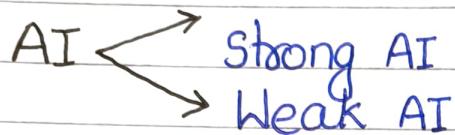


# Artificial Intelligence (AI)

- Introduction to AI
- How machine Can think ?
- Top 3 factors which help to grow AI
- Computer perform better
- Human perform better



- Subfield of AI
- Four types of AI applications
  - i) Think like human being
  - ii) Think rationally
  - iii) Act like human being
  - iv) Act rationally
- Pro and Cons of AI

## Chapter-2 :-

- Agent Environment = Agent function and mapping
  - Rational agent → human agent
  - intelligent agent → Software agent
  - Robotics agent
- Program
  - Rational
  - Intelligent

↳ characteristic  
(Abdul Kalam)
- PEAS — Performance measure, environment ,  
Actuators and Sensors.

### chapter-3. Problem solving approach

- state space
- Search a solution
- Blind Search & heuristic Search  
(BFS, DFS, ...) (Hill climb ...)
- Artificial Intelligence  
manmade able to solve Problem using reason and knowledge
- The art of Creating machines that performs functions requiring intelligence when performed by people.

How a machine Can like human being ?

#### stage-1 :- Machine learning

A Set of algorithms used by intelligent System to learn from experience.

E.g → face detection, face recognition,  
Attendance System in hostel

#### Stage-2 :- Machine intelligence

The advanced set of algorithm used by machine to interact with environment intelligently and can take action to maximise its chance of successfully achieve its goal.

- E.g → Self driving Car

#### Stage-3 :- Self learning from experience without need for external data

E.g → chatbot

AI is growing so fast in last decade  
factors = ?

Factor 1 :- Next Generation Computing architecture →

In general microprocessor and CPU are not intended to manage machine learning. Even faster term of CPU can not process complex situations.

Factor 2 :- Powerful algorithm designed to handle complex problems or situations :-  
Most important factor in AI is advancement of deep learning and artificial neural network.

Factor 3 :- Big data and cloud storage  
Data scientist need to access huge datasets to prepare machine learning models that can anticipate with increased precision.

Objective of Artificial intelligence  
Study of how to make computer do things which at this moment human perform better.

Which activities perform better by Computer?

- Memory storage + need no Rest
- Computation and storing the data
- Never require break

AI Based Health app developed by Oxford hospital → Able to perfectly detect deadly diseases in early stage.

LawGeex :-

AI based startup.

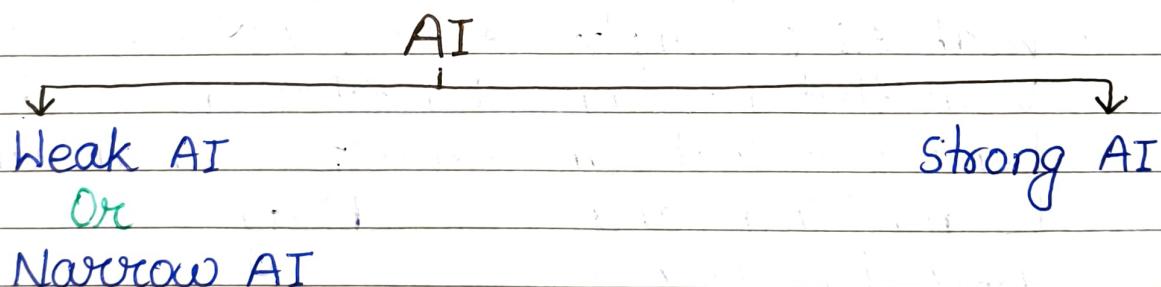
Giving decision regarding AI driven Contract review.

Art authentication → AI Based

where human can perform better?

- Creating music and ARTS ↳ A.R. Rahaman
- Translating

machine - i) memory storage  
ii) Computation



- Weak AI :- Weak AI is known as narrow AI.
- Also have artificial intelligent with limited functionalities.
- Weak AI refers the use of advanced algorithm to accomplish specific problem solving or reasoning task that do not encompass the full range of human Cognitive ability.

E.g :- chat bot / Virtual assistant , Google assistant , recommendation system , for a particular function software and hardware support , face detection , image and speech recognition.

### Strong AI :-

- Strong AI aims to Create intelligent machine that are indistinguishable from the human mind.
- Just like a child AI enabled machines would have to learn through input and experiences and constantly progressing and advancing its ability Over time.  
E.g :- chess board , Robot terminator  
(On screen)

### Weak AI

- Weak AI is simply view that intelligent behaviour that can be modelled and used by computers to solve complex problems.
- Weak AI refers to a system that are programmed a wide range of problems but operate within a predefined range of functions. e.g. self driving car

### Strong AI

- Strong AI refers to a hypothetical machine that exhibits human cognitive ability.
- Strong AI refers to m/c with the mind of their own and which can think and accomplish complex task of their own.

## Subfield of Artificial intelligence

- i) Artificial neural network
- ii) Robotics → Honeywell Automation:  
Texas instrumentation  
Mold tech Packaging
- iii) Expert Systems → Decision making
- iv) Speech Processing }  
v) Image Processing }  
vi) Video Processing }
- vii) Machine learning and Deep learning

Ques. 10 Jobs AI Can't Replace ?

- Teachers
- Politicians
- Singers
- Artist and writers
- Healthcare Professionals
- Social work

Cognitive Behaviour  $\therefore$  Focus is not Just in behaviour and input-output best looks like reasoning Process.

- Goal is not Just like human like behaviour but to produce Sequence of steps of the reasoning Process similar to steps followed by human in Solving the Same task.

four Categories of focus of AI

- i) Act like human
- ii) Think like human
- iii) Think rationally
- iv) Act rationally → Eg. Self driving Car  
Tele. marketing

## Questions :-

- i) Temperature manag. in a Room.  
→ Act like human being
- ii) Automatic Vacuum cleaner  
→ Act like human being
- iii) Tic/Tac/gamming machine  
→ Think rationally
- iv) Patient diagnoestic manag.  
→ Act rationally
- v) Self driving Car  
→ Act rationally
- vi) Color detection  
→ Think rationally
- vii) face detection  
→ Think like human
- viii) Automated sliding door  
→ Act like human
- ix) Part Picking Robot  
→ Act like human
- x) Spam filtering  
→ Think rationally

### \* • Advantage of AI :-

- Do not get tired or wear out easily.
- Rational decision maker.
- Calculate with precision without break.
- Reduction in Human Error

### Disadvantage of AI :-

- No improvement
- Lack of Creativity

- Incurs high Cost.
- leads to unemployment.
- Emotionless

## Chapter-2. Agents and Environment

- An AI System is Composed of an agent and its environment.
- An agent is anything that can be viewed as:
  - Perceiving its environment through Sensors.
  - Acting upon the environment through actuators.
  - In Context of the AI field an agent is an independent program or entity that interacts with the environment by perceiving its surrounding via Sensors then acting through actuators effectors.

four rules must follow by AI agents -

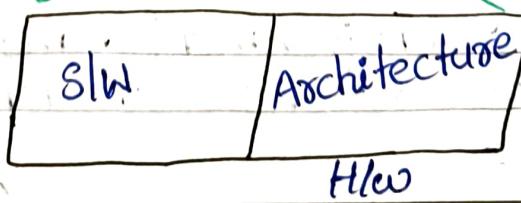
**Rule 1 :-** An agent must be able to perceive the environment.

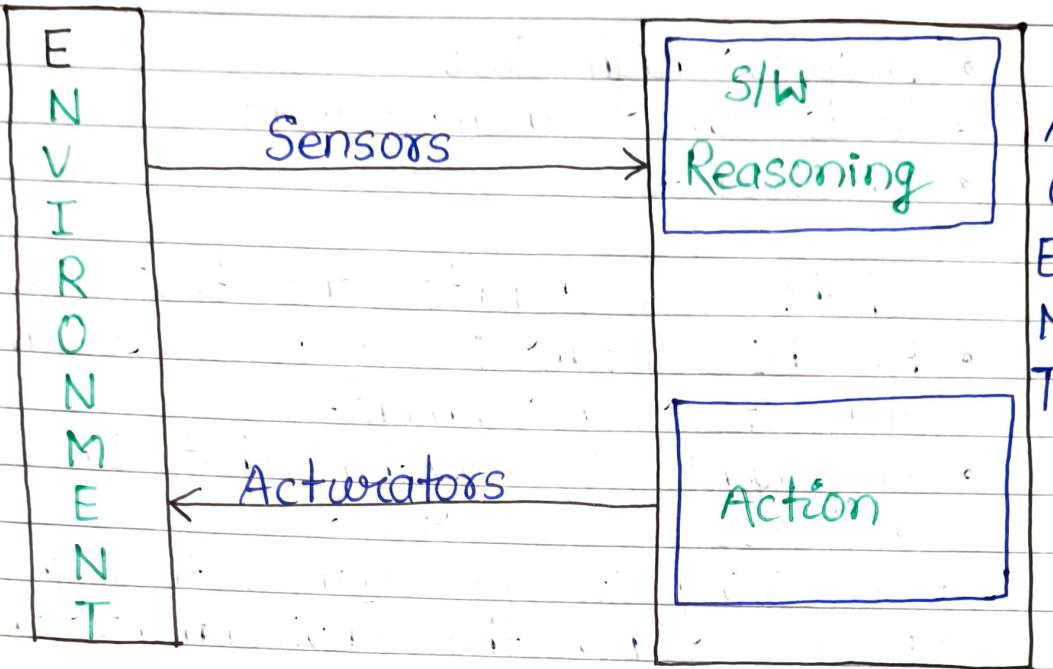
**Rule 2 :-** The environmental observation must be used to make decisions.

**Rule 3 :-** The decision should result in action.

**Rule 4 :-** The action taken by the AI agent must be rational which maximise the Performance and yield best positive outcome.

