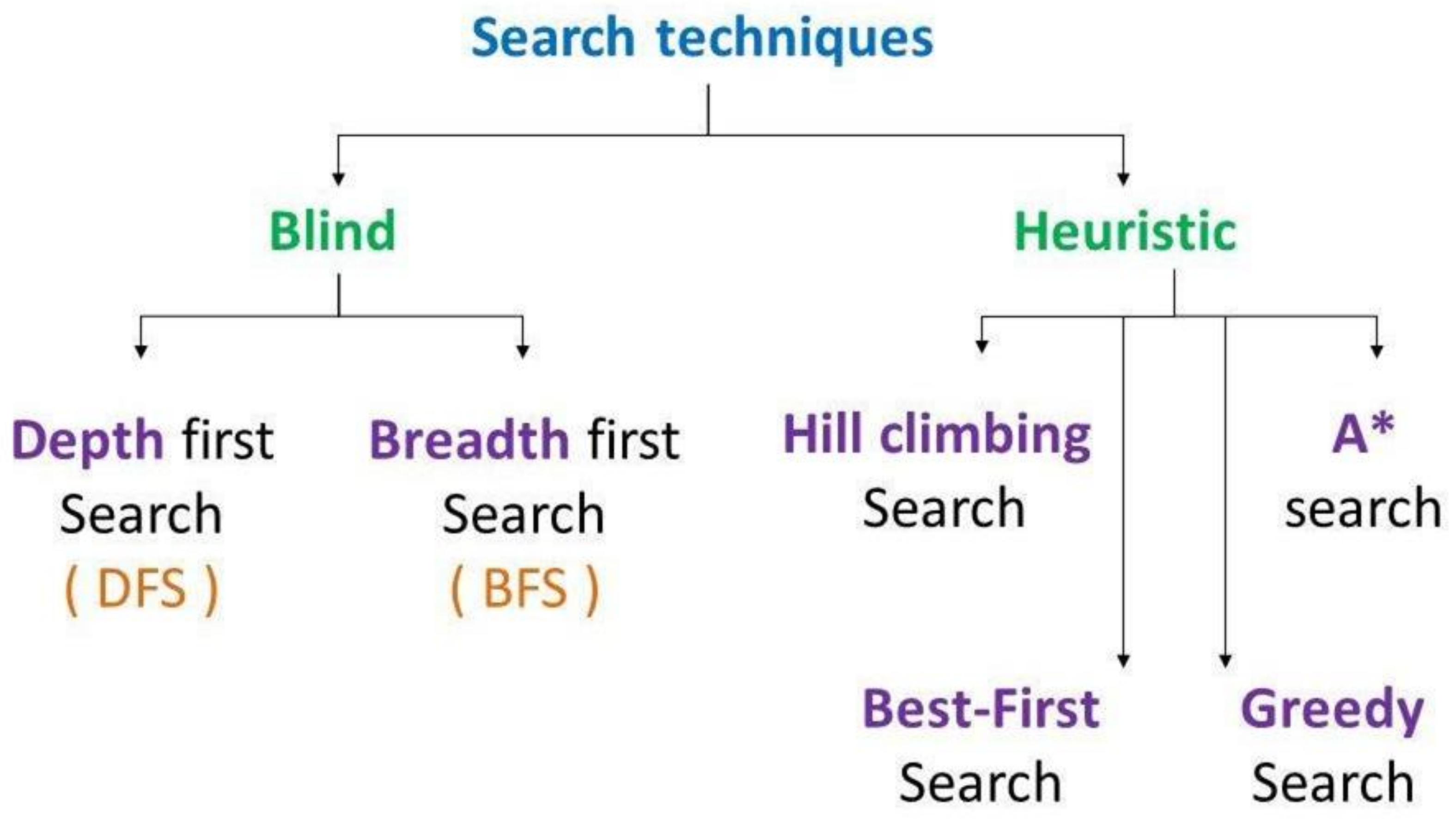
Completeness: A search algorithm is said to be complete if it guarantees to return a solution if at least any solution exists for any random input.

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.

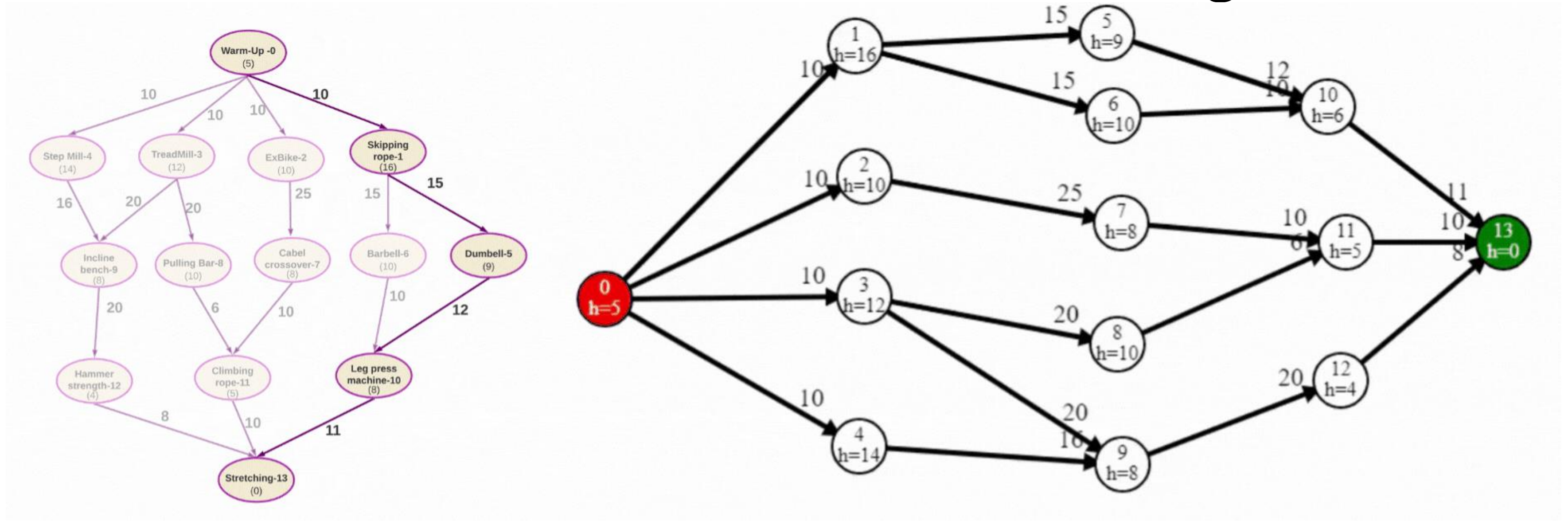
Space Complexity: It is the maximum storage space required at any point during the search, as the complexity of the problem.

- There are following two main types of searching algorithms:
    - Uninformed Search(Blind)
    - Informed Search(Heuristics)



