University of Technology
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Principles of Artificial Intelligence
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Week No1: **AI definition, history, concept, and applications, AI goals and AI environment**

What is Intelligence?

Intelligence is the ability to learn about, to learn from, to understand about, and interact with one's environment.

What is Artificial Intelligence (AI)?

AI:- Is a simply way of making a computer think.

AI:- Is a part of computer sciences concerned with designing intelligent computer system that exhibit the characteristics associated with intelligent in human behavior.

This requires two processes: -

1. **Learning: -** acquiring the knowledge and build rules that used this knowledge.
2. **Reasoning: -** Used the previous rules to access to nearly reasoning or fixed reasoning.

AI Principles

1. The data structures used in knowledge representation.
2. The algorithms needed to apply that knowledge.
3. The language and programming techniques used for the implementation.

Branches of AI

There are many branches of AI, such as:

1. Logical AI.
2. Search.
3. Patterns Recognition.
4. Representation.
5. Inference.
6. Learning from Experiences.
7. Planning.
8. Heuristics.
9. Natural language processing.

Applications of AI

There are many applications of AI, such as:

1. Game playing.
2. Speech recognition.
3. Computer vision.
4. Expert systems.
5. Translation.

Characteristics of AI

1. High societal impact (affect billions of people).
2. Diverse (language, vision, robotics).
3. Complex (really hard).
4. Better handling of information.
5. Relieves information overload.
6. Conversion of information into knowledge.

Brief History of AI

1943 McCulloh & Pitts: model of artificial neurons

1950 Turing's "Computing Machinery and Intelligence"

1956 McCarthy, Minsky, Newell, Simon, Shannon, Nash et al.
Dartmouth workshop: birth of "Artificial Intelligence"

1952-69 Early enthusiasm, great expectations, optimism fueled by early success on some problems thought to be hard

1966-73 Collapse in AI research: Progress was slower than expected.
Unrealistic predictions, Herbert Simon (1957)
AI discovers computational complexity.

Brief History of AI

1969-86	Expert systems
1980-	AI becomes an industry: expert systems booms, then busts (1988-93): AI Winter”
1986-	Neural networks regain popularity
1987-	Probabilistic reasoning and machine learning

Brief History of AI

1995- Emergence of intelligent agents

- AI technologies continue to find applications in
  - information retrieval
  - data mining and knowledge discovery
  - customizable software systems
  - smart devices (e.g., home, automobiles)
  - agile manufacturing systems
  - autonomous vehicles
  - bioinformatics
  - internet tools: search engines, recommender systems
  - …
- Steady progress on fundamental AI research problems continues.

Brief History of AI

2001- Big data

e.g., ImageNet

2011- Deep learning

- Successful large-scale real-world applications in
  - image recognition
  - natural language processing
  - speech recognition
  - machine translation
  - …
- Convolutional neural networks (CNNs)

h.w: Is artificial intelligence stopped being a story?Prove.

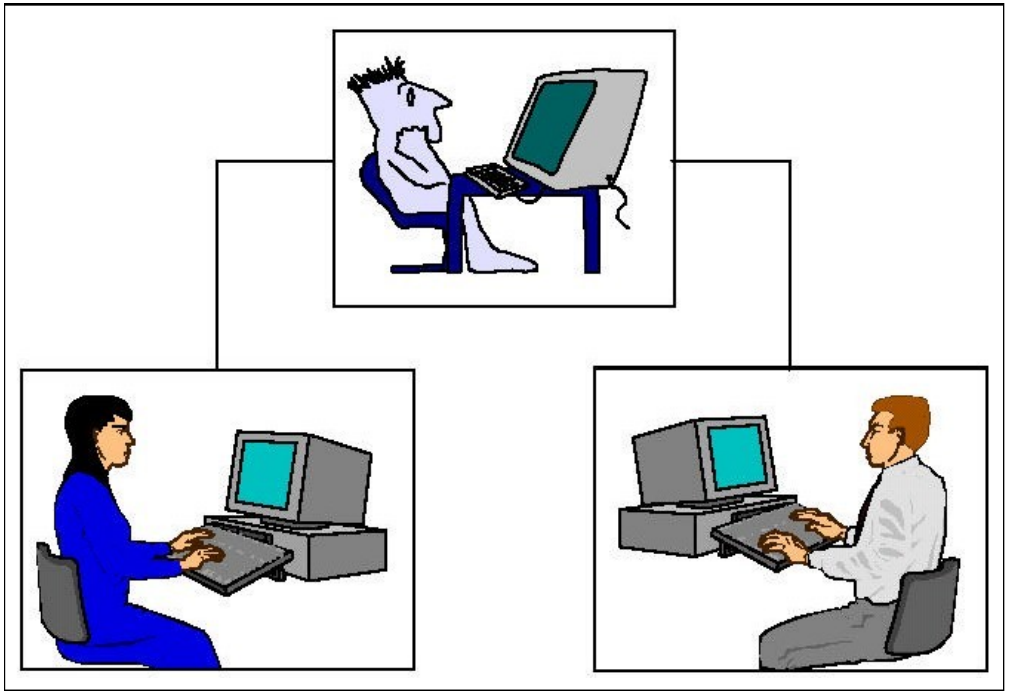
AI Goals

To make computers more useful by letting them take over tedious tasks from human.