Agent function  
Action<sup>1</sup>  
Action<sup>2</sup>  
Action<sup>3</sup>





## Building AI Systems

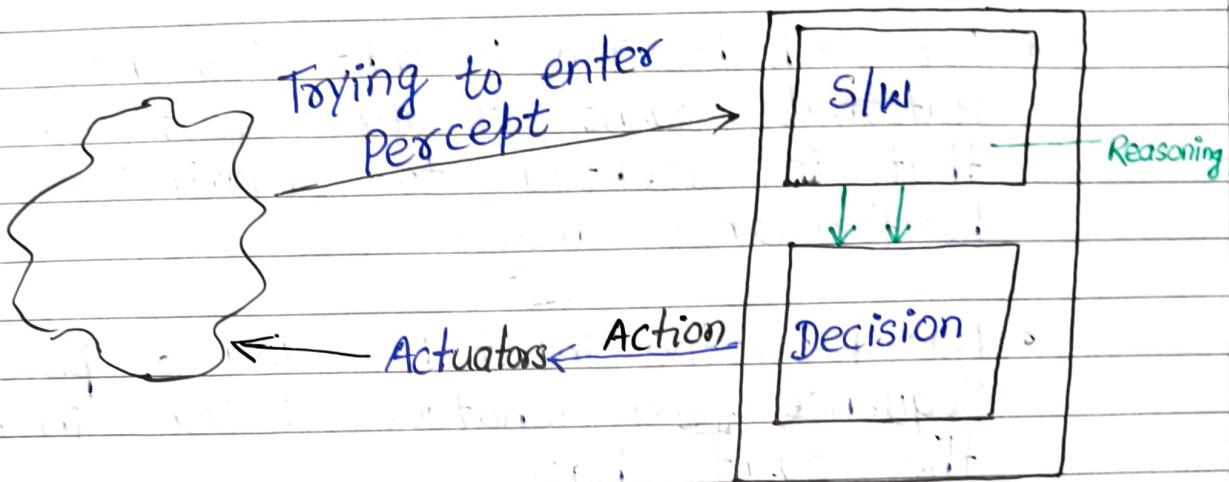
- i) Perception :- Intelligent biological agents are physically experience the world through sensors.
- ii) Reasoning :- Decision making capability to take action after sensing the environment.

To improve Performance -

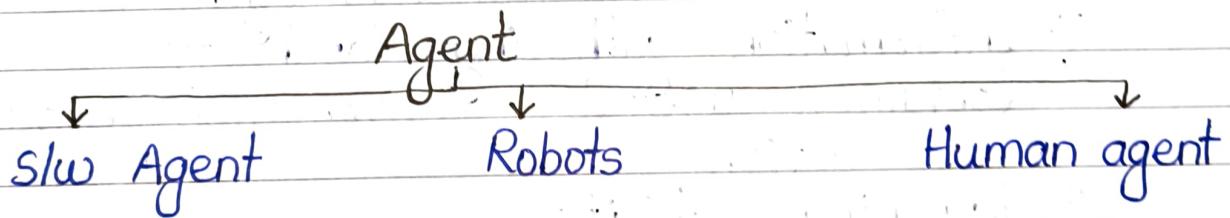
- a) Knowledge Representation
- \*\* b) Decision theory
- \*\* c) Planning
- \*\* d) Game theory
- e) Machine learning etc.

Agent :- An agent is a Computer Program or System that is designed to perceive its environment, make decisions and take actions to achieve a specific

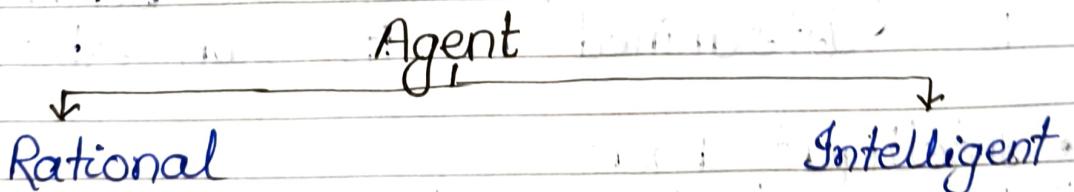
goal or set of goals. It is not directly controlled by a human operator.



- iii) Action :- All behaviour is centered around access in the world.
- Controlling the steering of a car.
  - Test suggest by patient diagnostic system.
  - Natural language generation.



firewall - 7 layer



- \* Rational :- An agent should try to do the right think based on what it can percept and the actions it can be performed the right action is the one that

will cause the agent to be more successful.

- For each possible Percept Sequence a rational agent should select an action that is accepted to maximise its performance major.
- Based on the input provided as percept Sequence and whatever build in knowledge the agent has.

Different factors on which rationality depend

- i) Agent prior knowledge regarding environment
- ii) Actions that agent can perform
- iii) Agent Percept Sequence till the moment

Requirement of rational agent :-

- i) Information gathering Capability (obtained useful information to take action).
- ii) learning ability
- iii) Ability to adopt  
An agent is autonomous (the behaviour is determined by its own experience).

• Intelligent Agent

- i) An agent is completely specific by its agent function which maps percepts Sequence to action.

- ii) An agent has some internal data structure

i.e updated as when new percepts arrive.

- iii) The data structures are operated or by the agents decision making procedures to generate an action choice which is then passed to the architecture to get executed.

\*\* four main factors to design intelligent Agent :-

- i) Percepts - Input to the System.
- ii) Action - the Output of Our System.
- iii) Environment - what the agent is interacting with
- iv) Goal - what the agent is expected to achieve.

Intelligent agent

- i) Definition - An intelligent agent is a system that can be percept environment and take action to achieve specific goal.

Rational agent

- i) A rational agent that makes decision based on logical reasoning and optimized its behaviour to achieve a specific goal.

- ii) Perception → An intelligent agent can percept ion and its environment through Sensors.

- ii) Rational agent perception is based on information available to it and logical reasoning.

- iii) Decision making - Make decision is based on Set of rules or predefined algorithm.

- Make decision is based on logical reasoning and optimize its behaviour to achieve its goal.

- iv) Autonomy - operate. it can run independently of human intervention but based on logical reasoning. it can't be run to another.
- v) Algorithm - Self-driving car, Virtual assistant, Recommendation System.
- iv) It can run independently of human intervention but based on logical reasoning.
- v) Financial advisor, logical planning etc.

### ★ PEAS :-

P → Performance  
 E → Environment  
 A → Actuators  
 S → Sensors

- Automated Taxi driver
  - P → Safe, fast, comfortable (maximize Profits)
  - E → Roads, other traffic, other vehicle, other object on roads
  - A → Steering, accelerator, brake, indicator, Signal, horn
  - S → Camera, Sonar, speedometer, GPS, accelerometer, speed
- Medical diagnostic System
  - A → Screen display, Report point out, doctor prescription
  - S → Different Sensors to take data regarding patients

P → diagnostic accurate, Patient satisfaction,  
minimum Cost  
E → Hospital staff, patient

### ★ Environment :-

- Fully observable :- An agent Sensor give it access to the Complete state of the environment at each point of time.  
Eg :- Image analysis, colour identification, chess board, driving etc

- Partially observable :- An environment might be partially observable because of noising or inaccurate Sensors and because parts of the states are missing from Sensor data.

Example :- Patient diagnostic System

### \* Fully observable Vs Partially observable

- Fully observable :- if the agent Sensors detect all aspects of the environment relevant to choice of action Could be partially observable because the being noisy or inaccurate or missing Sensors or inability to measured everything i.e required

- Fully observable Can keep track of what was sensed previously. For partially observable Can't be sensed but it may be Probable required.

## \* • Deterministic Vs stochastic

Deterministic - Next step of the environment is predictable from the current state and the action is executed by the agent.

Stochastic means that it means next state has some uncertainty associated with it.

- Uncertainty who come from randomness lack of good environment or lack of Sensors Coverage.

If deterministic are fully observable agent doesn't need to worry.

- Example -
- Robot on Man
  - Poker Game

## \* Competitive Vs Collaborative

- Competitive - An agent is said to be in a competitive environment when it competes against another agent to optimize the output.

An agent is said to be in a collaborative environment when multiple agents cooperate to produce the desired output.

## \* Single-agent Vs Multi-agent

An environment consisting of only one agent is said to be a single-agent environment.

An environment involving

more than one agent is a multi-agent environment.

#### \* Episodic Vs Sequential

- Episodic :- The agent experience is divided into atomic episodes. And the choice of action in each episodes depends only on the episodes itself. Example - chat board

- Sequential :- The Sequential environment is an environment where the next state is dependent on the current state. So agents current action will determine the next action. Example - image Processing

#### \* Static Vs Dynamic

Static :- An idle environment with no change in its state is called a static environment.

Dynamic :- The environment is unchange.

### \*\* Different types of Agent model :-

#### i) Simple Reflex Agent Model

Simple reflex agents ignore the rest of the percept history and act only on the basis of the current percept.

Percept history is the history of all that an agent has perceived to date.

The agent function is based on the Condition-action rule.

#### ii) Model Based agents

## Model based agents

↳ Current state

+

Historical Data

- Model Based agents can handle partially observable environment.
  - Its Current state is stored inside the agents.
  - Maintaining some kinds of structure.
  - It will also store the historical data or information. These additional information help to take the right action.
- \* \* • Compare to Simple reflex agents and Model Based agents are **Complex and Costly**.

Simple reflex agent	Model Based agents
Simple	Complex
Costless	Cost high
Fully observable	Partially observable

## Goals Based Agents

CS + Historical + strategy  
Data



chess board size

These kinds of agents take decision based on how far they are currently from their goal. Their

every action is intended to reduce their distance from the goal. This allows the agent a way to choose among multiple possibilities, selecting the one which reaches a goal state. The goal-based agent's behaviour can easily be changed.

