> StartBig

MESA

Second Practical

2023

WHO IS THIS GUY?

Giovanni Manfredi

- MESA active Member since October 2022
- Participant at IT Sprint 2023 in Skopje, North Macedonia
- HO and creator of StartBig
- Tech savvy since I was 6 years old

AGENDA

- **MESA** - What is MESA?
- What **does** MESA do?
- How do I **join**?
- What about **StartBig**?

What is MESA?

Local Association

MESA

Milan **E**ngineering
Student **A**ssociation

European Association

eestec

Electrical **E**ngineering **ST**udent
European Asso**C**iation

What does MESA do?

EVENTS!

Hard Skills

Soft Skills

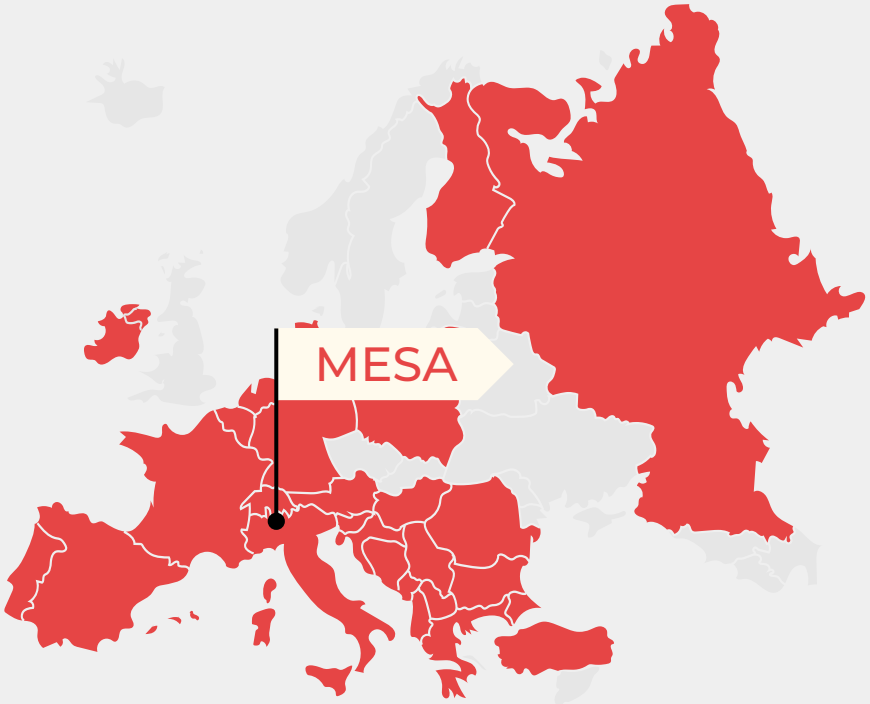
>startBig

EESTech Challenge

4th edition of SKILLING me softly

LEADERSHIP T.O.O.L.
LEADERS OF TOMORROW

An International Network



24 countries

43 universities

5000+ people

5 regions

How do I join?

Scan the QR and
click on the section Join us

What about StartBig?

CareerService session

How do we get to do a coding interview?

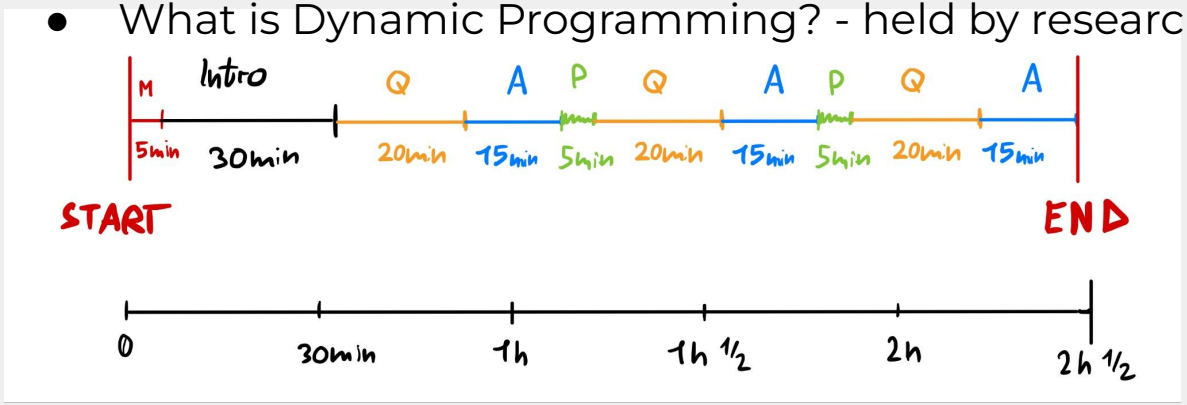
CareerService is here to help us find that out!

3 Practical sessions

How can we prepare for a coding interview?

Content of the sessions:

- Introduction to coding interview questions - held by me
- Trees & Graphs (DSF & BSF algorithms) - held by researcher Davide Yi Xian Hu
- What is Dynamic Programming? - held by researcher Nicolò Felicioni



LeetCode

GitHub

Company session

How is the true experience behind coding interviews?

Andrea from **Oracle** will help us understand that!

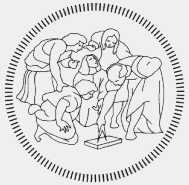
There will be a small ice-breaker interview and then open questions from you!

Tutors here to help!

STAGE TO ...

Davide Yi Xian Hu

PhD Student in
Information Technology



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Trees and Graphs

Davide Yi Xian Hu
Email: DavideYi.Hu@Polimi.it

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Intro Presentation

Davide Yi Xian Hu

👉 Ph.D. Student Information Technology

👉 Mail: DavideYi.Hu@Polimi.it

👉 Research Interests:

- 🔎 Deep Learning Testing
- 🔎 Computer Vision Applications

Trees

Tree Definition

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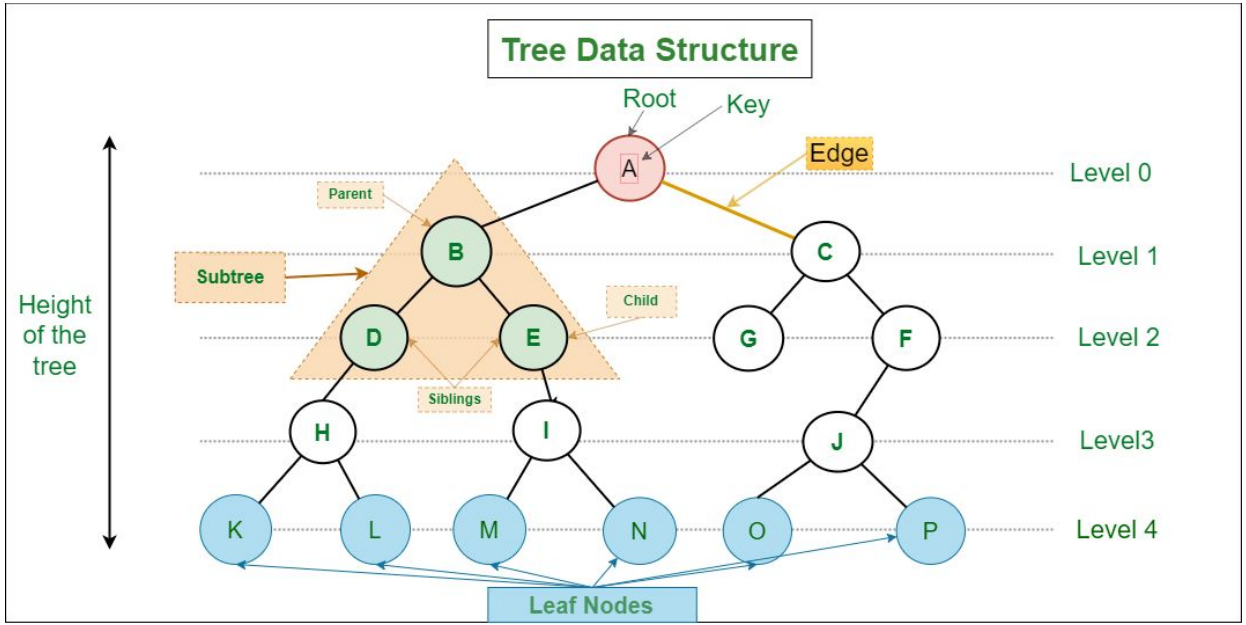
Tree Data Structure

- 👉 A **Tree** 🎄 is a **Hierarchical** Data Structure with a Set of Nodes
- 👉 Each Node can have **many Children**
- 👉 Each Node have **exactly one Parent** (except for the root node)
- 👉 **No Cycles/Loops**

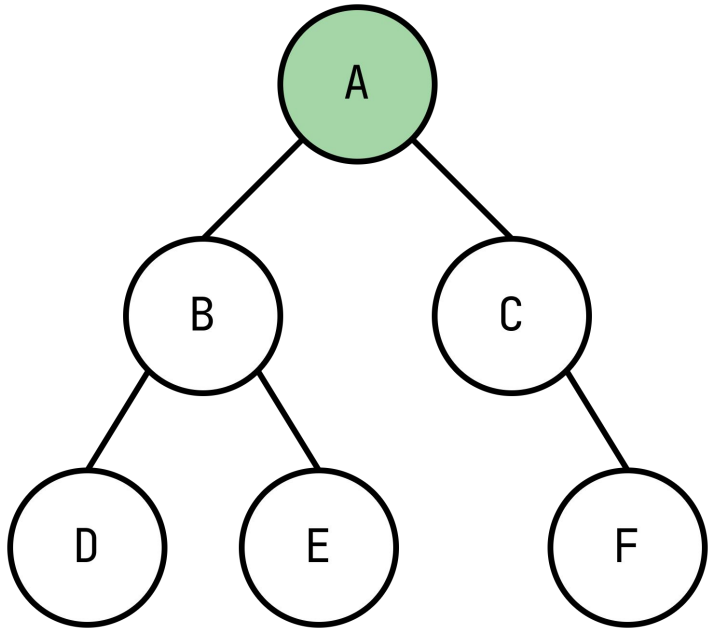
Example of Tree



Binary Tree 🌴

👉 One of the **most commonly** used type of Trees

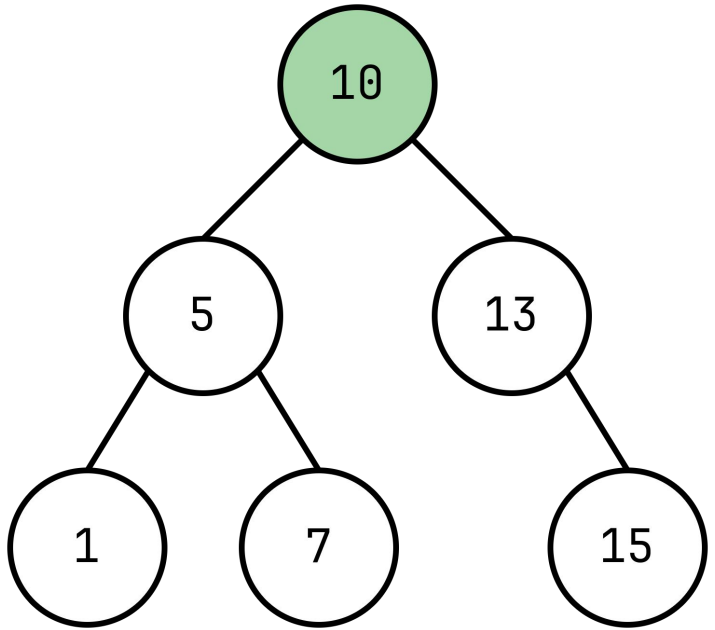
👉 Each node can have at most **two children** (k-ary tree with k=2)



Binary Search Tree 🎋

The **Key** of a Node is:

- 👉 Greater than the Keys in the left subtree.
- 👉 Less than the Keys in the right subtree.



