A presentaion on A* search algorithm

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Introduction

Figure: Using Navigation Assistants

Definition

What is Graph Traversal?

Graph traversal (also known as graph search) refers to the process of visiting (checking and/or updating) each vertex in a graph.

Definition

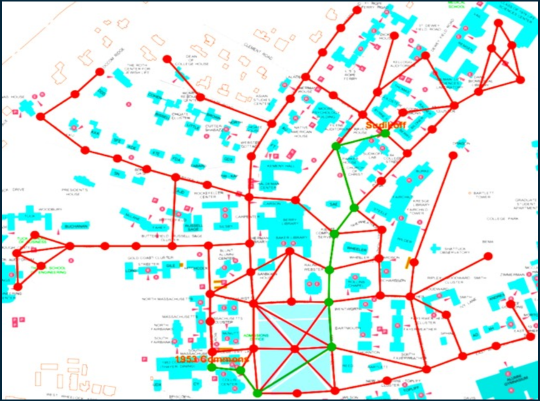

Figure: Using Graph Traversal Algorithms

Definition

What is A* search?

A* search is a path-finding and graph traversal algorithm which is basically an evolution of Dijkstra's algorithm

Why A* search?

As we have already mentioned, A* search is basically a modification of Dijkstra's algorithm.

- But why do we need A* search?

Why A* search?

As we have already mentioned, A* search is basically a modification of Dijkstra's algorithm.

- But why do we need A* search?
- What are the benefits of A* over Dijkstra's algorithm or other such algorithms which validates the modification?

A* search Overview

To answer that question we first need to know how the A* search algorithm works

- You see, Dijkstra's algorithm is a greedy algorithm and so it always immediately chooses the best possible path at every step

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- You see, Dijkstra's algorithm is a greedy algorithm and so it always immediately chooses the best possible path at every step
- Even if the chosen path strays away from the destination, it isn't smart enough to detect that
- That's why it needs to visit a lot more nodes to come to a conclusive decision

Figure: A* search vs Dijkstra

How does A* manage to be this efficient?

HEURISTICS

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- It employs a practical method not guaranteed to be optimal or perfect
- But it is sufficient for the immediate goals

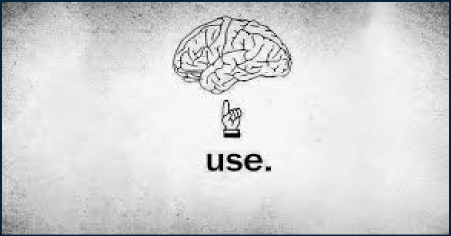

Figure: Using Heuristics

Let's come back to this diagram again

Figure: A* search vs Dijkstra

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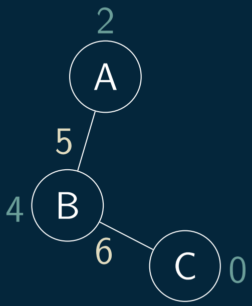
- It can be of many different kinds
- For example, the Euclidean distance can be an obvious one
- The shorter the Euclidean distance of a node from the destination the more likely it is to be included in the optimal path

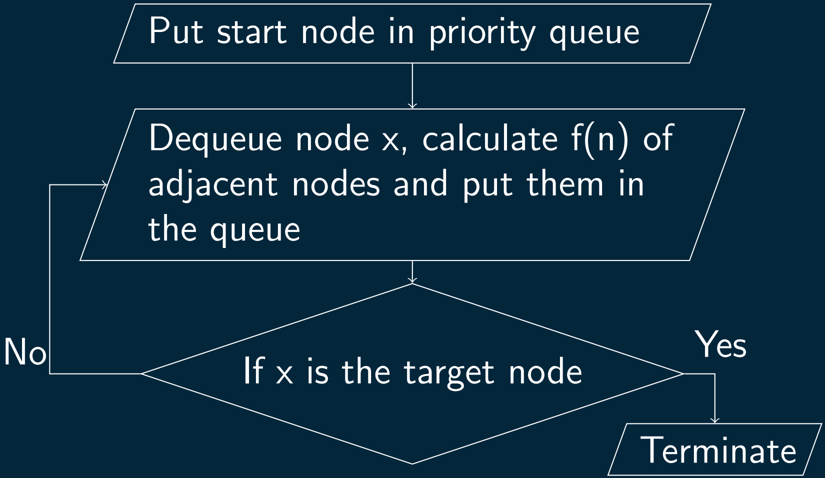
Figure: Using Euclidean Distance as a Heuristic measure

