Day 7 and 8

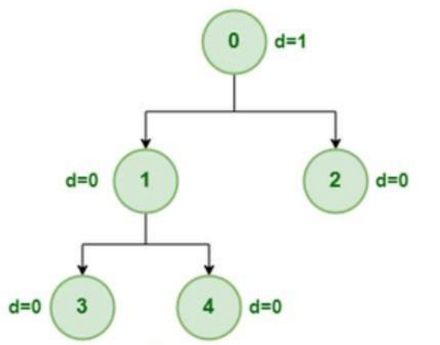
Task 1: Balanced Binary Tree Check

Write a function to check if a given binary tree is balanced. A balanced tree is one where the height of two subtrees of any node never differs by more than one.

A binary tree is balanced if the height of the tree is O(Log n) where n is the number of nodes. For Example, the AVL tree maintains O(Log n) height by making sure that the difference between the heights of the left and right subtrees is at most 1. Red-Black trees maintain O(Log n) height by making sure that the number of Black nodes on every root-to-leaf path is the same and that there are no adjacent red nodes. Balanced Binary Search trees are performance-wise good as they provide O(log n) time for search, insert and delete.

A balanced binary tree is a binary tree that follows the 3 conditions:

- The height of the left and right tree for any node does not differ by more than 1.
- The left subtree of that node is also balanced.
- The right subtree of that node is also balanced.



Balanced Binary Tree with depth at each level indicated

class TreeNode {

int val;

TreeNode left;

TreeNode right;

TreeNode(int x) {

val = x;

```java
}
}

public class BalancedBinaryTree {
    public boolean isBalanced(TreeNode root) {
        return checkHeight(root) != -1;
    }

    private int checkHeight(TreeNode node) {
        if (node == null) {
            return 0;
        }

        int leftHeight = checkHeight(node.left);
        if (leftHeight == -1) {
            return -1;
        }

        int rightHeight = checkHeight(node.right);
        if (rightHeight == -1) {
            return -1;
        }

        if (Math.abs(leftHeight - rightHeight) > 1) {
            return -1;
        }

        return Math.max(leftHeight, rightHeight) + 1;
    }
```

```
    public static void main(String[] args) {

        TreeNode root = new TreeNode(1);
        root.left = new TreeNode(2);
        root.right = new TreeNode(3);
        root.left.left = new TreeNode(4);
        root.left.right = new TreeNode(5);

        BalancedBinaryTree treeChecker = new BalancedBinaryTree();
        System.out.println(treeChecker.isBalanced(root));

        TreeNode unbalancedRoot = new TreeNode(1);
        unbalancedRoot.left = new TreeNode(2);
        unbalancedRoot.left.left = new TreeNode(3);

        System.out.println(treeChecker.isBalanced(unbalancedRoot));
    }
}
```

Output:

True

False

Task 2: Trie for Prefix Checking

Implement a trie data structure in C# that supports insertion of strings and provides a method to check if a given string is a prefix of any word in the trie.

Trie data structure in C# that supports insertion of strings and provides a method to check if a given string is a prefix of any word in the trie.

```
using System;
```

```
using System.Collections.Generic;

public class TrieNode
{
    public Dictionary<char, TrieNode> Children { get; private set; }
    public bool IsEndOfWord { get; set; }

    public TrieNode()
    {
        Children = new Dictionary<char, TrieNode>();
        IsEndOfWord = false;
    }
}

public class Trie
{
    private TrieNode root;

    public Trie()
    {
        root = new TrieNode();
    }
    // Insert a word into the trie
    public void Insert(string word)
    {
        TrieNode currentNode = root;
        foreach (char c in word)
        {
            if (!currentNode.Children.ContainsKey(c))
```

```
        {
            currentNode.Children[c] = new TrieNode();
        }
        currentNode = currentNode.Children[c];
    }
    currentNode.IsEndOfWord = true;
}

// Check if a prefix is present in any word in the trie
public bool StartsWith(string prefix)
{
    TrieNode currentNode = root;
    foreach (char c in prefix)
    {
        if (!currentNode.Children.ContainsKey(c))
        {
            return false;
        }
        currentNode = currentNode.Children[c];
    }
    return true;
}

// Check if a word is present in the trie
public bool Search(string word)
{
    TrieNode currentNode = root;
    foreach (char c in word)
    {
```

```
            if (!currentNode.Children.ContainsKey(c))
            {
                return false;
            }
            currentNode = currentNode.Children[c];
        }
        return currentNode.IsEndOfWord;
    }
}

class Program
{
    static void Main(string[] args)
    {
        Trie trie = new Trie();

        trie.Insert("apple");
        trie.Insert("app");

        Console.WriteLine(trie.Search("apple"));  // True
        Console.WriteLine(trie.Search("app"));     // True
        Console.WriteLine(trie.Search("appl"));   // False
        Console.WriteLine(trie.StartsWith("app")); // True
        Console.WriteLine(trie.StartsWith("apl")); // False
    }
}
```

