

# Artificial Intelligence

## Uninformed search techniques

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## Syllabus-

- **Uninformed Search strategies**

Formulation of real world problems, Breadth first search, Depth first search, Depth limited search, Iterative deepening depth first search, bidirectional search, Comparison of uninformed search strategies, searching with partial information, sensor less problems, Contingency problems

**Credits:- Algorithms and figures are taken from the book of Russell and Norvig artificial intelligence -a modern approach**

## AI Problem Solving Techniques

Searching is the important technique to solve many AI problems

1. Uninformed Search/Blind Search
2. Informed /Heuristic search

## What are uninformed search strategies?



-They are also called as “**blind search**” techniques

-**Definition:-** Search technique which “**do not have additional information**” about states beyond that provided in problem definition.

-They can only **generate successors** and **recognize the goal state** and **non-goal state**.

## Features of uninformed/blind search

- Searches the **state space** in an **exhaustive** way
- Can distinguish between **goal** and **non-goal** state
- They don't have **additional info** to guide the search.

## Why we need uninformed search strategies?

We do not have **additional information** (clue/hint) needed to quickly solve the problem

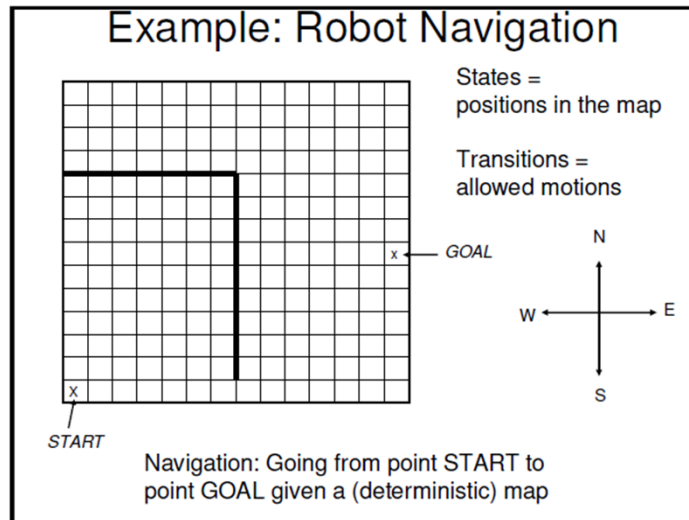


(Source: wikipedia)

### Missing Malaysian flight MH370

- Example1:-** Searching a location in the city assuming no body is present to help you
- Example2:-** Finding location of interest on Mars.

## Formulation of search problem-Robot navigation



<http://www.cs.cmu.edu/~awm/tutorials>

## Real world (generic) problem formulation

### Formulation

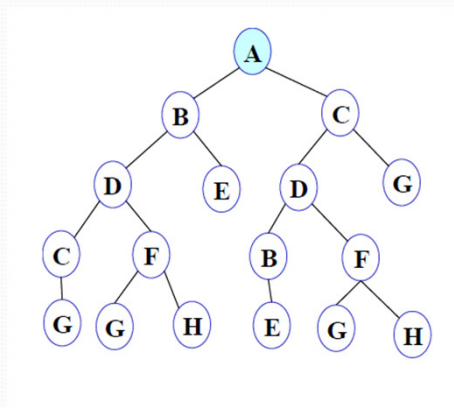
- $Q$ : Finite set of states
- $S \subseteq Q$ : Non-empty set of start states
- $G \subseteq Q$ : Non-empty set of goal states
- **succs**: function  $Q \rightarrow P(Q)$   
 $\text{succs}(s)$  = Set of states that can be reached from  $s$  in one step
- **cost**: function  $Q \times Q \rightarrow \text{Positive Numbers}$   
 $\text{cost}(s, s')$  = Cost of taking a one-step transition from state  $s$  to state  $s'$
- Problem: Find a sequence  $\{s_1, \dots, s_k\}$  such that:
  1.  $s_1 \in S$
  2.  $s_k \in G$
  3.  $s_{i+1} \in \text{succs}(s_i)$
  4.  $\sum \text{cost}(s_i, s_{i+1})$  is the smallest among all possible sequences (desirable but optional)

<http://www.cs.cmu.edu/~awm/tutorials>

## Breadth first search

- The **root node** is expanded first, then all the **successors** and so on.
- In general all the nodes are expanded at a given **depth** in the search tree before any nodes at the next level
- **BFS** uses **TREE-SEARCH** algorithm with an empty **fringe**, that is a **FIFO** queue, assuring that all the nodes visited first will be expanded first.
- Newly generated **successor nodes** are kept at the end of queue and hence **shallow nodes** are expanded before **deeper nodes**.

