Algorithm and Problem Solving Cheatsheet in C++

Data Structures, Algorithms and Coding Interview Problem Patterns in C++

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MOTIVATION

Motivation

The tech industry hiring standard is based on algorithm and data structure.

There are plenty of free resources available around algorithms and data structures. The purpose of this project is to be a quick guide where you can learn and review learned algorithms and data structures.

Some of the intended **key features:**

- Non-verbose, short-structured, and easy to follow descriptions

- Slide-based, practical for reviewing

- Free and open-source

⭐ **If you like, please add a star at *github.com/rfdavid/cpp-algo-cheatsheet***

Useful links

Tech Interview Handbook
https://www.techinterviewhandbook.org
A very well-structured resource for interview preparation

TUF
https://takeuforward.org/interviews/blind-75-leetcode-problems-detailed-video-solutions
Contains explanation and some videos for the problems from blind 75 list

Blind 75 Leetcode Questions
https://leetcode.com/discuss/general-discussion/460599/blind-75-leetcode-questions

Blind 75

- Blind 75 is a popular list of algorithm problems that intends to cover the main data structures and patterns.

- It is a curated list of 75 popular coding questions created by an ex-Meta Staff Engineer

Array
- ✓ Two Sum
- ✓ Best Time to Buy and Sell Stock
- Contains Duplicate
- Product of Array Except Self
- Maximum Subarray
- Maximum Product Subarray
- Find Minimum in Rotated Sorted Array
- Search in Rotated Sorted Array
- 3 Sum
- Container With Most Water

Binary
- Sum of Two Integers
- Number of 1 Bits
- Counting Bits
- Missing Number
- Reverse Bits

Dynamic Programming
- ✓ Climbing Stairs
- Coin Change
- Longest Increasing Subsequence
- Longest Common Subsequence
- Word Break Problem
- Combination Sum
- House Robber
- House Robber II
- Decode Ways
- Unique Paths
- Jump Game

Matrix
- Set Matrix Zeroes
- Spiral Matrix
- Rotate Image
- Word Search

Blind 75

Tree

✓ Maximum Depth of Binary Tree

Same Tree

Invert/Flip Binary Tree

Binary Tree Maximum Path Sum

Binary Tree Level Order Traversal

Serialize and Deserialize Binary Tree

Subtree of Another Tree

Construct Binary Tree from Preorder and Inorder Traversal

Validate Binary Search Tree

Kth Smallest Element in a BST

Lowest Common Ancestor of BST

Implement Trie (Prefix Tree)