Understand principles of human intelligence

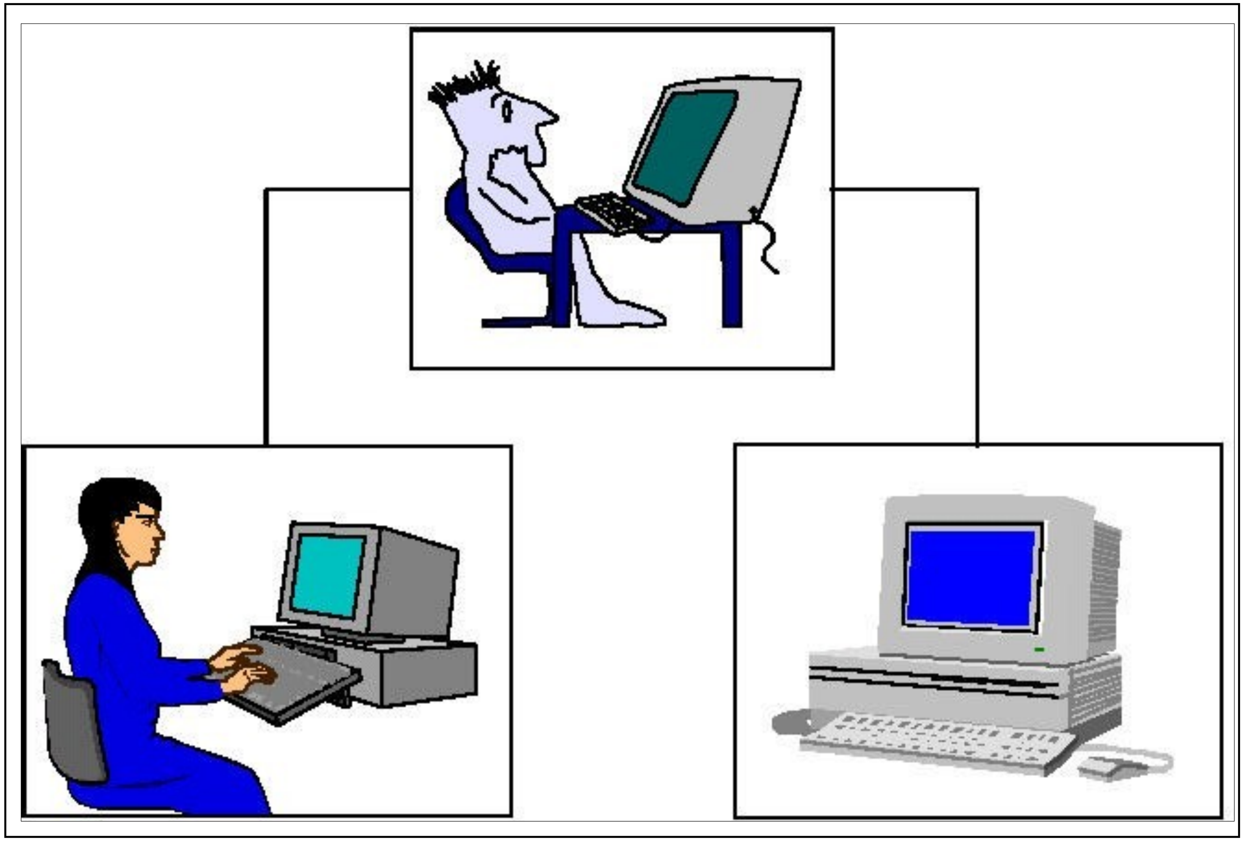
Acting Humanly: Turing Test

Alan Turing define an intelligent machine, in which the machine in question must pass the following test.



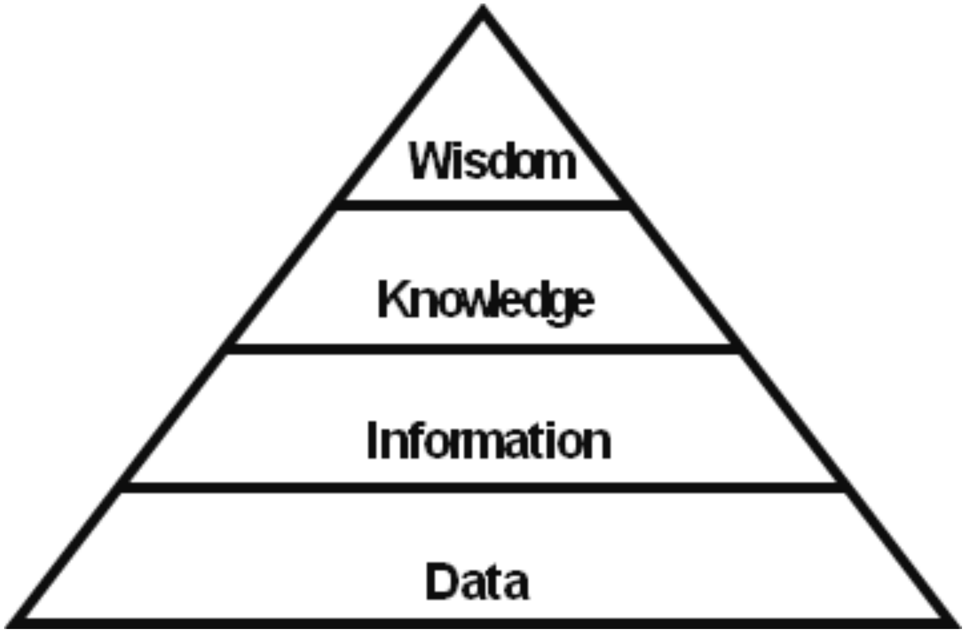
- The interrogator, a man and a woman are each placed in separate rooms.
- The interrogator's objective is to work out who is the man and who is the woman by questioning them.
- The man should attempt to deceive the interrogator that he is the woman, while the woman has to convince the interrogator that she is the woman.