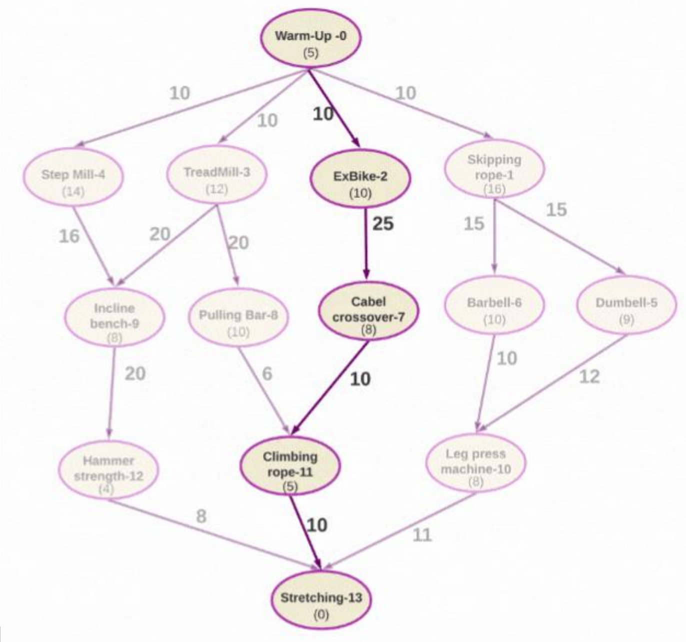
Uninformed/Blind Search

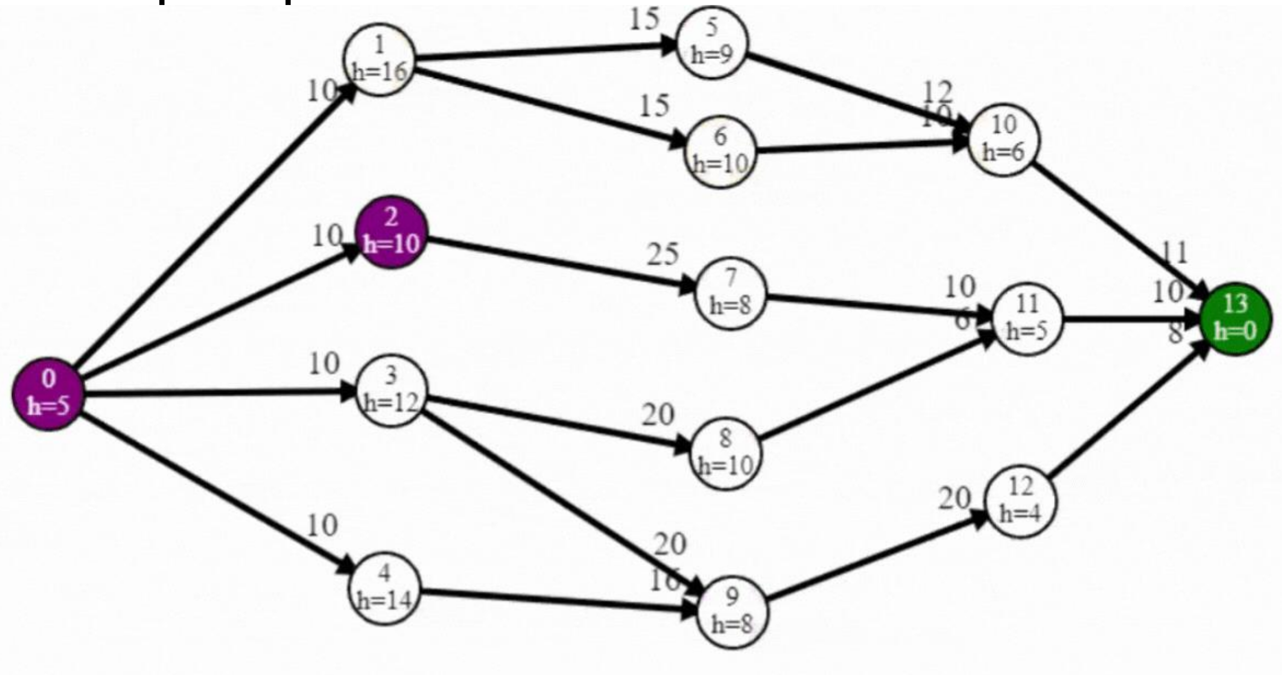
- It is a search algorithm that explores a problem space without any specific knowledge or information about the problem other than the initial state and the possible actions to take.
- It lacks domain-specific heuristics or prior knowledge about the problem.
- Uninformed search applies a way in which search tree is searched without any information, so it is also called **blind search.**
- It examines each node of the tree until it achieves the goal node.



Informed search

- It uses 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**.
- A heuristic is a way which might not always be guaranteed for best solutions but guaranteed to find a good solution in reasonable time.
- Informed search can solve much complex problem which could not be solved in another way.



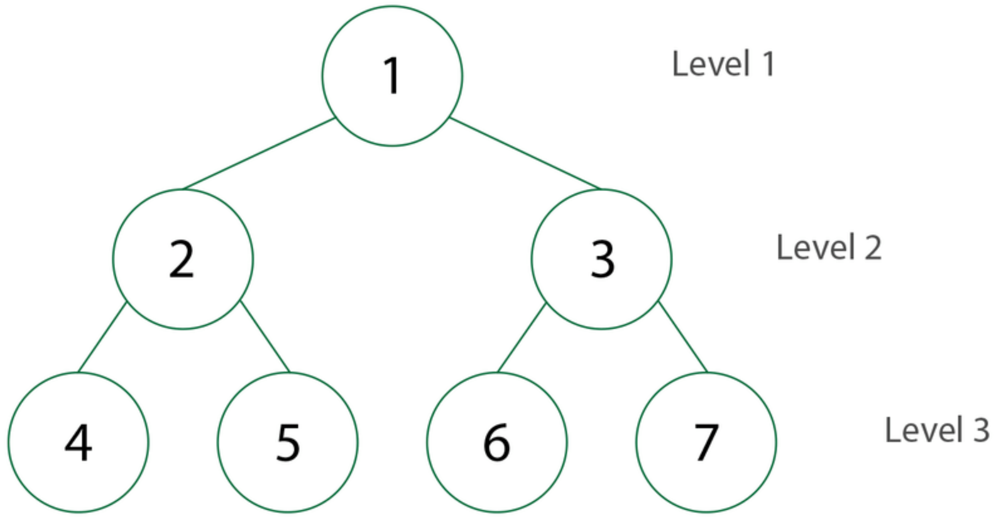


Informed Search	Uninformed Search
It is also known as Heuristic Search.	It is also known as Blind Search.
It uses knowledge for the searching process.	It doesn’t use knowledge for the searching process.
It finds a solution more quickly.	It finds solution slow as compared to an informed search.
It may or may not be complete.	It is always complete.
Cost is low.	Cost is high.
It consumes less time because of quick searching.	It consumes moderate time because of slow searching.
There is a direction given about the solution.	No suggestion is given regarding the solution in it.
It is less lengthy while implemented.	It is more lengthy while implemented.
It is more efficient as efficiency takes into account cost and performance. The incurred cost is less and speed of finding solutions is quick.	It is comparatively less efficient as incurred cost is more and the speed of finding the Breadth-Firstsolution is slow.
Computational requirements are lessened.	Comparatively higher computational requirements.
Having a wide scope in terms of handling large search problems.	Solving a massive search task is challenging.
Ex: Greedy Search, A* Search, AO* Search, Hill Climbing Algorithm	Ex: Depth First Search (DFS), Breadth First Search (BFS), Branch and Bound

Breadth-First Search (BFS)

- BFS is a graph traversal algorithm that systematically explores a graph level by level.
- It starts at a specific node and visits all its immediate neighbors before moving to the next level.
- BFS is widely used in various AI applications, including pathfinding, shortest path problems, and graph analysis.

- A graph is a data structure used to represent relationships between entities.
- It consists of nodes (vertices) representing entities and edges connecting these nodes.
- Imagine a map where cities are nodes and roads are edges.



How BFS Works

1. Start at a specific node (source).
2. Visit all its immediate neighbors (level 1).
3. Visit all neighbors of the level 1 nodes (level 2), and so on.
4. BFS uses a queue data structure to keep track of nodes to be visited.

BFS explores the graph level by level, ensuring all nodes at a specific level are visited before moving to the next.

1. **Initialize:**
   - Create a queue data structure.
   - Mark all nodes as unvisited.
2. **Start at the source node:**
   - Add the source node to the queue.
   - Mark it as visited.
3. **Iterate until the queue is empty:**
   - Dequeue a node from the queue.
   - For each of its unvisited neighbors:
     - Add the neighbor to the queue.
     - Mark it as visited.

General python code:

```
def bfs(graph, start):
   queue = []
   visited = set()
   queue.append(start)
   visited.add(start)
   while queue:
         node = queue.pop(0)
         for neighbor in graph[node]:
            if neighbor not in visited:
              queue.append(neighbor)
              visited.add(neighbor)
```

Initialize: Create an empty queue and a set for visited nodes.
Start: Add the starting node to the queue and mark it as visited.
Loop: While the queue is not empty, repeat the following steps:

- **Dequeue**: Remove a node from the front of the queue.
- **Explore Neighbors**: For each neighboring node of the current node:
  - If the neighbor hasn't been visited yet:
    - Add it to the queue.
    - Mark it as visited.