Add and Search Word

Word Search II

Heap

Merge K Sorted Lists

Top K Frequent Elements

Find Median from Data Stream

String

Longest Substring Without Repeating Characters

Longest Repeating Character Replacement

Minimum Window Substring

Valid Anagram

Group Anagrams

✓ Valid Parentheses

Valid Palindrome

Longest Palindromic Substring

Palindromic Substrings

Encode and Decode Strings ⭐

Linked List

Reverse a Linked List

Detect Cycle in a Linked List

Merge Two Sorted Lists

Merge K Sorted Lists

Remove Nth Node From End Of List

Reorder List

Graph

✓ Clone Graph

Course Schedule

Pacific Atlantic Water Flow

Number of Islands

Longest Consecutive Sequence

Alien Dictionary ⭐

Graph Valid Tree ⭐

Number of Connected Components in an Undirected Graph ⭐

Interval

Insert Interval

Merge Intervals

Non-overlapping Intervals

Meeting Rooms ⭐

Meeting Rooms II ⭐

⭐ = leetcode premium

Other problems

Tree

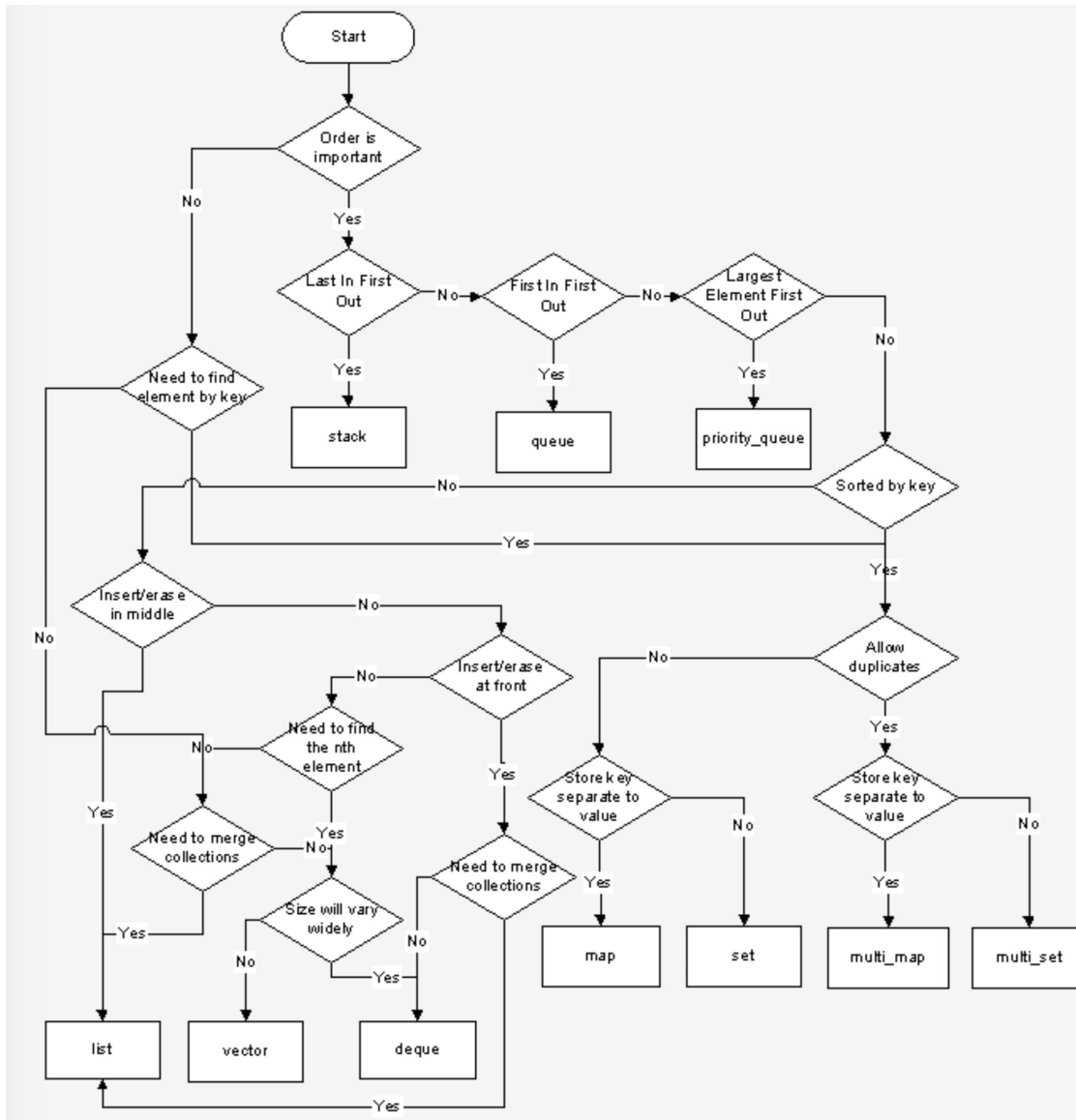✓ [Maximum Level Sum of a Binary Tree](#)

DATA STRUCTURES

Vectors

- std::vector is a sequence container that encapsulates dynamic sized arrays*

Data Structure Decision Diagram

- The following diagram gives you the direction to which data structure to use in C++ according to the problem you are trying to solve

ARRAY

Arrays

Characteristics

- **Memory layout**: hold values in a **contiguous** block of memory.

- **Fixed Size**: the size of an array is defined when it is created and cannot be changed. However, high-level languages have different implementations, making it dynamic.

- **Homogeneous elements:** all elements are of the same data type (int, float, char…)

- **Efficiency**: accessing elements by index is very efficient *O(1)*, since each index maps directly to a memory location. Also, range scans benefit from CPU cache lines since arrays are stored in contiguous blocks of memory.

Arrays – Kadane's algorithm

Problem – Two Sum

LeetCode leetcode.com/problems/two-sum

Problem Statement

- Given an **array** of numbers and a **target**, example: **array [2,7,11,15]** and **target 9**

- Return indices of two numbers where they add up to **target**

- **Output**: [0,1]

  ```
  array[0] + array[1] = 2 + 7 = 9
  ```

Solution

- Iterative over each number in the array

- Calculate the difference between target and each number, example:

  `array[0] = 2,` `target 9, then 9 – 2 = 7`

- Now we know we need the number **7** to sum up to **9**

- Check in a *hashmap* if we have 7 in some part of the array

  `hash[7] exists?`

- If yes, return the current index and the index of 7

- If not, store the index of the current number in the hashmap for future evaluation

  `hash[2] = 0`

Code – Two Sum

Code O(n)

```cpp
vector<int> twoSum(vector<int>& nums, int target) {
    std::unordered_map<int, int> numMap;
    // O(n)
    // n being the size of nums
    for (int i = 0; i < nums.size(); i++) {
        // current number of the array
        int number = nums[i];
        int diff = target - number;

        // check if the difference is in some part of the array
        // by using a hashmap
        if (numMap.find(diff) != numMap.end()) {
            return { numMap[diff], i};
        }

        // register the current number index
        numMap[number] = i;
    }
    // no matches
    return {};
}
```

Problem - Best Time to Buy and Sell Stock

https://leetcode.com/problems/best-time-to-buy-and-sell-stock

You are given an array **prices** where **prices[i]** is the price of a given stock on the ith day.

