E-LeetCoding: Graphs Session

UW
DATA SCIENCE
CLUB.

Presented by Jack Douglas

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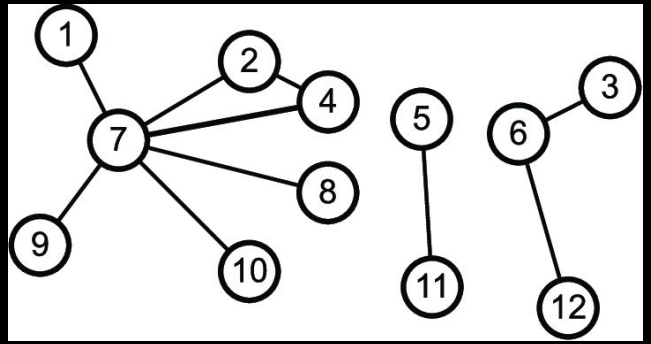
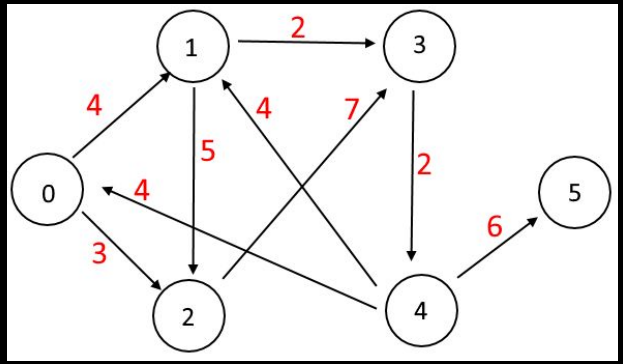
Session Outline

1. Graph Basics
    a. What is a graph?
    b. How are they stored?
    c. Space and Time Complexity Comparison
2. Types of Graph Questions
3. Depth First Search (DFS)
    a. What is DFS?
    b. Pseudocode
4. Number of Islands LeetCode Problem
    a. Discuss our approach
    b. Implement!

What is a graph?

- Vertices/Nodes (usually denoted V)
  - Collection of numbers, letters, coordinates, or any other object
- Edges (usually denoted E)
  - Connect two vertices
  - Can be weighted or unweighted
  - Can be directed and undirected
- Graph vs. Tree
  - Graph is non-linear
  - Graph has no root

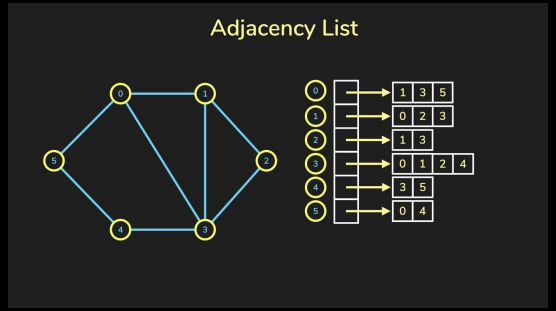


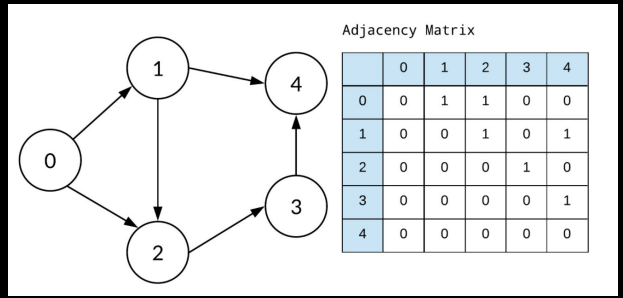


How are graphs stored?

- Vertices are stored in set/list

- Edges usually stored in 1 of 2 ways
  1. Adjacency List
     - Implemented as dictionary with the key being a vertex and the value being a list/set of the vertex's neighbours
  2. Adjacency Matrix
     - Implemented as a |V| x |V| list of lists





Space and Time Complexity Comparison

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- Adjacency List
  - Implemented as dictionary with the key being a vertex and the value being a list/set of the vertex's neighbours

- Adjacency Matrix
  - Implemented as a |V| x |V| list of lists

|V| - Number of Vertices && |E| - Number of Edges

Operation	Adjacency List	Adjacency Matrix
Add Vertex	O(1)	$O(\|V^2\|)$
Add Edge	O(1)	O(1)
Remove Vertex	O(|V| + |E|)	$O(\|V^2\|)$
Remove Edge	O(|E|)	O(1)
Query	O(|V| + |E|)	O(1)
Storage	O(|V| + |E|)	$O(\|V^2\|)$

Types of Graph Questions

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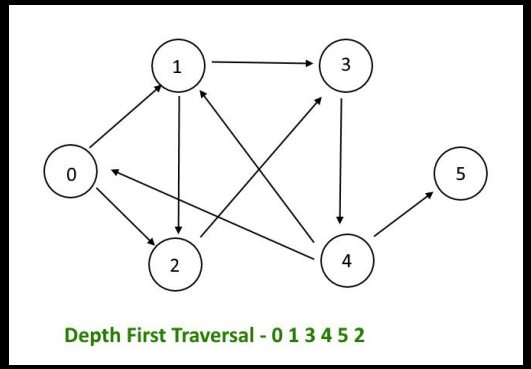
1. Depth First Search (DFS)
2. Breadth First Search (BFS)
3. Topological Sorting
    a. https://www.youtube.com/watch?v=eL-KzMXSXXI
    b. https://www.interviewcake.com/concept/java/topological-sort
4. Union-Find
    a. https://www.youtube.com/watch?v=ayW5B2W9hfo
    b. https://algorithms.tutorialhorizon.com/disjoint-set-union-find-algorithm-union-by-rank-and-path-compression/