Balanced Trees 🌴

Binary Search Trees

Are **not Balanced**

Balanced Tree:

The **Height** of the

Left and the Right

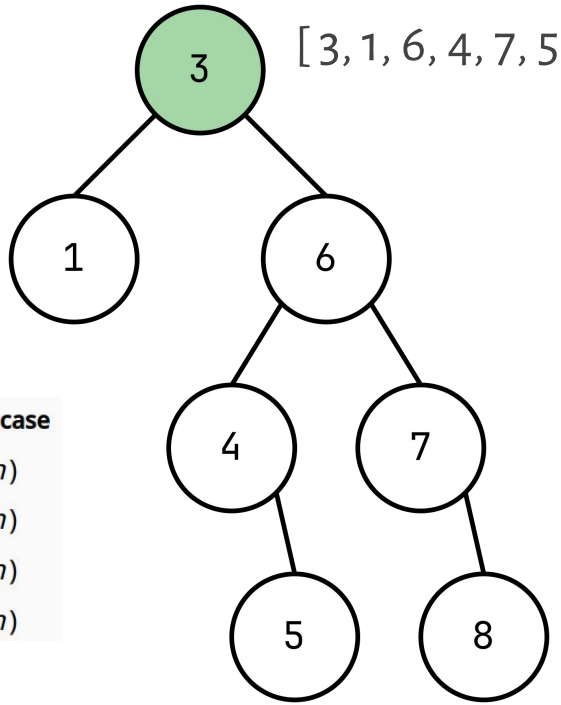
subtree for each node

is either Zero or One

Algorithm	Average	Worst case
Space	$O(n)$	$O(n)$
Search	$O(\log\ n)$	$O(n)$
Insert	$O(\log\ n)$	$O(n)$
Delete	$O(\log\ n)$	$O(n)$

Input Order

[3, 1, 6, 4, 7, 5, 8]



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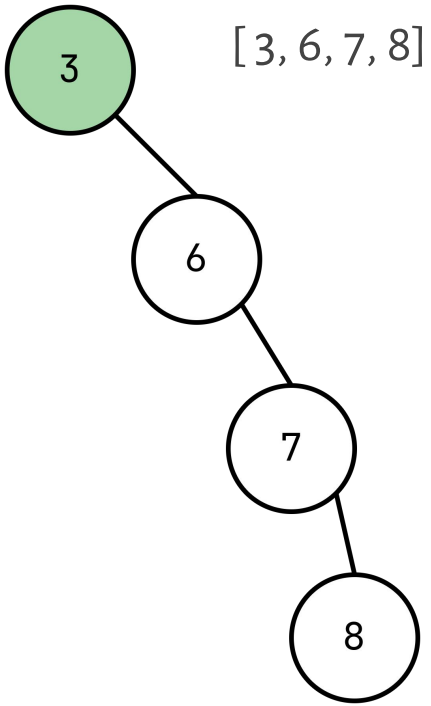
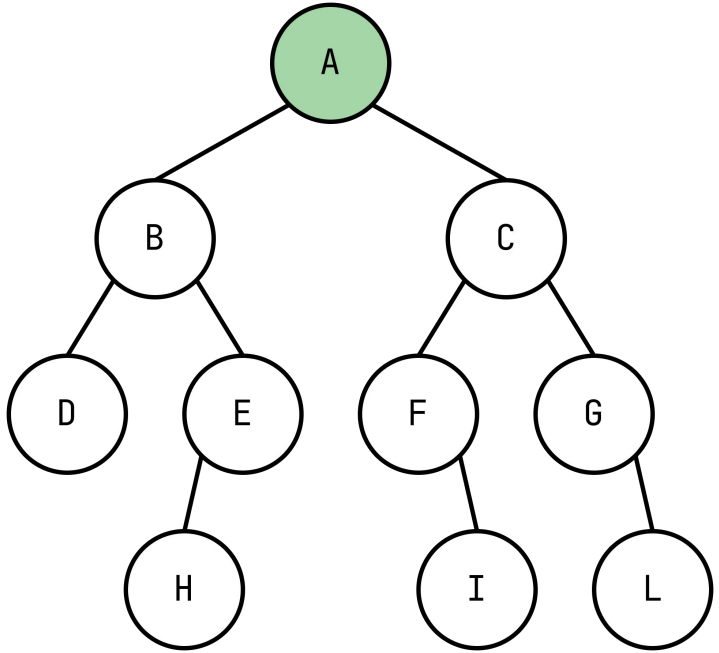


Balanced Search Trees 🌲

Examples of Balanced Trees:

- 👉 AVL (Binary) Tree
- 👉 Red-Black (Binary) Tree
- 👉 B-Tree (k-ary)

Search, Insertion and Deletion cost **O(log n)**



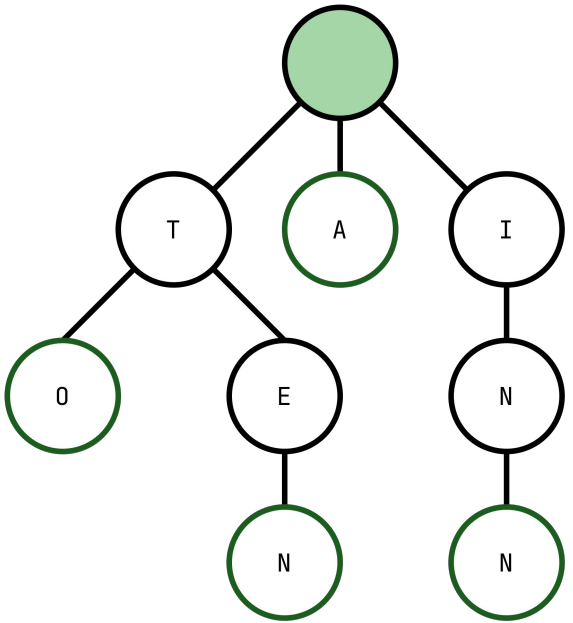
Trie 🌲

Known also as **Digital Tree** of **Prefix Tree**

String-indexed Lookup Data Structure

Applications:

- 👉 Autocomplete
- 👉 Full-text Search
- 👉 Blockchain (Merkle-Patricia)



Trie 🌲

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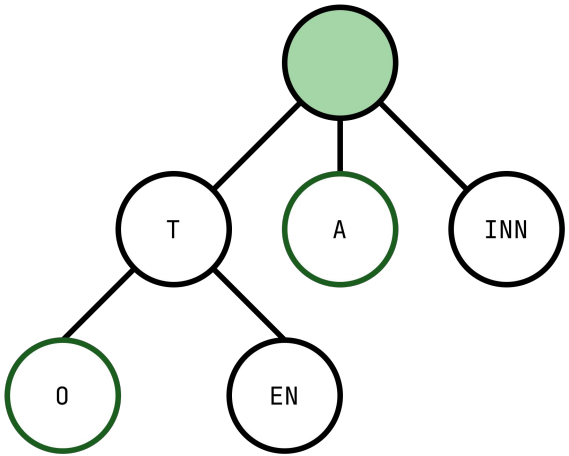

Compressed Trie

Graphs

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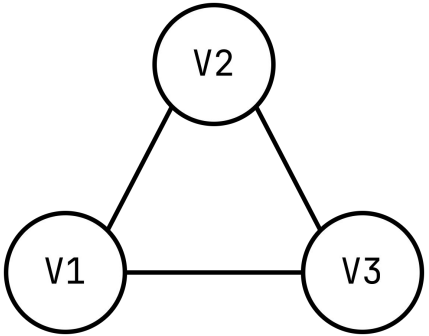
Graphs Definition

Graph Data Structure

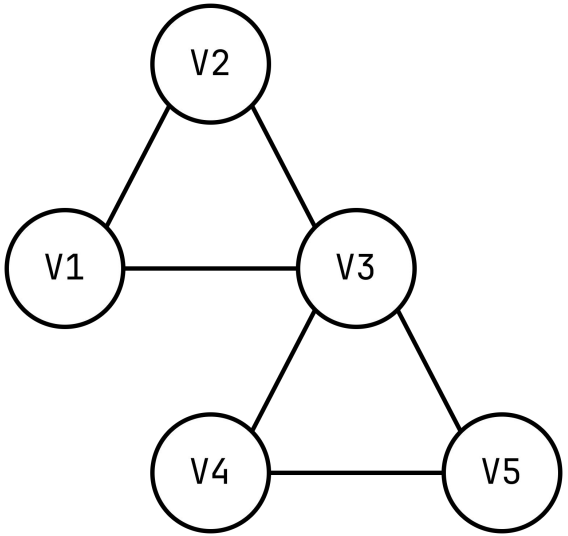
- 👉 A **Graph** 🍇 is a Data Structure with a Set of **Vertices** and **Edges**
- 👉 Graphs can be **Directed (DiGraph)** or **Undirected (Graph)**
- 👉 Both Vertices and Edges can hold Values
- 👉 Trees are a particular type of Graph



Graph Implementation

Graphs can be implemented as:

- 👉 **Adjacency List**
- 👉 **Adjacency Matrix**
- 👉 **Incidence Matrix**



Graph Implementation

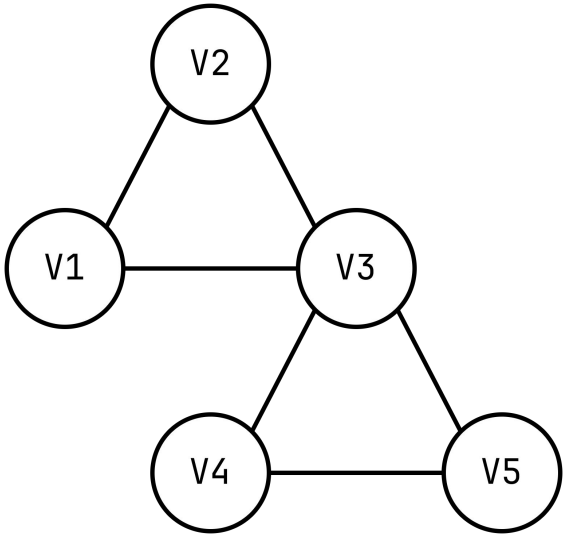
Adjacency List

List of Vertices and

Each Vertex has a list of

Adjacent Vertices

```
[ v1 [v2, v3],
  v2 [v1, v3],
  v3 [v1, v2, v3, v4],
  v4 [v3, v5]
  v5 [v3, v4]
]
```