You want to maximize your profit by choosing a single day to buy one stock and choosing a different day in the future to sell that stock.

Return the maximum profit you can achieve from this transaction. If you cannot achieve any profit, return 0.

Example 1

Input: prices = [7,1,5,3,6,4]

Output: 5

Explanation: Buy on day 2 (price = 1) and sell on day 5 (price = 6), profit = 6-1 = 5.

Note that buying on day 2 and selling on day 1 is not allowed because you must buy before you sell.

Example 2

Input: prices = [7,6,4,3,1]

Output: 0

Explanation: In this case, no transactions are done and the max profit = 0.

Solution - Best Time to Buy and Sell Stock

https://leetcode.com/problems/best-time-to-buy-and-sell-stock

```cpp
int maxProfit(vector<int>& prices) {
    int profit = 0;
    int buy = prices[0];
    for (auto i = 1; i < prices.size(); i++) {
        if (prices[i] < buy) {
            buy = prices[i];
        } else if (prices[i] - buy > profit) {
            profit = prices[i] - buy;
        }
    }
    return profit;
}
```

STRING

Problem – Valid Parentheses

LeetCode leetcode.com/problems/valid-parentheses

Problem Statement

- Given a string …

Solution – Valid Parentheses

LeetCode leetcode.com/problems/valid-parentheses

Solution

- Explain…

LeetCode leetcode.com/problems/valid-parentheses

Code

```cpp
bool isValid(string s) {
    // stack (LIFO)
    std::stack<char> brackets;
    // O(n)
    for (int i = 0; i < s.size(); ++i) {
        char bracket = s[i];
        if (bracket == '(' || bracket == '[' || bracket == '{') {
            brackets.push(bracket);
        } else {
            if (brackets.size() == 0) return false;
            char lastBracket = brackets.top();
            if (bracket == ')' && lastBracket != '(') return false;
            if (bracket == '}' && lastBracket != '{') return false;
            if (bracket == ']' && lastBracket != '[') return false;
            brackets.pop();
        }
    }
    // all brackets must be closed
    return brackets.size() == 0;
}
```

BINARY

Binary

- In C++, **std::bitset** represents a fixed-size sequence of N bits
- Example:

```
std::bitset<8> bitmask;
bitmask.reset(1)
bitmask.set(1)
if (bitmask.test(1)) { // true
…
```

- **reset** : set bit to false
- **set** : set a specific bit
- **test** : check a specific bit
- **count** : return the number of bits set to true
- **flip** : toggle the value of the bits (if true, set to false and vice-versa)

Given a string, the goal is to find the longest substring without repeating characters.

For example, given a string "abcdb", it should return 4:

abcd since "b" is repeated

Solution 3 – Longest Substring Without Repeating Characters

- Using bitset: create a bitmask with 128 bits where each bit represent a character

- Use sliding window using **left** and **right**

- Set the bit to true for each character found

- Check if it is repeated and reset the bit

```cpp
int lengthOfLongestSubstring(string s) {
    std::bitset<128> bitmask;
    uint32_t left = 0;
    uint32_t maxLength = 0;

    for (uint32_t right = 0; right < s.length(); ++right) {
        uint32_t bitIndex = s[right];
        // if char is already in the bitmask, move left until we reset the bits
        while (bitmask.test(bitIndex)) {
            bitmask.reset(s[left]);
            ++left;
        }

        bitmask.set(bitIndex);
        maxLength = std::max(maxLength, right - left + 1);
    }
    return maxLength;
}
```

Negabinary

- Non-standard positional numeral system that uses base of -2

- Allow representing negative numbers in binary

- Example:

  1101_{-2}

  $(-2)^3 + (-2)^2 + 0 + (-2)^0 = -8 + 4 + 0 + 1 = -3$

Summing Negabinary

- Add as a regular binary number, but with **negative carry**

  $0 + 0 = 0$

  $1 + 0 = 1$

  $1 + 1 = 0$ with a negative carry 1

  1 $+ 1 = 0$ (subtract)

  1 $+ 0 = 1$ with a positive carry 1

Negabinary

Example 1

$$11\ 1$$
$$1011$$
$$+\ 1110$$
$$= 110001$$

1 + 0 = 1

1 + 1 = 0 with negative carry 1

1 + 1 = 0

1 + 1 = 0 with negative carry 1

1 + 0 = 1 with positive carry 1

1 + 0 = 1

red 1 = negative carry

green 1 = regular carry

Example 2

$$1111$$
$$101010$$
$$+\ 101100$$
$$= 11110110$$

Reference

https://math.stackexchange.com/questions/3251605/how-to-add-negabinary-numbers

https://leetcode.com/problems/adding-two-negabinary-numbers

Given two numbers **arr1** and **arr2** in base -2, return the result of adding them together.

