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***

Some 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

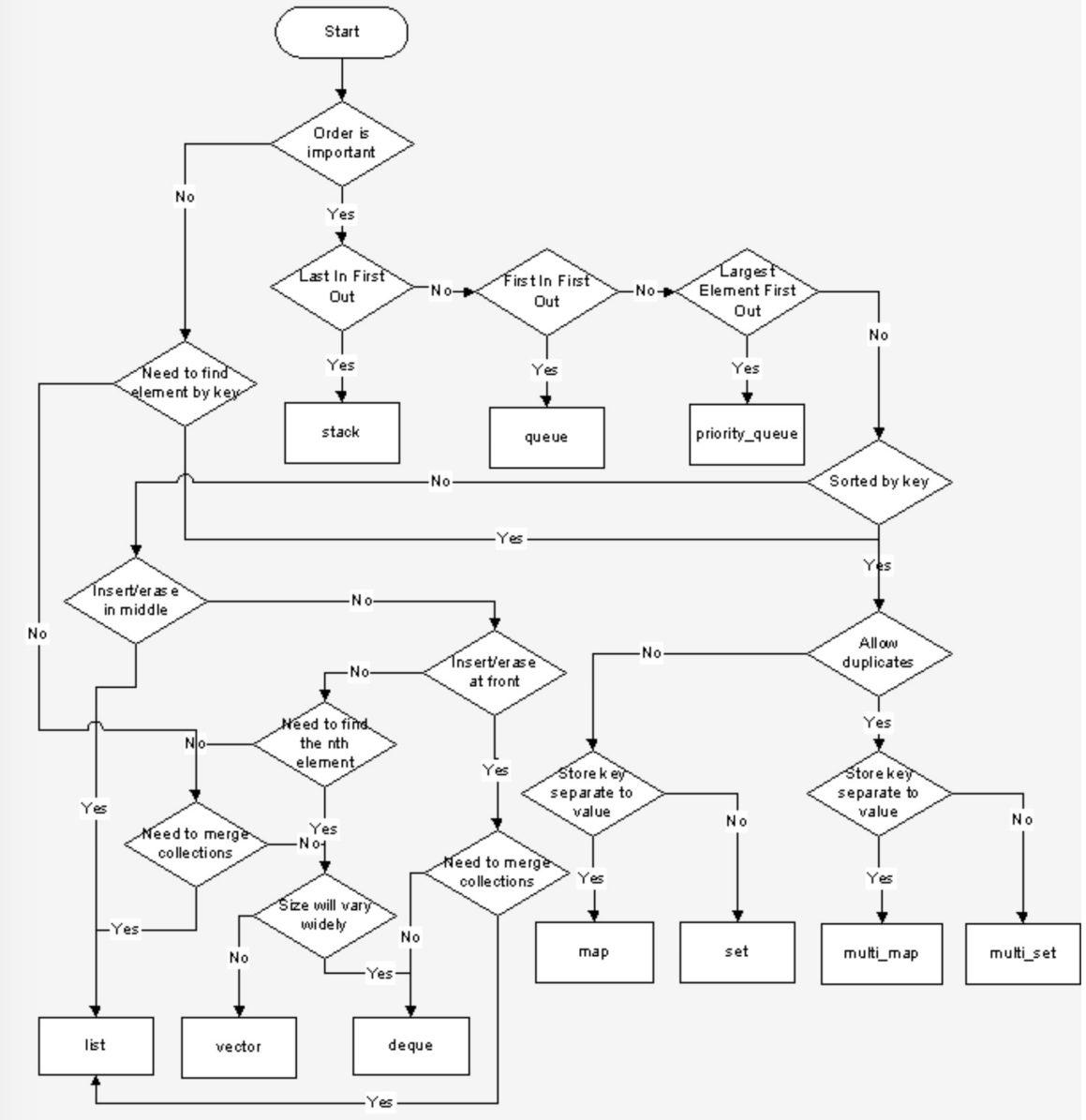
Tree

- ✓ Maximum Level Sum of a Binary Tree
- ✓ Minimum Number of Increments on Subarrays to Form a Target Array
- ✓ Leaf-Similar Trees
- ✓ Count Good Nodes in Binary Tree

⭐ = leetcode premium

DATA STRUCTURES IN C++

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

Note: I don't have the source of this diagram. If you know it, please drop me a msg so I can add it here.