- The man is replaced by a computer programmed to deceive the interrogator as the man did.
- It would even be programmed to make mistakes and provide fuzzy answers in the way a human would.



- If the computer can fool the interrogator as often as the man did, we may say this computer has passed the **intelligent behaviour** test.

DIKW Pyramid



Data – facts and statistics collected for reference or analysis.

Information – Facts provided or learned about something or someone.

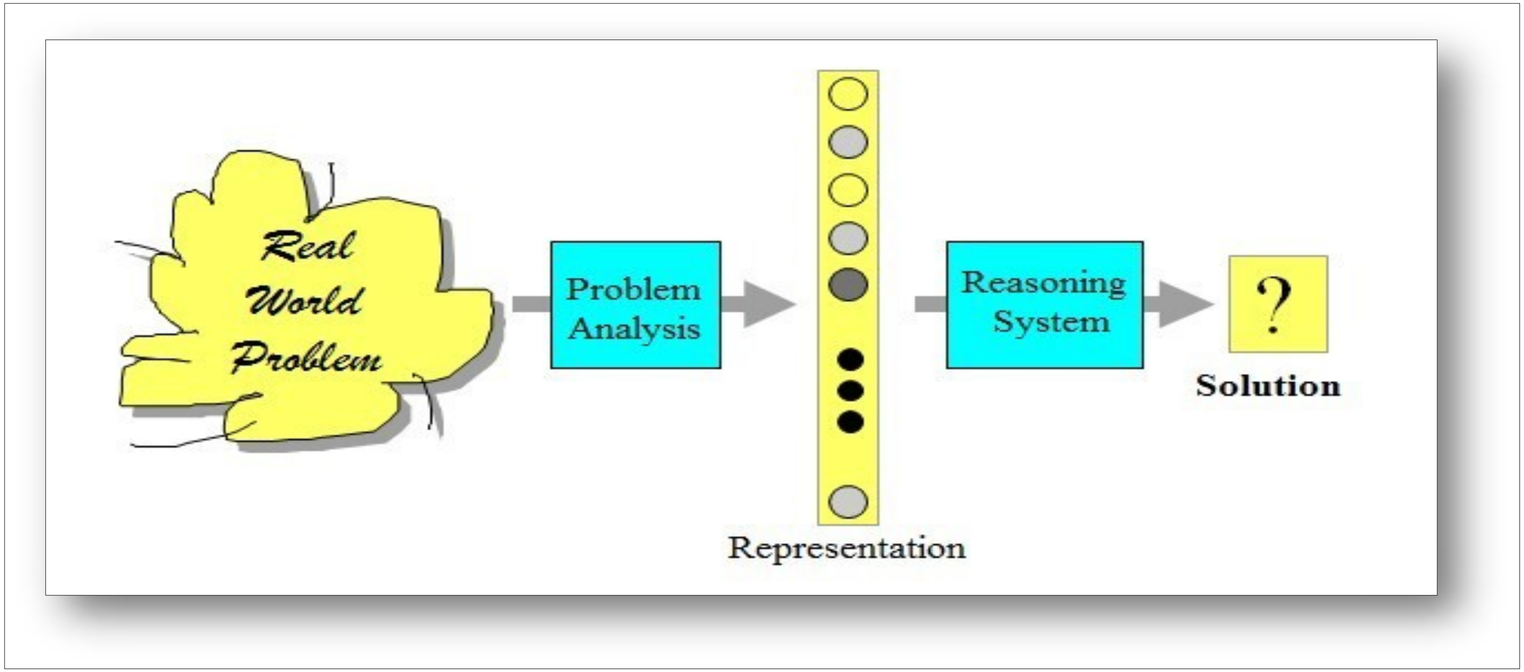
Knowledge – Facts, information, and skills acquired by a person through experience or education.

Wisdom – the quality of having experience, knowledge, and good judgment – or my favorite…knowledge rightly applied.

Problem Reduction

Problem Reduction **means that there is a hard problem may be one that can be reduced to a number of simple problems. Once each of the simple problems is solved, when the hard problem has been solved.**

A model of knowledge-based systems development



- Knowledge-Based Systems/Expert Systems

An information technology based on the application of rules derived from expert knowledge which can imitate some intelligent behaviour.

- The knowledgebase is a type of storage that stores knowledge acquired from the different experts of the particular domain. It is considered as big storage of knowledge. The more the knowledge base, the more precise will be the Expert System.
- It is similar to a database that contains information and rules of a particular domain or subject.
- One can also view the knowledge base as collections of objects and their attributes. Such as a Lion is an object and its attributes are it is a mammal, it is not a domestic animal, etc.

Knowledge Representation: It is used to formalize the knowledge stored in the knowledge base using the If-else rules.

- The knowledge of an expert system can be represented in a number of ways, including IF-THEN rules:

IF you are hungry THEN eat

Knowledge Acquisitions: It is the process of extracting, organizing, and structuring the domain knowledge, specifying the rules to acquire the knowledge from various experts, and store that knowledge into the knowledge base.

Knowledge Base Components

- Factual Knowledge: The knowledge which is based on facts and accepted by knowledge engineers comes under factual knowledge.
- Heuristic Knowledge: This knowledge is based on practice, the ability to guess, evaluation, and experiences.

Knowledge Engineering

- The process of building intelligent knowledge based systems is called knowledge engineering

Problem fundamentals and characteristics

In problem solving, we try to move from a given initial state to a goal state which is the solution

On the way, we move through a number of intermediate states

The initial, final and all possible intermediate steps make up the state space for the given problem or the problem space

A problem space can be represented as a graph with nodes (states) and arcs (legal moves) between nodes

State space search characterises problem solving as the process of finding a solution path from the start to the goal

The task of a search algorithm is to find a solution path through a problem space (which intermediate state should be the next one?)