Graph Implementation

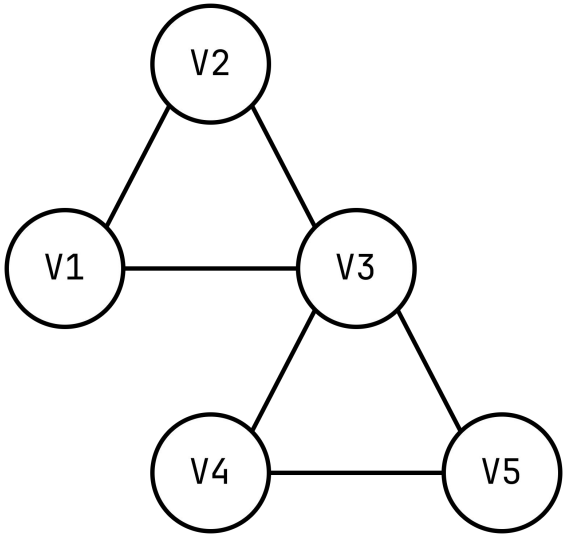
Adjacency Matrix

Two-dimensional Matrix

Rows represents **Source** vertices

Columns represents **Destination** Vertices

	V1	V2	V3	V4	V5
V1	-	X	X	0	0
V2	X	-	X	0	0
V3	X	X	-	X	X
V4	0	0	X	-	X
V5	0	0	X	X	-



Graph Implementation

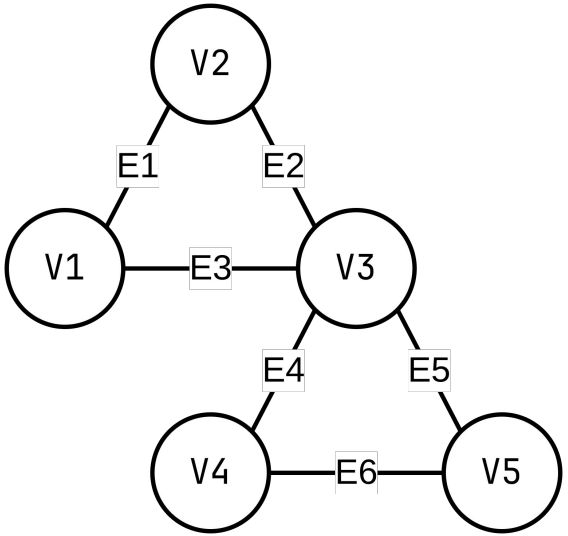
Incidence Matrix

Two-dimensional Matrix

Rows represents **Vertices**

Columns represents **Edges**

	E1	E2	E3	E4	E5	E6
V1	X	0	X	0	0	0
V2	X	X	0	0	0	0
V3	0	X	X	X	0	X
V4	0	0	0	X	X	0
V5	0	0	0	0	X	X



Graph Implementation

	Adjacency list	Adjacency matrix	Incidence matrix
Store graph	$O(\|V\| + \|E\|)$	$O(\|V\|^2)$	$O(\|V\| \cdot \|E\|)$
Add vertex	$O(1)$	$O(\|V\|^2)$	$O(\|V\| \cdot \|E\|)$
Add edge	$O(1)$	$O(1)$	$O(\|V\| \cdot \|E\|)$
Remove vertex	$O(\|E\|)$	$O(\|V\|^2)$	$O(\|V\| \cdot \|E\|)$
Remove edge	$O(\|V\|)$	$O(1)$	$O(\|V\| \cdot \|E\|)$
Are vertices *x* and *y* adjacent (assuming that their storage positions are known)?	$O(\|V\|)$	$O(1)$	$O(\|E\|)$
Remarks	Slow to remove vertices and edges, because it needs to find all vertices or edges	Slow to add or remove vertices, because matrix must be resized/copied	Slow to add or remove vertices and edges, because matrix must be resized/copied

Graph Compressed Representation

Sparse Matrix

Is the most efficient way to represent

a Matrix with lot of Zeros

Fast Construction:

LIL - List of Lists (Adjacency List)

DOK - Dictionary of Keys

COO - Coordinate List

(Fast Data Access):

CSR - Compressed Sparse Row

CSC - Compressed Sparse Column

Graph Compressed Representation

LIL

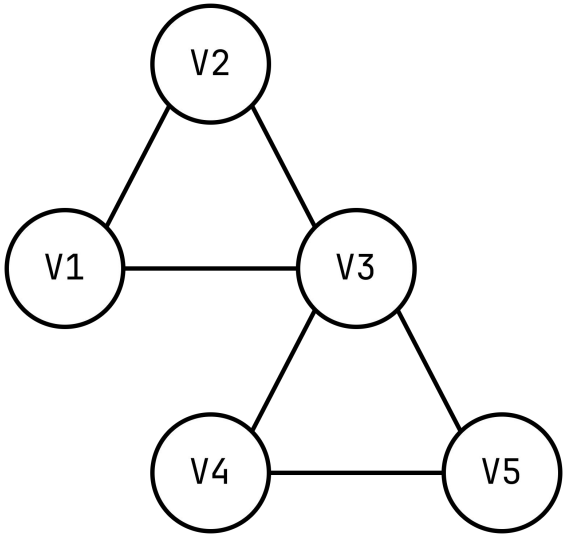
```
[ v1 [v2, v3],
  v2 [v1, v3],
  v3 [v1, v2, v3, v4],
  v4 [v3, v5]
  v5 [v3, v4]
]
```

DOK

```
{ (v1, v2),
  (v1, v3),
  (v2, v3),
  (v3, v4),
  (v3, v5),
  (v4, v5)}
```

COO

```
[ (v1, v2),
  (v1, v3),
  (v2, v3),
  (v3, v4),
  (v3, v5),
  (v4, v5)]
```



Search Algorithms

Search Algorithms

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Search Algorithms

👉 They are used to Traverse or Explore a graph or tree in order to find a specific element or path.

👉 The most popular Algorithms are: **DFS (Depth First Search)** and **BFS (breadth First Search)**.

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DFS
Depth First Search

Depth First Search

- 👉 Uses a stack data structure.
- 👉 Visits nodes depth-first (i.e., goes as deep as possible along each branch before **backtracking**).
- 👉 Good for traversing an entire tree or graph.
- 👉 Can get stuck in an infinite loop if the graph has cycles.

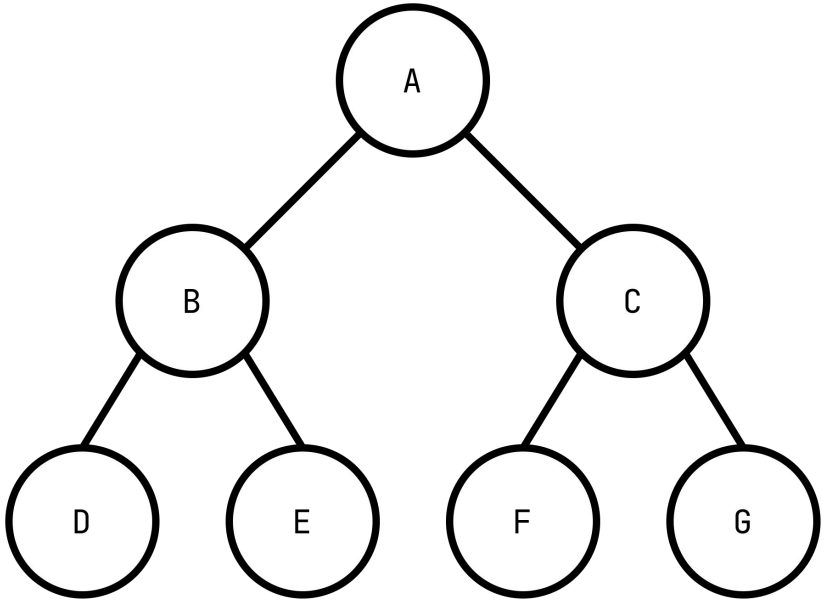
Depth First Search

Example:

Find a Path from A to F

Visited: [ ]

Stack: [ ]



Depth First Search

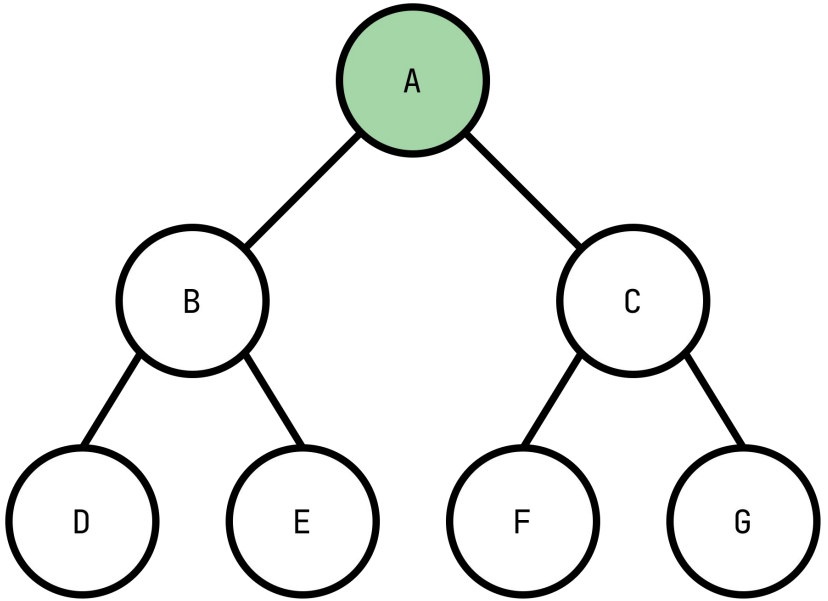
Example:

Find a Path from A to F

Visit Node A

Visited: [A]

Stack: [B, C]



Depth First Search

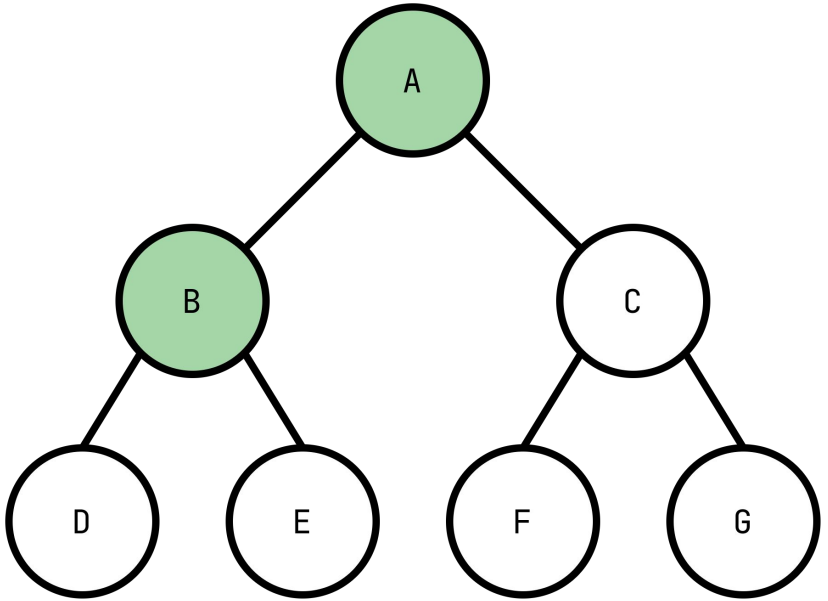
Example:

Find a Path from A to F

Visit Node B

Visited: [A, B]

Stack: [D, E, C]