Vectors

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

*https://en.cppreference.com/w/cpp/container/vector

Linked List

- desc

Stack

- desc

*https://en.cppreference.com/w/cpp/container/vector

Queue

- desc

*https://en.cppreference.com/w/cpp/container/vector

Heap

- desc

Hash Table

- desc

Tree

- desc

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

- Kadane's algorithm is a dynamic programming algorithm to solve **maximum subarray sum**
- At every **index i**:

  start a new subarray at **i**

  extend the previous subarray to include **array[i]**
- **Algorithm**

1. Initialize:

```
int maxSoFar = array[0];
int maxEndingHere = array[0];
```

2. Loop through the array

```
for (int i = 1; i < array.size(); ++i) {
    maxEndingHere = max(array[i], maxEndingHere + array[i]);
    maxSoFar = max(maxSoFar, maxEndingHere);
}
```

3. Return maxSoFar;

Problem – Two Sum

Easy

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 – Two Sum

Easy

LeetCode leetcode.com/problems/two-sum

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

Easy

LeetCode leetcode.com/problems/two-sum

Code

Time: **O(n)** Space: **O(n)**

```
vector<int> twoSum(vector<int>& nums, int target) {
    std::unordered_map<int, int> numMap;
    // 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

Easy

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

Problem Statement

- You are given an integer **array** of stock prices
- Choose a **price[i]** to buy and **price[i]** to sell where you achieve maximum profits
- **Example:**

```
prices = [9, 1, 3, 4]
```

- **Output**: [1,3]

```
array[3] - array[1] = 4 + 1 = 3
```

Solution - Best Time to Buy and Sell Stock

Easy

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

Solution

- Initialize **profit = 0**
- Initialize **lowestBuyPrice = prices[0]**
- Loop through the prices
- Track the lowest buy price → **min(lowestBuyPrice, prices[i])**
- Check if selling "today" will make the maximum profit and update profit:

  max(prices[i] – buy > profit, profit)
- Update profit

  max(prices[i] - buy

Code - Best Time to Buy and Sell Stock

Easy

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

Code (simplified)

Time: **O(n)** Space: **O(n)**

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

Code - Best Time to Buy and Sell Stock

Easy

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

Code (optimized)

Time: **O(n)** Space: **O(n)**

- Same logic, but with better branch prediction and less computation

```
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 - Best Time to Buy and Sell Stock II

Medium

LeetCode leetcode.com/problems/best-time-to-buy-and-sell-stock-ii

Problem Statement

- You are given an integer **array** of stock prices
- Choose a **price[i]** to buy and **price[i]** to sell where you achieve maximum profits
- You can buy/sell **multiple times**, but only hold **at most one** transaction at a time
- Output is the **maximum profits**
- **Example:**

  `prices = [9, 1, 3, 4]`

  Output: 2 + 1 = 3

  buy (price = 1), **sell** (price = 3), **profit** = 2

  buy (price = 3), **sell** (price = 4), **profit** = 1

Solution - Best Time to Buy and Sell Stock II

Medium

LeetCode leetcode.com/problems/best-time-to-buy-and-sell-stock-ii

Solution

- Loop through the array starting from index 1
- If current **price[i]** is lower than previous **price[i - 1]**, buy and sell
- **Example:**

```
prices = [1, 8, 4]      prices[0] = 1, prices[1] = 8, prices[2] = 4
prices[0] < prices[1] → true, profit = 8 - 1 = 7
prices[2] < prices[1] → false, do nothing
```

Code - Best Time to Buy and Sell Stock II

Medium

LeetCode leetcode.com/problems/best-time-to-buy-and-sell-stock-ii

Code

Time: **O(n)** Space: **O(n)**

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

Problem - Best Time to Buy and Sell Stock IV

Hard

LeetCode leetcode.com/problems/best-time-to-buy-and-sell-stock-iv

Problem Statement

- ...