#### \* Pseudo Code for Simplex Reflex function

Simple reflex (percept) returns actions

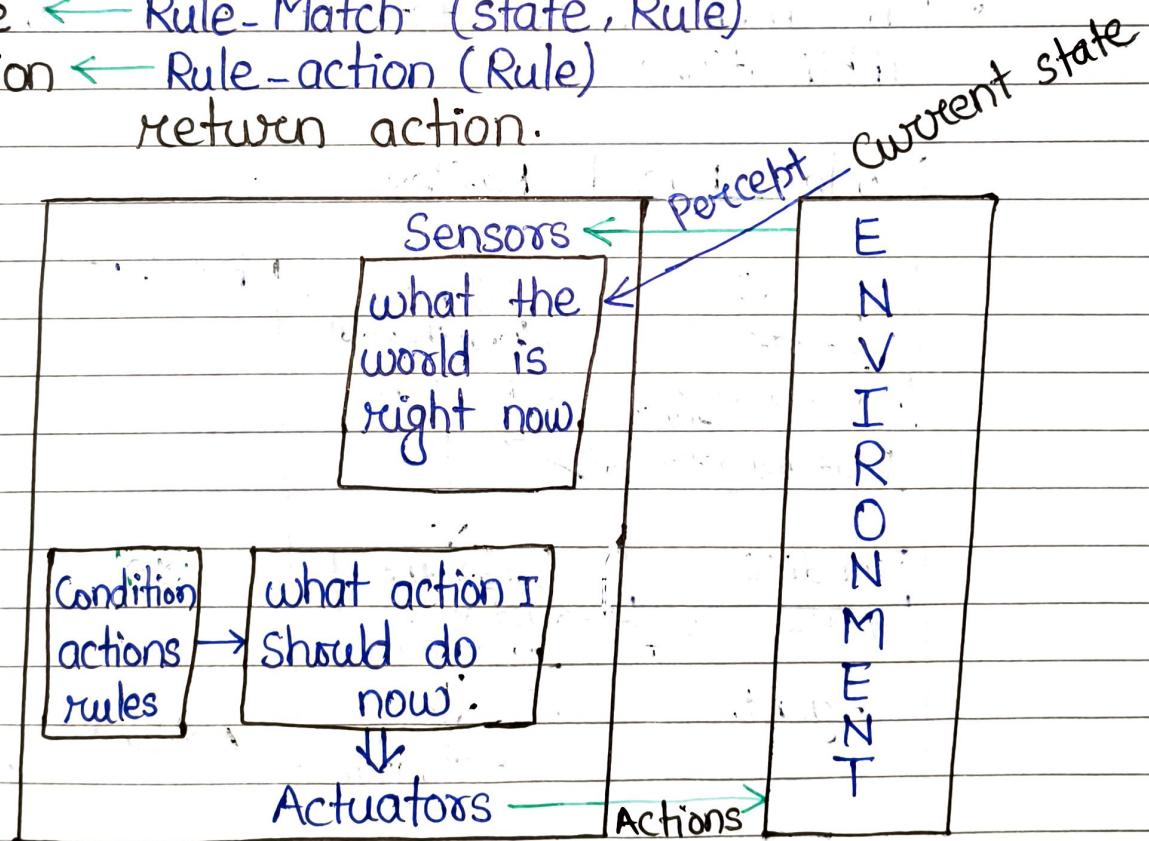
static : Rules or Set of Condition and action.

State  $\leftarrow$  Interpret - Input (Percept)

Rule  $\leftarrow$  Rule - Match (state, Rule)

action  $\leftarrow$  Rule - action (Rule)

return action.



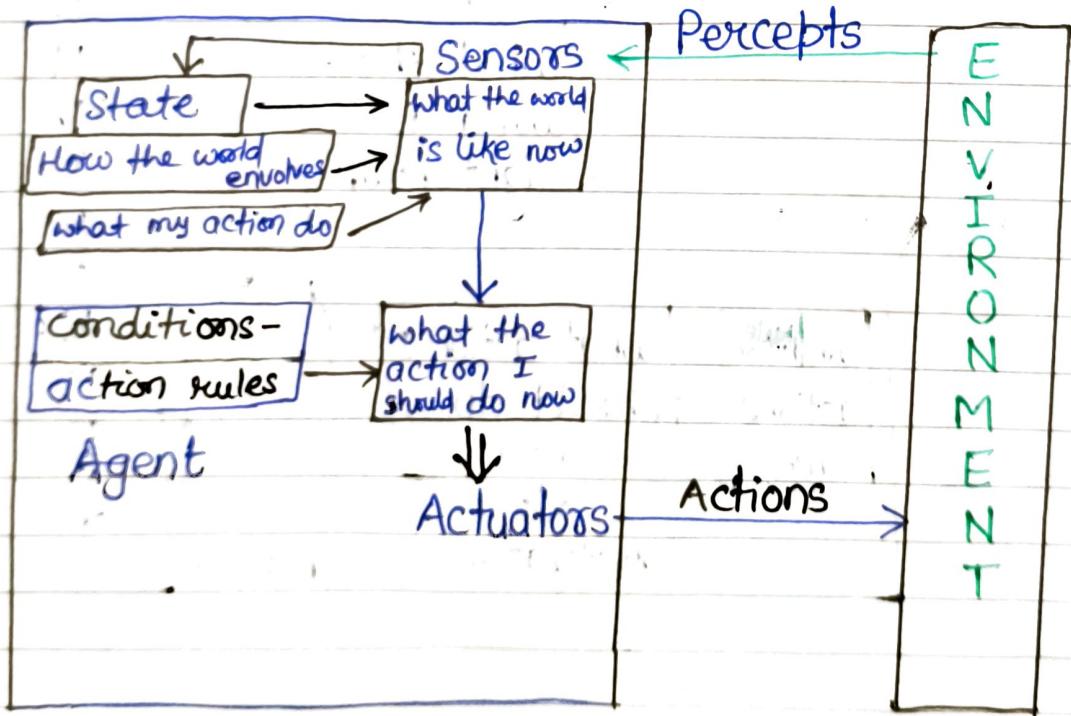
## Advantage of Simple Reflex

- Easy to design and implement.
- Requiring minimal resources.
- Real time response to environmental changes.
- Highly reliable in situation where the Sensors providing input are accurate and the rules are well designing.

## Disadvantage -

- Prone to error if Sensors are faulty and poorly designing.
- No memory or state so there are limit in applications.

## Model Based Reflex



Model Based agents working in four stages

i) Sense

→ Perceive Current state.

ii) Model → It constructs and internal model of the world what it observe.

iii) Region → It uses its model of the world to decide how it act based on a set of pre defined rules.

iv) Action → Carries Out the action that it has been chosen.

Advantages :-

- Quick and efficient decision making.
- Better equipped to make accurate decision by constructing and internal model of the world.
- Adaptability of changes in the environment by updating there internal structure.

Example - firewall

Disadvantage -

- Building and maintaining.
- The model can be expensive.
- Model may miss real world Complexity.

\* Goal Based Agent

Rule → Action + Historical data + Goal.

- Goal is to provide high quality response to user queries.
- It selects actions that are likely to assist users in finding the information seek and achieving their desired goal.
- Used Search based algorithm to find efficient path towards their objective within a given environment.
- Goal based agent can handle complex tasks like robotics, natural processing lang., Computer vision Program etc.

Goal based agents have five steps :-

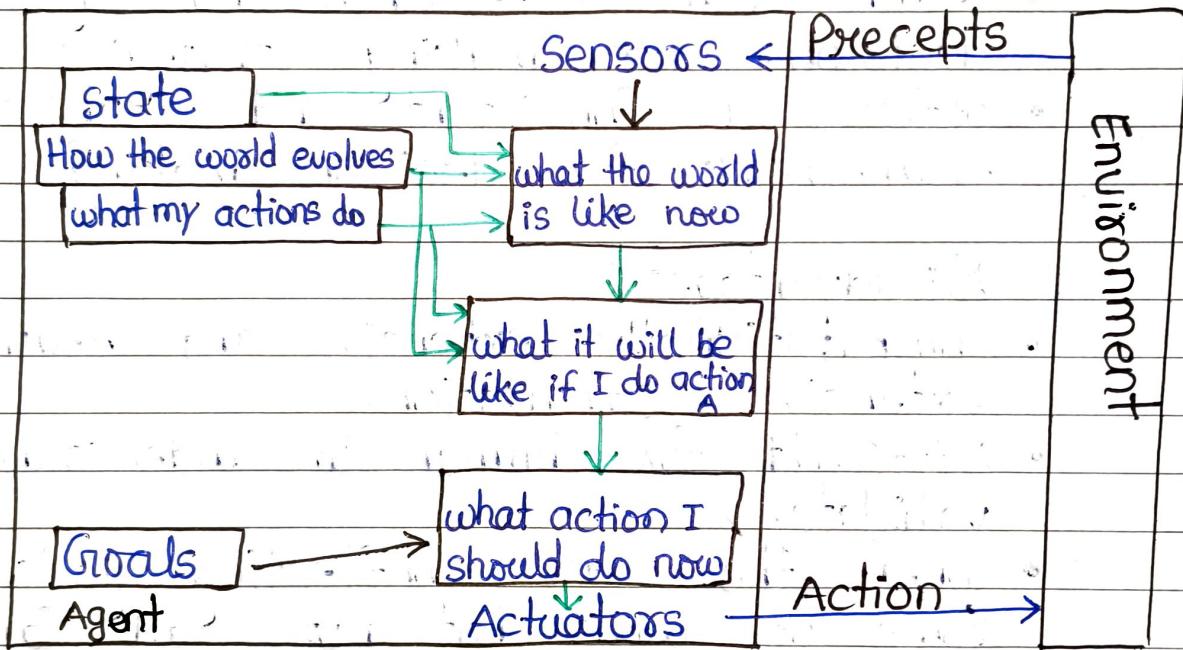
- i) Perception :- Percept from environment.
- ii) Reasoning :- Agent analyses the information collected and decided on the based course of action to achieve the goal.
- iii) Action :- Agent takes action to achieve its goal.
- iv) Evaluation :- After taking action the agent evaluates its progress towards the goal and adjust its actions if necessary.
- v) Goal Completion :- After agent achieves its goal it either stops working on new one. Eg. :- Part picking robot.

## Advantages :-

- i) Simple to implement and understand.
- ii) Efficient for achieving a specific goal.
- iii) Easy to evaluate performance based on goal completion.

## Disadvantages :-

- i) Limited to specific goal.
- ii) Unable to change with adopting environment.



## iv) Utility Based Agent

- Utility Based Agents are AI agents that make decisions based on maximizing utility functions or value.
- They choose the action with the highest expected utility which measure the how good the outcome is.

- Helps to deal with the Complex and uncertain situations with flexibility and adoptability.