Depth First Search

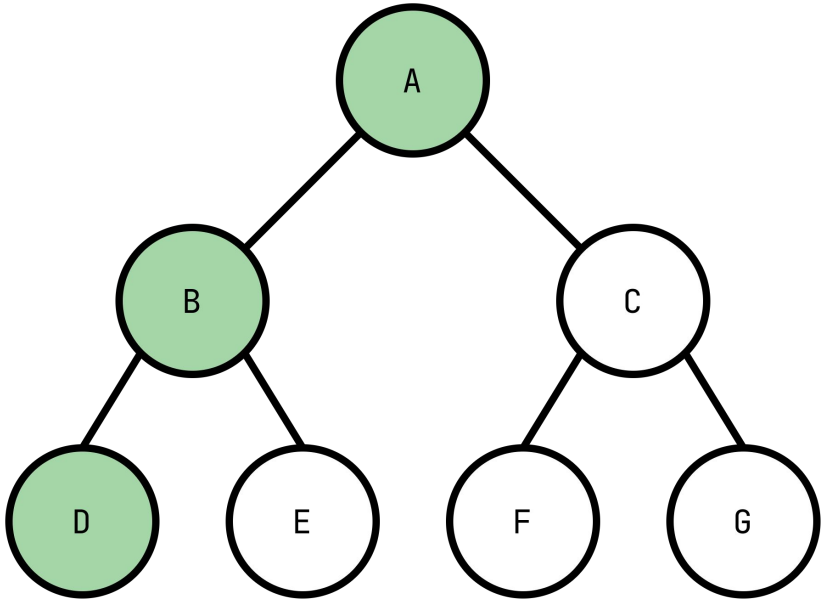
Example:

Find a Path from A to F

Visit Node D

Visited: [A, B, D]

Stack: [E, C]



Depth First Search

Example:

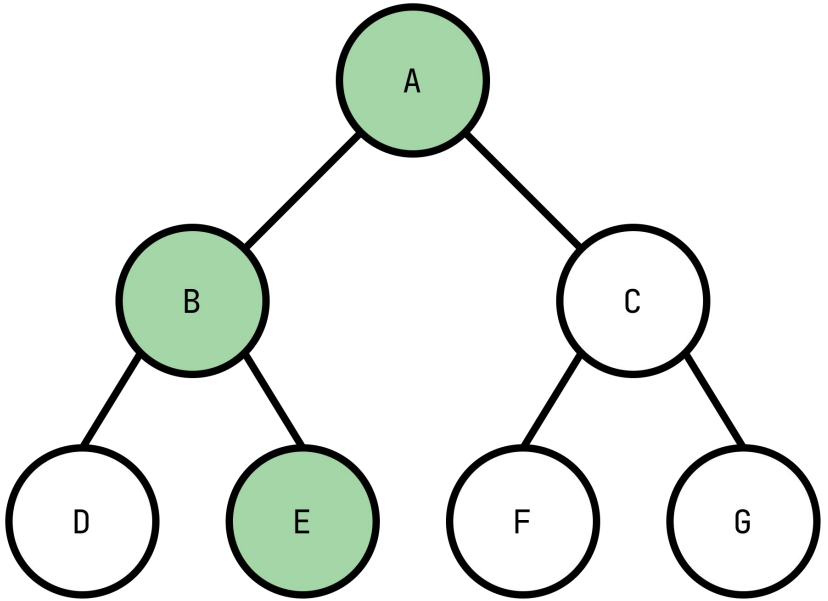
Find a Path from A to F

Backtracking

And Visit Node E

Visited: [A, B, D, E]

Stack: [C]



Depth First Search

Example:

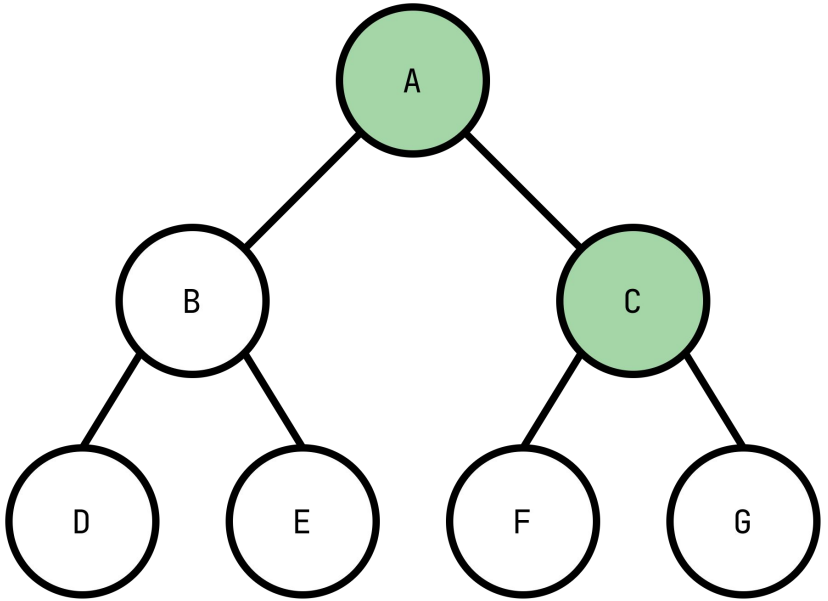
Find a Path from A to F

Backtracking

And Visit Node C

Visited: [A, B, D, E, C]

Stack: [F, G]



Depth First Search

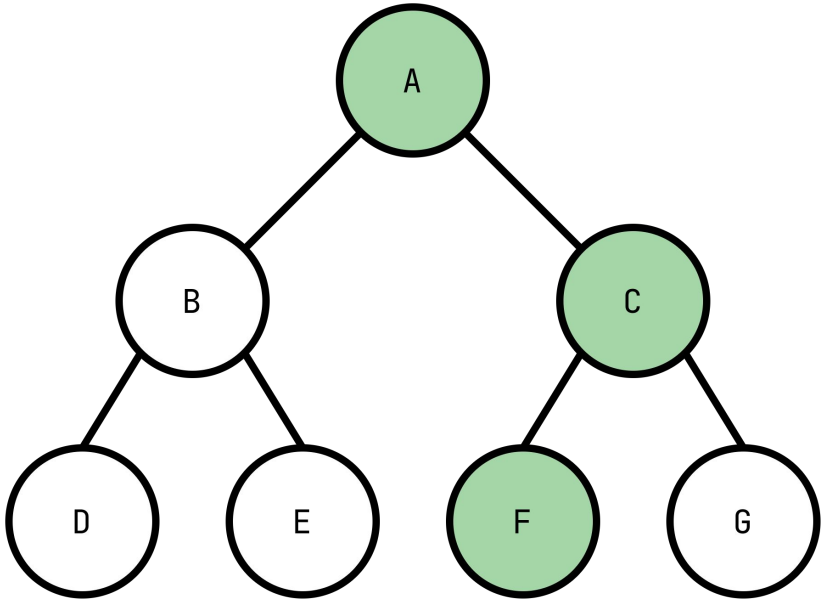
Example:

Find a Path from A to F

Visit Node F

Visited: [A, B, D, E, C, F]

Stack: [G]



BFS
Breadth First Search

Breadth First Search

- 👉 Uses a queue data structure.
- 👉 Visits nodes breadth-first (i.e., explores all the neighbors of a node before moving on to the next level).
- 👉 Good for finding the shortest path between two nodes.
- 👉 May use more memory than DFS if the graph is large.
- 👉 May be slower than DFS for traversing the entire tree or graph.

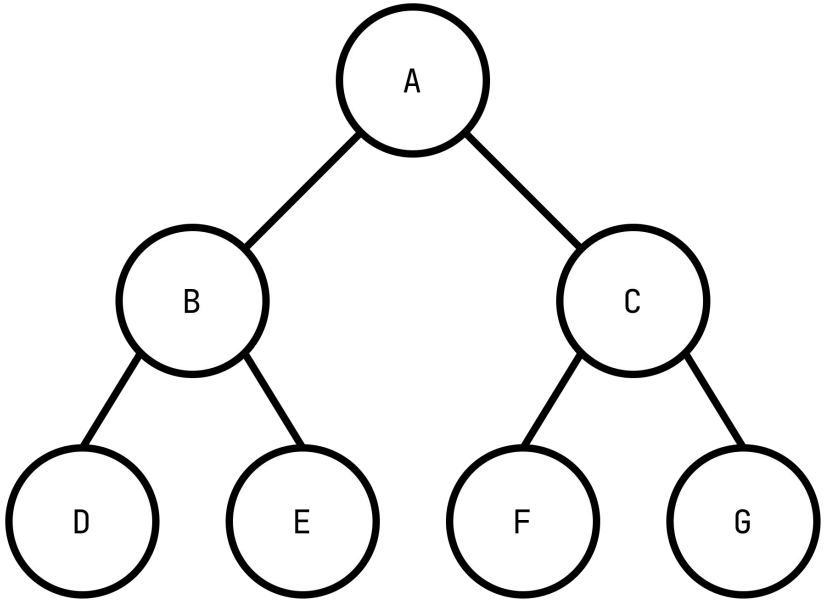
Breadth First Search

Example:

Find a Path from A to F

Visited: [ ]

Queue: [ ]



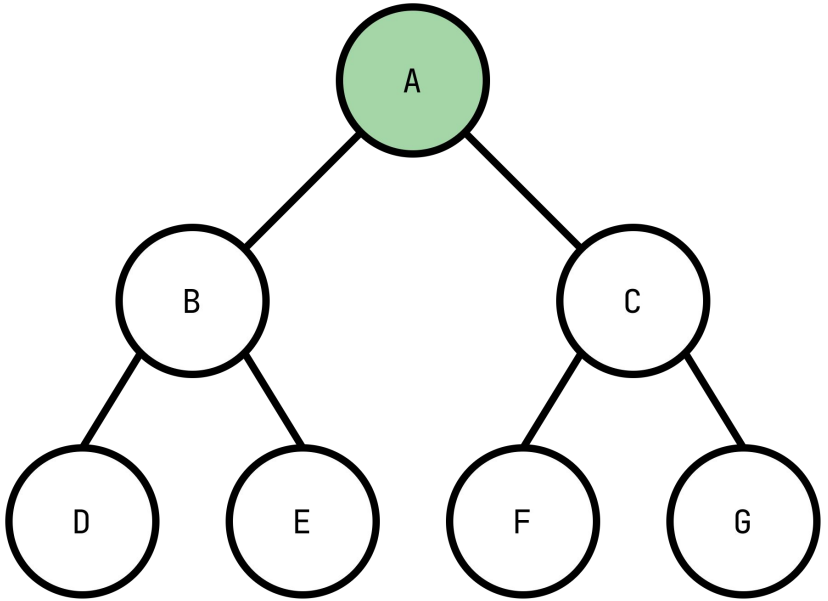
Breadth First Search

Example:

Find a Path from A to F

Visited: [A]

Queue: [B, C]



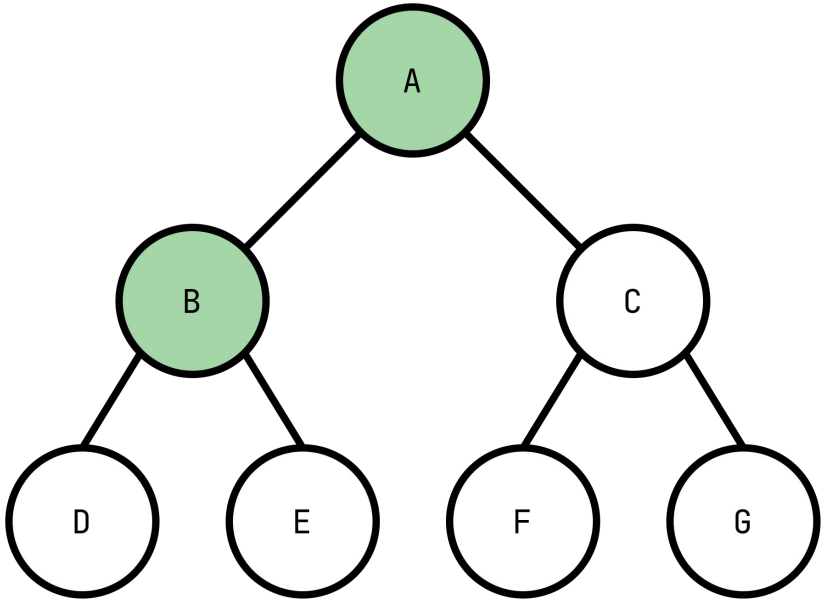
Breadth First Search

Example:

Find a Path from A to F

Visited: [A, B]

Queue: [C, D, E]



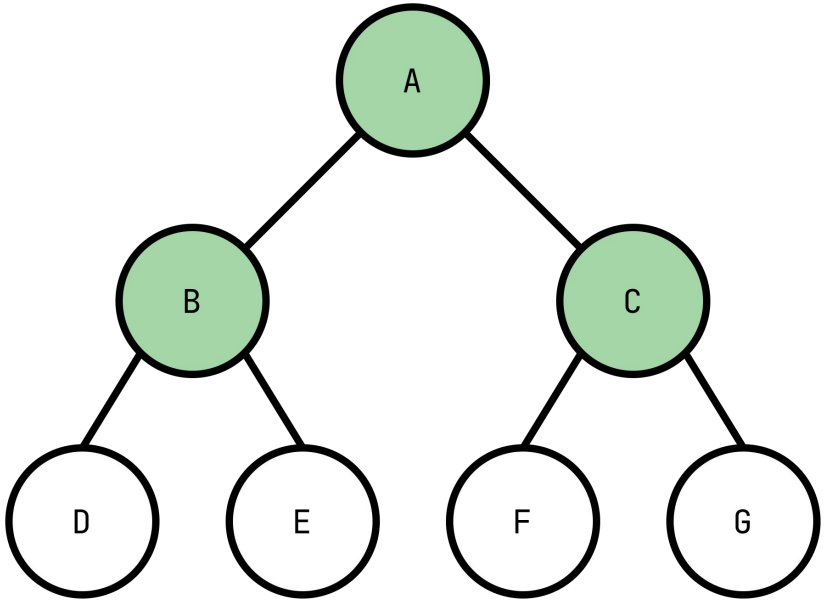
Breadth First Search

Example:

Find a Path from A to F

Visited: [A, B, C]

Queue: [D, E, F, G]



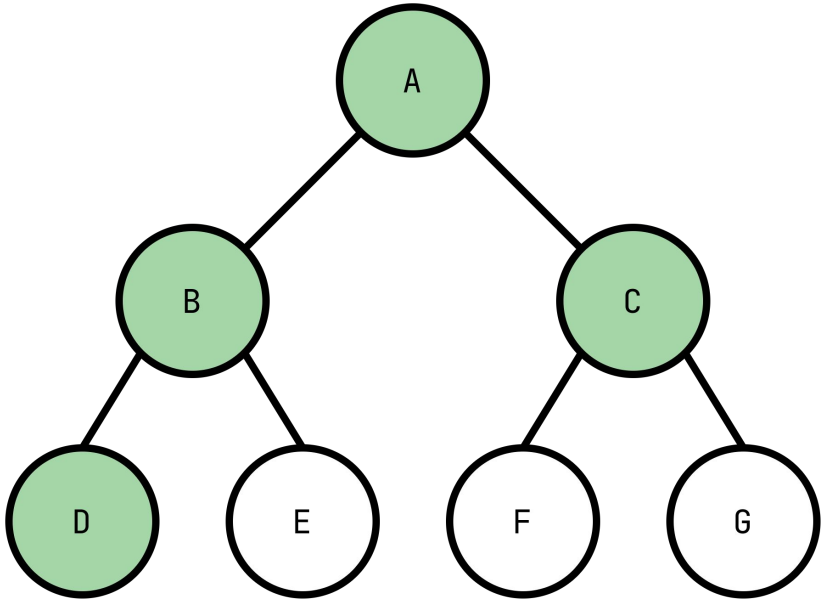
Breadth First Search

Example:

Find a Path from A to F

Visited: [A, B, C, D]

Queue: [E, F, G]



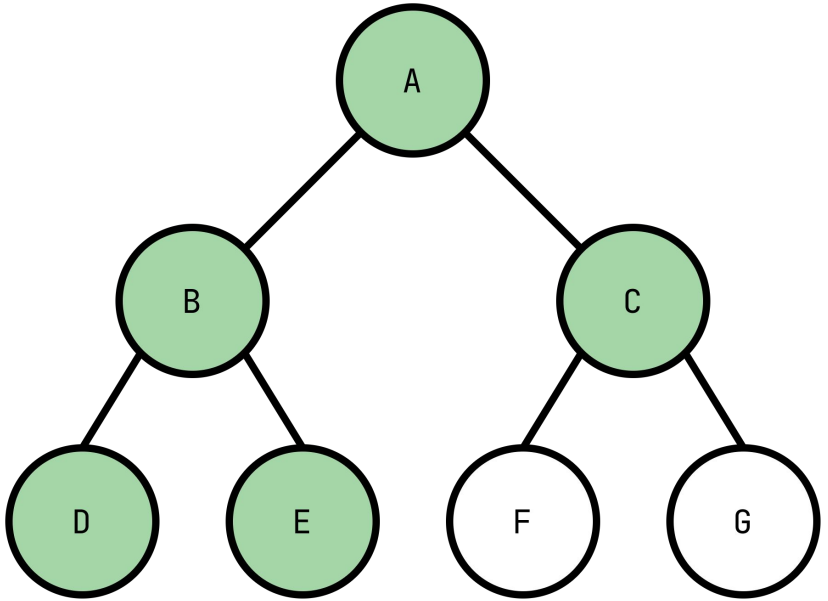
Breadth First Search

Example:

Find a Path from A to F

Visited: [A, B, C, D, E]

Queue: [F, G]



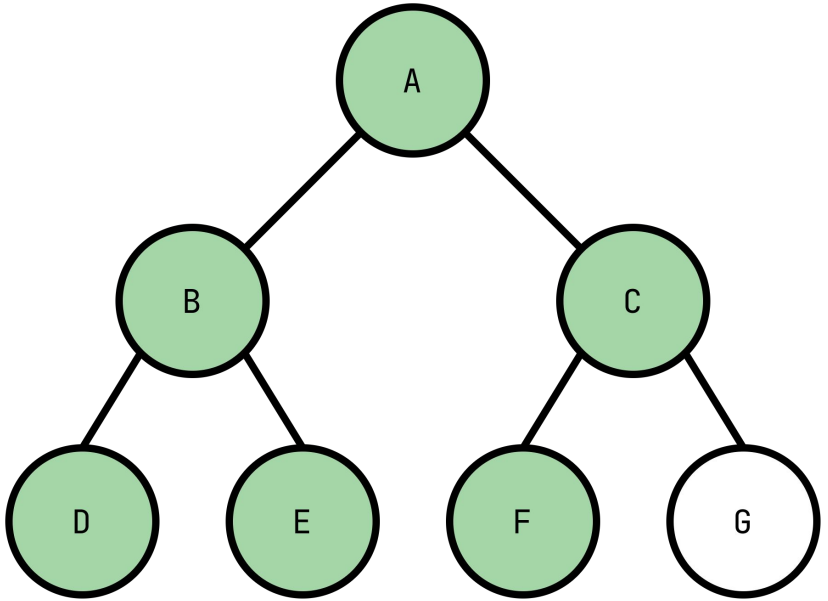
Breadth First Search

Example:

Find a Path from A to F

Visited: [A, B, C, D, E, F]

Queue: [G]



Search Algorithms

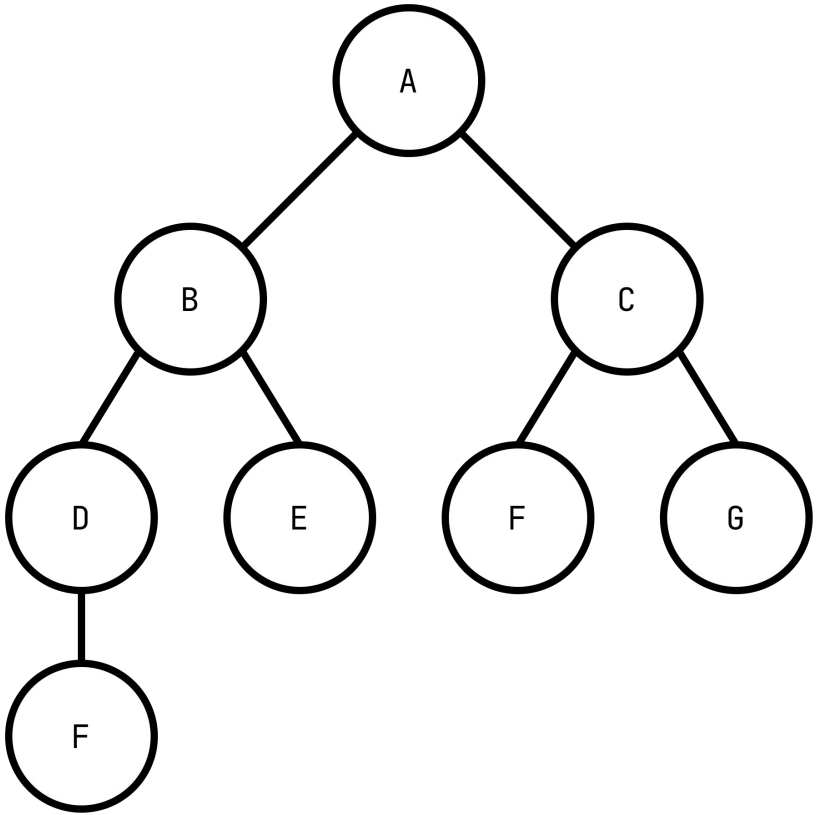
Complexity and Solution Optimality

- 👉 Worst case complexities of both algorithms are the same.
  - 🔎 **Time complexity**: $O(|V| + |E|)$
  - 🔎 **Space complexity**: $O(|V|)$
- 👉 **BFS is optimal** if the path cost is a non-decreasing function of d(depth). Normally, BFS is applied when all the actions have the same cost.