Solution - Best Time to Buy and Sell Stock IV

Hard

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

Solution

- ...

Code - Best Time to Buy and Sell Stock IV

Hard

LeetCode leetcode.com/problems/best-time-to-buy-and-sell-stock-iv

Code (simplified)

Time: **O(n)** Space: **O(n)**

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

STRING

Problem – 3. Longest Substring Without Repeating Characters

Medium

LeetCode leetcode.com/problems/longest-substring-without-repeating-characters

Problem Statement

- You are given a string and the goal is to find the longest substring without repeating characters
- **Example**

  Input: “abcdb”

  Output: 4 (abcd since “b” is repeated)

Solution – 3. Longest Substring Without Repeating Characters

Medium

LeetCode leetcode.com/problems/longest-substring-without-repeating-characters

Solution

- Use sliding window algorithm (left and right)
- Loop through the string
- Try to find if the current character is already added by using unordered set or bitmap
- If added, remove from the set alongside with others using left pointer
- If not, add to the unordered set or bitmap
- Maximum length will be right – left + 1

Example – 3. Longest Substring Without Repeating Characters

Medium

LeetCode leetcode.com/problems/longest-substring-without-repeating-characters

Example

- String: abcbd. Our goal is to return 3 (**abc**bd)
- Initialize `maxLength = 0`
- Loop through the string

Iteration 1: `left = 0, right = 0, string[left] = 'a',`
`bitmap = ['a']` ('a' is not in bitmap, add), `maxLength = max(maxLength, right - left + 1) = 1`

Iteration 2: `left = 0, right = 1, string[right] = 'b'`
`bitmap = ['a','b'], maxLength = 2`

Iteration 3: `left = 0, right = 2, string[right] = 'c'`
`bitmap = ['a','b', 'c'], maxLength = 3`

Iteration 4: `left = 0, right = 3, string[right] = 'b'`
`bitmap = ['a','b','c','b']`
'b' is already in the bitmap. start "clearing" the character using left:

Iteration 4a: `left = 0, string[left] = 'a'` is different from 'b', so remove 'a'
`bitmap = ['b', 'c','b']`

Iteration 4b: `left = 1, string[left] = 'b'` is the same as the repeated one, remove
`bitmap = ['c','b']`

Iteration 5: `left = 1, right = 4, string[right] = 'd'`
`bitmap = ['c','b','d']`

Code – 3. Longest Substring Without Repeating Characters

Medium

Code (unordered_set)

- Use unordered_set when question requires unicode chars

```
int lengthOfLongestSubstring(string s) {
    int maxLength = 0;
    int left = 0, right = 0;
    // track the seen characters
    unordered_set<char> seen;
    for (right = 0; right < s.size(); ++right) {
        char currentChar = s[right];
        // if currentChar is in the set, clean
        // the character and everything from left of it
        // basically, reset the longest substring
        while (seen.count(currentChar)) {
            char c = s[left];
            seen.erase(c);
            left++;
        }
        // insert the current read character
        seen.insert(currentChar);
        // set max length
        maxLength = max(maxLength, right - left + 1);
    }
    return maxLength;
}
```

Code – 3. Longest Substring Without Repeating Characters

Medium

Code (bitmap)

- Using bitset: create a bitmask with 128 bits where each bit represent a character
- Optimal solution for ASCII since ASCII size is 127 characters
- Unicode / UTF-8 can represent over 1.1 million characters, so use **unordered_set** approach instead

```
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;
}
```