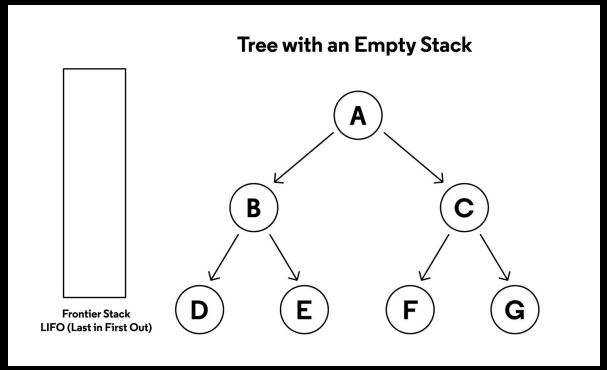
What is Depth First Search (DFS)

- Start at a vertex and travel as far down a path as you can, then backtrack until you find an unexplored path

- It can be implemented iteratively with a stack or recursively

- Applications
  - Detecting cycles in directed
  - Topological sorting of directed acyclic graphs (DAG's)





DFS Recursion Pseudocode

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Typical function signature looks like this:

dfs(current vertex, adjacency list, visited vertices set)

Pseudocode:

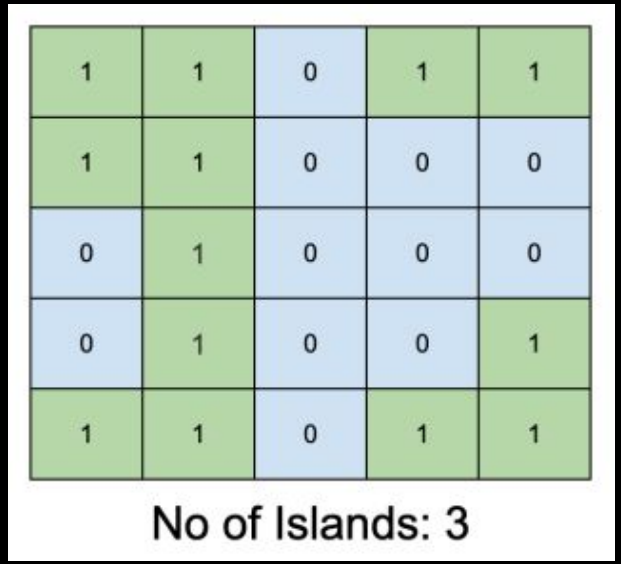
1. Add current vertex to visited vertices set
2. Iterate through neighbours of current vertex using adjacency list
3. If a neighbour has not been visited yet, recursively call dfs with the neighbour:

   ie. dfs(neighbour, adjacency list, visited vertices set)

Problem Statement

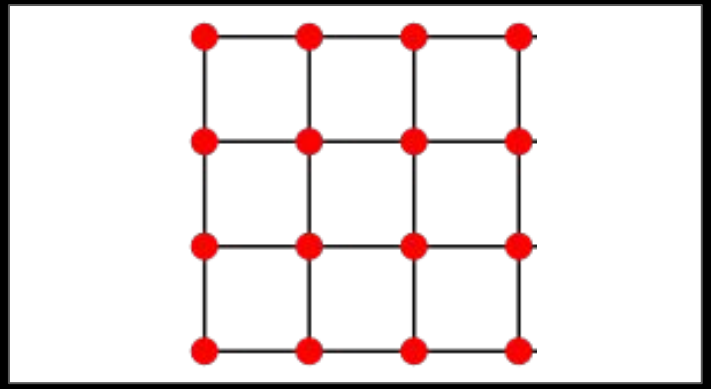
Number of Islands:
https://leetcode.com/problems/number-of-islands/description/

- Given an m x n grid which contains 0's and 1's
  - 0 is water, 1 is land
- Return the # of islands
- How do we make this a graph question?



Identifying the Vertices and Edges

- Each land cell in the grid is vertex!
- Adjacent land cells represent edges!
- How will we use DFS? When will we call DFS?



Key Observations

We’re going to iterate through every cell in the grid

1. What do we do if the current cell is water?
2. [redacted]
3. [redacted]
4. [redacted]

Key Observations

We're going to iterate through every cell in the grid

1. What do we do if the current cell is water?
   a. A: Nothing!

2. What happens when we call DFS on a land cell?

3.

4.

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1. What do we do if the current cell is water?
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2. What happens when we call DFS on a land cell?
   a. A: We visit every land cell in the island!

3. When do we call DFS?

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Key Observations

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1. What do we do if the current cell is water?
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2. What happens when we call DFS on a land cell?
   a. A: We visit every land cell in the island!

3. When do we call DFS?
   a. A: We call DFS when it's a land cell that we haven't visited!

4. What is the significance of this?

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1. What do we do if the current cell is water?
   a. A: Nothing!

2. What happens when we call DFS on a land cell?
   a. A: We visit every land cell in the island!

3. When do we call DFS?
   a. A: We call DFS when it's a land cell that we haven't visited!

4. What is the significance of this?
   a. A: We will be calling DFS at every new island!

Let’s Implement!

Number of Islands:
https://leetcode.com/problems/number-of-islands/description/

Solution:

http://bit.ly/3TG6eUs

Final Advice & Resources

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- DFS and BFS can solve many problems and many of the same problems
  - For practice, implement the recursive and iterative for both

- More Graph Questions + Other LeetCode Questions
  1. Blind 75: https://leetcode.com/discuss/general-discussion/460599/blind-75-leetcode-questions

  2. Grind 75: https://www.techinterviewhandbook.org/grind75

  3. Neetcode: https://neetcode.io/practice