Problem Solving

State Space Search

A ***state space*** is the set of all possible states of the problem under solving.

Problem Solving Operations

To solve any problem in AI, must do the following operations:

1. Define space search **(state space)** that contains all possible

states.

2. Specify the **initial state** which the problem-solving process may start.
3. Specify (operators, possible moves, rules) that describe the actions available.
4. Specify the **goal state** that would be acceptable as solution to the problem.
5. Determine a suitable **inference technique** to reach the goal

AI Problems

1- Monkey and Banana Problem

There is a monkey at the door in the room. In the middle of the room there is a banana hanging in the ceiling. The monkey is hungry and wants to get the banana, but it cannot stretch high enough off the floor. At the window in the room there is a box the monkey may use.

Solution:

The monkey can perform the following actions to get the banana:-

1. Walk on the floor.
2. Climb the box.
3. Push the box a round (if the monkey is already at the box).
4. Grasp the banana if standing on the box directly under the banana.

The question is (*Can the monkey get the banana?*).

The **Initial state** can be determined by:-

1. Monkey is at door.
2. Monkey is on floor.
3. Box is at window.
4. Monkey does not have banana.

Initial state:- state (at door, on floor, at window, has

not). The **Goal state** can be determined by:-

1. Monkey is at box (middle).
2. Monkey is on box.
3. Box is under banana (middle).
4. Monkey has get banana.

Goal state:- state (middle, on box, middle, has).

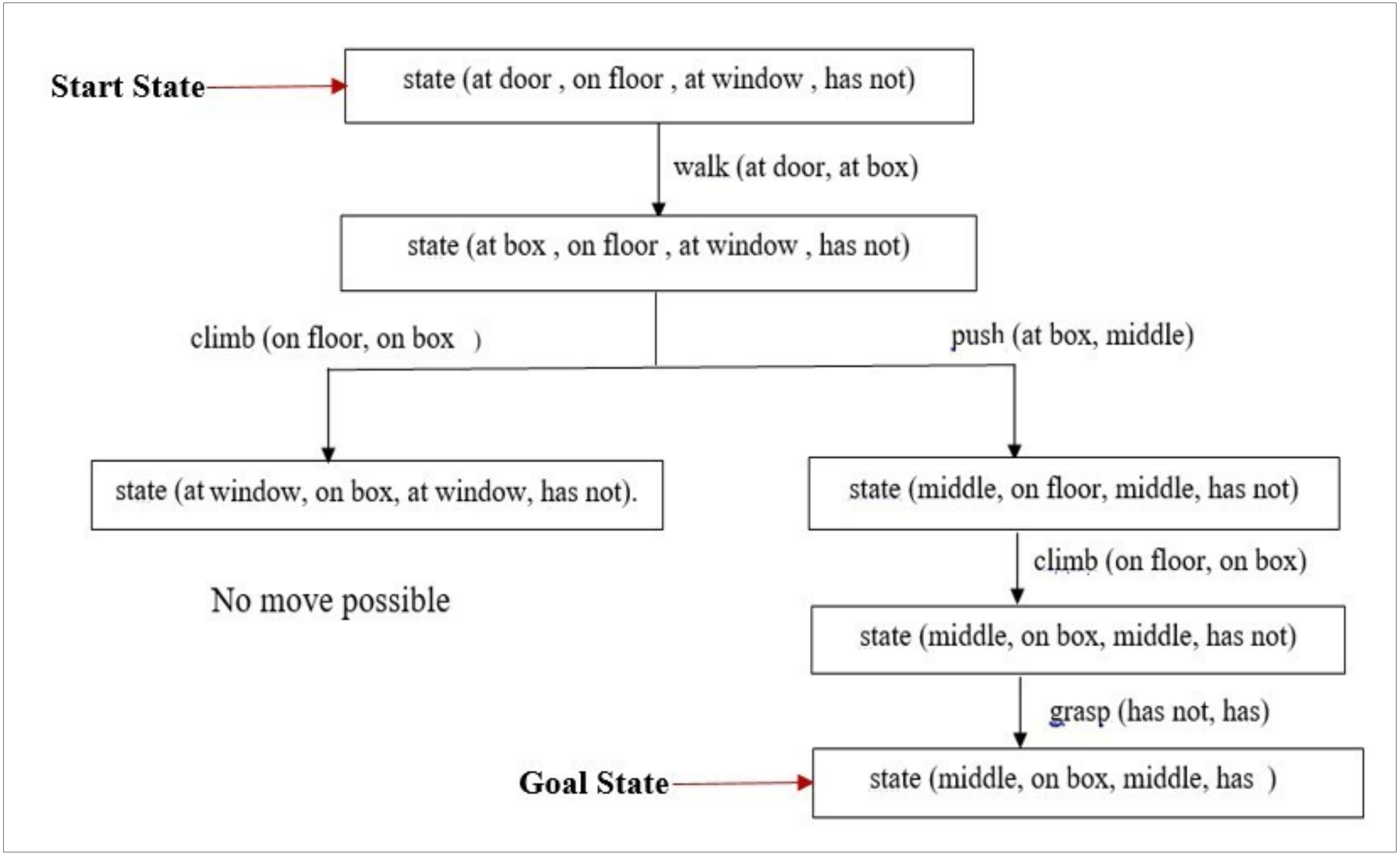
state1 state2

move (state1, state2).

state1: is the state before the move. **move**: is the move executed.

state2: is the state after the move.