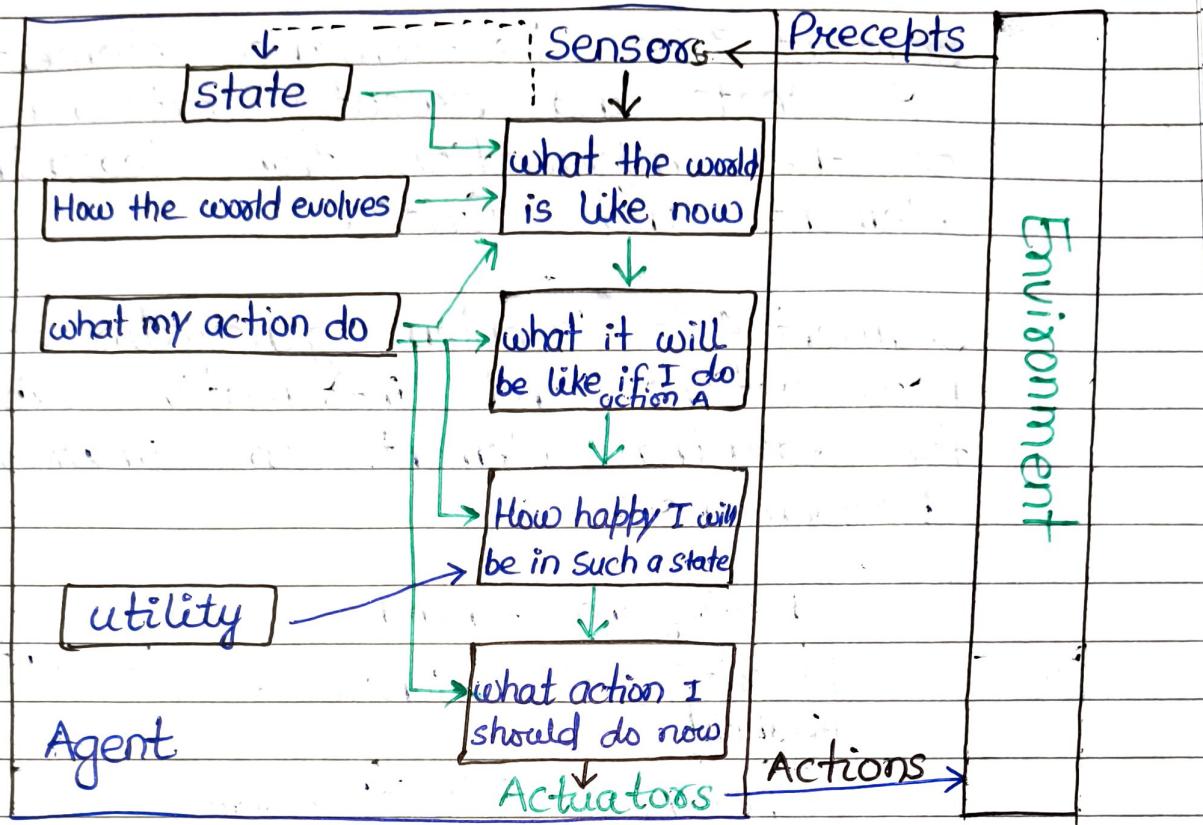
E.g → Resource allocation in Scheduling, Different web based App or S/w, SAP System, SBI Banking System:

Advantages :-

- Handle wide range of decisions.
- Learn from experience and adjust their decisions for making strategies.
- offers a Consistent and objective framework for decision making.

Disadvantages :-

- Computationally expensive and require extensive calculation.
- Difficult for human to understand and validate.
- when there are conflicting goals only Some of goals but not all can be achieved.
- Does not Consider moral or ethical Consideration.



### v) Learning Based Agent Models

- An AI based learning agent is a software agent that can learn from past experiences and improve its performance.
- It acts with basic knowledge and adopts automatically through machine learning.

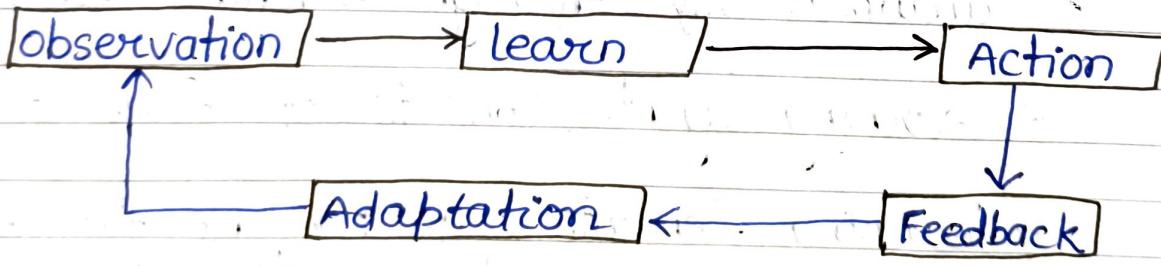
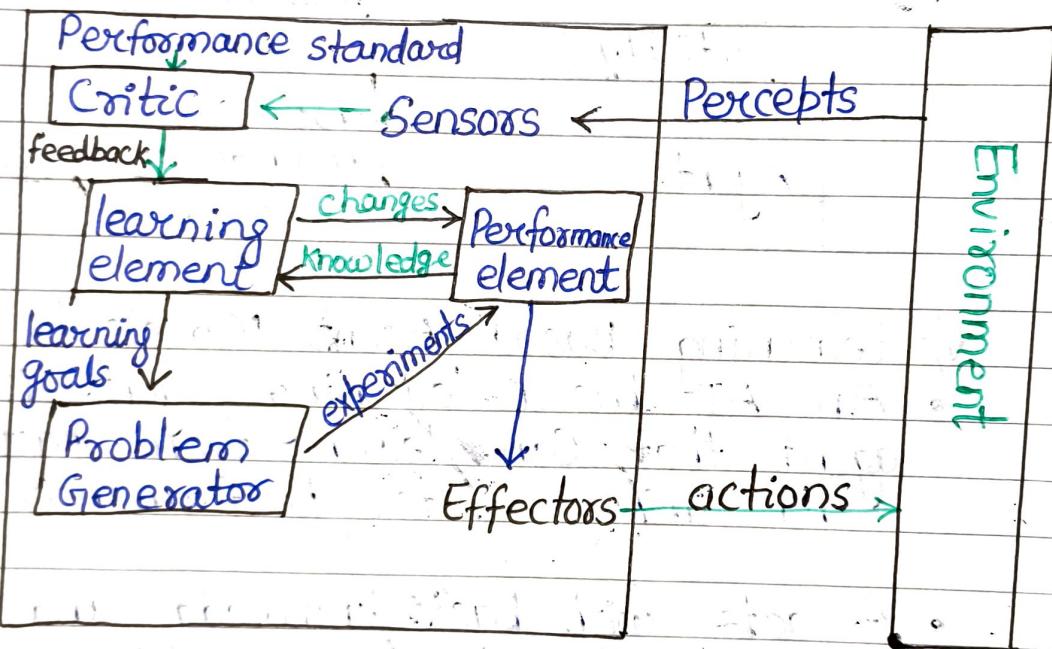
\* Learning agent consists of four steps :-

i) learning elements :- Responsible for learning and making improvements based on experiences.

ii) Segment 2 :- Critic :- It provides feedback to the learning element by the agent's performance for a predefined standard.

Segment 3 :- Performance element :- It selects and executes external action on the information from learning element. and Critic.

Segment 4 :- Problem generator :- Suggest new actions and informative experience for learning element to improve its performance.



Learning Cycle.

Advantages :-

- Agent can convert ideas into action based on AI decisions.

- learning intelligent agent can follow basic Command like spoken instructions to Perform task.
- AI agents works on realistic approach.
- Disadvantages :-
  - Prone to biased or incorrect decision.
  - High deployment and maintenance cost.
  - Requiring Significant Computing resources.

## Chapter - 3.

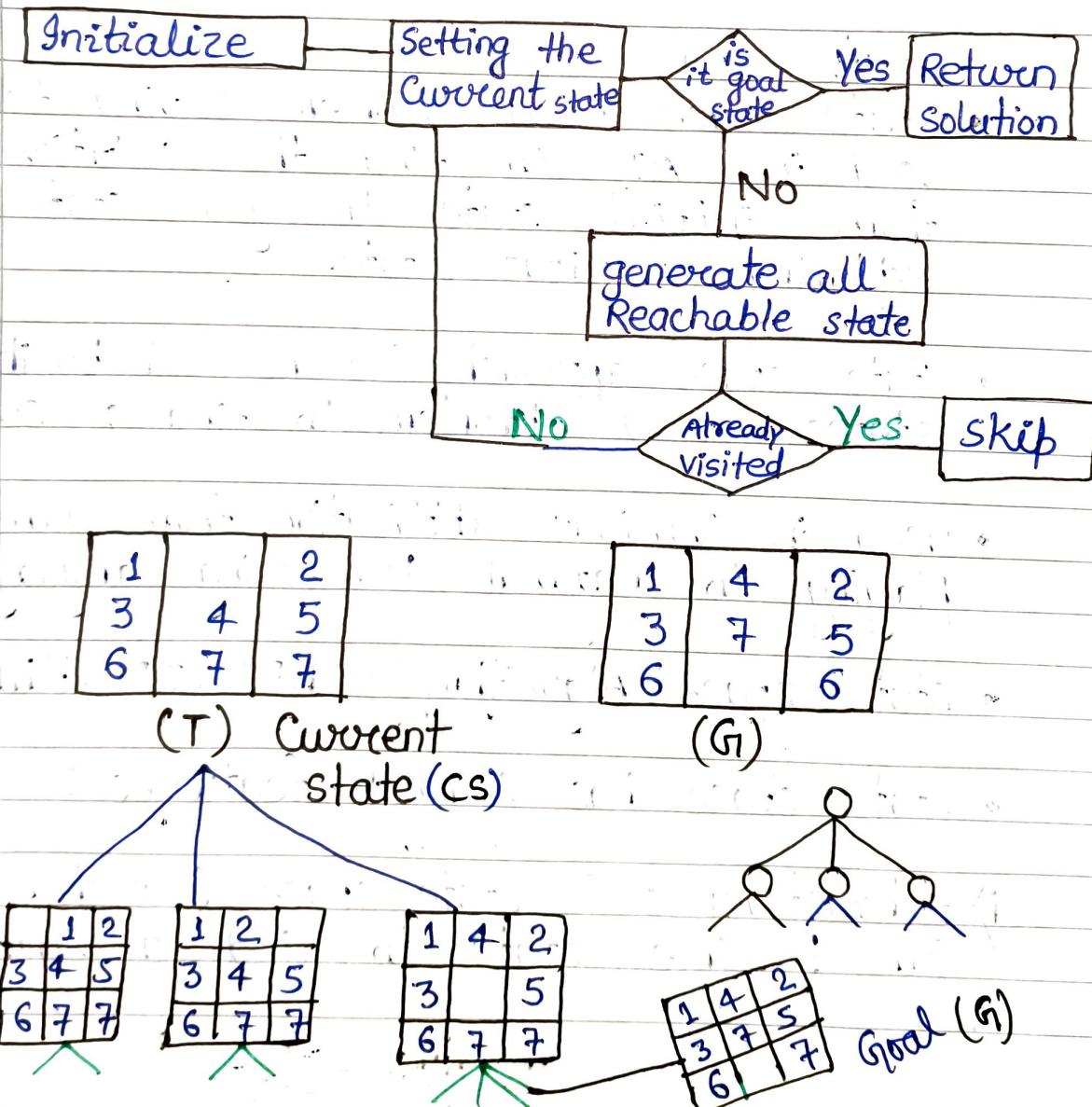
### State space.