## Apply Breadth first search- FIFO fringe



G, C, F, B, F

G is Goal node,  
thus algo. halts

Let G is a goal node

Fringe- is a FIFO queue

A initially

B, C

C, D, E

D, E, D, G

E, D, G, C, F

D, G, C, F

E has no child

## Breadth first search-Analysis

- BFS has **exponential** time and space complexity.
- Let
  - **b**- be the branching factor of non-leaf nodes
  - **d**- be the depth of search tree
- Then **total nodes** on search tree

$$1 + b + b^2 + \dots + b^d = (b^{(d+1)} - 1) / (b - 1)$$

- Thus BFS has time and space complexity of  $O(b^d)$

## Breadth first search-Analysis

Let  $d=15$  and  $b=10$ , then BFS will generate  $10^{15}$  nodes and thus requires lot of time. Even if we have time it will run out of memory soon.

So BFS is efficient for small search spaces only.

### Advantages of Breadth First Search

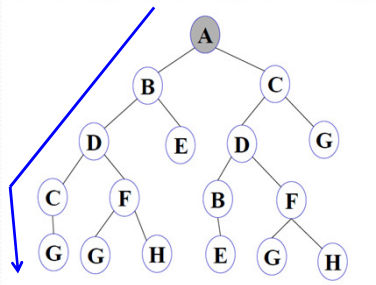
Finds the path of minimal length to the goal.

### Disadvantages of Breadth First Search

Requires the generation and storage of a tree whose size is exponential the the depth of the shallowest goal node

## Depth first search- LIFO fringe

- The fringe is LIFO now



A initially

B,C

D,E,C

C,F,E,C

G,F,E,C

G is Goal node,  
thus algo. halts

## Depth first search-Analysis

DFS takes worst case exponential time i.e  $O(b^d)$ .

Let N be the maximum depth of a node in search tree.

However the space taken is linear in the depth of search tree i.e  $O(bN)$

If search tree has infinite depth DFS may not terminate

If the search tree has infinite depth (due to cycles) then algorithm may not terminate, this drawback can be eliminated using **Depth limited search Algorithm**

## Depth Limited Search

- It is a variant of DFS that uses a depth “**Bound/limit**”.
- Nodes are only expanded if they have depth less than or equal to the bound. Fringe is **LIFO** structure.

Depth limited search (limit) Let fringe be a list containing the initial state Loop if fringe is empty return failure Node $\leftarrow$ remove-first (fringe) if Node is a goal then return the path from initial state to Node else if depth of Node = limit return cutoff else add generated nodes to the front of fringe End Loop
---