Explanation

TrieNode Class:

- **Children**: A dictionary that maps each character to the corresponding child node.

- **IsEndOfWord**: A boolean flag to indicate if the node corresponds to the end of a word.

Trie Class:

- **root**: The root node of the trie.
- **Insert**(string word): Inserts a word into the trie by iterating through its characters and creating new nodes if necessary.
- **StartsWith**(string prefix): Checks if there is any word in the trie that starts with the given prefix.
- **Search(string word):** Checks if a given word exists in the trie.

Main Method:

Demonstrates how to use the Trie class by inserting words and checking for their existence and prefixes.

Here's a breakdown of each line in the output:

- **True**
- **True**
- **False**
- **True**
- **False**

- **trie.Search("apple"):** This returns True because "apple" was inserted into the trie.
- **trie.Search("app"):** This returns True because "app" was also inserted into the trie.
- **trie.Search("appl"):** This returns False because "appl" was not inserted into the trie.
- **trie.StartsWith("app"):** This returns True because both "apple" and "app" start with the prefix "app".
- **trie.StartsWith("apl"):** This returns False because there is no word in the trie that starts with the prefix "apl".

Task 3: Implementing Heap Operations

Code a min-heap in C# with methods for insertion, deletion, and fetching the minimum element. Ensure that the heap property is maintained after each operation.

using System;

using System.Collections.Generic;

```
public class MinHeap
{
    private List<int> heap;

    public MinHeap()
    {
        heap = new List<int>();
    }

    // Insert a new element into the heap
    public void Insert(int value)
    {
        heap.Add(value);
        HeapifyUp(heap.Count - 1);
    }

    // Delete the minimum element (the root) from the heap
    public int DeleteMin()
    {
        if (heap.Count == 0)
        {
            throw new InvalidOperationException("Heap is empty");
        }

        int minValue = heap[0];
        heap[0] = heap[heap.Count - 1];
        heap.RemoveAt(heap.Count - 1);
        HeapifyDown(0);
```

```
    return minValue;
}
// Fetch the minimum element (the root) without deleting it
public int GetMin()
{
    if (heap.Count == 0)
    {
        throw new InvalidOperationException("Heap is empty");
    }

    return heap[0];
}
// Heapify up to maintain the heap property after insertion
private void HeapifyUp(int index)
{
    while (index > 0)
    {
        int parentIndex = (index - 1) / 2;

        if (heap[index] >= heap[parentIndex])
        {
            break;
        }

        Swap(index, parentIndex);
        index = parentIndex;
    }
}
```

```
// Heapify down to maintain the heap property after deletion
private void HeapifyDown(int index)
{
    int lastIndex = heap.Count - 1;

    while (index < lastIndex)
    {
        int leftChildIndex = 2 * index + 1;
        int rightChildIndex = 2 * index + 2;
        int smallestChildIndex = index;

        if (leftChildIndex <= lastIndex && heap[leftChildIndex] < heap[smallestChildIndex])
        {
            smallestChildIndex = leftChildIndex;
        }

        if (rightChildIndex <= lastIndex && heap[rightChildIndex] < heap[smallestChildIndex])
        {
            smallestChildIndex = rightChildIndex;
        }

        if (smallestChildIndex == index)
        {
            break;
        }

        Swap(index, smallestChildIndex);
        index = smallestChildIndex;
    }
```

```
    }

    // Swap two elements in the heap
    private void Swap(int index1, int index2)
    {
        int temp = heap[index1];
        heap[index1] = heap[index2];
        heap[index2] = temp;
    }
}

class Program
{
    static void Main(string[] args)
    {
        MinHeap minHeap = new MinHeap();

        // Insert elements
        minHeap.Insert(5);
        minHeap.Insert(3);
        minHeap.Insert(8);
        minHeap.Insert(1);
        minHeap.Insert(2);

        // Get the minimum element
        Console.WriteLine("Min: " + minHeap.GetMin());  // Output: 1
        // Delete the minimum element
        Console.WriteLine("Deleted Min: " + minHeap.DeleteMin());
        Console.WriteLine("New Min: " + minHeap.GetMin());
```

```
        // Delete the minimum element
        Console.WriteLine("Deleted Min: " + minHeap.DeleteMin());
        Console.WriteLine("New Min: " + minHeap.GetMin());
    }
}
```