- State space is a Problem solving techniques used in AI to find the solution Path from initial state to goal state by exploring various state.
- State space approach Searches all possible states of a problem to find a solution.
- used in Various application, from game playing to natural Processing language.
- state space Algorithm :- BFS , DFS, Hill climbing, etc.
- state space has Several features :-
  - i) Exhaustiveness :- state space Search , explore all Possible state to find a solution.

ii) Completeness :- If a solution exist state space Search will find it.

iii) Optimality :- Searching through a state space for optimal solution.

iv) Uninformed and informed Search :- state space can be classified into uninformed if no additional information provided Vice Versa informed Search Provided additional information.



## \* State Space Flow chart

- i) Tower of Hanoi
- ii) Water Jug Problem
- iii) Four Queen's Problem

Q	-		
X	X	Q <sub>2</sub>	X
X	X		
Q <sub>3</sub>	X	X	

⇒ 3 Queen

-	Q <sub>1</sub>	-	
X	X	X	Q <sub>2</sub>
Q <sub>3</sub>	X	X	X
X	X	Q <sub>4</sub>	X

↳ non-linear

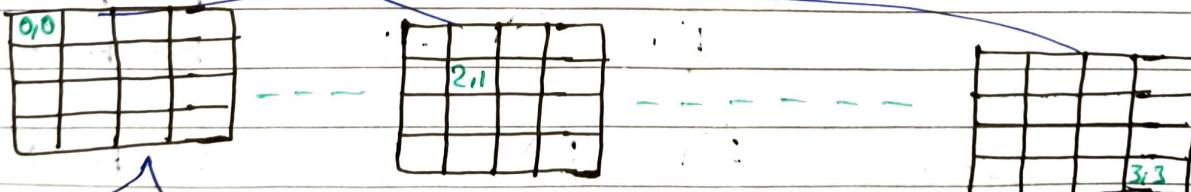
- Brute force method :- A brute force method is a simple, comprehensive search strategy that systematically explores every option until a problem's answer is discovered. It's a generic approach to problem solving that's employed when the issue is small enough to make an in-depth investigation possible.

Ques.

0,0			
			3,3

= 16

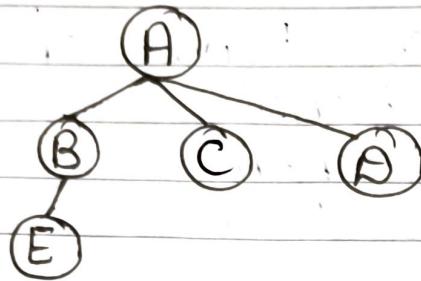
Current state



16 ways

①

15



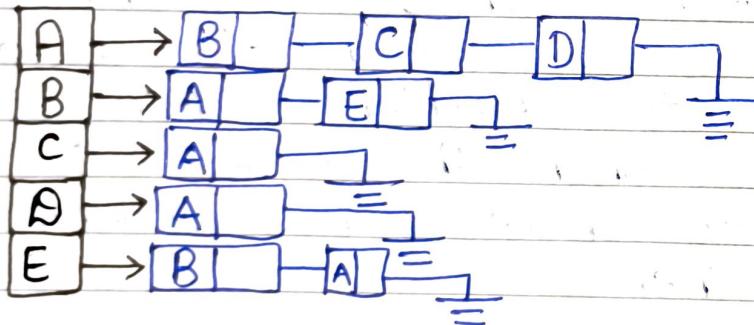
	A	B	C	D	E
A	X	1	1	1	0
B	1	X	0	0	1
C	1	0	X	0	0
D	1	0	0	X	0
E	0	1	0	0	X

Time Complexity  
 $O(n^2)$

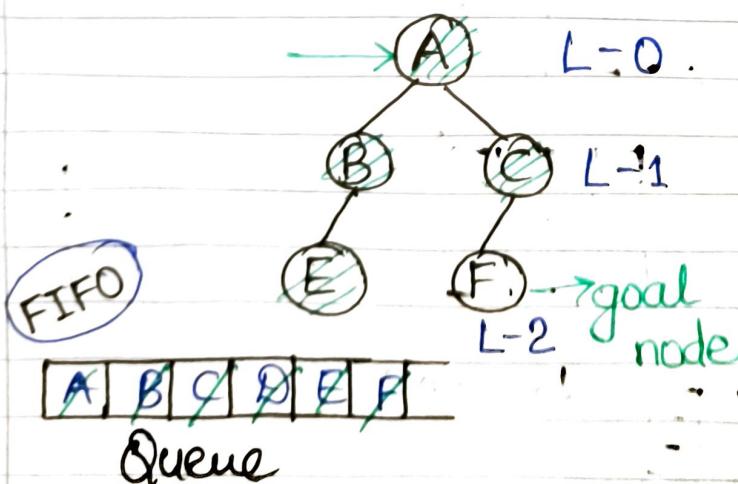
who is neighbour node of E.  
 $i=4$

```
for (i=0; i<=4; i++)
    if M[i][j] == 1
        Point (" ");
```

- Representation of linked list



- Breadth first Search (BFS)



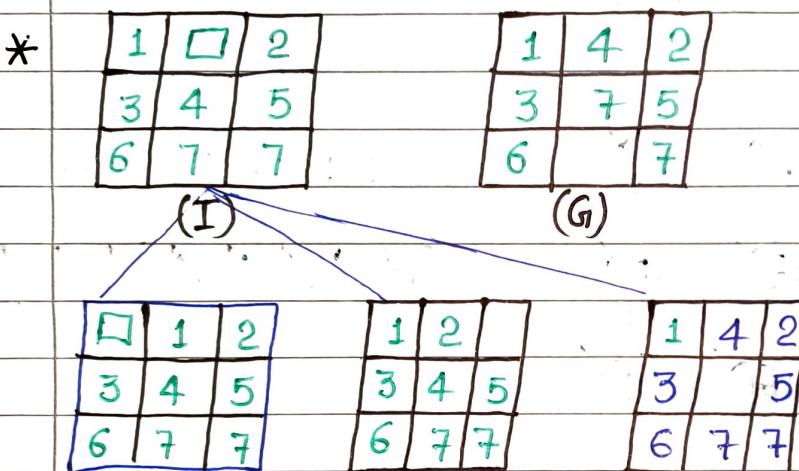
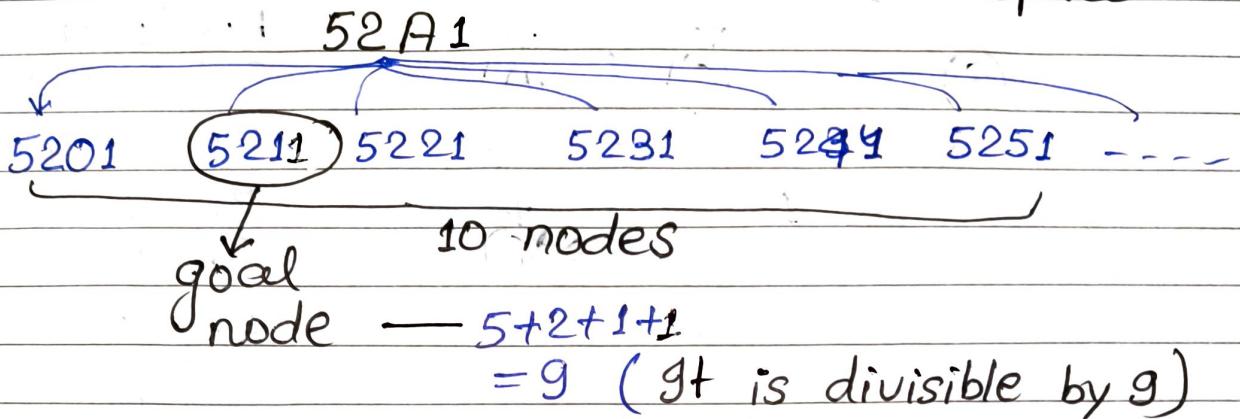
$\rightarrow$   
 $A \rightarrow B \rightarrow C \rightarrow D$   
 $B \rightarrow A - E$

$C - A - F$

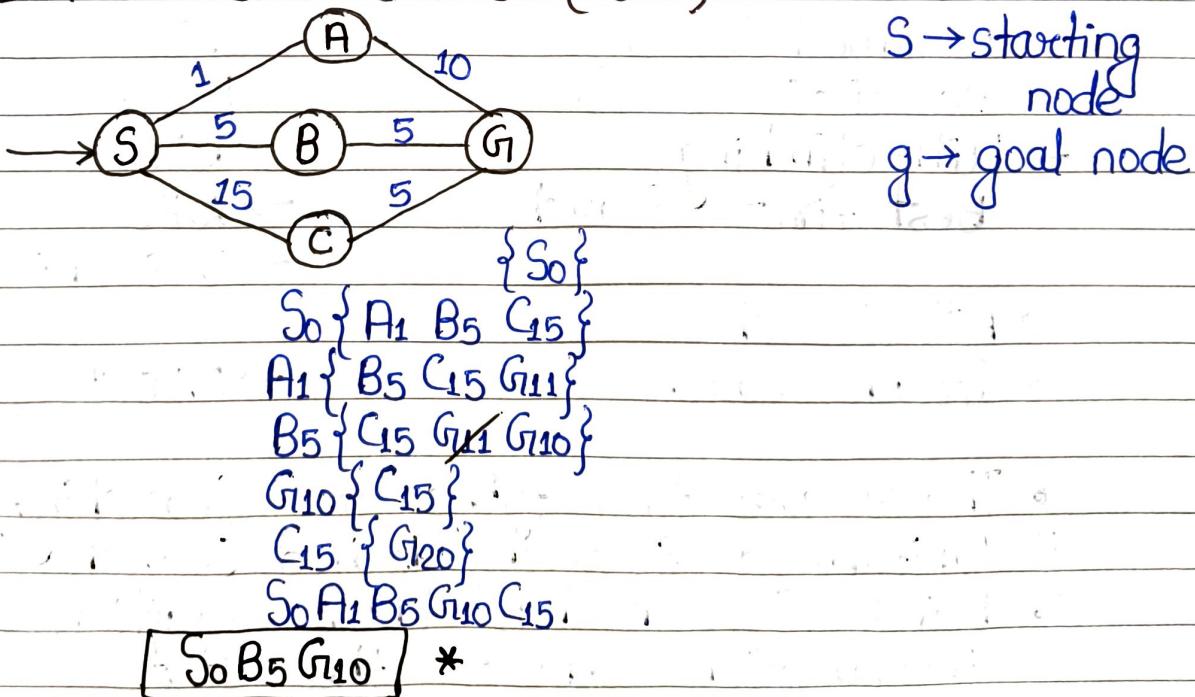
$D \rightarrow A$   
 $E \rightarrow B$

Ques.

