Search Algorithms

General Search Framework

Use 2 arrays

> **Frontier :** Store unexplored states
> **Explored :** Store explored states (if don't want to re-explore)

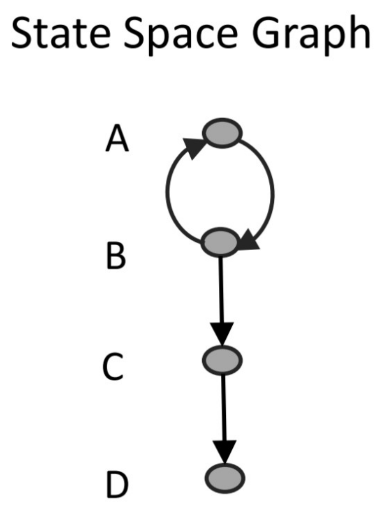
Repeat until solution is found (success) or lost (failure)

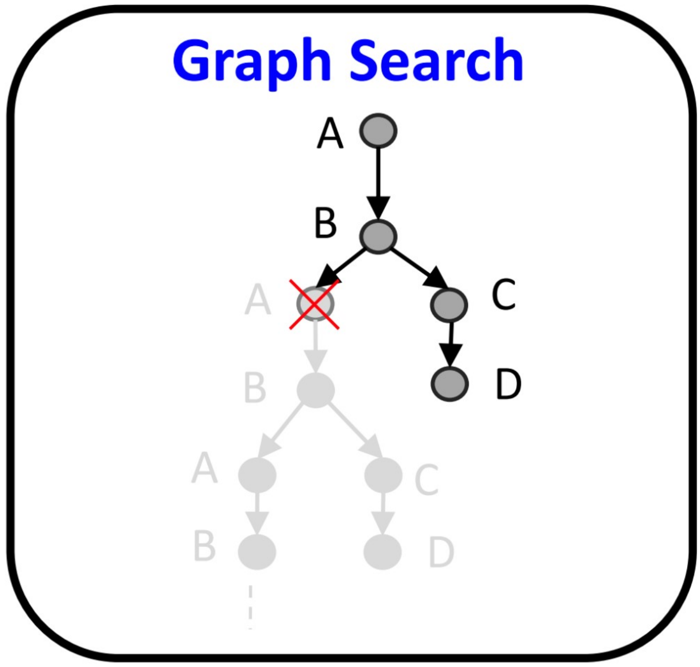
General Tree Search

- There is **repeated states** (Will result in infinite size tree)
- Goal states are checked when a node is explored (not when generated)

General Graph Search

There is **no repeated states** (Make use of **explored** array)





> Check out both Tree and Graph Search flowchart in lecture slides 🎗

Uniform Search Algorithms

Each Algorithm has its Tree (repeat) and Graph (no repeat) variants

Breadth First Search (BFS)

- Starts with the **shallowest** nodes in the frontier first
- Nodes are explored **lvl by lvl**
- **FIFO Strategy** (Use a **Queue**)
- Stop when **goal node found (success)** or **no more nodes to expand (failure)**
- Always returns the shallowest solution at depth **s**

> **Cost is not considered** in BFS **(Existence of goal is more important)**

BFS can have **BFS Tree Search and BFS Graph Search**

Refer to slide 35 and 36 for propeties of BFS (Time Complexity, etc..) 🔍

Depth First Search (DFS)

- Explores the deepest node in the frontier first
- Proceeds immediately to the leaf nodes before turning back (Backtracking)
- **LIFO Strategy** (Uses a **Stack**)

Refer Slide 53 and 54 for DFS Propeties 🔍

Iterative Deepening DFS (IDS)

- Solves the problem of DFS traversing infinitely deep by gradually increasing the depth limit
- Combines the best of BFS and DFS
  - BFS - **Completeness** (When BF is finite and optimal when the path cost is increasing monotnically layer to layer) (Means that a high level, low cost)
  - DFS - **Low Mem Requirement**

> Preferred when **large search space** and the **Unknown depth of solution**

Refer Slide 58 🔍

Optimality

Both DFS and BFS don't consider path cost 💰

DFS	BFS
Shallowest Solution	Left/Right-most solution

Both are not necessarily the optimal solution

Refer Slide 60 🔍

Uniform Cost Search (UCS)

- Selects the frontier node with **lowest path cost**
- Implemented using **priority queue** (auto sort the states based on ascending cost)

Refer to Slide 72 to 74 for UCS propeties 🔍

Informed Search

> UCS is **backward looking**, processed **based on distance from start node** $g(n)$

An informed search algorithm uses a **heuristic function** to choose a good node from the frontier

Heuristic Function

A **heuristic function** $h(n)$

- **Estimates** how close is a state to the goal
- Makes the algorithm **forward-looking**
- Designed for particular search problem
- Not necessarily perfect

Types of Informed Search Algorithms

- **Greedy Best First Search** considers only $h(n)$, $f(n) = h(n)$
- A* Search considers both $g(n)$ and $h(n)$, $f(n) = g(n) + h(n)$ (current + foward)

Example of heuristics

- Manhattan Distance (x and y)
- Euclidean Distance (Diagonal)

A* Search

Make use of a new evaluation function, $f(n)$ that combines

- Actual performance of the various paths explored so far, $g(n)$
- Estimated cost to the goal, $h(n)$

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

Admissibility Requirement for A* Graph Search

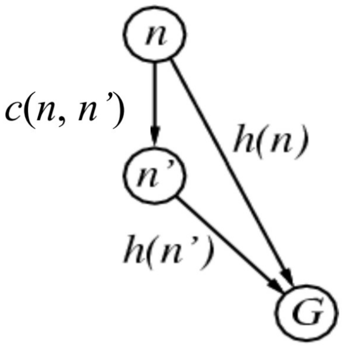
> **Admissibility :** For A* Tree Search to be optimal, the heuristic estimation must be less than actual cost

Consistency Requirement for A* Graph Search

For graph search, the $h(n)$ needs to be ***consistent*** to make it optimal

Definition of **Consistency**

> $h(n)$ is consistent if for every node n, every successor n' of n generated by any action a, obeys the **triangle inequality**



$$h(n) \leq c(n, n') + h(n')$$

--> propety of triangle

> **Consistency** requirement is a **stricter** requirement compared to **admissibility**.
> **A consistent heuristic must be admissible too**

Refer Slide 93 🔍

A* Search Evaluation

Refer slide 94 🔍

Choosing Heuristics

A better heuristic **provides better estimates**

N-puzzle has 2 possible heuristics

- Number of misplaced tiles
- Manhattan Distance (Distance of tiles to their correct position) ☑️