The monkey and banana problem can be represented by the following state space:-



AI Problems

2- Tower of Hanoi Problem

The Tower of Hanoi is a mathematical puzzle. It consists of three rods, and a number of disks of different sizes which can slide onto any rod. The puzzle starts with the disks in a neat stack in ascending order of size on one rod, the smallest at the top, thus making a conical shape.

Tower of Hanoi Problem

The objective of the puzzle is to move the entire stack to another rod, observing the following rules:

1. Only one disk can be moved at a time.
2. Each move consists of taking the upper disk from one of the rods and placing it on top of another rod (i.e. a disk can only be moved if it is the uppermost disk on a stack).
3. No disk may be placed on top of a smaller disk.

With **three disks**, the puzzle can be solved in **seven moves**.

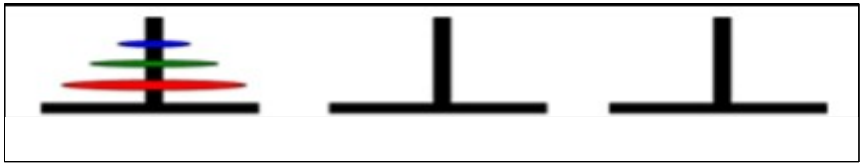
The minimum number of moves required to solve a Tower of Hanoi puzzle is **2N+1**, where **N** is the number of disks.

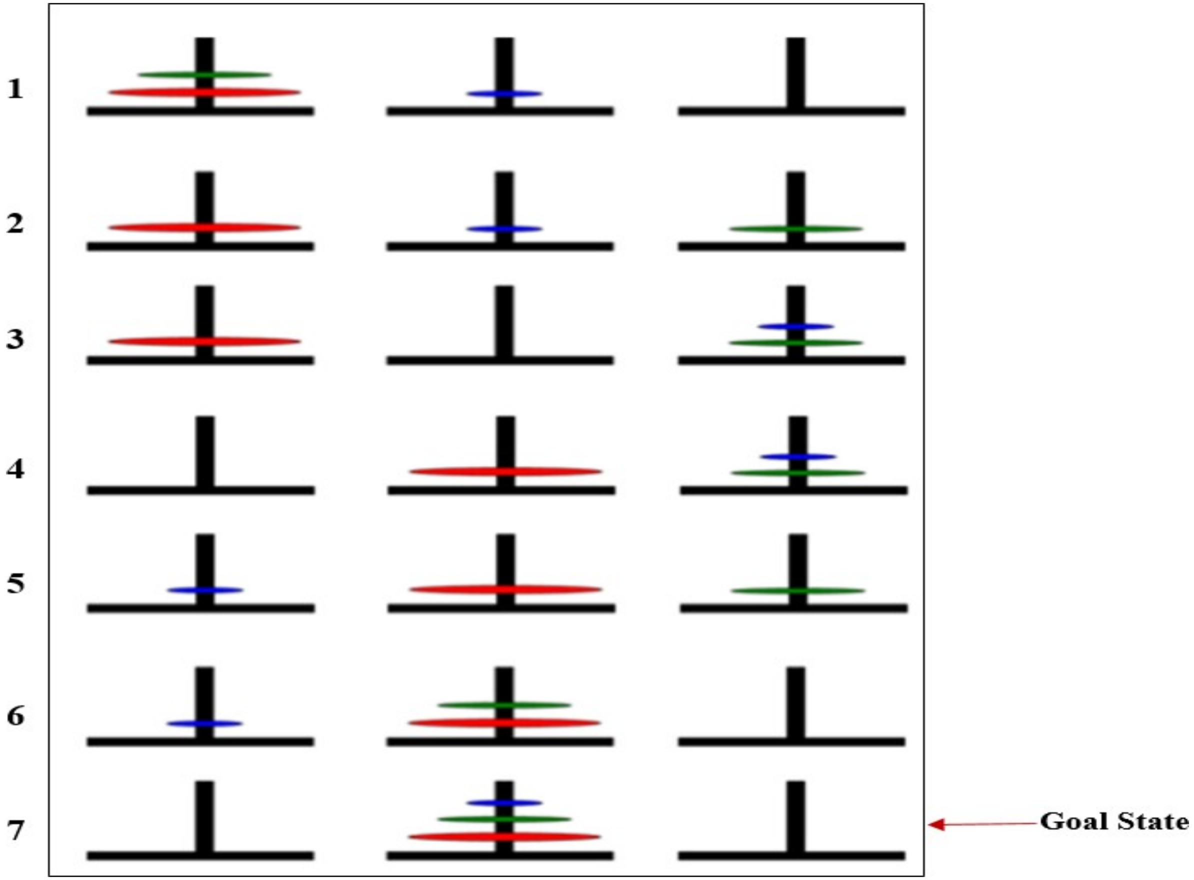
The below figure shows the steps to solve the Tower of Hanoi problem:

The number of moves required to solve this problem is:

2N+1

Initial State





AI Problems

3- Water Jugs Problem

There are two jugs, the first one is **4-liters** and another is **3-liters**. Neither have any measuring marker on them. There is a pump that can be used to fill the jugs with water. How can get exactly **2 liters** of water in the **4-liters** jug?

The state space for this problem can be described as the set of ordered pairs of integers (X,Y), such that X=0,1,2,3, or 4 and Y=0,1,2, or 3; where X represents the number of litters of water in the 4-liters jug, and Y represents the number of liters of water in 3-liters jug.

The start state is (0,0) and the goal state is (2,N) for any value of N (since the problem does not specify how many liters should be in the 3-liters jug).