This process ensures that each node is visited level by level, starting from the given start node.

BFS Traversal:

1.Start at node A:

  i. Add A to the queue.
  ii. Mark A as visited.

2.Visit A's neighbors:

  i. Dequeue A from the queue.
  ii. Visit B, C, and D.
  iii. Mark B, C, and D as visited.
  iv. Add B, C, and D to the queue.

3.Visit B's neighbors:

  i. Dequeue B from the queue.
  ii. Visit E.
  iii. Mark E as visited.
  iv. Add E to the queue.

4.Visit C's neighbors:

  i. Dequeue C from the queue.
  ii. No unvisited neighbors.

5. Visit D's neighbors:

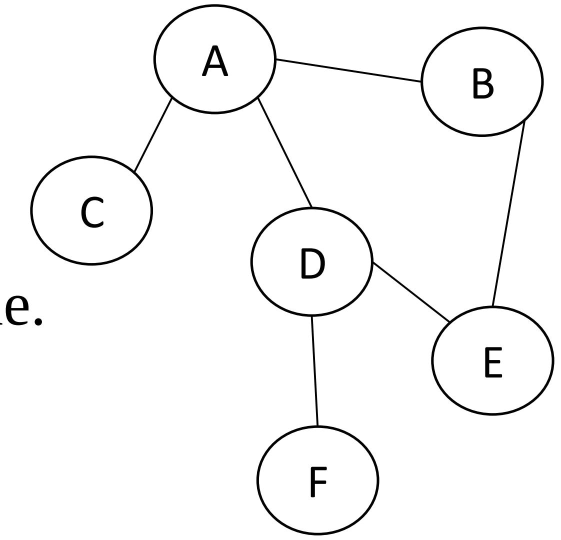
  i. Dequeue D from the queue.
  ii. Visit F.
  iii. Mark F as visited.
  iv. Add F to the queue.

6.Visit E's neighbors:

  i. Dequeue E from the queue.
  ii. No unvisited neighbors.

7.Visit F's neighbors:

  i. Dequeue F from the queue.
  ii. No unvisited neighbors.



BFS Traversal Order: A, B, C, D, E, F

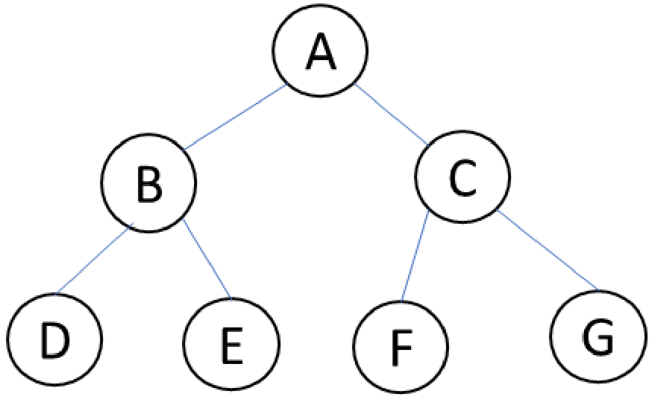
Example program:

```
def bfs(graph, start):
    queue = []
    visited = set()
    queue.append(start)
    visited.add(start)
    while queue:
        node = queue.pop(0)
        print(node, end=' ')
        for neighbor in graph[node]:
            if neighbor not in visited:
                queue.append(neighbor)
                visited.add(neighbor)
```

```
graph = {
    'A': ['B', 'C'],
    'B': ['D', 'E'],
    'C': ['F', 'G'],
    'D': [],
    'E': [],
    'F': [],
    'G': []
}

start_node = 'A'

print("BFS traversal starting from node 'A':", end=' ')
bfs(graph, start_node)
```



Output:
BFS traversal starting from node 'A': A B C D E F G

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

$T(b) = 1+b^2+b^3+.......+ b^d= O(b^d)$ indicates the number of nodes that BFS explores until it finds the shallowest solution, where d is the depth at which this first solution is located. Essentially, BFS explores all nodes level by level, starting from the root, until it reaches the first solution, making d the depth of the most immediate solution.

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

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

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

Applications of BFS

- Pathfinding: Finding the shortest path between two points in a map or game.
- Shortest Path Problems: Identifying the most efficient route in various scenarios.
- Network Routing: Optimizing data flow in communication networks.
- Graph Search and Analysis: Exploring and analyzing social networks and other complex structures.

Examples:

- A robot navigating a maze uses BFS to find the shortest path to the exit.
- A social network platform can use BFS to recommend friends to users based on their connections.

Advantages:

- Guaranteed to find the shortest path (in terms of edges) if one exists.
- Easy to understand and implement.

Limitations:

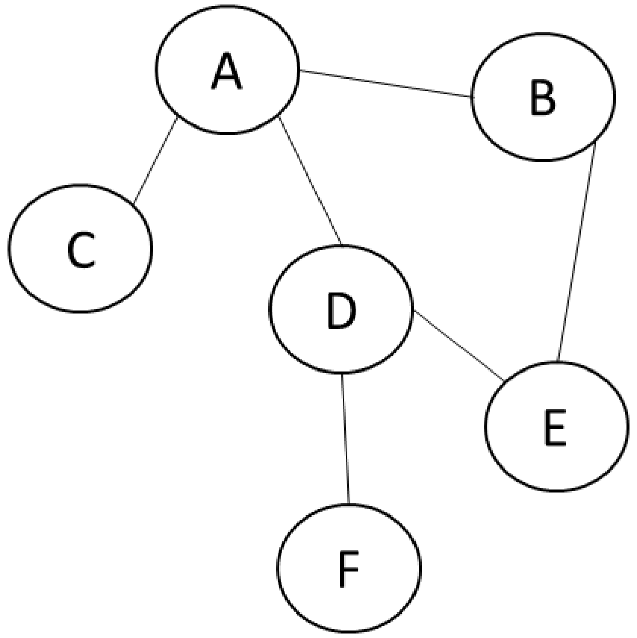
- May not be the most efficient for deep searches (e.g., finding the deepest node in a graph).
- Can be memory-intensive for large graphs.

Do it yourself:

Perform the breadth first traversal for the following graphs.

- Write the python code for BFS for the graph provided.
- Write the step by step traversal.

1)



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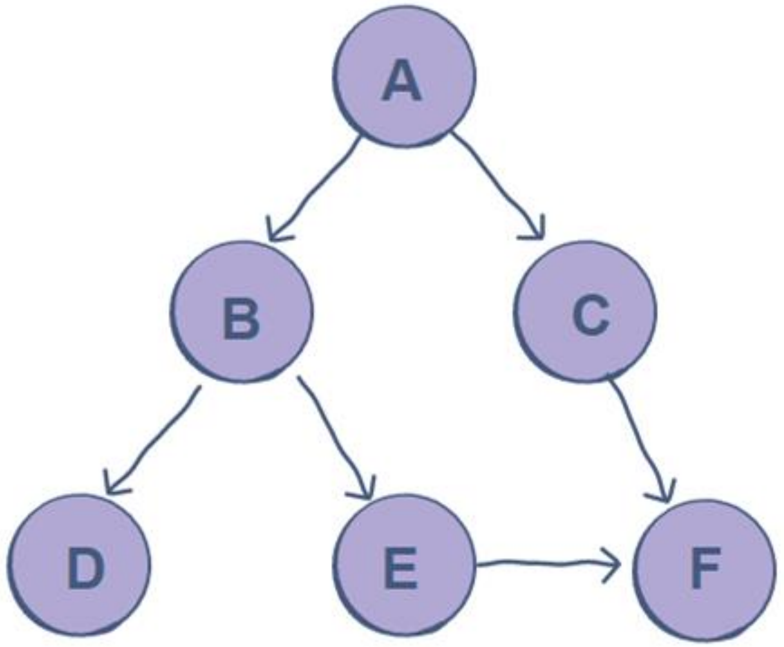
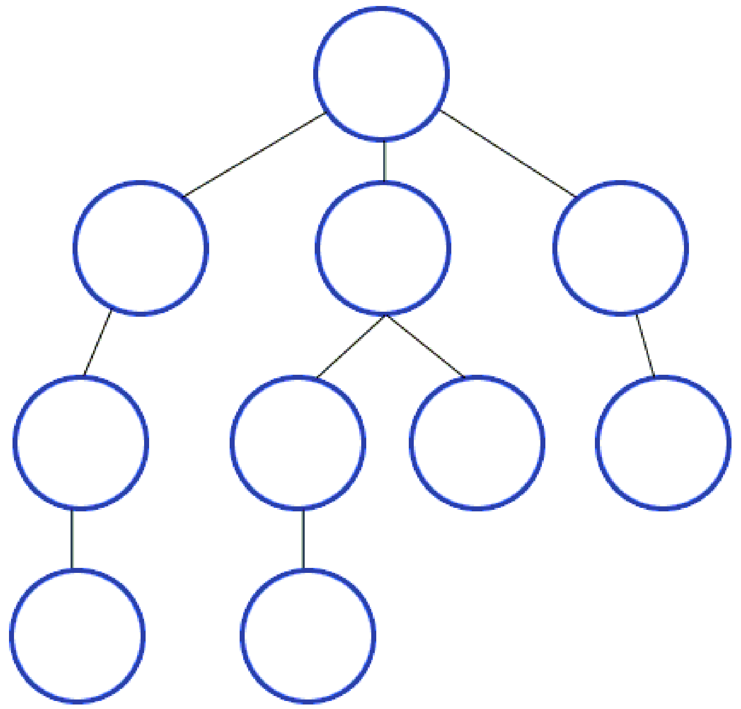