Explanation:

MinHeap Class:

- **heap**: A list that stores the heap elements.
- **Insert(int value):** Adds a new element to the heap and ensures the heap property is maintained by calling **HeapifyUp**.
- **DeleteMin():** Removes and returns the minimum element (the root) from the heap, ensuring the heap property is maintained by calling **HeapifyDown**.
- **GetMin**(): Returns the minimum element (the root) without removing it.
- **HeapifyUp**(int index): Ensures the heap property is maintained from the given index upwards to the root.
- **HeapifyDown(int index):** Ensures the heap property is maintained from the given index downwards to the leaves.
- **Swap(int index1, int index2):** Swaps two elements in the heap.

Program Class:

- Demonstrates the use of the **MinHeap** class by inserting elements, fetching the minimum element, and deleting the minimum element.

Output:

Min: 1

Deleted Min: 1

New Min: 2

Deleted Min: 2

New Min: 3

Insert Elements:

- Elements 5, 3, 8, 1, and 2 are inserted into the min-heap.

Get the Minimum Element:

- **minHeap.GetMin()** returns 1 because 1 is the smallest element in the heap.

Delete the Minimum Element:

- **minHeap.DeleteMin()** removes 1 (the root) from the heap, and 2 becomes the new root. The heap property is restored by **HeapifyDown.**

Get the New Minimum Element:

minHeap.GetMin() now returns 2 because 2 is the new smallest element in the heap.

Delete the Minimum Element Again:

- **minHeap.DeleteMin()** removes 2 (the root) from the heap, and 3 becomes the new root. The heap property is restored by **HeapifyDown.**

Get the New Minimum Element Again:

- **minHeap.GetMin()** now returns 3 because 3 is the new smallest element in the heap.

Task 4: Graph Edge Addition Validation

Given a directed graph, write a function that adds an edge between two nodes and then checks if the graph still has no cycles. If a cycle is created, the edge should not be added.