A* Search Algorithm



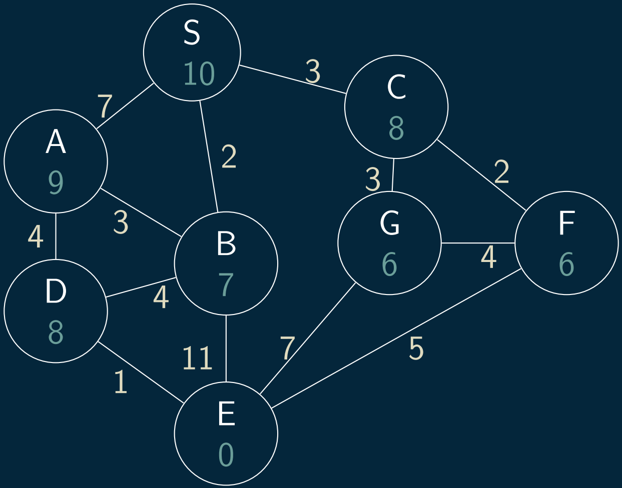
$$f(n) = d(n) + h(n)$$

Flow Chart

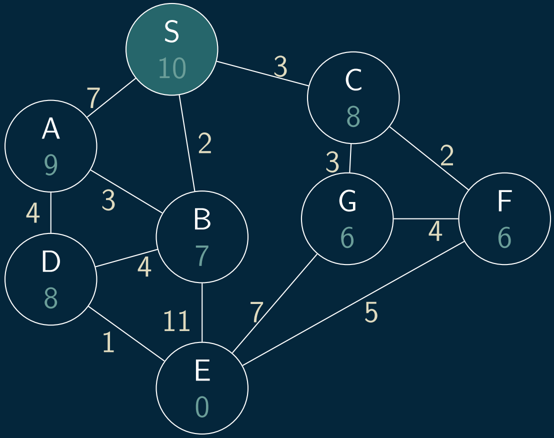

Put start node in priority queue
Dequeue node x, calculate f(n) of adjacent nodes and put them in the queue
If x is the target node
No
Yes
Terminate