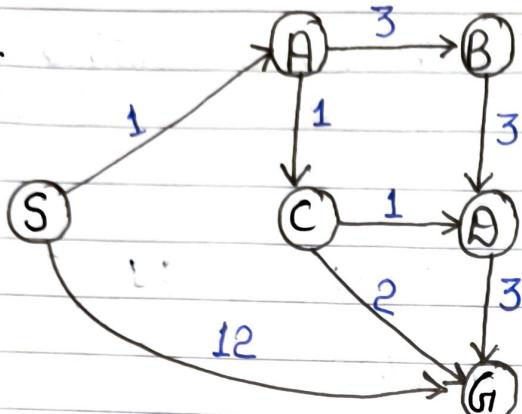
$52A_1 \rightarrow$  divisible by 9 using state space.



\* Uniform Cost Search (UCS)



Ques.

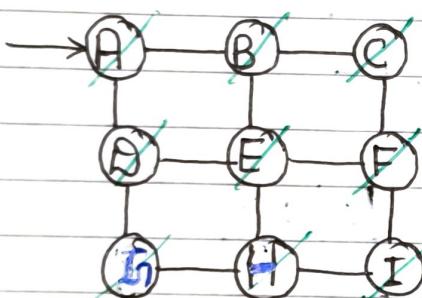


$\{S_0\}$   
 $S_0 \{A_1 G_{12}\}$ ,  
 $A_1 \{G_{12} B_4 C_2\}$ ,  
 $C_2 \{G_{12} B_4 D_3 G_4\}$ ,  
 $D_3 \{B_4 G_4 G_6\}$ ,  
 $B_4 \{G_4 D_7\}$ ,  
 $G_4 \{D_7\}$ ,  
 $D_7 \{G_{10}\}$ ,  
 $\emptyset$

$S_0 A_1 C_2 D_3 B_4 G_4 D_7$

SACG.

Ques.



ABACEGF.HI



★ Searching are two types -

Informed Search /  
Heuristic Search

→ Hill climbing /  
Best first Search

→ A\* Search

→ Graph Search

Uniformed Search /  
Blind Search

→ BFS

→ DFS

→ UCS (uniform cost  
Search)

→ DLS (Depth limited  
Search)

• There are two types of Searching -

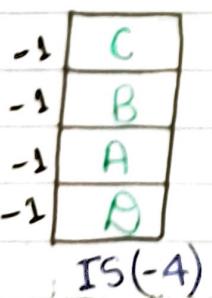
i) Uniformed Search / Blind Search :-

• Blind Search has know additional  
information about the state that

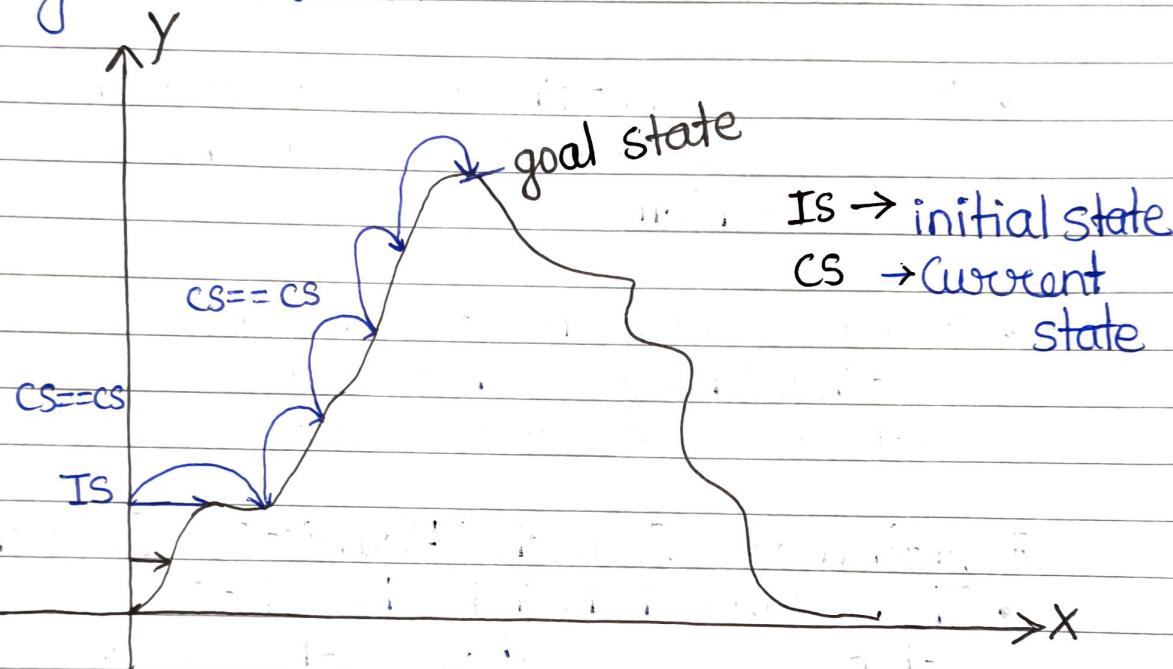
- Provided in the Problem definition.
- Blind Search does not take into account either execution efficiency or Planning efficiency.
- Does not contain no information about domain except information given by the definition of Problem.
- Blind Search might generates Successor state distinguishing between a goal state and non goal state.

## ii) Informed Search / Heuristic Search

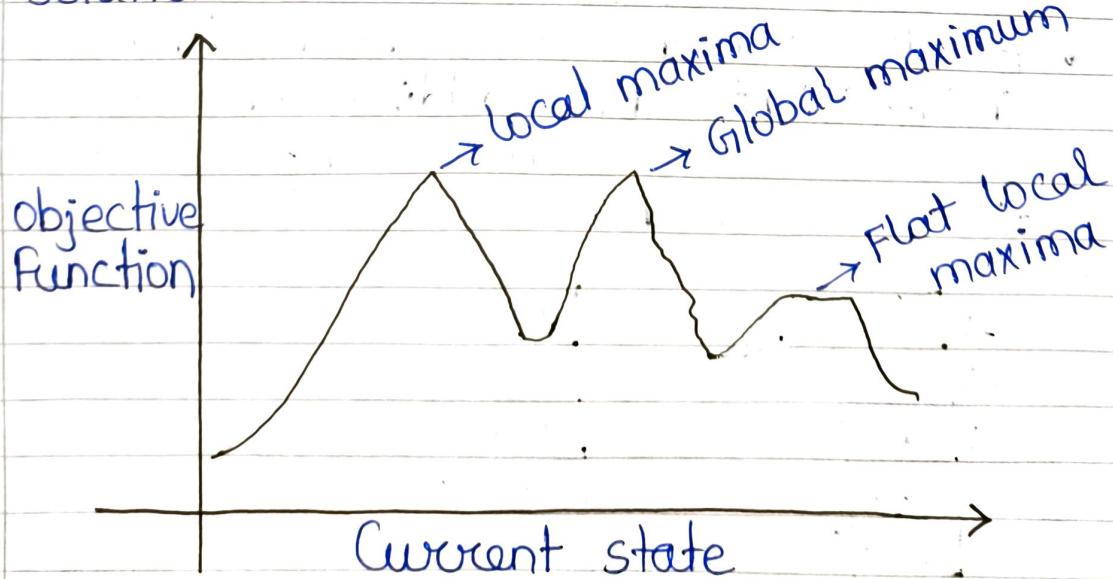
- The idea behind heuristic Search is that we explore the node or state i.e most likely to be nearest to the goal state.
- A Heuristic function has some knowledge about the Problem so that it can judge how the Current state is nearer to goal state.
- Blind Search are normally insufficient. By adding the domain knowledge we can improve it to heuristic Search.



- \* Hill climbing :- It is a simple optimization algorithm used in artificial intelligence to find the best possible solution for a given problem.



- \* Hill Climbing Algorithm  
One may like to climb hill whose each step taken moves you hire towards the peak that is optimal solution.



## key features of Hill climbing :-

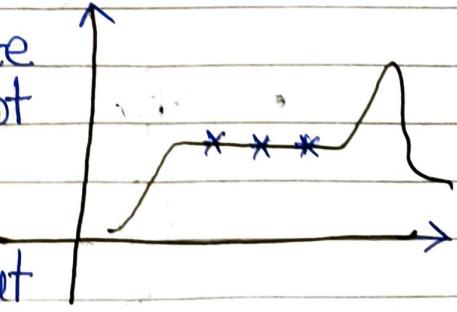
- i) Generates and Test approach.
- ii) Greedy local Search :- Algorithm use a cheap strategy of optaining for immediate benical move that promise local improvement.  
Generates and Test approach :- Generating neighbouring solution and evaluating their effectiveness.
- iii) No Backtracking :- The Search space does not go backward since it does not remember the previous state.

### \* Advantages and Disadvantages

- Simplicity :- The Algorithm is state forward to understand and implement.
- Memory efficient :- It is memory efficient maintaining only the current state.

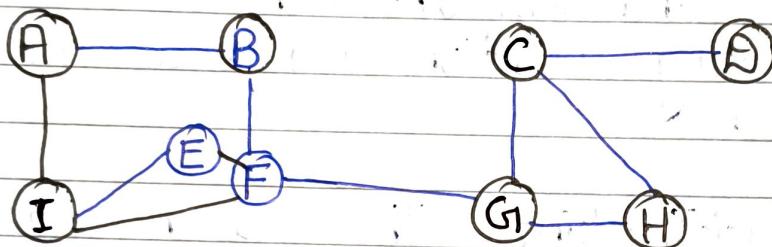
### Disadvantage

- local maxima - One Significant drawback is to get stuck in local maxima.
- Plateau :- Plateau is a plate where the algorithm does not find any improvement that may lead the algorithm to wander aimlessly without making further progress.

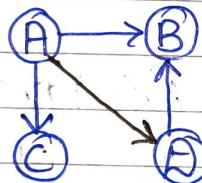


- Ridges :- Because all directions of movement are downward, every location on the ridge can be seen as a Summit. Therefore in this Circumstance , the algorithm fails .