## Depth Limited Search-Analysis

**Let  $l$  be the depth limit and  $d$  be the actual depth of search tree**

**DLS may not find solutions present at depths  $> l$**

**DLS will also be nonoptimal if we choose  $l > d$**

**DLS has time and space complexity of  $O(b^l)$  and  $O(bl)$**

**DLS can report two kinds of failure**

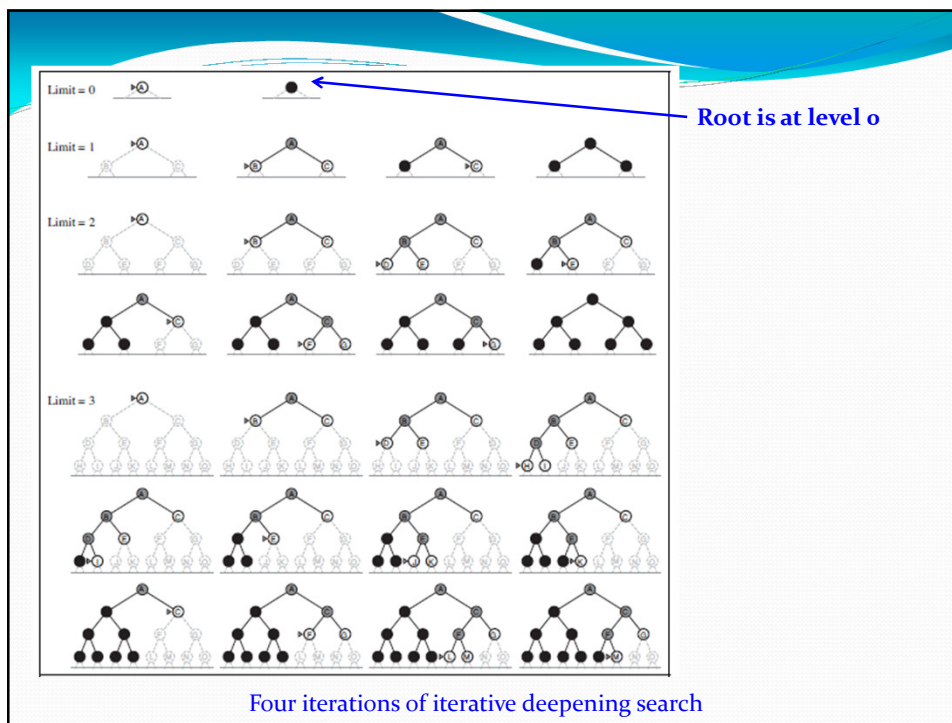
**standard failure and cut-off**

## Iterative Deepening Search

- It is also called **Iterative deepening Depth First Search**
- It combines benefits of **DFS** and **BFS**.
- Per iteration it **increases** the depth limit by **1**.

```

function ITERATIVE-DEEPENING-SEARCH(problem) returns a solution, or failure
  for depth = 0 to  $\infty$  do
    result  $\leftarrow$  DEPTH-LIMITED-SEARCH(problem, depth)
    if result  $\neq$  cutoff then return result
  
```



## Iterative Deepening Search (IDS)

- The **upper levels** of search tree are generated **multiple times** and thus, **IDS** needs **more efforts**.
- But it is **not very costly**, since **most** of the nodes are present at the **bottom of the tree**.

$$N = (d)b + (d-1)b^2 + \dots + (1)b^d$$

- IDS is preferred **blind search** method when there is **large search space** and **depth** of solution is **not known**.
- It finds **shallowest solution** (solution at lower levels)

## Iterative Deepening Search (IDS)

In **IDS** nodes at the **bottom level** (depth **d**) are generated once, thus total nodes generated (**N**) in **IDS** is

$$N = (d)b + (d-1)b^2 + \dots + (1)b^d$$

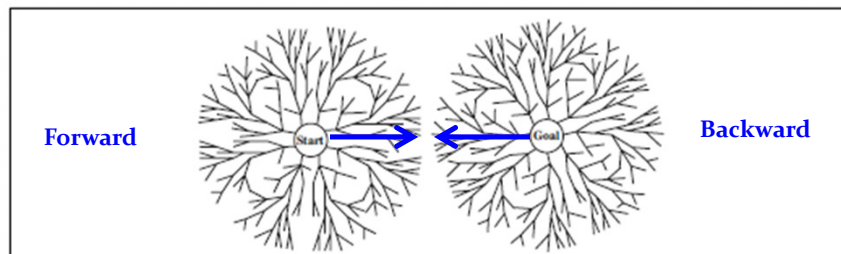
**b<sup>d</sup>** are created only **once**, then **b<sup>(d-1)</sup>** nodes are created twice and so on.... and **b** nodes are created **d** times

## Iterative Deepening Search (IDS)

- Class exercise 1:-
- Compare **BFS** and **IDS** for some combinations of d and b. (refer :- Russell and Norvig)

## Bidirectional search

- It uses **two simultaneous searches** one **forward** -from initial state and the other **backward** from the goal, and stops when two searches **meet** in the **middle**.
- Each search takes **alternate** turns.