Each number is given in *array format*: as an array of 0s and 1s, from most significant bit to least significant bit.

For example, **arr = [1,1,0,1]** represents the number $(-2)^3 + (-2)^2 + (-2)^0 = -3$. A number **arr** in array, format is also guaranteed to have no leading zeros: either **arr == [0]** or **arr[0] == 1**.

Return the result of adding **arr1** and **arr2** in the same format: as an array of 0s and 1s with no leading zeros.

Example 1

Input: arr1 = [1,1,1,1,1], arr2 = [1,0,1]

Output: [1,0,0,0,0]

Explanation: arr1 represents 11, arr2 represents 5, the output represents 16.

Example 2

Input: arr1 = [0], arr2 = [0]

Output: [0]

Example 3

Input: arr1 = [0], arr2 = [1]

Output: [1]

https://leetcode.com/problems/adding-two-negabinary-numbers

GRAPH (DFS)

Problem - Keys and Rooms

https://leetcode.com/problems/keys-and-rooms

```cpp
int maxProfit(vector<int>& prices) {
    int profit = 0;
    int buy = prices[0];
    for (auto i = 1; i < prices.size(); i++) {
        if (prices[i] < buy) {
            buy = prices[i];
        } else if (prices[i] - buy > profit) {
            profit = prices[i] - buy;
        }
    }
    return profit;
}
```

Problem – Clone Graph

https://leetcode.com/problems/clone-graph

Problem Statement

- Given a node reference, create a deep copy of the graph
- The class node has two variables: val and neighbours

```
class Node {

    public int val;

    public List<Node> neighbors;

}
```

- **Output** is the node reference of the copy

LeetCode https://leetcode.com/problems/clone-graph

Solution

- First check the edge cases (is the node null?)

- Create a hash map to store the nodes that is already created

  ```
  unordered<int, Node*> graph;
  ```

- Check if the current node already exists in the graph

- If not, create a new Node object and store in the hashmap

- Visit all the neighbors and add the neighbors to this current node

Code – Clone Graph

🔶 **LeetCode** https://leetcode.com/problems/clone-graph

```cpp
std::unordered_map<int, Node*> graph;


Node* cloneGraph(Node* node) {
    if (node == NULL) {
        return NULL;
    }
    // does this node object exists?
    if (graph.find(node->val) == graph.end()) {
        // node wasn't visited yet, store in the hashmap
        graph[node->val] = new Node(node->val);
        // visit all neighnours
        for (const auto& n : node->neighbors) {
            graph[node->val]->neighbors.push_back(cloneGraph(n));
        }
    }
    return graph[node->val];
}
```
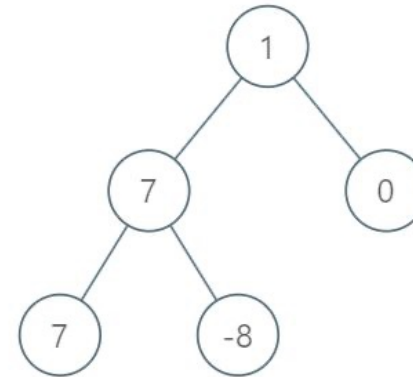
GRAPH (BFS)

Problem Statement

- Given the root of a binary tree, find the smallest level with the maximum sum

- For example, the tree below has the follow sums for each level:

  level 1 (root) = 1

  level 2 = 7 + 0 = 7

  level 3 = 7 – 8 = -1

- Therefore, **level 2** has the maximum sum

Solution – Maximum Level Sum of a Binary Tree

LeetCode https://leetcode.com/problems/maximum-level-sum-of-a-binary-tree

Solution

- Have a queue with the nodes for the current level

- Sum the values from that level by taking the nodes from the queue

- Example, we know that level 1 has one node. Hence, pop the first node from the queue

  If level 2 has 2 nodes, pop two nodes, sum the values

- In addition, add left and right to the end of the queue to process the next level