Depth-First Search (DFS)

- 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 stack data structure for its implementation.
- The process of the DFS algorithm is similar to the BFS algorithm.

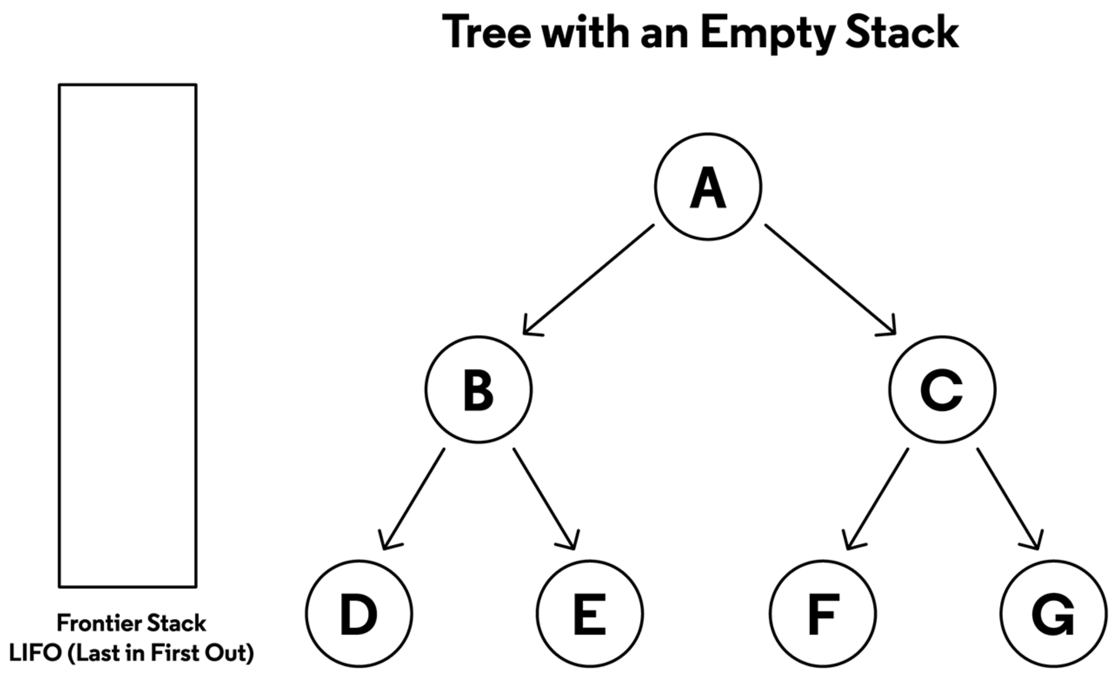


The step by step process to implement the DFS traversal is given as follows -

1. First, create a stack with the total number of vertices in the graph.
2. Now, choose any vertex as the starting point of traversal, and push that vertex into the stack.
3. After that, push a non-visited vertex (adjacent to the vertex on the top of the stack) to the top of the stack.
4. Now, repeat steps 3 and 4 until no vertices are left to visit from the vertex on the stack's top.
5. If no vertex is left, go back and pop a vertex from the stack.
6. Repeat steps 2, 3, and 4 until the stack is empty.

General python code:

```
def dfs(graph, start):
    stack = []
    visited = set()
    stack.append(start)
    while stack:
        node = stack.pop()
        if node not in visited:
            print(node, end=" ")
            visited.add(node)
            for neighbor in reversed(graph[node]):
                if neighbor not in visited:
                    stack.append(neighbor)
```



DFS Traversal:

Start at node A:

Add A to the stack.

Visit A:

Pop A from the stack.

Mark A as visited.

Visit A's neighbors in reversed order (to maintain typical DFS order):

Add D, C, B to the stack.

Visit B:

Pop B from the stack.

Mark B as visited.

Visit B's neighbors:

Add E to the stack.

Visit E:

Pop E from the stack.

Mark E as visited.

No unvisited neighbors.

Visit C:

Pop C from the stack.

Mark C as visited.

No unvisited neighbors.

Visit D:

Pop D from the stack.

Mark D as visited.

Visit D's neighbors:

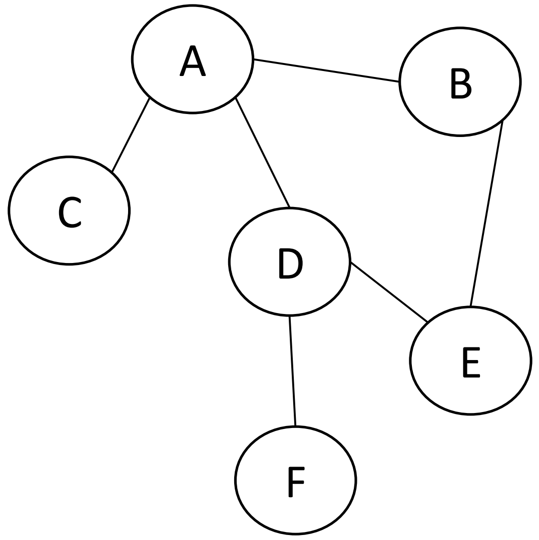
Add F to the stack.

Visit F:

Pop F from the stack.

Mark F as visited.

No unvisited neighbors.



DFS Traversal Order: A, B, E, C, D, F

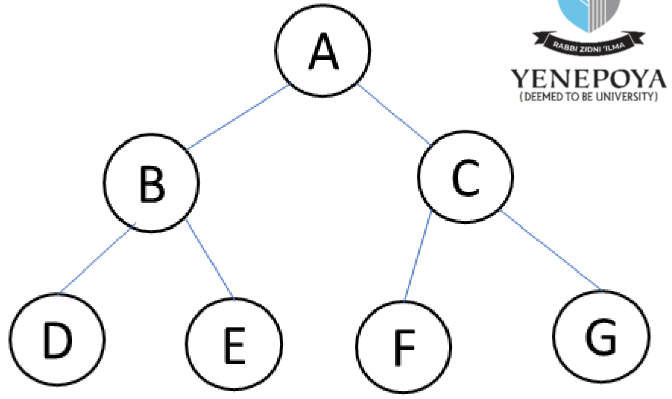
Example program:

```
def dfs(graph, start):
    stack = []
    visited = set()
    stack.append(start)
    while stack:
        node = stack.pop()
        if node not in visited:
            print(node, end=' ')
            visited.add(node)
            for neighbor in reversed(graph[node]):
                if neighbor not in visited:
                    stack.append(neighbor)
```

```
graph = {
    'A': ['B', 'C'],
    'B': ['D', 'E'],
    'C': ['F', 'G'],
    'D': [],
    'E': [],
    'F': [],
    'G': []
}

start_node = 'A'

print("DFS traversal starting from node 'A':", end=' ')
dfs(graph, start_node)
```



Output:
DFS traversal starting from node 'A': A B D E C F G

- **Completeness:** DFS search algorithm is complete within finite state space as it will expand every node within a limited search tree.
- **Time Complexity:** Time complexity of DFS will be equivalent to the node traversed by the algorithm. It is given by:

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

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

- **Space Complexity:** DFS algorithm needs to store only single path from the root node, hence space complexity of DFS is equivalent to the size of the fringe set, which is **O(bm)**.
- **Optimal:** DFS search algorithm is non-optimal, as it may generate a large number of steps or high cost to reach to the goal node.