Optimality Comparison

👉 Assume there are
Two paths to Reach F

👉 Assume Each step
Have the same Cost
(for simplicity 1)



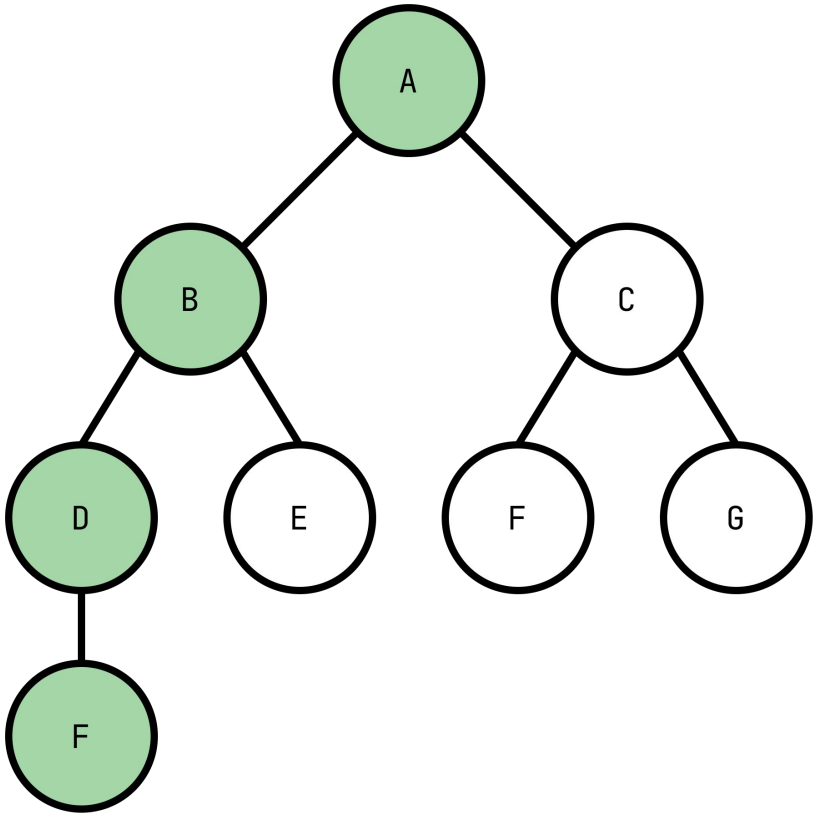
Optimality Comparison

Depth First Search

Path Found:

[A → B → D → F]

Path Cost: 3



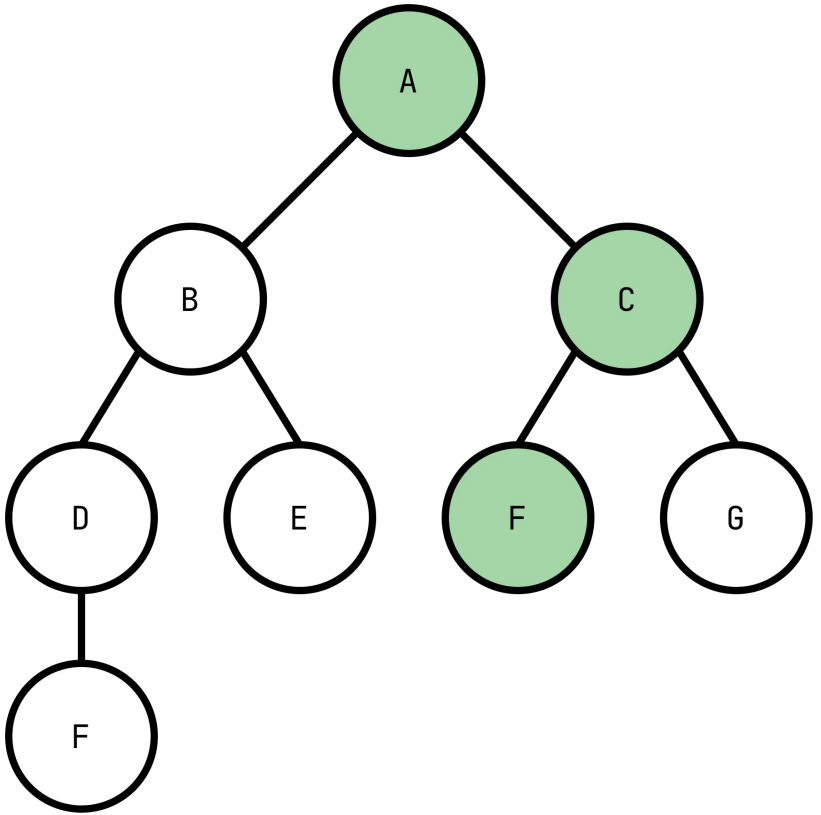
Optimality Comparison

Breadth First Search

Path Found:

[A → C → F]

Path Cost: 2



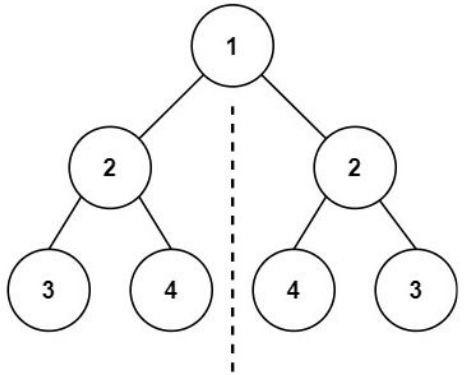
LeetCode

LeetCode Problem 1

101 Symmetric Tree

https://leetcode.com/problems/symmetric-tree/

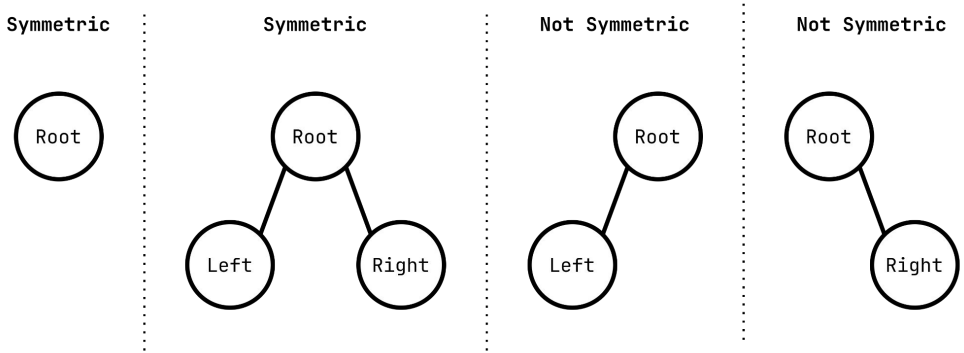
Given the root of a binary tree, check whether it is a mirror of itself (i.e., symmetric around its center).



LeetCode Solution 1

101 Symmetric Tree

https://leetcode.com/problems/symmetric-tree/



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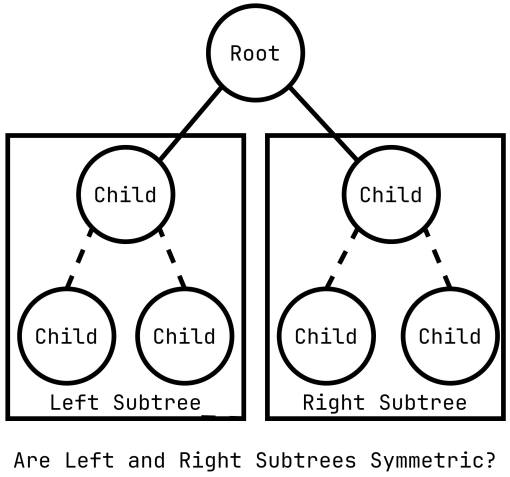
LeetCode
Solution 1

101 Symmetric Tree

https://leetcode.com/problems/symmetric-tree/



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LeetCode Problem 2

98 Validate Binary Tree

https://leetcode.com/problems/validate-binary-search-tree/

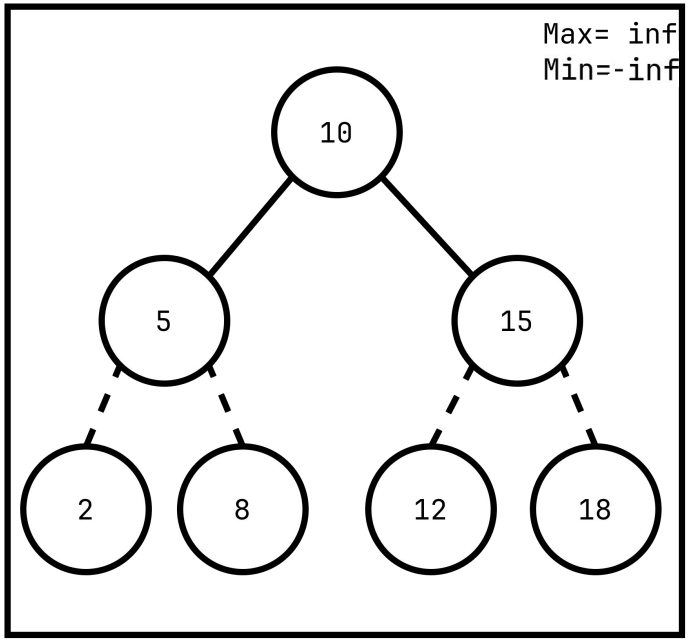
Given the root of a binary tree, determine if it is a valid binary search tree (BST). A valid BST is defined as follows:

- 👉 The left subtree of a node contains only nodes with keys less than the node's key.
- 👉 The right subtree of a node contains only nodes with keys greater than the node's key.
- 👉 Both the left and right subtrees must also be binary search trees.

LeetCode Solution 2

98 Validate Binary Tree

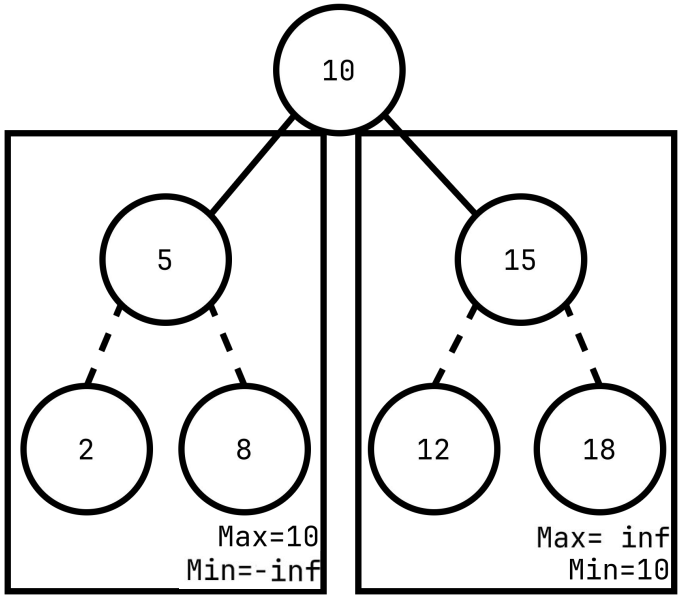
https://leetcode.com/problems/validate-binary-search-tree/



LeetCode
Solution 2

98 Validate Binary Tree

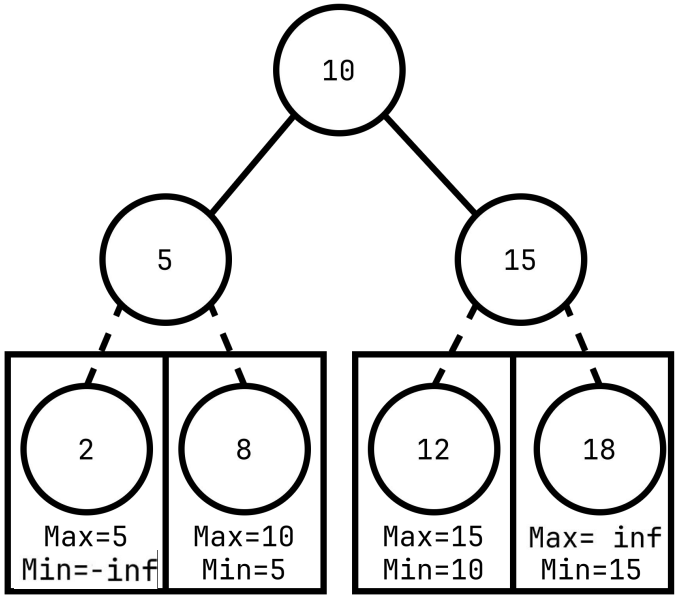
https://leetcode.com/problems/validate-binary-search-tree/



LeetCode
Solution 2

98 Validate Binary Tree

https://leetcode.com/problems/validate-binary-search-tree/



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LeetCode Problem 3

207 Course Schedule

https://leetcode.com/problems/course-schedule/

There are a total of numCourses courses you have to take, labeled from 0 to numCourses - 1. You are given an array prerequisites where prerequisites[i] = [ai, bi] indicates that you must take course bi first if you want to take course ai.