Code – Maximum Level Sum of a Binary Tree

LeetCode https://leetcode.com/problems/maximum-level-sum-of-a-binary-tree

```cpp
int maxLevelSum(TreeNode* root) {
    std::queue<TreeNode*> nodes;
    int currentLevel = 0;
    int maxLevel = 1;
    int maxSum = INT_MIN;

    nodes.push(root);

    // traverse the graph
    while(!nodes.empty()) {
        int levelSum = 0;
        int levelSize = nodes.size();
        currentLevel++;

        // sum the values in current level
        for (int i = 0; i < levelSize; ++i) {
            TreeNode* node = nodes.front();
            levelSum += node->val;
            nodes.pop();

            if (node->left) nodes.push(node->left);
            if (node->right) nodes.push(node->right);
        }

        if (levelSum > maxSum) {
            maxLevel = currentLevel;
            maxSum = levelSum;
        }
    }

    return maxLevel;
}
```
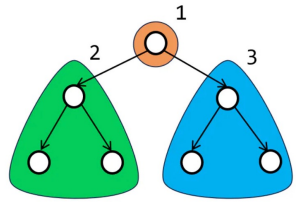
SHORTEST PATH

Shortest Path Algorithms

- BFS

- Dijkstra

- Bellman-Ford

- Floyd-Warshall

- A* search

- Johnson's

- SPFA (Shortest Path Faster)
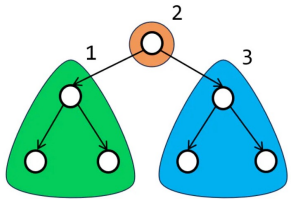
- Bidirectional Search
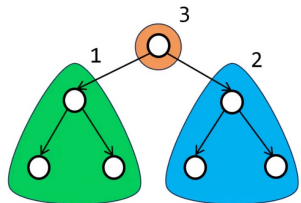
TREE

Tree Traversals

Depth-First Traversals

- **Pre-order**: Root – Left – Right

- **In-order**: Left – Root – Right

- **Post-order**: Left – Right – Root

Breadth-First Traversal (Level Order Traversal)

Visit every node on a level before moving to a lower level.

Tree Traversals

Depth-First Traversals

Use a recursive algorithm to traverse according to the order

- **Pre-order**: Root – Left – Right

```
if (!root) return;
doSomething();
visit(node.left);
visit(node.right);
```

- **In-order**: Left – Root – Right

```
if (!root) return;
visit(node.left);
doSomething();
visit(node.right);
```

- **Post-order**: Left – Right – Root

```
if (!root) return;
visit(node.left);
visit(node.right);
doSomething();
```

Tree Traversals

Example of pre-order and in-order

```cpp
struct TreeNode {
    int val;
    TreeNode *left, *right;
    TreeNode(int x) : val(x), left(nullptr), right(nullptr) {}
};

// Pre-order traversal
void preorderTraversal(TreeNode* root) {
    if (root == nullptr) return;
    cout << root->val << " ";
    preorderTraversal(root->left);
    preorderTraversal(root->right);
}

// In-order traversal
void inorderTraversal(TreeNode* root) {
    if (root == nullptr) return;
    inorderTraversal(root->left);
    cout << root->val << " ";
    inorderTraversal(root->right);
}
```

Tree Traversals

Example of post-order and level-order

```cpp
struct TreeNode {
    int val;
    TreeNode *left, *right;
    TreeNode(int x) : val(x), left(nullptr), right(nullptr) {}
};

// Post-order traversal
void postorderTraversal(TreeNode* root) {
    if (root == nullptr) return;
    postorderTraversal(root->left);
    postorderTraversal(root->right);
    cout << root->val << " ";
}

// Level-order traversal using a queue
void levelOrderTraversal(TreeNode* root) {
    if (root == nullptr) return;
    queue<TreeNode*> q;
    q.push(root);
    while (!q.empty()) {
        TreeNode* current = q.front();
        q.pop();
        cout << current->val << " ";
        if (current->left != nullptr) q.push(current->left);
        if (current->right != nullptr) q.push(current->right);
    }
}
```
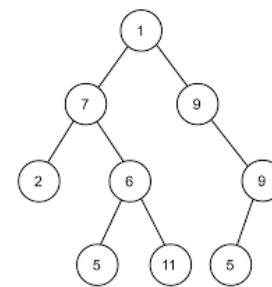
Problem – Maximum Depth of Binary Tree

Problem Statement

- Given the root of a binary tree, find the *maximum depth*

- **Example:**

  root = [1,7,9,2,6,null,9,null,null,5,11,5,null]