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:

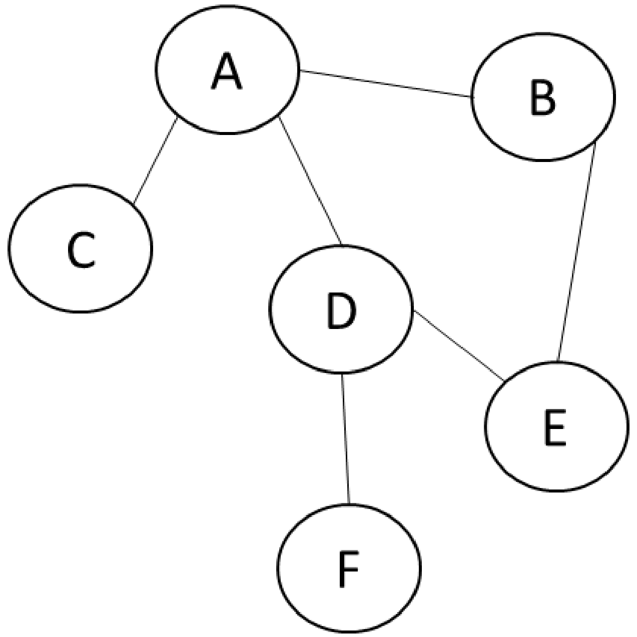
- There is the possibility that many states keep re-occurring, and there is no guarantee of finding the solution.
- DFS algorithm goes for deep down searching and sometime it may go to the infinite loop.

Do it yourself:

Perform the depth first traversal for the following graphs.

- Write the python code for DFS for the graph provided.
- Write the step by step traversal.

1)



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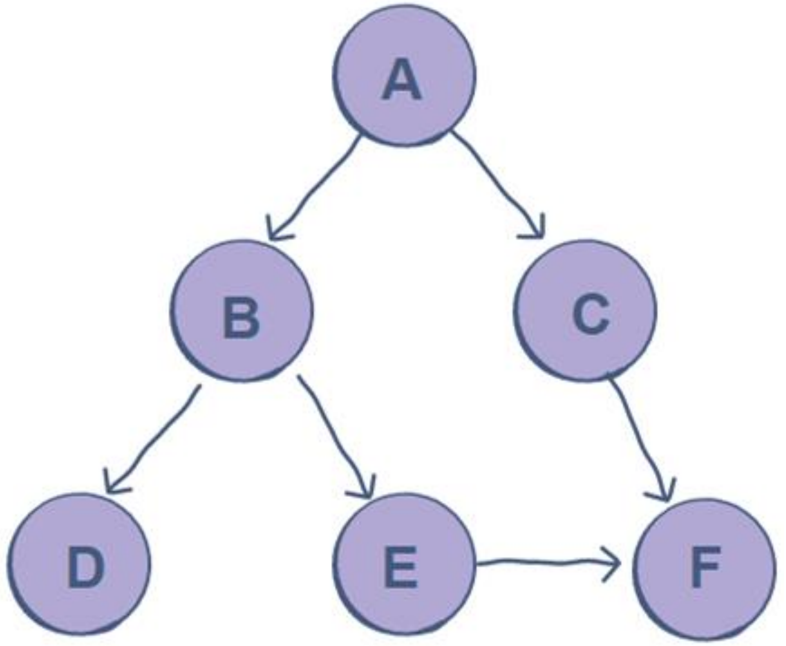
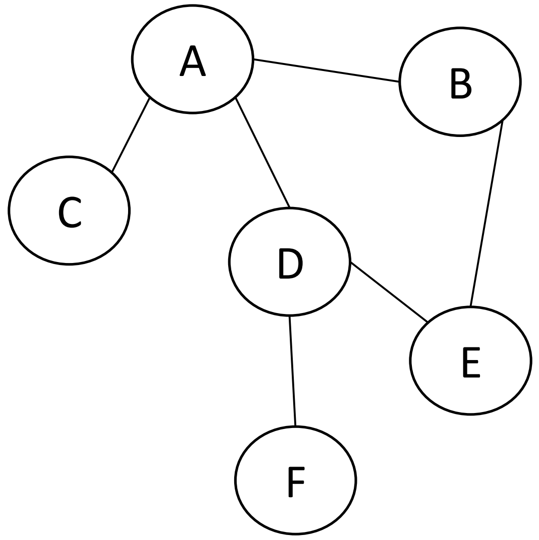


```
#Program to find bfs and dfs
from collections import deque
def bfs(graph, start):
    queue = deque([start])
    visited = set([start])
    while queue:
        node = queue.popleft()
        print(node, end=" ")
        for neighbor in graph[node]:
            if neighbor not in visited:
                queue.append(neighbor)
                visited.add(neighbor)
def dfs(graph, start):
    visited = set()
    def dfs_recursive(node):
        visited.add(node)
        print(node, end=" ")
        for neighbor in graph[node]:
            if neighbor not in visited:
                dfs_recursive(neighbor)
    dfs_recursive(start)
```

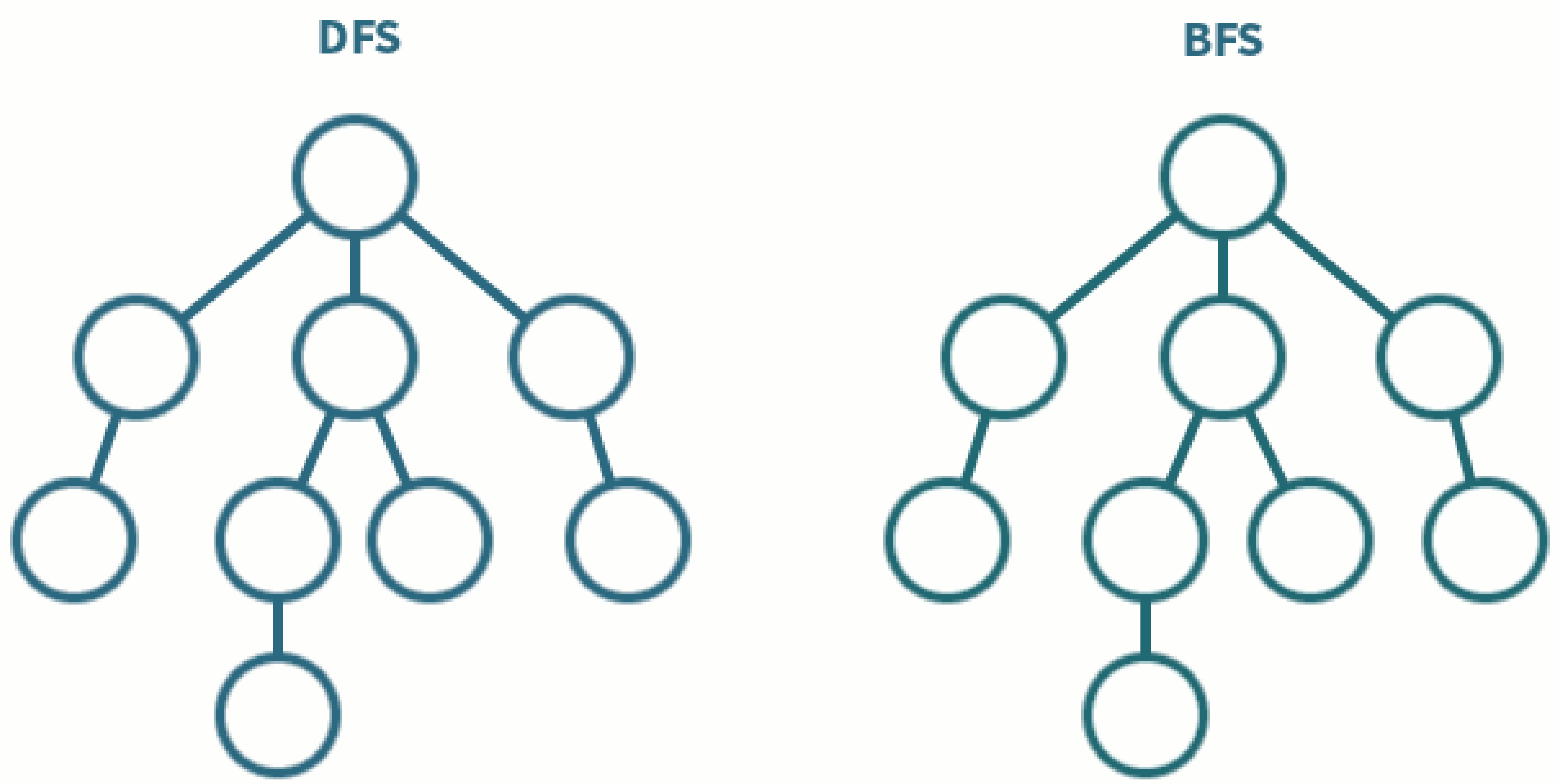
```
graph = {
    'A': ['B', 'C', 'D'],
    'B': ['E'],
    'C': [],
    'D': ['E', 'F'],
    'E': [],
    'F': []
}

print("BFS traversal:")
bfs(graph, 'A')
print("\nDFS traversal:")
dfs(graph, 'A')
```