For example, the pair [0, 1], indicates that to take course 0 you have to first take course 1.

Return true if you can finish all courses. Otherwise, return false.

LeetCode Solution 3

207 Course Schedule

https://leetcode.com/problems/course-schedule/

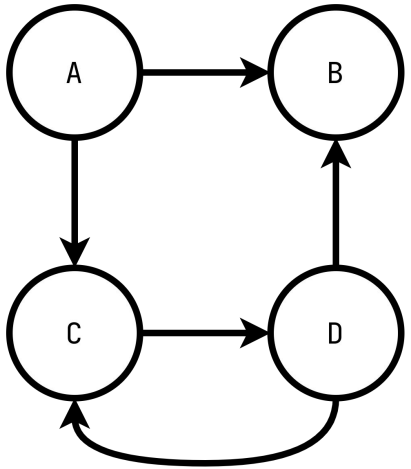
Depth First Search

With **Visited** and **Stack**

Visit All Nodes By Depth

A → B: Finish A to do B

Visit - Check - Add - Adjacent - Remove



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LeetCode Solution 3

207 Course Schedule

https://leetcode.com/problems/course-schedule/

Depth First Search

Mark the current node as visited and also mark the index in the recursion stack.

Iterate a loop for all the vertices and for each vertex, call the recursive function if it is not yet visited.

(This step is done to make sure that if there is a forest of graphs, we are checking each forest)

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LeetCode Solution 3

207 Course Schedule

https://leetcode.com/problems/course-schedule/

Depth First Search

In each recursion call, Find all the adjacent vertices of the current vertex which are not visited:

- 👉 If an adjacent vertex is already marked in the recursion stack then return true.
- 👉 Otherwise, call the recursive function for that adjacent vertex.

LeetCode Solution 3

207 Course Schedule

https://leetcode.com/problems/course-schedule/

Depth First Search

While returning from the recursion call, unmark the current node from the recursion stack, to represent that the current node is no longer a part of the path being traced.

If any of the functions returns true, stop the future function calls and return true as the answer.

LeetCode Solution 3

207 Course Schedule

https://leetcode.com/problems/course-schedule/

Depth First Search

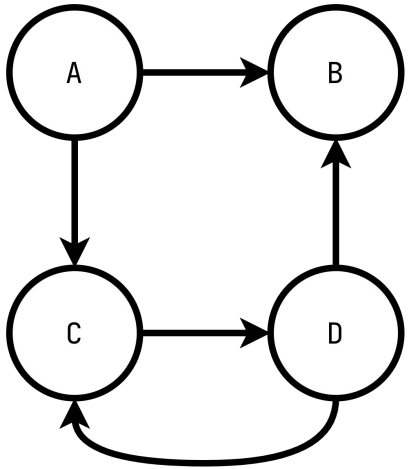
Visit A

Current: [A]

Visited: [ ]

Stack: [ ]

AdjList: [[ ], [A, D], [A, D], [C]]



LeetCode Solution 3

207 Course Schedule

https://leetcode.com/problems/course-schedule/

Depth First Search

Check A →

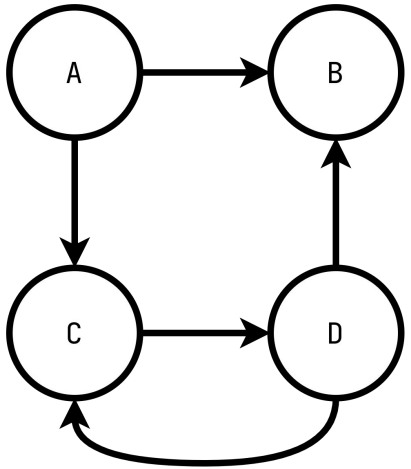
not visited and not stack

Current: [A]

Visited: [ ]

Stack: [ ]

AdjList: [[ ], [A, D], [A, D], [C]]



LeetCode Solution 3

207 Course Schedule

https://leetcode.com/problems/course-schedule/

Depth First Search

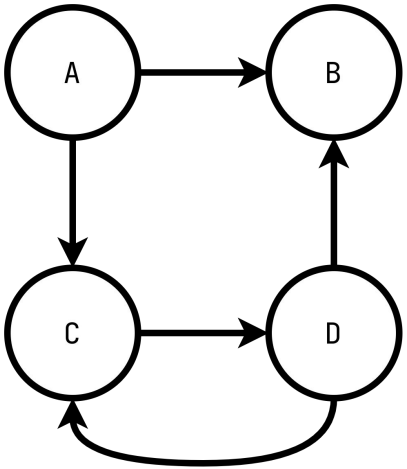
Add A to Visited and Stack

Current: [A]

Visited: [A]

Stack: [A]

AdjList: [[ ], [A, D], [A, D], [C]]



LeetCode Solution 3

207 Course Schedule

https://leetcode.com/problems/course-schedule/

Depth First Search

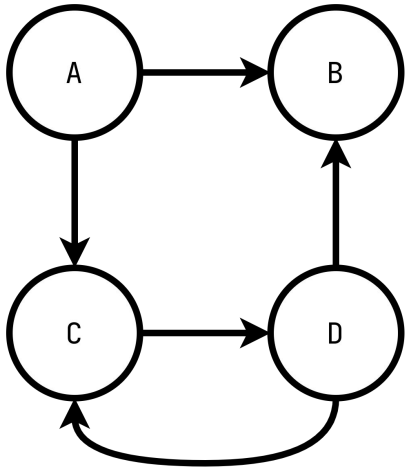
Visit adjList of A ([ ])

Current: [A]

Visited: [A]

Stack: [A]

AdjList: [[ ], [A, D], [A, D], [C]]



LeetCode Solution 3

207 Course Schedule

https://leetcode.com/problems/course-schedule/

Depth First Search

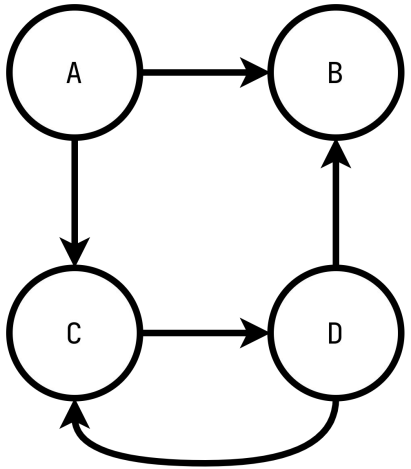
Remove A from Stack

Current: [A]

Visited: [A]

Stack: [ ]

AdjList: [[ ], [A, D], [A, D], [C]]



LeetCode Solution 3

207 Course Schedule

https://leetcode.com/problems/course-schedule/

Depth First Search

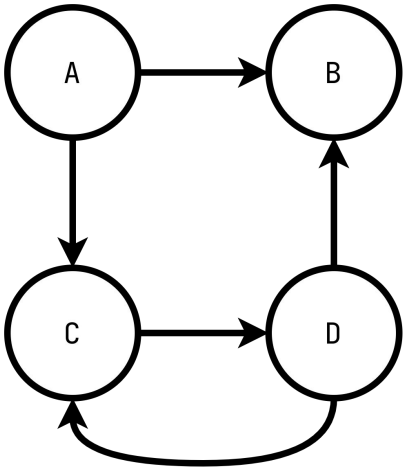
Visit B

Current: [B]

Visited: [A]

Stack: [ ]

AdjList: [[ ], [A, D], [A, D], [C]]



LeetCode Solution 3

207 Course Schedule

https://leetcode.com/problems/course-schedule/

Depth First Search

Check B →

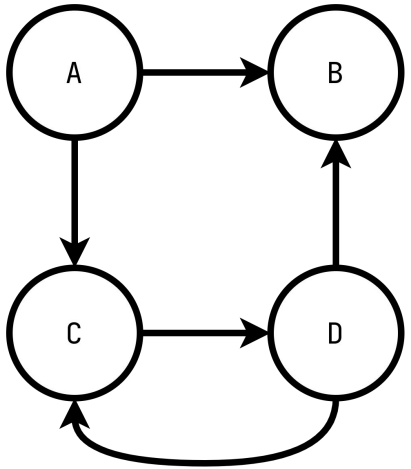
not visited and not stack

Current: [B]

Visited: [A]

Stack: [ ]

AdjList: [[ ], [A, D], [A, D], [C]]



LeetCode Solution 3

207 Course Schedule

https://leetcode.com/problems/course-schedule/

Depth First Search

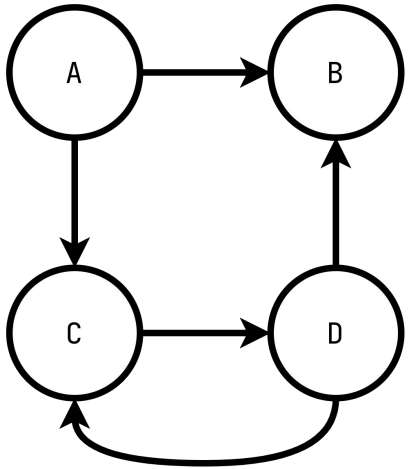
Add B to Visited and Stack

Current: [B]

Visited: [A, B]

Stack: [B]

AdjList: [[ ], [A, D], [A, D], [C]]



LeetCode Solution 3

207 Course Schedule

https://leetcode.com/problems/course-schedule/

Depth First Search

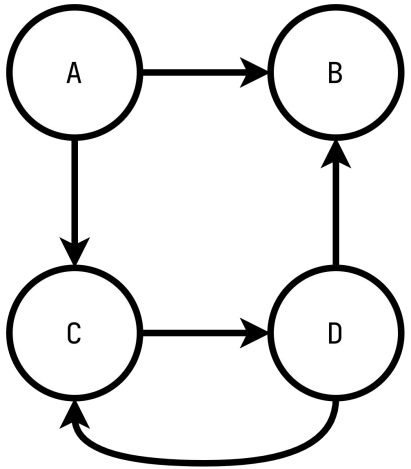
Visit adjList of B ([A, D])

Current: [B]

Visited: [A, B]

Stack: [B]

AdjList: [[ ], [A, D], [A, D], [C]]



LeetCode Solution 3

207 Course Schedule

https://leetcode.com/problems/course-schedule/

Depth First Search

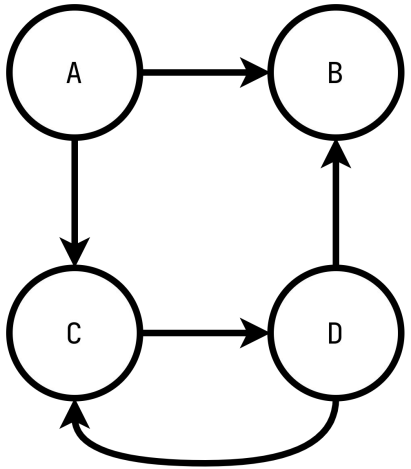
Visit A

Current: [A]

Visited: [A, B]

Stack: [B]

AdjList: [[ ], [A, D], [A, D], [C]]