- **Output**: 4

Solution – Maximum Depth of Binary Tree

 LeetCode   https://leetcode.com/problems/maximum-depth-of-binary-tree

Solution

- Perform **post-order** traversal: left - right - root

- Recursively go left and right to find each value

- Return the max of each one

Code – Maximum Depth of Binary Tree

LeetCode https://leetcode.com/problems/maximum-depth-of-binary-tree

```cpp
int maxDepth(TreeNode* root) {

    if (!root) return 0;

    // find max left

    int maxLeft = maxDepth(root->left);

    // find max right

    int maxRight = maxDepth(root->right);

    // return max +1 (account for root)

    return std::max(maxLeft, maxRight) + 1;

}
```

Problem – Path Sum

Problem Statement

- It is given the **root** of a binary tree and an integer **target sum**
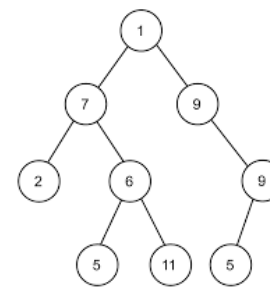
- **Example:**

  root = [1,7,9,2,6,null,9,null,null,5,11,5,null]

  target sum = 10

- Return true if there is a path from root to leaf that adds up to 10

- **Output**: true

  Node 1 + Node 7 + Node 2 = 10
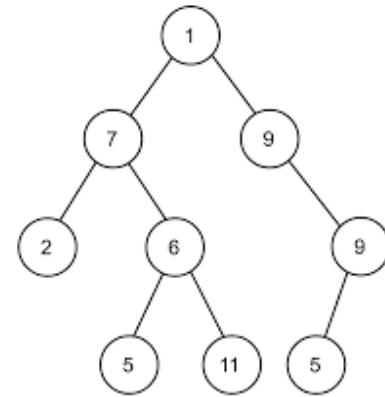
Solution – Path Sum

Solution

- Start from root node (1)

- Subtract from target number (example 10 – 1 = 9)

- Continue going down the tree, until the target is 0, return true

- After visiting all nodes, if the target is not zero, return false

Code – Path Sum

LeetCode https://leetcode.com/problems/path-sum

```cpp
bool hasPathSum(TreeNode* root, int targetSum) {
    if (!root) {
        return false;
    }
    // we want targetSum to be zero
    targetSum -= root->val;
    // if there is no left, no right, we've reached the end of the path
    // so if the targetSum is zero, then the nodes summed up to the targetSum
    if (!root->left && !root->right && targetSum == 0) {
        return true;
    }
    // propagate to left and right
    return hasPathSum(root->left, targetSum) || hasPathSum(root->right, targetSum);
}
```

Also, a small performance tweak can be made by avoiding writing *targetSum:* *targetSum -= root->val*

This will avoid a memory write access, making the calculation directly in the CPU, but also at a cost of readability

```cpp
    if (!root->left && !root->right && targetSum – root->val == 0) {
      …
    return hasPathSum(root->left, targetSum – root->val) || hasPathSum(root->right, targetSum – root->val);
```

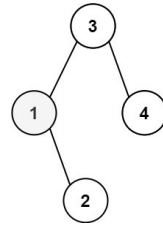https://leetcode.com/problems/kth-smallest-element-in-a-bst

Given the **root** of a binary search tree, and an integer **k,** return the **k**th smallest value (1-indexed) of all the values of the nodes in the tree.

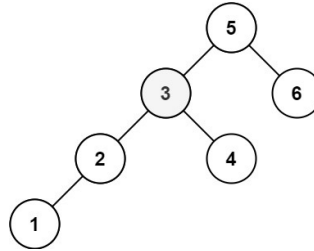**Example 1**

Input: root = [3,1,4,null,2], k = 1

Output: 1

Example 2

Input: root = [5,3,6,2,4,null,null,1], k = 3

Output: 3

https://leetcode.com/problems/maximum-depth-of-binary-tree

```cpp
int kthSmallest(TreeNode* root, int k) {
    int count = 0;
    int output;
    traverse(root, count, output, k);
    return output;
}

// perform in-order traversal:  left, node, right
void traverse(TreeNode* node, int& count, int &output, int k) {
    if (!node) return;
    traverse(node->left, count, output, k);
    count++;
    if (count == k) {
        output = node->val;
        return;
    }
    traverse(node->right, count, output, k);
}
```

LINKED LIST

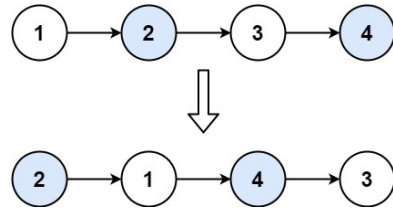https://leetcode.com/problems/swap-nodes-in-pairs

Problem

Given a linked list, swap every two adjacent nodes and return its head. You must solve the problem without modifying the values in the list's nodes (i.e., only nodes themselves may be changed.)