Output:

```
BFS traversal:
A B C D E F
DFS traversal:
A B E C D F
```

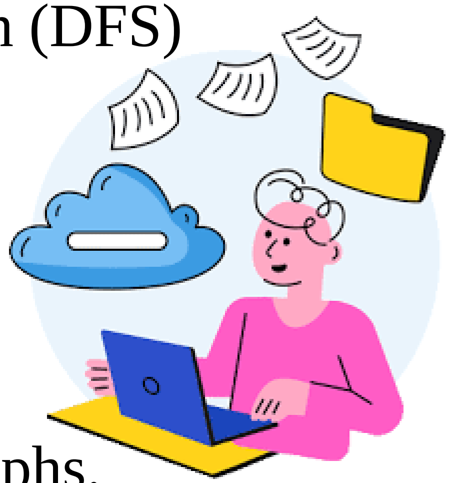

DFS
BFS

BFS	DFS
BFS stands for Breadth First Search.	DFS stands for Depth First Search.
BFS uses a Queue to find the shortest path.	DFS uses a Stack to find the shortest path.
BFS is better when target is closer to Source.	DFS is better when target is far from source.
As BFS considers all neighbor so it is not suitable for decision tree used in puzzle games.	DFS is more suitable for decision tree. As with one decision, we need to traverse further to augment the decision. If we reach the conclusion, we won.
BFS is slower than DFS.	DFS is faster than BFS.
Time Complexity of BFS = O(V+E) where V is vertices and E is edges.	Time Complexity of DFS is also O(V+E) where V is vertices and E is edges.
BFS requires more memory space.	DFS requires less memory space.
In BFS, there is no problem of trapping into finite loops.	In DFS, we may be trapped into infinite loops.
BFS is implemented using FIFO (First In First Out) principle.	DFS is implemented using LIFO (Last In First Out) principle.

Activity 03

Objective:
Demonstrate understanding of Breadth-First Search (BFS) and Depth-First Search (DFS) algorithms in graph traversal.

Tasks:
Create a graph with 6 nodes and 8 edges.
Implement BFS and DFS algorithms to traverse the graph from a specified node.
Compare BFS and DFS in terms of traversal order and suitability for different graphs.
Explain real-world applications of BFS and DFS.



Submission:
Code for BFS and DFS implementations, traversal order, comparison analysis, and application.

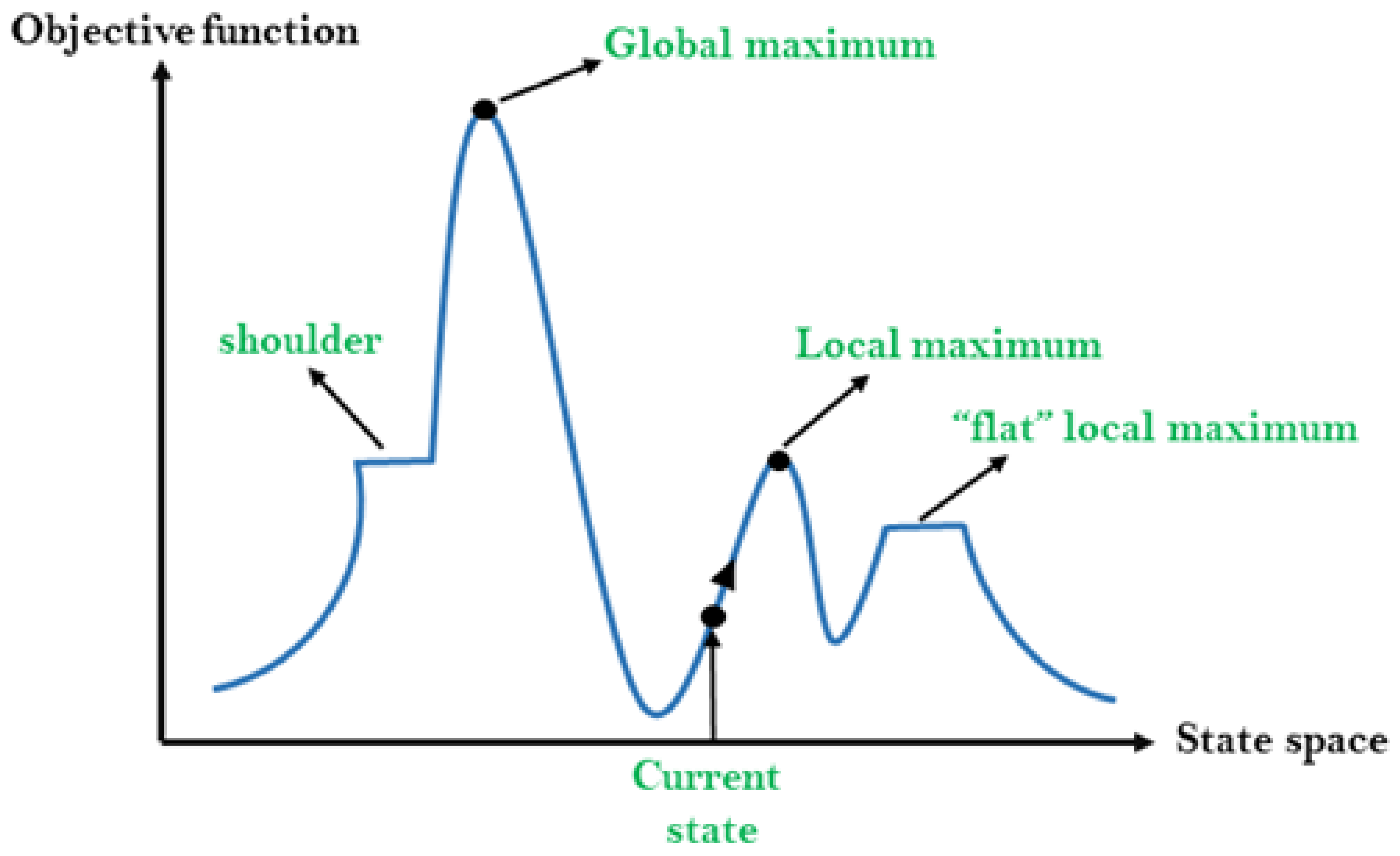
Informed/ Heuristic search..