LeetCode Solution 3

207 Course Schedule

https://leetcode.com/problems/course-schedule/

Depth First Search

Check A →

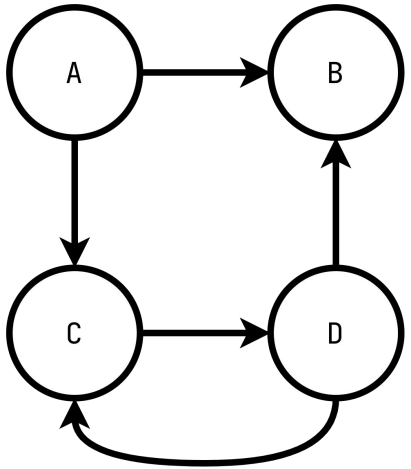
visited and not stack → False

Current: [A]

Visited: [A, B]

Stack: [B]

AdjList: [[ ], [A, D], [A, D], [C]]



LeetCode Solution 3

207 Course Schedule

https://leetcode.com/problems/course-schedule/

Depth First Search

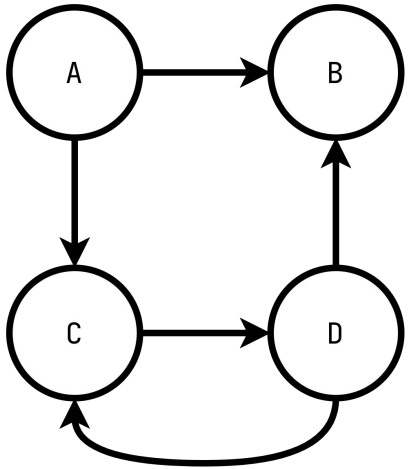
Visit D

Current: [D]

Visited: [A, B]

Stack: [B]

AdjList: [[ ], [A, D], [A, D], [C]]



LeetCode Solution 3

207 Course Schedule

https://leetcode.com/problems/course-schedule/

Depth First Search

Check D →

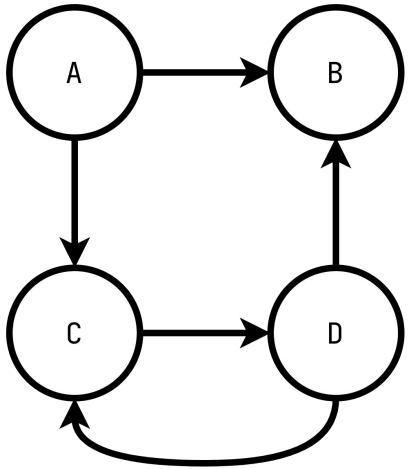
Not visited and not stack

Current: [D]

Visited: [A, B]

Stack: [B]

AdjList: [[ ], [A, D], [A, D], [C]]



LeetCode Solution 3

207 Course Schedule

https://leetcode.com/problems/course-schedule/

Depth First Search

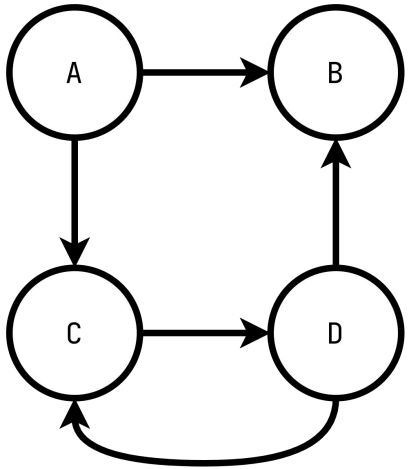
Add D to Visited and Stack

Current: [D]

Visited: [A, B, D]

Stack: [B, D]

AdjList: [[ ], [A, D], [A, D], [C]]



LeetCode Solution 3

207 Course Schedule

https://leetcode.com/problems/course-schedule/

Depth First Search

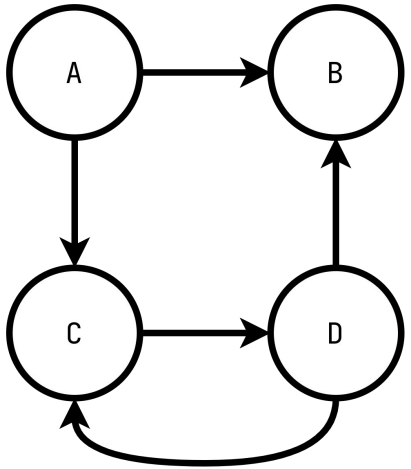
Visit adjList of D ([C])

Current: [D]

Visited: [A, B, D]

Stack: [B, D]

AdjList: [[ ], [A, D], [A, D], [C]]



LeetCode Solution 3

207 Course Schedule

https://leetcode.com/problems/course-schedule/

Depth First Search

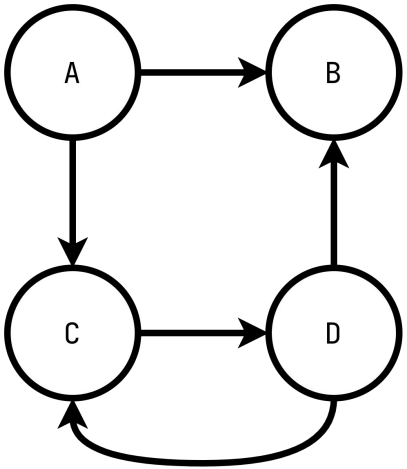
Visit C

Current: [C]

Visited: [A, B, D]

Stack: [B, D]

AdjList: [[ ], [A, D], [A, D], [C]]



LeetCode Solution 3

207 Course Schedule

https://leetcode.com/problems/course-schedule/

Depth First Search

Check C →

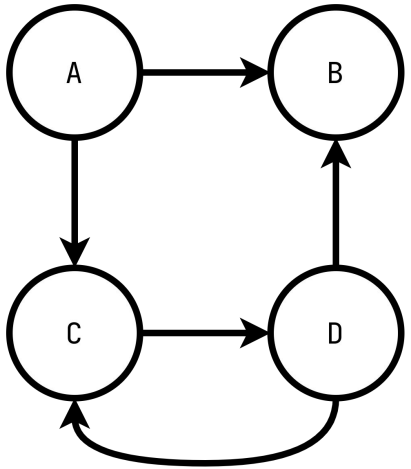
Not visited and not stack

Current: [C]

Visited: [A, B, D]

Stack: [B, D]

AdjList: [[ ], [A, D], [A, D], [C]]



LeetCode Solution 3

207 Course Schedule

https://leetcode.com/problems/course-schedule/

Depth First Search

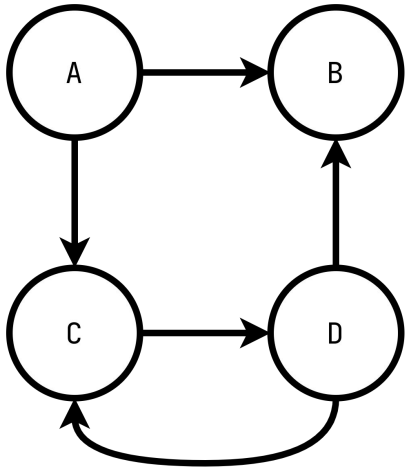
Add C to Visited and Stack

Current: [C]

Visited: [A, B, D, C]

Stack: [B, D, C]

AdjList: [[ ], [A, D], [A, D], [C]]



LeetCode Solution 3

207 Course Schedule

https://leetcode.com/problems/course-schedule/

Depth First Search

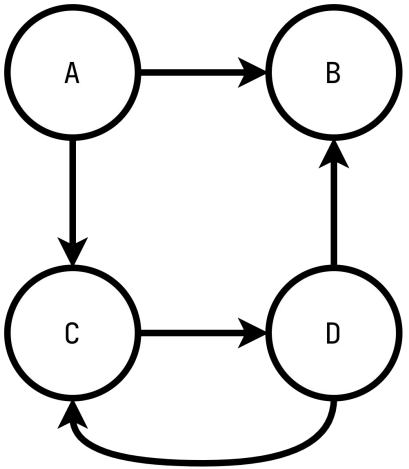
Visit adjList of C ([A, D])

Current: [C]

Visited: [A, B, D, C]

Stack: [B, D, C]

AdjList: [[ ], [A, D], [A, D], [C]]



LeetCode Solution 3

207 Course Schedule

https://leetcode.com/problems/course-schedule/

Depth First Search

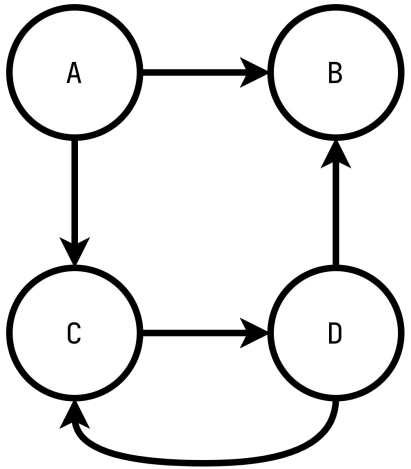
Visit A

Current: [A]

Visited: [A, B, D, C]

Stack: [B, D, C]

AdjList: [[ ], [A, D], [A, D], [C]]



LeetCode Solution 3

207 Course Schedule

https://leetcode.com/problems/course-schedule/

Depth First Search

Check A →

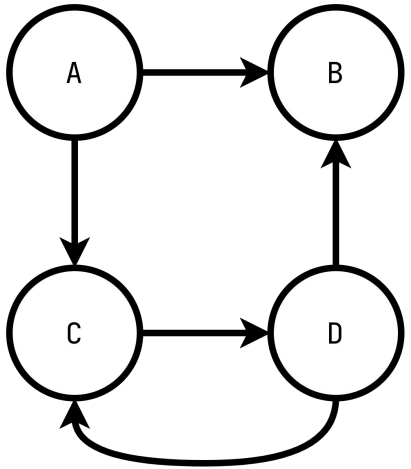
visited and not stack → False

Current: [A]

Visited: [A, B, D, C]

Stack: [B, D, C]

AdjList: [[ ], [A, D], [A, D], [C]]



LeetCode Solution 3

207 Course Schedule

https://leetcode.com/problems/course-schedule/

Depth First Search

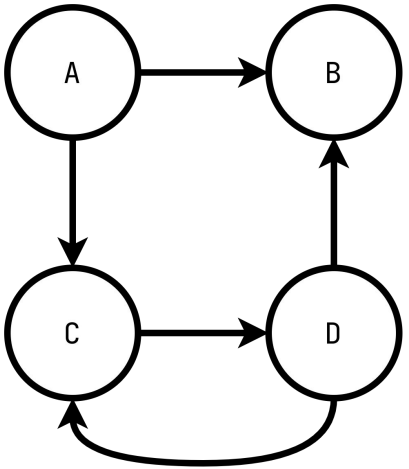
Visit D

Current: [D]

Visited: [A, B, D, C]

Stack: [B, D, C]

AdjList: [[ ], [A, D], [A, D], [C]]



LeetCode Solution 3

207 Course Schedule

https://leetcode.com/problems/course-schedule/

Depth First Search

Check D →

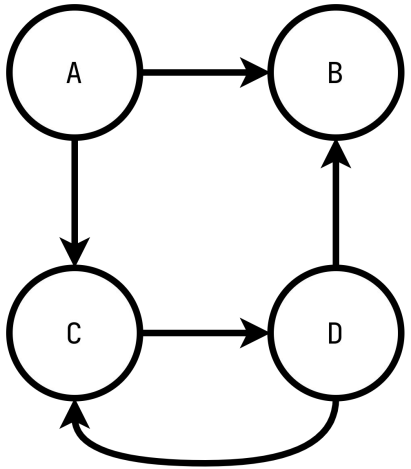
visited and stack → True

Current: [D]

Visited: [A, B, D, C]

Stack: [B, D, C]

AdjList: [[ ], [A, D], [A, D], [C]]



T.HANKS everyone!