Example 1

Input: head = [1,2,3,4]

Output: [2,1,4,3]

Example 2

Input: head = []

Output: []

Example 3:

Example 3

Input: head = [1]

Output: [1]

Solution – Swap Nodes in Pair

https://leetcode.com/problems/swap-nodes-in-pairs

```cpp
ListNode* swapPairs(ListNode* head) {
    if (head == NULL || head->next == NULL) {
        return head;
    }
    ListNode *node = head;
    ListNode *prev = NULL;
    head = head->next;

    while (node && node->next) {
        ListNode *second = node->next;
        ListNode *next_pair = second->next;
        second->next = node;
        node->next = next_pair;
        if (prev) {
            prev->next = second;
        }
        prev = node;
        node = next_pair;
    }
    return head;
}
```

https://leetcode.com/problems/swap-nodes-in-pairs

```
ListNode* swapPairs(ListNode* head) {
    if(!head || !head->next)
        return head;
    ListNode* newHead = head->next;
    head->next = swapPairs(head->next->next);
    newHead->next = head;
    return newHead;
}
```
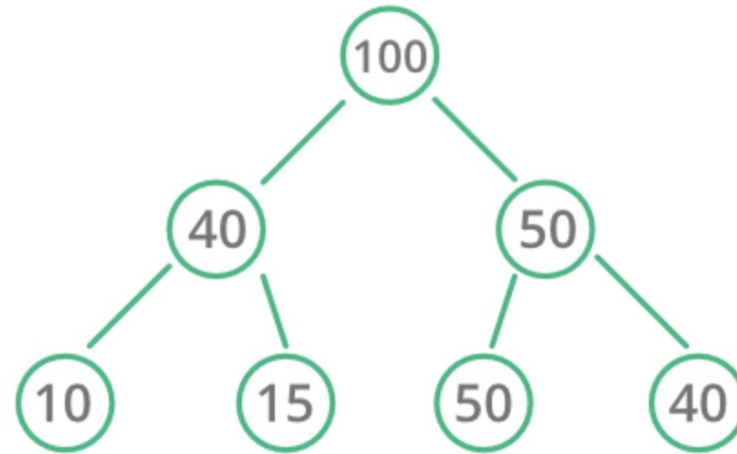
HEAP / PRIORITY QUEUE

Heap

- **Heap** is a complete binary tree that satisfy the heap property (max or min)

- **Min heap**: root node contains the minimum value

- **Max heap**: root node contains the maximum value
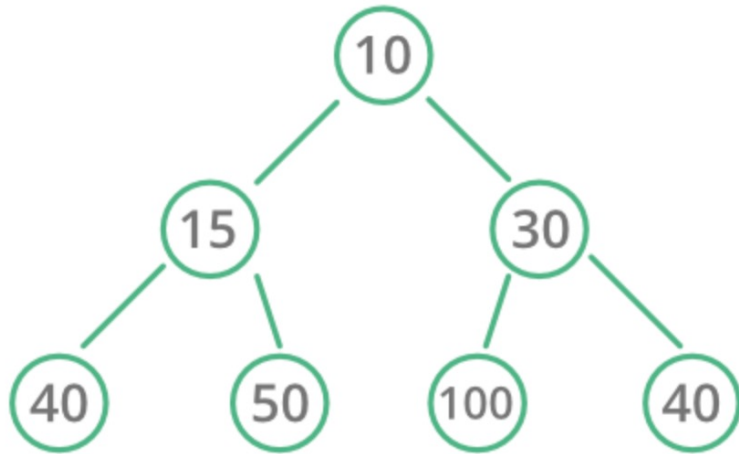
Heap in C++

Two main ways to implement:

1. Using **std::make_heap** from **<algorithm>**

```
std::make_heap(RandomIt first, RandomIt last)

std::push_heap(RandomIt first, RandomIt last)

std::pop_heap(RandomIt first, RandomIt last)

std::sort_heap(RandomIt first, RandomIt last)
```

2. Using **std::priority_queue** from **<queue>** **(recommended)**

```
std::priority_queue<T, Container, Compare>
```

Heap in C++ – std::priority_queue example

Min heap

```
std::priority_queue<int, std::vector<int>, std::greater<int>>
```

Max heap

```
std::priority_queue<int> or

std::priority_queue<int, std::vector<int> std::less<int>>
```

```cpp
// Min heap
std::priority_queue<int, std::vector<int>, std::greater<int>> minHeap;

minHeap.push(3);
minHeap.push(6);
minHeap.push(4);
// remove top element (3)
minHeap.pop();
// root node (top) is now 4
std::cout << minHeap.top();
```

Problem – Kth Largest Element in an Array

https://leetcode.com/problems/kth-largest-element-in-an-array

Problem

Given an integer array **nums** and an integer **k**, return the **k**[th] largest element in the array.