## Bidirectional search

- If a problem has solution **depth=6**, and each direction runs **BFS** one node at a time, then in worst case two searches will meet at **depth=3**.
- **Both searches** check **each node** before it is expanded, to see if it is the **fringe** of other search. If so, **a solution** has been found.

Time and space complexity of BDS is  $O(b^{d/2})$

## Bidirectional search

- Reduction in time complexity makes **BDS** attractive.
- But **how to search backward**? Is a problem.
  - Using two functions **Predecessor** and **Successor**
  - **$Pred(n)$** - gives all the **predecessors** of node **n**
  - **$Succ(n)$** - gives all the **successors** of node **n**
- Forward search will use  **$Succ()$**  and backward will use  **$Pred()$** .
- For **BDS** is good to have **one or very few goal states** e.g in 8-puzzle there is only **one goal state** that makes it easy to search backward.
- More goal states (like in chess) makes **backward** search difficult.

## Comparison of uninformed search strategies

Criterion	Breadth First Search	Depth First search	Depth limited	Iterative deepening	Bidirectional
Complete?	YES	No	No	Yes if b is finite	Yes if both directions uses BFS (Y)
Time	$O(b^{d+1})$	$O(b^m)$	$O(b^l)$	$O(b^d)$	$O(b^{d/2})$
Space	$O(b^{d+1})$	$O(bm)$	$O(bl)$	$O(bd)$	$O(b^{d/2})$
Optimal?	YES	No	No	Yes, if all steps has same cost (X)	Yes, if X and Y

$m$  – is maximum depth of any branch,  $l$  – is depth limit

$d$  – is actual depth of tree,  $b$  – is branching factor

## Searching with partial information

- Most of the time, an agent works in a **fully observable** and **deterministic** environment.
- Thus, agent can compute exactly the **state** resulting from applying a **sequence of actions**.
- What happens when knowledge of **states** or **actions** is incomplete?
- This **in-completeness** leads to **3 kinds** of problems
  1. **Sensor less problems**
  2. **Contingency Problems**
  3. **Exploration problems**

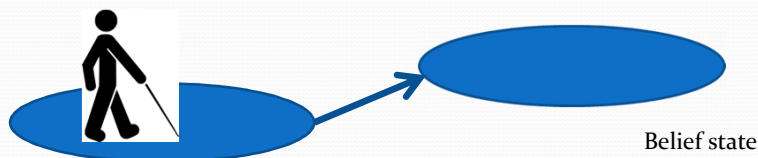
## Searching with partial information

- **Sensor less problems:-** (conformant Problems) If an agent has no sensors at all, then it could be in one of the several **initial state** and each **action** might lead to one of the several **successor states**.
- E.g (movement of visually impaired person)



## Sensor less problems

- When the world is not **fully observable**, the agent must reason about **sets of states** it might get to, rather than single states. Such sets of states is called “**belief state**”, representing **belief** about possible physical states.
- **Exercise2:-** Learn vacuum cleaner agent example from Russell and Norvig



## Searching with partial information

- **Sensor less problems**
- How to solve sensor less problems?
- We search in the space of **belief states** rather than **physical states**.
- The initial state is a **belief state** and each action maps from one **belief state** to another.
- A **path** now connects several **belief states** and a **solution** is now a path that leads to a **belief state**, all of whose members are goal states.

## Searching with partial information

- **Contingency Problems:-**

(Contingency is unpredicted event)

- Agent has **sensors** to sense its environment and can get new information (called **Contingency**).
- No “**fixed action sequence**” guarantees a solution and hence agent can not **plan**.

NASA path finder Mars exploration



## Searching with partial information

### Contingency Problems:-

-The solution to the contingency problem often takes the form of a tree, where each branch may be selected based on percept received at that point in the tree.

- Start acting and see Which contingencies do arises?



Exercise3:- Learn working of an agent in Murphy's Law World from Russell and Norvig

## Searching with partial information

### Exploration Problems:-

- When the states and actions of the environment are unknown, the agent must act to discover them.
- These are extreme cases of contingency problems.
- Agents discover states
- Agents optimizes a function to decide best possible action