Click here

Hill climbing Search

- Hill climbing algorithm is a local search algorithm which continuously moves in the direction of increasing elevation/value to find the peak of the mountain or best solution to the problem. It terminates when it reaches a peak value where no neighbor has a higher value.
- It is also called greedy local search as it only looks to its good immediate neighbor state and not beyond that.
- Greedy Algorithm involves making the locally optimal choice at each step.
- Local Search focuses on exploring the neighborhood of the current solution to find better solutions.
- A node of hill climbing algorithm has two components which are state and value.
- The state represents a specific configuration or condition of the solution at a given point in the search space.
- The value is a measure of the quality or fitness of the current state.
- Hill Climbing is the variant of Generate and Test method. The Generate and Test method produce feedback which helps to decide which direction to move in the search space.
- It does not backtrack the search space, as it does not remember the previous states.

State-space Diagram for Hill Climbing:



Local Maximum: Local maximum is a state which is better than its neighbor states, but there is also another state which is higher than it.
Global Maximum: Global maximum is the best possible state of state space landscape. It has the highest value of objective function.
Current state: It is a state in a landscape diagram where an agent is currently present.
Flat local maximum: It is a flat space in the landscape where all the neighbor states of current states have the same value.
Shoulder: It is a plateau region which has an uphill edge.

Problem: Find the highest point on the curve y = x^2, where x is a real number and max value for y is 16.

1. **Start at a Point:** Let's start at x = 2. So, our initial solution is x = 2.
2. **Look Around:** At x = 2, we calculate the curve's value: y = 2^2 = 4. Now, we check nearby points: x = 1 and x = 3. Calculating their values, we get y = 1^2 = 1 and y = 3^2 = 9. Since 9 is the highest, we move in the direction of x = 3.
3. **Take a Step:** We move to x = 3 and calculate y = 3^2 = 9.
4. **Repeat:** Now, at x = 3, we check the nearby points again: x = 2 and x = 4. The values are y = 4 and y = 4^2 = 16. We see that y = 16 is higher, so we move to x = 4.
5. **Stop:** At x = 4, we calculate y = 4^2 = 16. Now, when we check nearby points (x = 3 and x = 5), both give y = 9 and y = 25, respectively. Neither of these points is higher than the current point (x = 4, y = 16).

Types of Hill Climbing Algorithm:

- Simple hill Climbing
- Steepest-Ascent hill-climbing
- Stochastic hill Climbing

Simple Hill Climbing

Step 1: Evaluate the initial state, if it is goal state then return success and Stop.

Step 2: Loop Until a solution is found or there is no new operator left to apply.

Step 3: Select and apply an operator to the current state.

Step 4: Check new state:

- If it is goal state, then return success and quit.
- Else if it is better than the current state then assign new state as a current state.
- Else if not better than the current state, then return to step2.

Step 5: Exit.

Steepest-Ascent hill-climbing

It first examines all the neighboring nodes and then selects the node closest to the solution state as of the next node.

Step 1: Evaluate the initial state, if it is goal state then return success and stop, else make current state as initial state.
Step 2: Loop until a solution is found or the current state does not change.

- Let SUCC be a state such that any successor of the current state will be better than it.
- For each operator that applies to the current state:
    - Apply the new operator and generate a new state.
    - Evaluate the new state.
    - If it is goal state, then return it and quit, else compare it to the SUCC.
    - If it is better than SUCC, then set new state as SUCC.
    - If the SUCC is better than the current state, then set current state to SUCC.

- **Step 5:** Exit.

- **Simple Hill Climbing**: Here, at each iteration, the algorithm generates a single neighboring solution and moves to it if it's better than the current solution. It doesn't necessarily choose the best neighboring solution; it just takes the first one that leads to improvement.

- **Steepest Ascent Hill Climbing**: Steepest ascent hill climbing takes a more cautious approach. It examines all the neighboring solutions and selects the one that has the steepest increase in the objective function value. It's more systematic in evaluating potential improvements.

Stochastic hill climbing:

- Stochastic hill climbing does not examine for all its neighbor before moving.
- Rather, this search algorithm selects one neighbor node at random and decides whether to choose it as a current state or examine another state.

1. **Initialization:** Start from an initial point in the search space.
2. **Evaluation:** Evaluate the current solution by calculating the value of the objective function.
3. **Neighbour Generation:** Generate neighbouring solutions by making small modifications to the current solution.
4. **Selection with Probability:** Instead of always selecting the best neighbouring solution, Stochastic Hill Climbing accepts the new solution with a certain probability. The probability of accepting a worse solution is determined by a parameter (often called the "temperature") that decreases over time.

5.Comparison: Compare the objective function values of the current solution and the selected neighboring solution.

6.Update: If the selected neighboring solution is better, always move to that solution. If it's worse, decide whether to accept it based on the probability determined by the temperature.

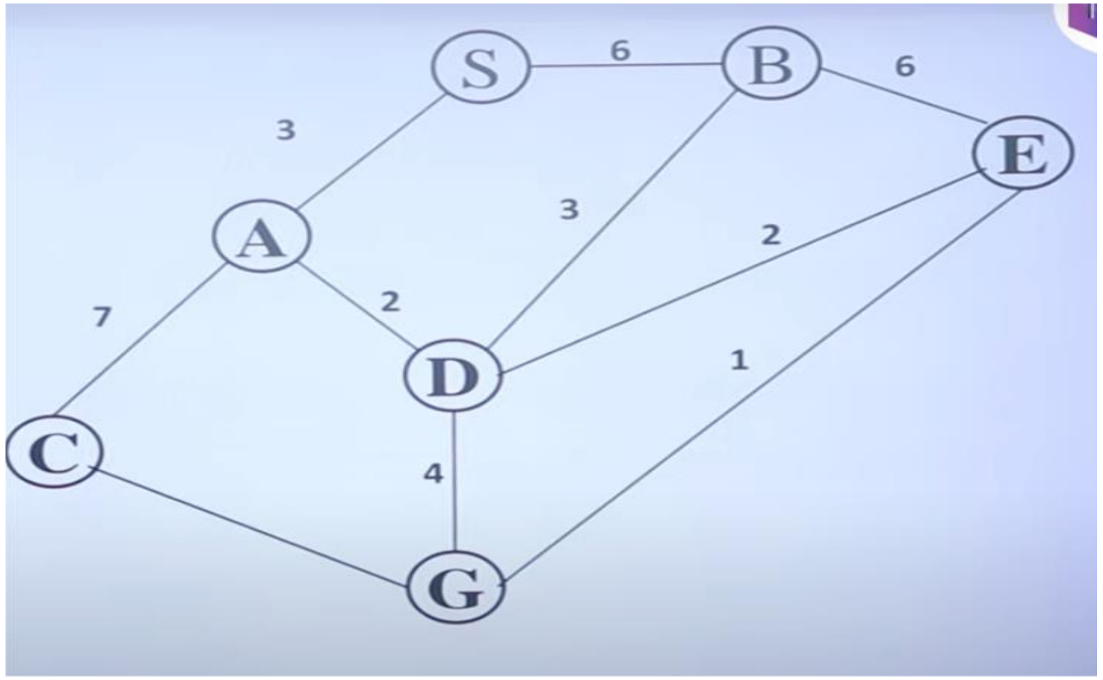
7.Temperature Update: Decrease the temperature according to a predefined schedule. This reduces the probability of accepting worse solutions over time, making the algorithm more focused on exploiting better solutions as it progresses.

8.Termination: The algorithm terminates based on a predefined stopping criterion, such as reaching a certain number of iterations or when the temperature becomes very low.