Problem – Valid Parentheses

Easy

LeetCode leetcode.com/problems/valid-parentheses

Problem Statement

- You are given a string containing only the characters **'(', ')', '{', '}', '[' and ‘]’**
- A valid input have closed brackets by its own type
- **Example**

  ()[]{} → valid

  []{}(→ invalid

  {()} → valid

Solution – Valid Parentheses

Easy

LeetCode leetcode.com/problems/valid-parentheses

Solution

- Loop through the string
- If **open** brackets **([{** push to a stack
- If **closed** brackets:

  pop the last added bracket

  check if the **closed** bracket corresponds to the **popped** bracket

  if not, return false
- after the loop, **return true** if the **size** of the stack is empty (all brackets closed)

Code – Valid Parentheses

Easy

LeetCode leetcode.com/problems/valid-parentheses

Code

Time: **O(n)** Space: **O(n)**

```
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;
}
```

Problem – Minimum Number of Increments on Subarrays

Hard

LeetCode leetcode.com/problems/minimum-number-of-increments-on-subarrays-to-form-a-target-array

Problem Statement

- You are given an array of integers initialized with zeros (e.g. **[0,0,0,0]**)
- The goal is to reach some target (e.g. **[1, 2, 2, 3]**)
- The valid operations is to increment a subarray by one
- The output is the total number of operations

  In this case:

  [1,1,1,1] → increment the subarray starting from 0 to total size

  [1,2,2,2] → increment the subarray starting from 1 to total size

  [1,2,2,3] → increment the subarray starting and ending from the last element

  Output: 3 (total number of operations)

Solution – Minimum Number of Increments on Subarrays

Hard

LeetCode leetcode.com/problems/minimum-number-of-increments-on-subarrays-to-form-a-target-array

Solution

- Explain…

Code (2) – Minimum Number of Increments on Subarrays

Hard

LeetCode leetcode.com/problems/minimum-number-of-increments-on-subarrays-to-form-a-target-array

Code (optimized)

```
int minNumberOperations(vector<int>& target) {
    return target[0] +
        inner_product(target.begin() + 1, target.end(),
                target.begin(), 0,
                plus<int>(),
                [](int curr, int prev) { return max(curr - prev, 0); });
}
```

Code – Minimum Number of Increments on Subarrays

Hard

LeetCode leetcode.com/problems/minimum-number-of-increments-on-subarrays-to-form-a-target-array

Code

```
int minNumberOperations(vector<int>& target) {
    int totalOp = target[0];
    for (int i = 1; i < target.size(); ++i) {
        // can't reuse
        if (target[i - 1] < target[i]) {
            totalOp += target[i] - target[i - 1];
        }
    }
    return totalOp;
}
```

TWO POINTERS

Problem – 11. Container With Most Water

Medium

LeetCode leetcode.com/problems/container-with-most-water

Problem Statement

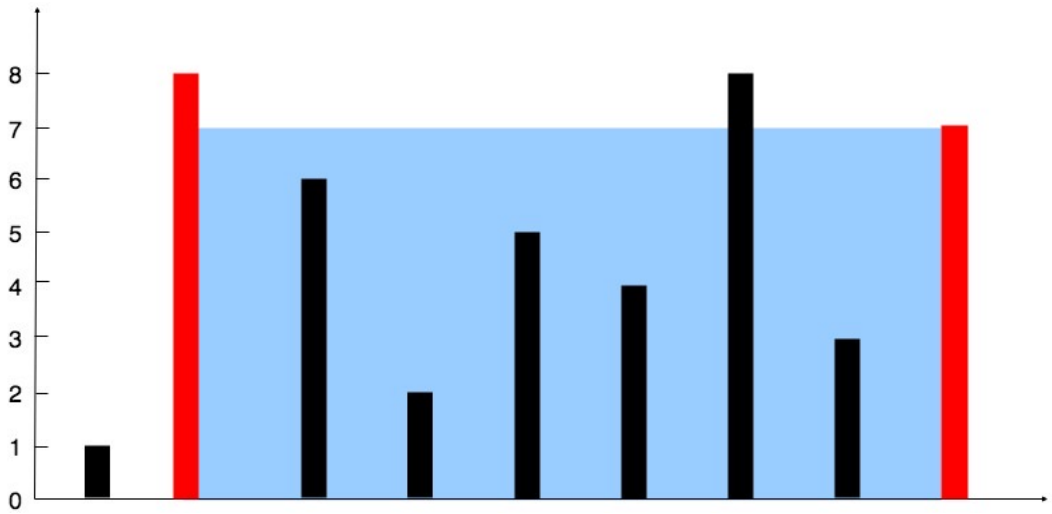
- You are given an integer array **height**
- Find two lines that together with x-axis form a container with most water
- Example:

Input:

height = [1,8,6,2,5,4,8,3,7]

Output:

49



Solution – Container With Most Water

Medium

LeetCode leetcode.com/problems/container-with-most-water

Solution

- Initialize the maximum area **maxArea = 0**
- Initialize two pointers, **left = 0** and **right = height.size – 1**
- Loop while pointer **left < right**
- Calculate the area:

  area = min(height[left], height[right]) * (right – left)
- Update the global maximum area:

  maxArea = max(maxArea, area)
- Move the smallest pointer (increment **left** or decrement **right**)
- Return **maxArea**

Code – Container With Most Water

Medium

LeetCode leetcode.com/problems/container-with-most-water

Code

```
int maxArea(vector<int>& height) {
    // initialize the two pointers (left and right)
    int left = 0;
    int right = height.size() - 1;
    int maxArea = 0;
    while (left < right) {
        // calculate the area, think about the x-axis and y-axis
        int area = min(height[left], height[right]) * (right - left);
        // update maximum area
        maxArea = max(area, maxArea);
        // is the left pointer (y) smaller than right?
        if (height[left] < height[right]) {
            // move left pointer to right
            left++;
        } else {
            // otherwise, move right pointer to left
            right--;
        }
    }
    return maxArea;
}
```

BINARY

Bit Manipulation in C

- **Operators**

  & AND **|** OR **^** XOR **~** NOT **<<** LEFT SHIFT **>>** RIGHT SHIFT

- **Common Operations**

  set bit: `num |= (1 << pos)`

  clear bit: `num &= ~(1 << pos)`

  toggle bit: `num ^= (1 << pos)`

  check bit: `(num & (1 << pos)) != 0`

  extract bit: `(num >> pos) & 1`

  extract a range of bits: `(num >> pos) & ((1 << length) - 1)`

- **Example**

```
void copyBit(int *dst, int src, int srcPos, int dstPos) {
      int bit = (src >> srcPos) & 1;  // extract bit
      *dst &= ~(1 << dstPos);  // clear destination bit
      *dst |= (bit << dstPos);  // set destination bit
}
```

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)

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
```

red 1 = negative carry

green 1 = regular carry

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

Example 2

```
  1111
  101010
+ 101100
--------
= 11110110
```

Reference

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

Problem 1073 – Adding Two Negabinary Numbers

Medium

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]

Solution 1073 – Adding Two Negabinary Numbers

Medium

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

GRAPH (DFS)

Problem - Keys and Rooms

Medium

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

```
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

Medium

LeetCode 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

Solution – Clone Graph

Medium

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

Medium

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

```
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 – Maximum Level Sum of a Binary Tree

Medium

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

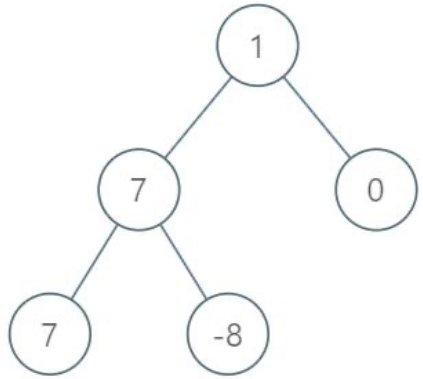
Problem Statement

- 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

Medium

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

Medium

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