\* Depth first Search

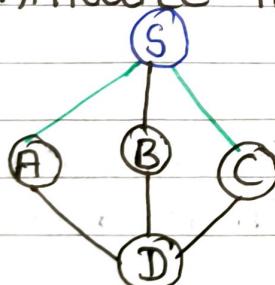


• Hill climbing

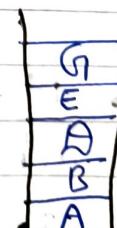
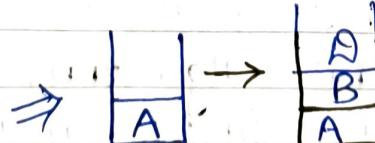
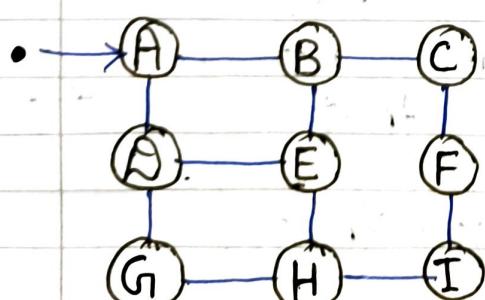


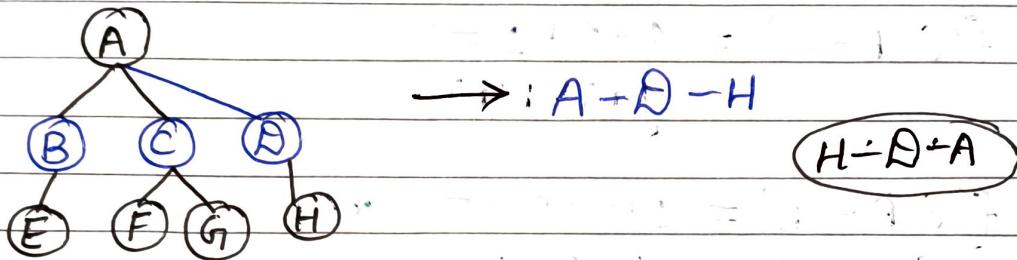
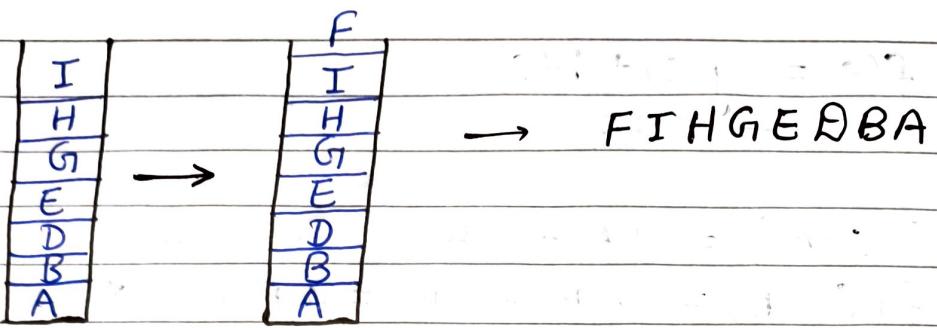
	A	B	C	D
A	0	1	1	1
B	0	0	0	0
C	0	1	0	0
D	0	0	0	0

• Initialize the stack



B C D A S

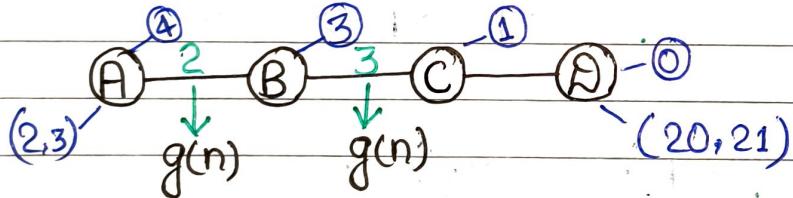




### \* A\* Search Algorithm

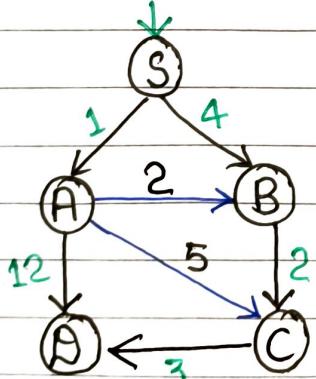
$$f(n) = g(n) + h(n)$$

↓      ↴ Heuristic value  
     ↴ The cost to reach the next node.  
     Total Cost



$$h(A) = \sqrt{(20-2)^2 + (21-3)^2}$$

\*



	$h(n)$
S	7
A	6
B	2
C	1
D	0

$$f(s) = g(s) + h(s)$$

$$= 0 + 7$$

$$f(s-A) = g(A) + h(A) = 1+6 = 7 \times$$

$$f(s-B) = g(B) + h(B) = 4+2 = 6 \times$$

$$f(s-B-C) = \frac{4+2+1}{g(n) \cdot h(n)} = 7 \times$$

$$f(s A \rightarrow B) = 1+2+2 = 5 \times$$

$$f(s A \rightarrow C) = 1+5+1 = 7$$

$$f(s A \rightarrow D) = 1+12 = 13$$

$$f(s AB \rightarrow C) = 1+2+2+1 = 6 \times$$

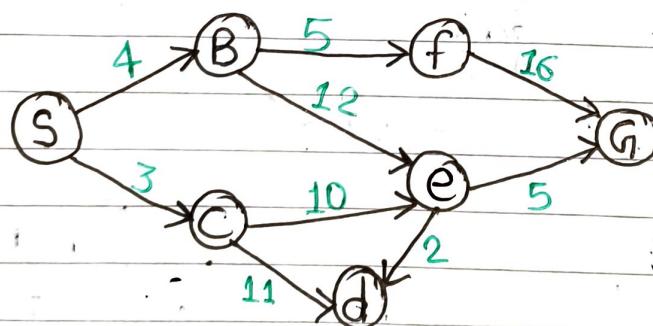
$$f(s BC \rightarrow D) = 4+2+3+0 = 9$$

$$f(s ABC \rightarrow D) = 8$$

$$f(s AC \rightarrow D) = 9$$

$s \rightarrow A \rightarrow B \rightarrow C \rightarrow D$

Q.



S - 14

B - 12

C - 11

D - 6

E - 4

f - 11

G - 0

$$f(n) = g(n) + h(n)$$

$$f(S) = 0 + 14 = 14$$

$$f(S-B) = 4 + 12 = 16$$

$$f(S-C) = 3 + 11 = 14$$

$$f(SC-d) = 3 + 11 + 6 = 20$$

$$f(SC-e) = 3 + 10 + 4 = 17$$

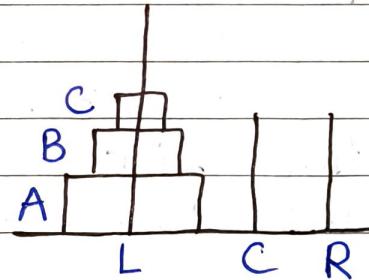
$$f(SB-e) = 4 + 12 + 4 = 20$$

$$f(SB-F) = 4 + 5 + 11 = 20$$

$$f(SC-e-g) = 18 \quad ***$$

### \* Tower of Hanoi :-

- Initially all the disks are stacked left.
- Requirement to transfer all the disk to right pole.
- One disk can removed at a time.
- Large disk can't be placed on a smaller disk.
- Center pole is temporary storage.



### \* Tower of Hanoi - Recursion

- Top  $N-1$  to be move from left (L) to Center (C).
- large disk from left to right.
- Move  $n-1$  disk from Center to right.

```
#include <stdio.h>
```

```
void transfer (int n) char from, char to ,  
char Temp);
```

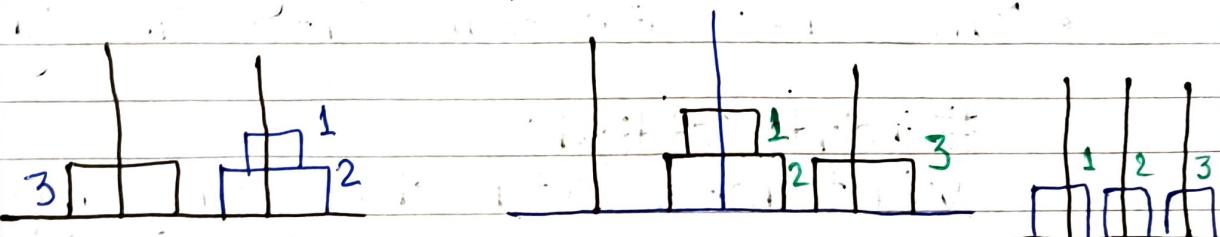
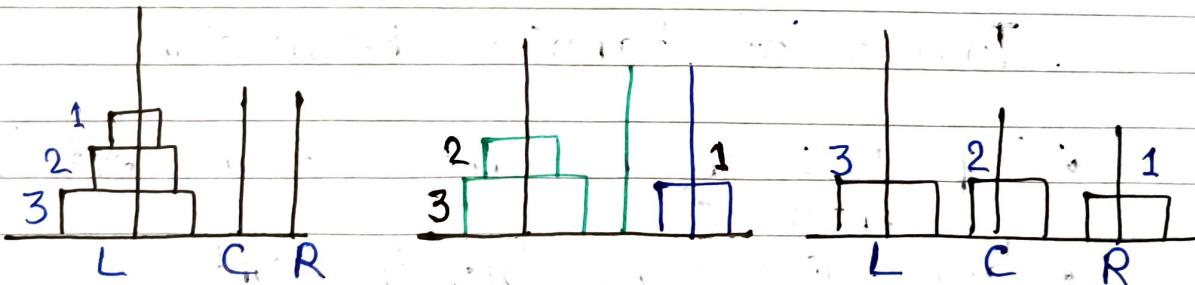
```

main() {
    int n
    Printf (" enter no. of disks");
    Scanf ("%d", &n);
    transfer('n', 'L', 'R', 'c');
}
void transfer (int n, char from, char to,
               char temp)
{
    transfer (n-1, from, temp, to);
    Print ("Move disk %d from %c to %c"; n,
           from, to);
    transfer (n-1, temp, to, from);
}

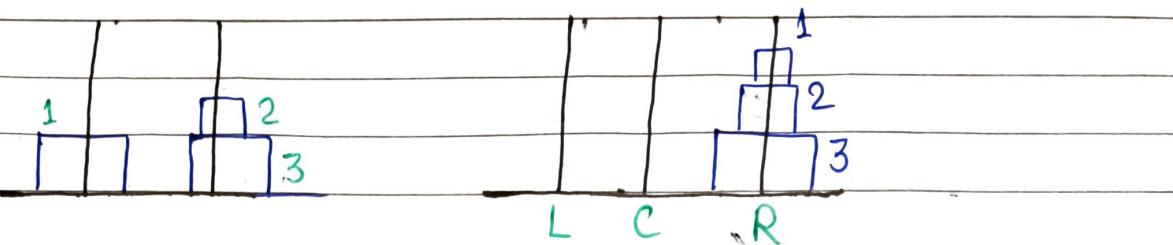
```

$n=3$

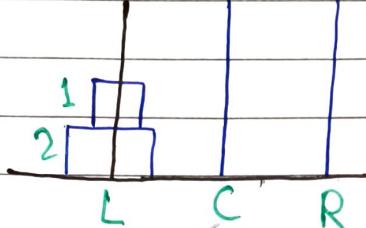
Move Disk 1 from L to R  
 Move Disk 2 from L to C  
 Move Disk 1 from R to C  
 Move Disk 3 from C to L  
 Move Disk 2 from C to R  
 Move Disk 1 from L to R.