Branch and Bound

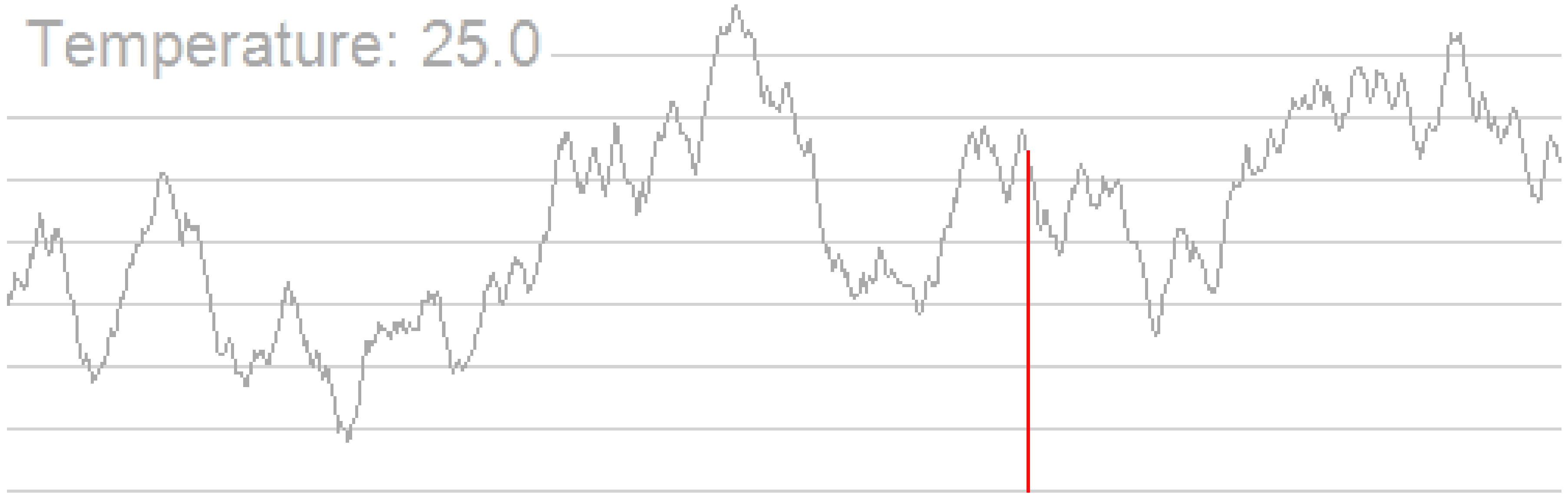
- Branch and Bound is an algorithmic technique which finds the optimal solution by keeping the best solution found so far.
- Branching is the processes of generating sub problems
- Bounding refer to ignoring solution that can not be better than current best solution
- It eliminates those parts of a search space which does not contain better solution
- Branch and Bound search is a way to combine space saving of depth first search with heuristic info.
- Idea in Branch and Bound search is to maintain lowest cost path to a goal found so far and its cost.

Step 1: Traverse the root node.
Step 2: Traverse any neighbor of the root node that is maintaining least distance from the root node.
Step 3: This process will continue until we are getting the goal node.



Activity 04

Explain how the Hill Climbing algorithm works and explain its limitations in finding the optimal solution in optimization problems. Provide a real-world example to illustrate the algorithm's application and challenges.



A* search algorithm

- A* search algorithm finds the shortest path through the search space using the heuristic function.
- It uses h(n) i.e. search heuristic and g(n) i.e. cost to reach the node n from the start state. Hence we combine both costs as,

  $f(n)= g(n) + h(n)$ where f(n) is the estimated cost of the cheapest solution.
- This algorithm expands less search tree and provides optimal result faster.
- This algorithm is complete if the branching factor is finite and every action has fixed cost.
- A* requires heuristic function to evaluate the cost of path that passes through the particular state.

- **Graph Search:** Operates on nodes and edges with associated costs.
- **Heuristic Function (h(n)):** Estimates the cost to reach the goal from node n.
- **Cost Function (g(n)):** Represents the actual cost from the start node to node n.
- **Evaluation Function (f(n)):** Combines g(n) and h(n) as f(n) = g(n) + h(n).

Algorithm Steps

1. Initialize the open list with the start node.
2. Initialize the closed list as empty.
3. Repeat until the open list is empty:
    - Select the node n with the lowest f(n) from the open list.
    - If n is the goal, reconstruct the path and return it.
    - Move n from the open list to the closed list.
    - For each neighbor of n:
        - If the neighbor is in the closed list, skip it.
        - If the neighbor is not in the open list or has a lower f(n), update its g(n) and f(n) and add it to the open list.

Advantages

- Guaranteed to find the shortest path if the heuristic is admissible. It is complete and optimal.
- It is used to solve very complex problems.
- Efficient in both time and space for many practical problems.

Limitations

- Performance depends heavily on the quality of the heuristic.
- Can be computationally expensive for large graphs with many nodes.
- This algorithm is complete if the branching factor is finite and every action has fixed cost.
- The speed execution of A* search is highly dependant on the accuracy of the heuristic algorithm that is used to compute h(n).
- It has complexity problems.

AO* search algorithm

- AO* (AND-OR) search is a best-first search algorithm for solving problems with AND-OR graphs.
- Used for finding the optimal solution by exploring AND-OR graphs which include multiple possible paths and subproblem.
- Often used in decision-making, planning, and problem-solving.
- Nodes:
  - OR Nodes: Represents a choice between multiple alternatives.
  - AND Nodes: Represents a set of subproblems that need to be solved collectively.
  - Edges: Connect nodes and represent the relationship between decisions and subproblems.

Components of AO* Search

- **Open List:** Nodes that are generated but not yet expanded.
- **Closed List:** Nodes that have already been expanded.
- **Heuristic Function (h):** Estimates the cost from the current node to the goal.
- **Cost Function (g):** Actual cost from the start node to the current node.
- **Evaluation Function (f):** Combines g and h to guide the search (f = g + h).

Steps of AO* Search

- **Initialization:** Add the start node to the open list.
- **Selection:** Select the most promising node (lowest f value) from the open list.
- **Expansion:** Expand the selected node by generating its successors.
- **Evaluation:** Compute the cost for each successor and update the parent node's cost.
- **Backtracking:** If an AND node's successors are all solved, mark it as solved and update its parent.
- **Repetition:** Repeat the process until the goal is reached or no more nodes can be expanded.

Advantages:

- Efficient in solving AND-OR graphs.
- Finds the optimal solution if the heuristic is admissible.
- Can handle complex decision trees and problem-solving scenarios.

Disadvantages:

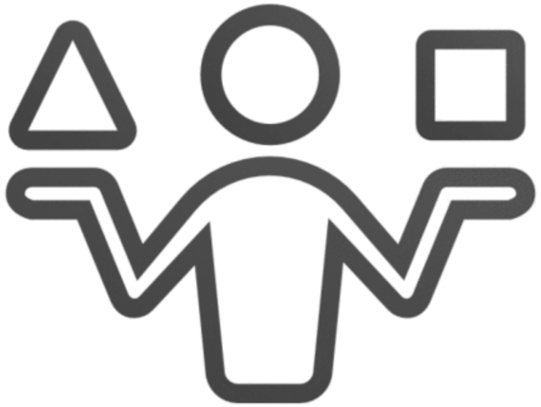
- Relies on the quality of the heuristic for efficiency.
- Computationally expensive for large graphs.

Applications:

- Search Expert Systems: Used in decision-making processes.
- Robotics: Path planning and navigation.
- Game Playing: Solving game trees with AND-OR structures.
- AI Planning: Complex problem-solving involving subproblems.

Activity 05

1. Implement A* and AO* algorithm using Python
2. Compare and contrast between the algorithms



Feature	A* Algorithm	AO* Algorithm
Optimality	Guaranteed to find optimal solution if heuristics are consistent	Does not guarantee optimality; provides approximate solutions
Completeness	Complete: Will find a solution if one exists	Complete: Will converge to a solution over time
Memory Requirement	Requires memory to store entire search tree/graph	More memory efficient; does not require storing entire search tree/graph
Time Complexity	Can have exponential time complexity	Typically converges faster than A*, but may sacrifice optimality
Resource Allocation	Fixed computational resources	Adapts resource allocation, can be interrupted at any time
Iterative Improvement	Does not iteratively improve solution	Iteratively improves solution over time
Interruptibility	Not interruptible during computation	Interruptible at any time, providing a solution at any point
Solution Quality Control	Produces optimal solutions if possible	Provides solutions of varying quality depending on resources
Application	Well-suited for scenarios where finding the optimal solution is crucial, e.g., pathfinding in robotics or games	Useful for real-time systems or resource-constrained scenarios

ANY Questions?

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