The state space search for the water Jugs problem is:

- **(X,Y)**: order pair.

➢ **X**: the quantity of water in 4-liters jug ➔ X = 0,1,2,3 or 4.

➢ **Y**: the quantity of water in 3-liters jug ➔ Y = 0,1,2 or 3.

- **start state**: (0,0).

- **goal state**: (2,N) where N = any value.

The required rules to solve the water Jugs problem:

1) (X,Y: X<4) → (4,Y) Fill the 4–liters jug

2) (X,Y: Y<3) → (X,3) Fill the 3-liters jug

3) (X,Y: X>0) → (X-D,Y) Pour some water out of the 4-liters jug

4) (X,Y: Y>0) → (X,Y-D) Pour some water out of the 3-liters jug

5) (X,Y: X>0) → (0,Y) Empty the 4-liters jug on the ground

6) (X,Y: Y>0) → (X,0) Empty the 3-liters jug on the ground

7) (X,Y: X+Y>=4 ∧ Y>0) → (4,Y-(4-X)) Pour water from the 3-liters jug into the 4-liters jug until the 4-liters jug is full.

8) (X,Y: X+Y>=3 ∧ X>0) → (X-(3-Y),3) Pour water from the 4-liters jug into the 3-liters jug until the 3-liters jug is full.

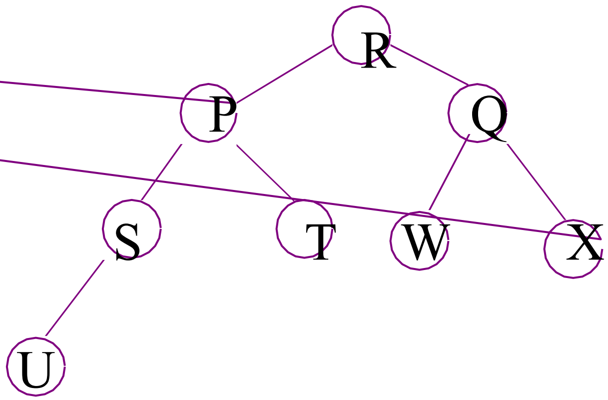
9) (X,Y: X+Y<=4 ∧ Y>0)	(X+Y,0)	Pour all the water from 3-liters jug into the 4-liters jug.
10) (X,Y: X+Y<=3 ∧ X>0)	(0,X+Y)	Pour all the water from 4-liters jug into the 3-liters jug.

The below steps show how the goal was achieved, when the first jug is 4-liters and the second is 3-liters and the start state is (0,0), goal state is (2,N):

4-liters Jug	***3-liters Jug***	***Rule Applied No.***	
0	**0**		
0	**3**	**2**	Fill the 3-liters jug
3	**0**	**9**	pour all the water from 3- liters jug into the 4-liters jug
3	**3**	**2**	Fill the 3-liters jug
4	**2**	**7**	Pour water from the 3-liters jug into the 4-liters jug until the 4-liters jug is full.
0	**2**	**5**	Empty the 4-liters jug on the ground
2	**0**	**9**	Pour all the water from 3-liters jug into the 4-liters jug.

TREEs

Search problems and strategies can be described using trees.



A tree is a graph in which two nodes have at most one path between them

The node at top (eg R above) is called the root and represents the initial state

Each node can have zero or more child nodes Eg, P and Q are child nodes of node R R is the parent of nodes P and Q
R is also the ancestor of all nodes in the tree

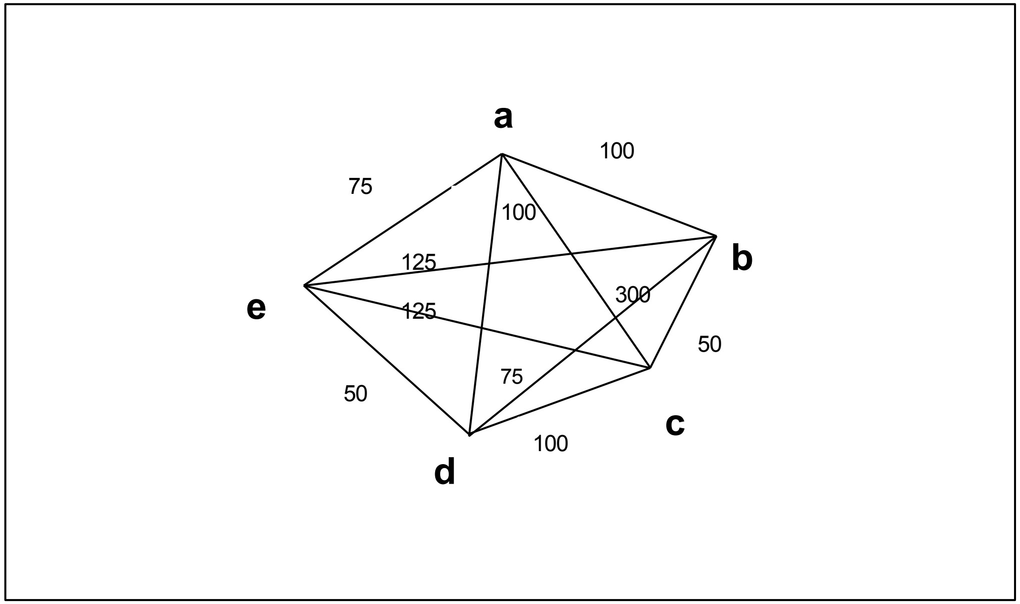
Nodes with the same parent are siblings eg, S and T Nodes with no child nodes are called leaf nodes