Example

Graph



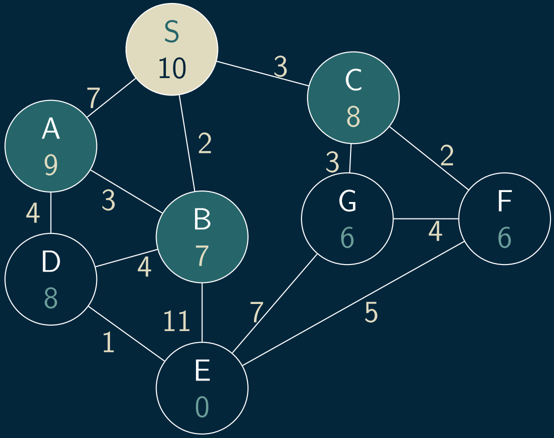
Example



Priority Queue

S(NULL) -> 0 -> 10

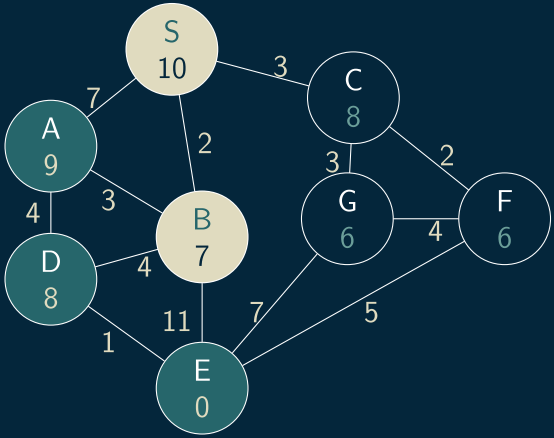
Example



Priority Queue

B(S) -> 2 -> 9
C(S) -> 3 -> 11
A(S) -> 7 -> 16

Example



Priority Queue

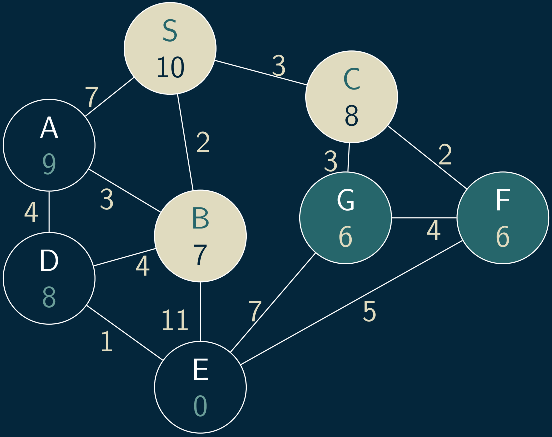
C(S) -> 3 -> 11

E(B) -> 13 -> 13

A(B) -> 5 -> 14

D(B) -> 6 -> 14

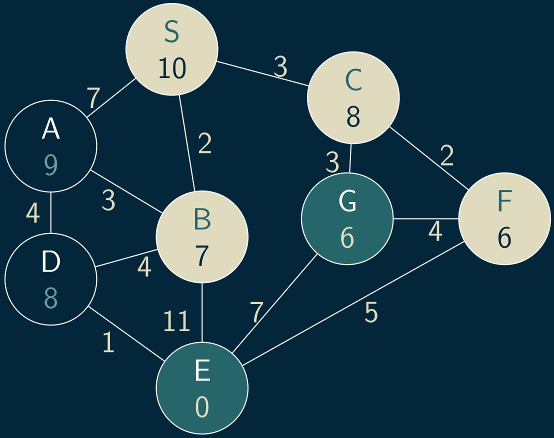
Example



Priority Queue

F(C) -> 5 -> 11
G(C) -> 6 -> 12
E(B) -> 13 -> 13
A(B) -> 5 -> 14
D(B) -> 6 -> 14

Example



Priority Queue

E(F) -> 10 -> 10
G(C) -> 6 -> 12
A(B) -> 5 -> 14
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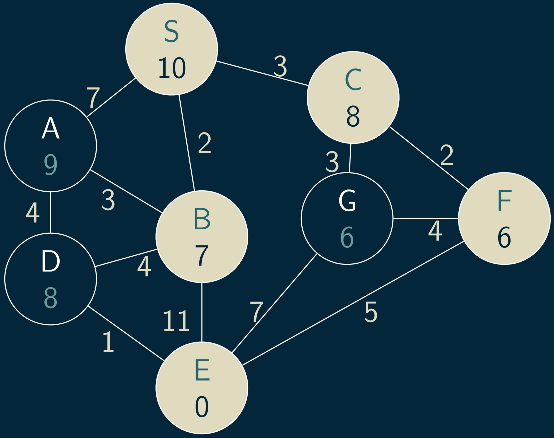
Example



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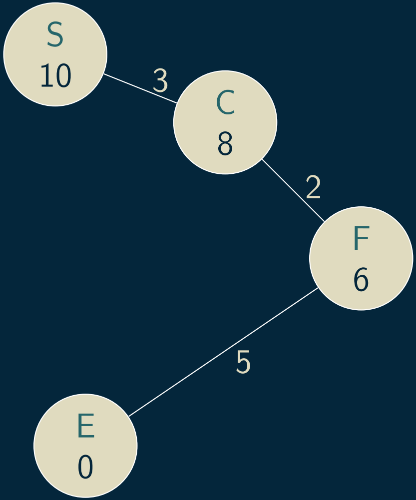

Figure: Expected shortest path

Exact Heuristics

Using exact distance from any node n to goal node as $h(n)$

- Precompute distances between each pair of nodes

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Exact Heuristics

Using exact distance from any node n to goal node as $h(n)$

- Precompute distances between each pair of nodes
- Time-consuming
- Equal to Euclidean distance if there is no other node on the direct path

Manhattan Distance

$$h(n) = \mid n.x - g.x \mid + \mid n.y - g.y \mid$$

- Suitable for 2D grids
- Movement is allowed only in x or y axis (4 directions)

Diagonal Distance

$$h(n) = \max\{|\ n.x - g.x\ |, |\ n.y - g.y\ |\}$$

- Suitable for games like chess
- Both axial and diagonal movements are allowed (8 directions)

Euclidean Distance

$$h(n) = \sqrt{(n.x - g.x)^2 + (n.y - g.y)^2}$$

- Suitable for graphs
- Movement in any direction is allowed

Implementation

Implementation details that can affect the performance of A*

- Breaking ties in deciding minimum element of priority queue

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Implementation details that can affect the performance of A*

- Breaking ties in deciding minimum element of priority queue
- Alternative heap implementations of priority queue

Breaking Ties

How to break ties in priority queue?

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  - Prefer the nodes closest to the goal
- **cross product of s-g and n-g vectors**
  - Prefer paths on the start-goal straight line
- **LIFO like DFS**
  - Prefer new insertions to old insertions

Which heap to use?

Binary Heap

VS

Fibonacci Heap

Which heap to use?

Operation	Delete-min	Insert	Decrease-key
Binary Heap	$\Theta(\log n)$	$\mathcal{O}(\log n)$	$\mathcal{O}(\log n)$
Fibonacci Heap	Amortized $\mathcal{O}(\log n)$	$\Theta(1)$	Amortized $\Theta(1)$

Table: Time-complexity comparisons

Which heap to use?

Binary Heap

VS

Fibonacci Heap

Time Complexity

Branching Factor (b)

Average number of neighbours at each node

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Average number of neighbours at each node

Depth of Solution (d)

Number of nodes in the shortest path

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Time Complexity : $\mathcal{O}(b^d)$ or $\mathcal{O}(\mid E \mid)$

Where do we use A*?

Figure: Tower Defense

Where do we use A*?

- **Finding shortest path in games**

  - mostly single source, single destination

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- **Graph Traversal**
  - originally designed for this purpose
- **Artificial Intelligence**
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- **Navigation**
  - Google Maps & other digital maps

THE END

Thank You !

Feel free to ask any questions