Java implementation of a function that adds an edge to a directed graph and checks for cycles. If a cycle is created by adding the edge, the edge is not added.

```
import java.util.*;

public class DirectedGraph {

  private Map<Integer, List<Integer>> adjList;

  public DirectedGraph() {

    adjList = new HashMap<>();

  }

  // Add a node to the graph

  public void addNode(int node) {

    adjList.putIfAbsent(node, new ArrayList<>());

  }


  // Add an edge to the graph and check for cycles

  public boolean addEdge(int from, int to) {
```

```
    addNode(from);
    addNode(to);

    // Temporarily add the edge
    adjList.get(from).add(to);
    // Check for cycles
    if (hasCycle()) {
        // Remove the edge if a cycle is detected
        adjList.get(from).remove((Integer) to);
        return false;
    }
    return true;
}

// Helper method to check if the graph has a cycle
private boolean hasCycle() {
    Set<Integer> visited = new HashSet<>();
    Set<Integer> recursionStack = new HashSet<>();

    for (Integer node : adjList.keySet()) {
        if (hasCycleUtil(node, visited, recursionStack)) {
            return true;
        }
    }

    return false;
}

// DFS based utility method to detect cycle
```

```
    private boolean hasCycleUtil(int node, Set<Integer> visited, Set<Integer> recursionStack)
{
        if (recursionStack.contains(node)) {
            return true;
        }
        if (visited.contains(node)) {
            return false;
        }

        visited.add(node);
        recursionStack.add(node);

        List<Integer> neighbors = adjList.get(node);
        if (neighbors != null) {
            for (Integer neighbor : neighbors) {
                if (hasCycleUtil(neighbor, visited, recursionStack)) {
                    return true;
                }
            }
        }

        recursionStack.remove(node);
        return false;
    }

    public static void main(String[] args) {
        DirectedGraph graph = new DirectedGraph();
        System.out.println(graph.addEdge(1, 2));
        System.out.println(graph.addEdge(2,  3));
        System.out.println(graph.addEdge(3,  4));
```

```
        System.out.println(graph.addEdge(4, 2));
        // Print the adjacency list to verify edges
        System.out.println(graph.adjList);
    }
}
```

Explanation:

Graph Representation:

- We use an adjacency list (adjList) to represent the directed graph.
- Each node maps to a list of its neighbors.

Adding Nodes and Edges:

- The **addNode** method ensures that a node is added to the graph if it does not already exist.
- The **addEdge** method tries to add an edge from from to to and checks for cycles using DFS. If a cycle is detected, the edge is removed and the method returns false. Otherwise, it returns true.

Cycle Detection:

- The **hasCycle** method iterates over all nodes to check for cycles using a helper method **hasCycleUtil**.
- The **hasCycleUtil** method performs a DFS to detect cycles. It uses two sets: visited to keep track of all visited nodes, and **recursionStack** to keep track of the nodes in the current DFS path.
- If a node is found in the **recursionStack**, a cycle is detected.

Main Method:

The main method demonstrates adding edges and prints the results. It also prints the adjacency list to verify the graph structure.

output

true

true

true

false

{1=[2], 2=[3], 3=[4]}

Task 5: Breadth-First Search (BFS) Implementation

For a given undirected graph, implement BFS to traverse the graph starting from a given node and print each node in the order it is visited.

Breadth-First Search (BFS) for traversing an undirected graph starting from a given node. The implementation includes a graph class that uses an adjacency list to represent the graph, and a BFS function that traverses the graph and prints each node in the order it is visited.

```
import java.util.*;

public class UndirectedGraph {
   private Map<Integer, List<Integer>> adjList;

   public UndirectedGraph() {
      adjList = new HashMap<>();
   }
   // Add a node to the graph
   public void addNode(int node) {
      adjList.putIfAbsent(node, new ArrayList<>());
   }
   // Add an undirected edge to the graph
   public void addEdge(int node1, int node2) {
      addNode(node1);
      addNode(node2);
      adjList.get(node1).add(node2);
      adjList.get(node2).add(node1);
   }
   // BFS traversal starting from a given node
   public void bfs(int startNode) {
      Set<Integer> visited = new HashSet<>();
      Queue<Integer> queue = new LinkedList<>();
```

```
    visited.add(startNode);
    queue.add(startNode);

    while (!queue.isEmpty()) {
        int currentNode = queue.poll();
        System.out.print(currentNode + " ");

        List<Integer> neighbors = adjList.get(currentNode);
        if (neighbors != null) {
            for (Integer neighbor : neighbors) {
                if (!visited.contains(neighbor)) {
                    visited.add(neighbor);
                    queue.add(neighbor);
                }
            }
        }
    }
}

public static void main(String[] args) {
    UndirectedGraph graph = new UndirectedGraph();
    graph.addEdge(1, 2);
    graph.addEdge(1, 3);
    graph.addEdge(2, 4);
    graph.addEdge(3, 4);
    graph.addEdge(4, 5);

    System.out.println("BFS traversal starting from node 1:");
```

```
        graph.bfs(1);
    }
}
```

Explanation:

Graph Representation:

- The graph is represented using an adjacency list (**adjList**), where each node maps to a list of its neighbors.