A node with b children is said to have a branching factor of b

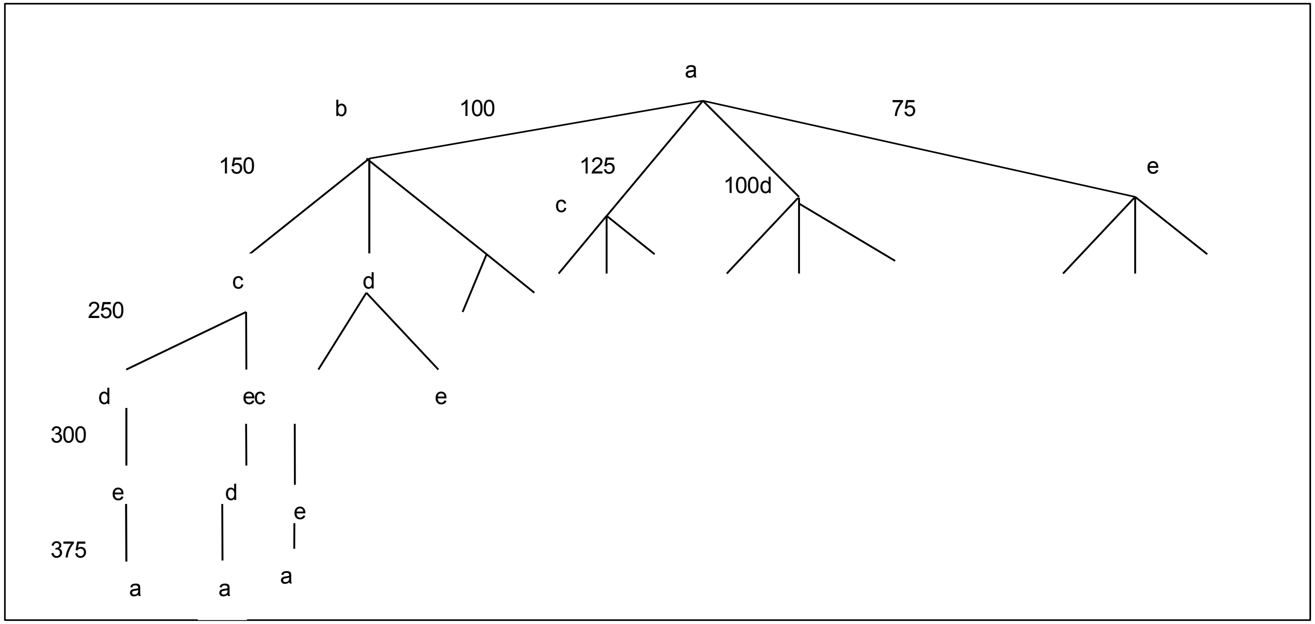
Example:- Traveling Saleman Problem

Starting at A , find the shortest path through all the cities , visiting each city exactly once returning to A.

The complexity of exhaustive search in the traveling Salesman is (N-1)!, where N is the No. of cities in the graph. There are several technique that reduce the search complexity.



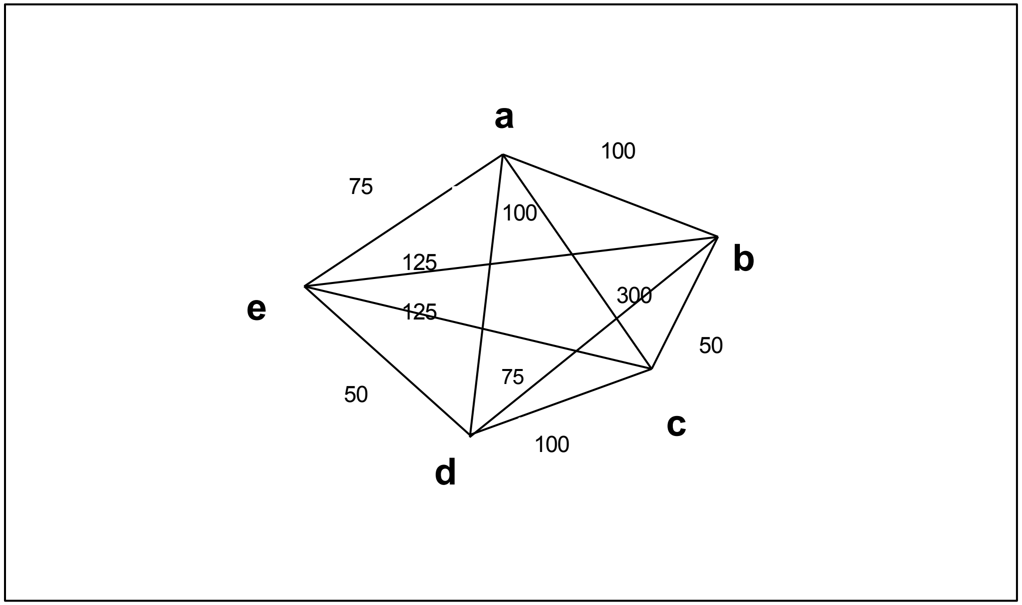
1- Branch and Bound Algorithm:-Generate one path at a time, keeping track of the best circuit so far. Use the best circuit so far as a bound of future branches of the search. Figure below illustrate branch and bound algorithm.



a b c d e a=375 a b c e d a =425 a b d c e a=474 ....