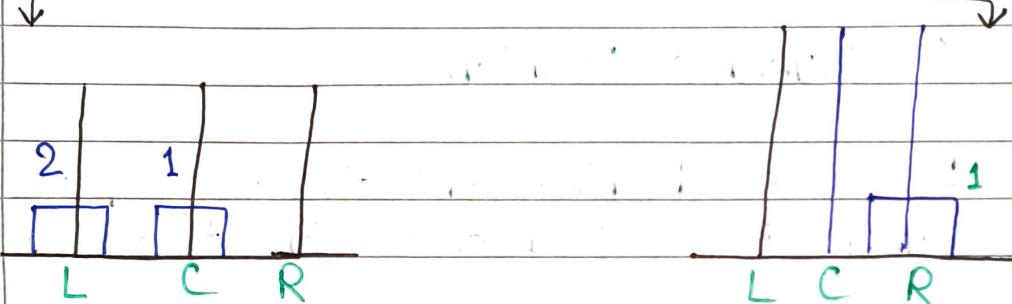
— / —



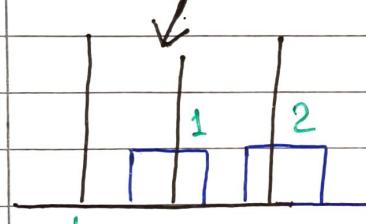
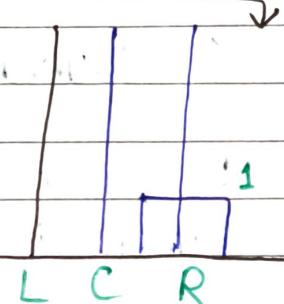
L C R



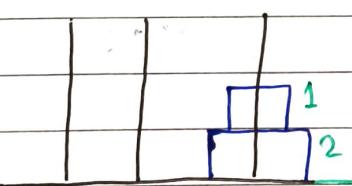
L C R



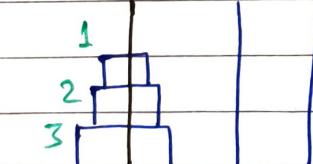
L C R



L

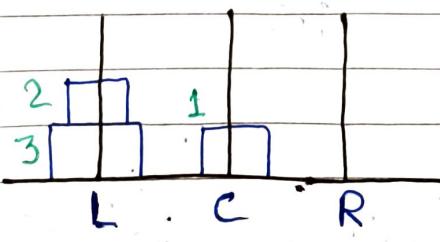


L-O



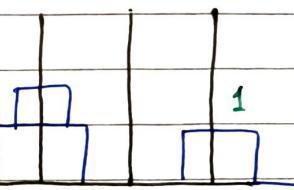
\*

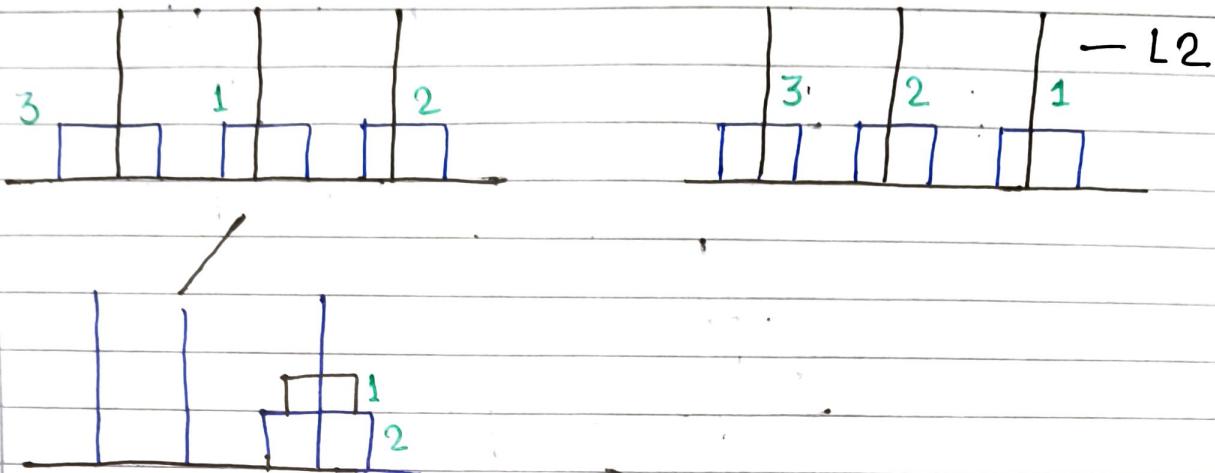
L-1



L C R

↔

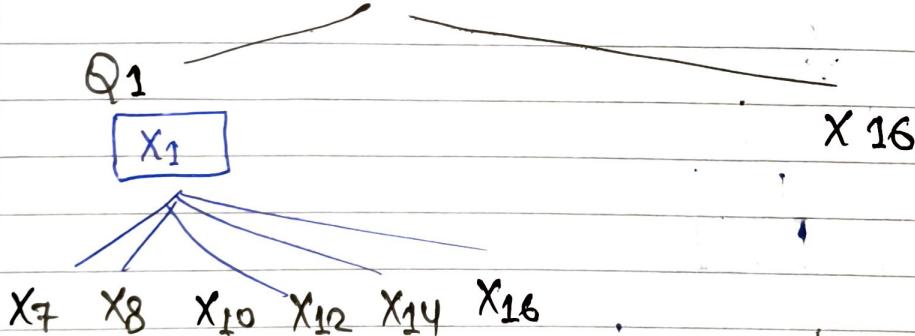




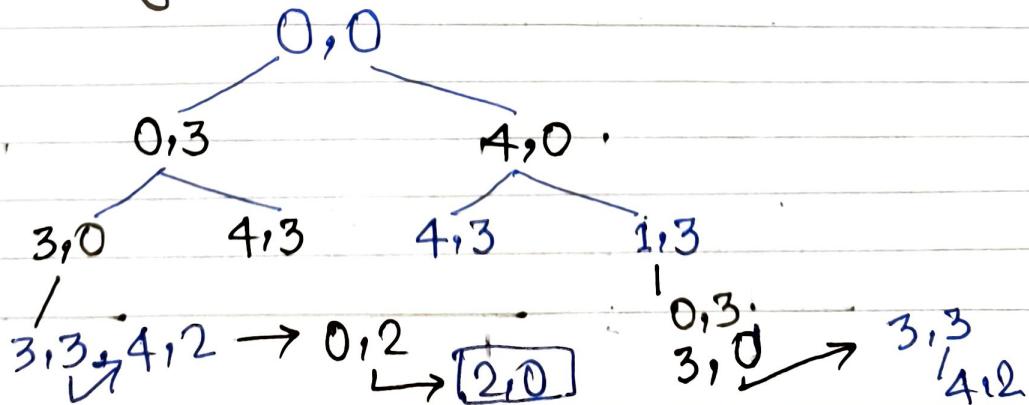
## \* 4 Queen's Problem

4 Queen's Problem objective is to place the Queen in  $4 \times 4$  matrix without any Conflict.

Q1	2	3	4
5	6	7	8
9	10	11	12
13	14	15	16



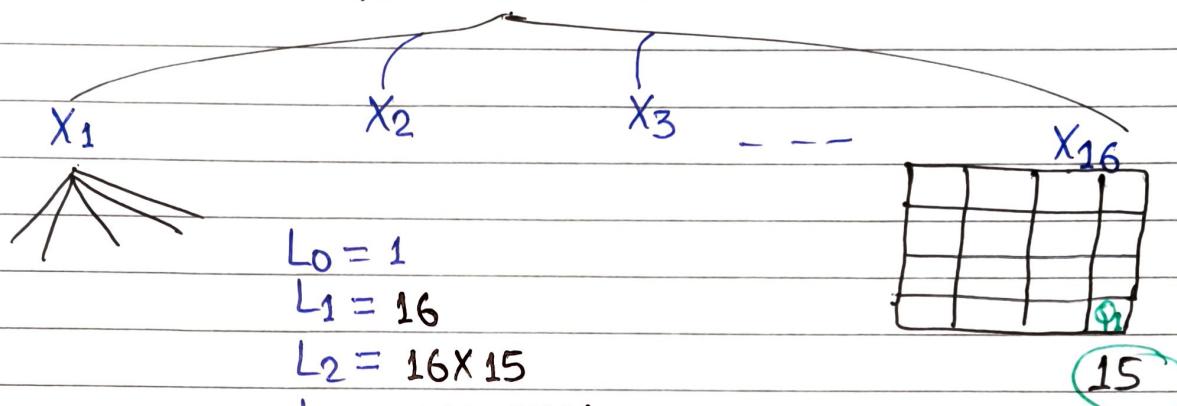
## \* Water Jug Problem :-



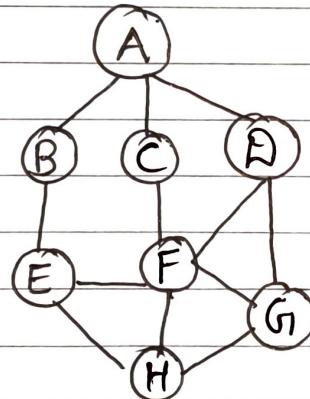
\*

1	2	3	4
5	6	7	8
9	10	11	12
13	14	15	16

Time complexity  
 $\downarrow$   
 $O(1)$ .



\*



E
G
F
D
C
B
A

E - G - F D C B A.