Adding Nodes and Edges:

- **addNode(int node**): Adds a node to the graph if it does not already exist.
- **addEdge(int node1, int node2):** Adds an undirected edge between node1 and node2. It ensures both nodes are present in the graph and then adds each node to the other's adjacency list.

BFS Traversal:

- **bfs(int startNode**): Performs BFS traversal starting from **startNode**.
- Uses a set **visited** to keep track of visited nodes.
- Uses a queue **queue** to manage the nodes to be visited next.
- Visits each node in the order they are dequeued, printing each node as it is visited.
- Adds each unvisited **neighbor** of the current node to the queue and marks them as visited**.**

Main Method:

- The main method demonstrates adding edges to the graph and performing a BFS traversal starting from node 1.
- The expected output of the traversal is printed, showing the order in which the nodes are visited.

Output:

BFS traversal starting from node 1:

1 2 3 4 5

Task 6: Depth-First Search (DFS) Recursive

Write a recursive DFS function for a given undirected graph. The function should visit every node and print it out.

Java implementation of Depth-First Search (DFS) for an undirected graph. The implementation includes a graph class using an adjacency list and a recursive DFS function that visits every node and prints it.

```
import java.util.*;

public class UndirectedGraph {

    private Map<Integer, List<Integer>> adjList;

    public UndirectedGraph() {

        adjList = new HashMap<>();

    }


    public void addNode(int node) {

        adjList.putIfAbsent(node, new ArrayList<>());

    }


    public void addEdge(int node1, int node2) {

        addNode(node1);

        addNode(node2);

        adjList.get(node1).add(node2);

        adjList.get(node2).add(node1);

    }



    public void dfs(int startNode) {

        Set<Integer> visited = new HashSet<>();

        dfsUtil(startNode, visited);

    }
```

```
    // Recursive utility function for DFS traversal
    private void dfsUtil(int node, Set<Integer> visited) {
        // Mark the current node as visited and print it
        visited.add(node);
        System.out.print(node + " ");

        // Recur for all the vertices adjacent to this vertex
        List<Integer> neighbors = adjList.get(node);
        if (neighbors != null) {
            for (Integer neighbor : neighbors) {
                if (!visited.contains(neighbor)) {
                    dfsUtil(neighbor, visited);
                }
            }
        }
    }

    public static void main(String[] args) {
        UndirectedGraph graph = new UndirectedGraph();
        graph.addEdge(1, 2);
        graph.addEdge(1, 3);
        graph.addEdge(2, 4);
        graph.addEdge(3, 4);
        graph.addEdge(4, 5);

        System.out.println("DFS traversal starting from node 1:");
        graph.dfs(1);
    }
}
```

Explanation:

Graph Representation:

- The graph is represented using an adjacency list (adjList), where each node maps to a list of its neighbors.

Adding Nodes and Edges:

- addNode(int node): Adds a node to the graph if it does not already exist.
- addEdge(int node1, int node2): Adds an undirected edge between node1 and node2. It ensures both nodes are present in the graph and then adds each node to the other's adjacency list.

DFS Traversal:

- **dfs(int startNode):** Initiates DFS traversal starting from startNode.
- Uses a set visited to keep track of visited nodes.
- Calls the recursive utility function **dfsUti**l to perform the traversal.
- **dfsUtil**(int node, Set<Integer> visited): Recursively visits nodes.
- Marks the current node as visited and prints it.
- Recursively visits all unvisited **neighbors** of the current node.

Main Method:

- The main method demonstrates adding edges to the graph and performing a DFS traversal starting from node 1.
- The expected output of the traversal is printed, showing the order in which the nodes are visited.

Output:

DFS traversal starting from node 1:

1 2 4 5 3

DFS Traversal Path:

- **The traversal starts at node 1.**
- **From node 1, it visits node 2.**
- **From node 2, it moves to node 4.**
- **From node 4, it goes to node 5.**
- **After visiting node 5, it backtracks to node 4 and then moves to node 3.**