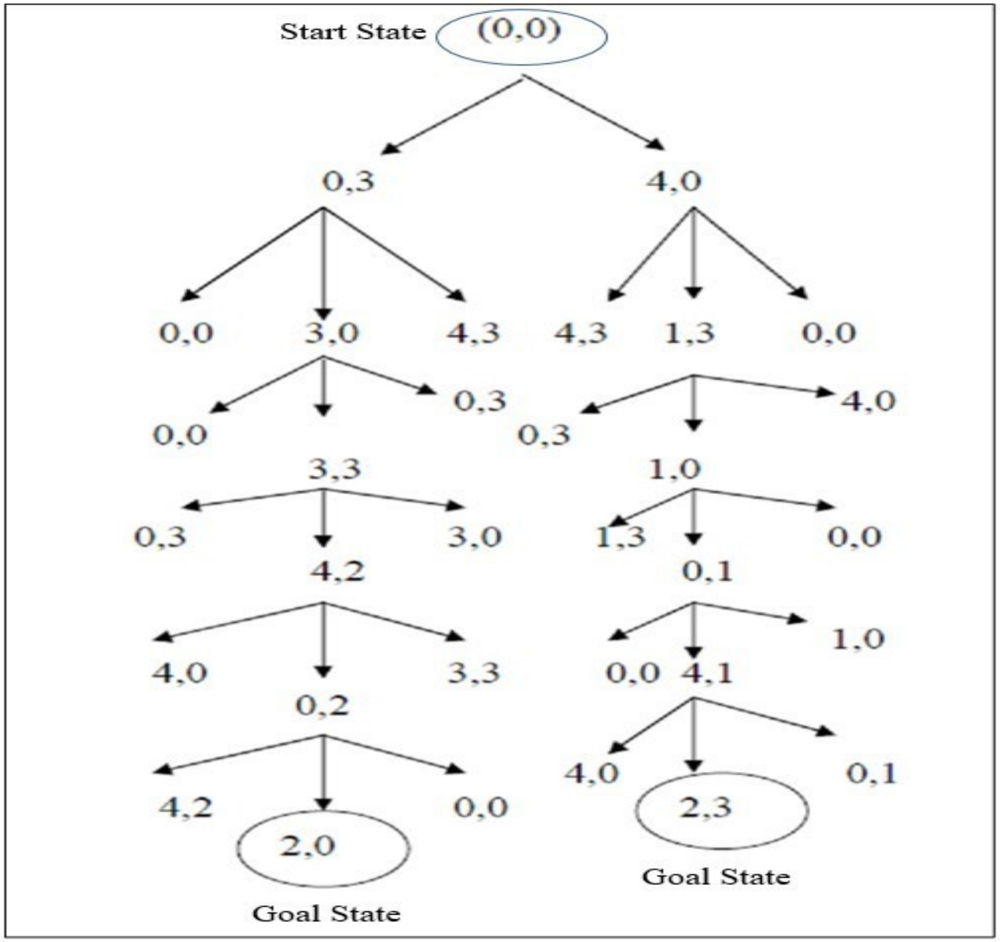
2- Nearest Neighbor Heuristic: At each stage of the circuit, go to the nearest unvisited city. This strategy reduces the complexity to N, so it is

highly efficient, but it is not guaranteed to find the shortest path, as the following example:



Cost of Nearest neighbor path is a e d b c a=550
Is not the shortest path , the comparatively high cost of arc (C,A) defeated the heuristic.

The solution can be shown as a search tree as follows for water Jugs problem



AI Problem Characteristics

The ***AI problem characteristics***: is a heuristic technique designed for solving a problem more quickly, or for finding a satisfactory solution to problems in AI. These characteristics are often used to classify problems in AI, The 7 characteristics are:

1. Decomposable to smaller or easier problems.
2. Solution steps can be ignored or undone.
3. Predictable problem universe.
4. Good solutions are obvious.
5. Uses internally consistent knowledge base.
6. Requires lots of knowledge or uses knowledge to constrain solutions.
7. Requires periodic interaction between human and computer.

Below is an example of the 7 AI problem characteristics being applied to solve a Tower of Hanoi problem.

Characteristics	Answer	Description
Is the problem decomposable?	No	Problem cannot broken down into sub-problems.
Can solution steps be ignored or undone?	Yes	Previous steps can be undone.
Is the problem universe predictable?	Yes	**Problem universe** is predictable to solve this problem it requires only one person who can predict what will happen in the next step. There is only a single possible outcome.

Is a good solution absolute or relative?	Absolute	**Absolute solution**: once you get one solution you do not need to bother about other possible solution. **Relative solution**: once you get one solution you have to find another possible solution to check which solution is best (i.e. low cost) By considering tower of Hanoi solution is absolute
Is the solution state or path?	Path	The solution is a path to the goal state.
What is the role of knowledge?	----	A lot of knowledge helps to constrain the search for the solution
Does the task require human interaction?	No	**Human Interaction means** there is intermediate communication between a human and the computer, either to provide additional assistance to the computer or to provide additional information to the human, or both. In the tower of Hanoi additional assistance is not required.

Below is an example of the 7 AI problem characteristics being applied to solve water jugs problem.

Characteristics	Answer	Description
Is the problem decomposable?	No	Problem cannot broken down into sub-problems.
Can solution steps be ignored or undone?	Yes	Previous steps can be undone.
Is the problem universe predictable?	Yes	**Problem universe** is predictable to solve this problem it requires only one person who can predict what will happen in the next step. There are more than one outcome.

Is a good solution absolute or relative?	Absolute	An **absolute** solution, water jugs problem may have a number of solutions, when found one solution, no need to bother about other solution. Because it does not effect on the cost.
Is the solution state or path?	Path	The solution is a path to the goal state.
What is the role of knowledge?		A lot of knowledge helps to constrain the search of the solution
Does the task require human interaction?	Yes	Additional assistance is required. Additional assistance, like to get jugs or pump.