Note that it is the **k**[th] largest element in the sorted order, not the **k**[th] distinct element.

Example 1

Input: nums = [3,2,1,5,6,4], k = 2

Output: 5

Example 2

Input: nums = [3,2,3,1,2,4,5,5,6], k = 4

Output: 4

Although this problem is classified as "medium", in my opinion it should be classified as "easy"

https://leetcode.com/problems/kth-largest-element-in-an-array

```cpp
// SOLUTION 1

int findKthLargest(vector<int>& nums, int k) {
    std::priority_queue<int, std::vector<int>, std::greater<int>> minHeap;
    for (const auto& num : nums) {
        if (minHeap.size() < k) {
            minHeap.push(num);
        } else if (num > minHeap.top()) {
            minHeap.pop();
            minHeap.push(num);
        }
    }
    return minHeap.top();
}
```

https://leetcode.com/problems/kth-largest-element-in-an-array

```cpp
// SOLUTION 2 – Simpler approach

int findKthLargest(vector<int>& nums, int k) {
    // min heap: minimum values will be always at the top
    std::priority_queue<int, std::vector<int>, std::greater<int>> minHeap;
    for (const auto& num : nums) {
        // push each num to the heap
        minHeap.push(num);
        // we need the kth largest element only, so once after pushing more than k
        // elements, remove the smallest one (the top)
        if (minHeap.size() > k) {
            minHeap.pop();
        }
    }
    return minHeap.top();
}
```

DYNAMIC PROGRAMMING

Dynamic Programming

Dynamic Programming (DP) is an algorithm technique used to solve problems that can be broken down into **simpler, overlapping subproblems.**

Key Concepts of Dynamic Programming

- **Overlapping subproblems**: a problem has overlapping subproblems if it can be broken down into subproblems.
- **Memoization (Top-Down Approach)**: store the results in a cache (typically a dictionary or array) to avoid recalculation – recursion and caching approach.
- **Tabulation (Bottom-Up Approach)**: first solve all possible subproblems iteratively, and store them in a table.

Dynamic Programming – Example – Fibonacci Sequence

Naive Recursive Approach $O(2^n)$

```cpp
int fib(int n) {
    if (n <= 1) {
        return n;
    }
    return fib(n - 1) + fib(n - 2);
}
```

Memoization (Top-Down DP) $O(n)$

```cpp
std::unordered_map<int, int> memo;
int fib(int n) {
    if (n <= 1) {
        return n;
    }
    if (memo.find(n) != memo.end()) {
        return memo[n];
    }
    memo[n] = fib(n - 1) + fib(n - 2);
    return memo[n];
}
```

Tabulation (Bottom-up DP) $O(n)$

```cpp
int fib(int n) {
    if (n <= 1) {
        return n;
    }
    int dp[n + 1];
    dp[0] = 0;
    dp[1] = 1;
    for (int i = 2; i <= n; i++) {
        dp[i] = dp[i - 1] + dp[i - 2];
    }
    return dp[n];
}
```

Problem – Climbing Stairs

LeetCode leetcode.com/problems/climbing-stairs

Problem Statement

You need to climb a staircase with n steps to get to the top. Each time you can choose to climb either **1 step** or **2 steps** at a time. Find out how many different ways you can climb to the top of the staircase.

Example 1

Input: n = 2

Output: 2

Explanation: There are two ways to get to the top

       1. Climb 1 step at a time, twice

       2. Climb 2 steps in one go

Example 2:

Input: n = 3

Output: 3

Explanation: There are three ways to get to the top:

       1. Climb 1 step at a time, three times

       2. Climb 1 step, then 2 steps

       3. Climb 2 steps, then 1 ste.

LeetCode

```cpp
std::unordered_map<int, int> memo;

int climbStairs(int n) {
    // Identify the sequence, when:
    // n = 0 (0 way), there is no way to get up
    // n = 1 (1 way): only one way : 1-step
    // n = 2 (2 ways): 1s + 1s | 2s
    // n = 3 (3 ways): 1s + 1s + 1s |  1s + 2s | 2s + 1s
    // n = 4 (5 ways): 1s + 1s + 1s + 1s | 1s + 1s + 2s | 1s + 2s + 1s | 2s + 1s + 1s | 2s + 2s |

    if (n <= 2) {
        return n;
    }

    if (memo.find(n) != memo.end()) {
        return memo[n];
    }

    memo[n] = climbStairs(n - 1) + climbStairs(n - 2);
    return memo[n];
}
```