```
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

Algorithms

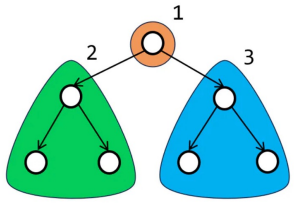
- BFS
- Dijkstra
- Bellman-Ford
- Floyd-Warshall
- A* search
- Johnson's
- SPFA (Shortest Path Faster)
- Bidirectional Search

TREE

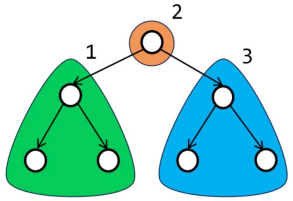
Tree Traversals

Depth-First Traversals

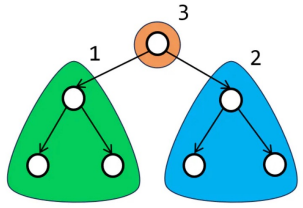
- **Pre-order**: Root – Left – Right



- **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.

Image credits:
https://deriveit.org/coding/tree-dfs-113

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

```
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

```
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);
    }
}
```

BFS Using Stack

BFS with std::stack

- This might be useful for problems when you want to return and resume (for example, 872. Leaf-Similar Trees)

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

// Pre-order traversal
void bfs(std::stack<TreeNode*>& tree) {
    while(!tree.empty()) {
        TreeNode* root = tree.top();
        tree.pop();
        // do something ...
        if (root->right) tree.push(root->right);
        if (root->left) tree.push(root->left);
    }
}
```

Problem – Maximum Depth of Binary Tree

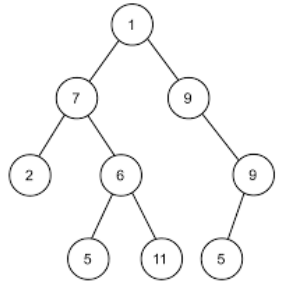
Easy

LeetCode https://leetcode.com/problems/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

Easy

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

Easy

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

```
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

Easy

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

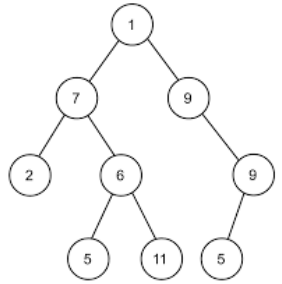
Problem Statement

- 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



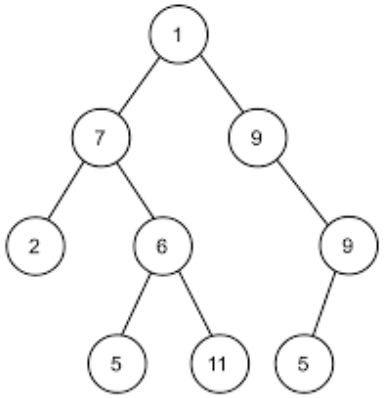
Solution – Path Sum

Easy

LeetCode https://leetcode.com/problems/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

Easy

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

```
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

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

Problem – Kth Smallest Element in a BST

Medium

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

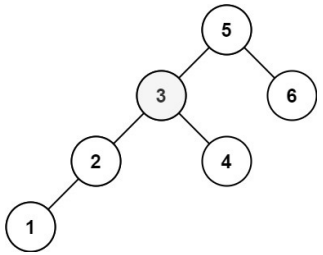
Problem Statement / Solution

- You are given the **root** of a binary search tree and an **integer k**
- Find the k^{th} smallest value
- **Example**

  From all values in the tree: 1,2,3,4,5,6

  k = 3 so find the 3^{th} smallest value

  Output is 3: 1,2,**3**,4,5,6 (3th)



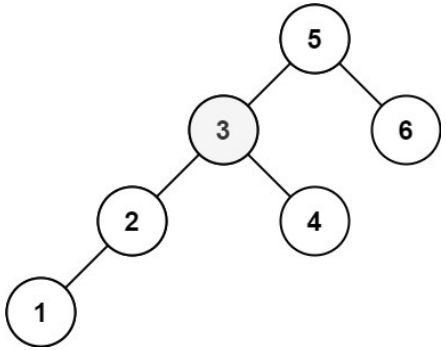
Solution – Kth Smallest Element in a BST

Medium

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

Solution

- Note that the smallest element is in the left leaf
- Therefore, there is an order from small → big values from left → root → right
- Perform in-order traversal **k** times and stop in the desired node



Code – Kth Smallest Element in a BST

Medium

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

Code

Time: **O(k)** Space: **O(h)** where **h** is the height of the tree

```
// in-order traversal: left, node: right
void traverse(TreeNode* node, int& k, int& result) {
    // base case
    if (!node) return;
    // visit left first
    traverse(node->left, k, result);
    // visit node
    k--;
    if (k == 0) {
        result = node->val;
        return;
    }
    // visit right
    traverse(node->right, k, result);
}

int kthSmallest(TreeNode* root, int k) {
    // perform pre-order traversal
    int result;
    traverse(root, k, result);
    return result;
}
```

BINARY TREE (DFS)

Problem – 872. Leaf-Similar Trees

Easy

LeetCode leetcode.com/problems/leaf-similar-trees

Problem Statement

- You are given two trees
- The goal is to compare if they have the same leaves
- The leaves should be in the same order
- Example:

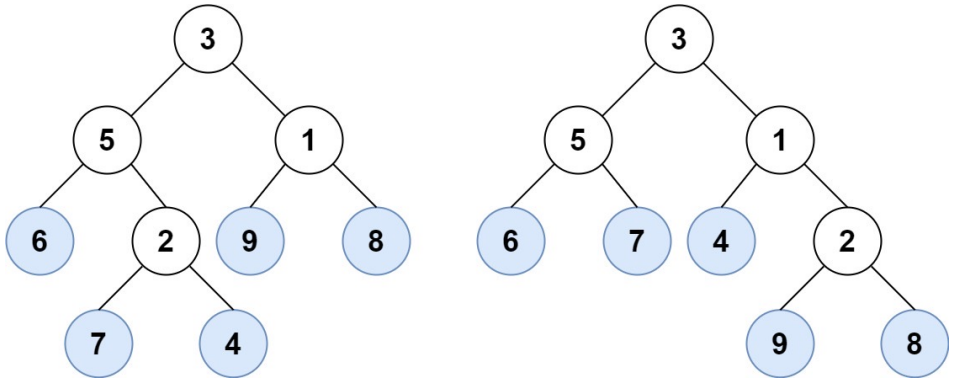
  First tree:

  leaves = 6,7,4,9,8 (blue nodes)

  Second tree:

  leaves = 6,7,4,9,8

- Return true if the leaves are the same



Solution – Leaf-Similar Trees

Easy

LeetCode leetcode.com/problems/leaf-similar-trees

Solution

- Get the first leaf value from tree 1
- Get the first leaf value from tree 2
- Compare, if they are different, return false immediately
- Otherwise, continue finding the next leaf value for tree 1 and 2

Implementation

- Create two stacks **stack<TreeNode*> left** and **stack<TreeNode*> right**
- Add the

Code – Leaf-Similar Trees

Easy

LeetCode leetcode.com/problems/leaf-similar-trees

Code

Time: **O(n + m)** where n and m are the numbers of nodes for trees 1 and 2 Space: **O(h1 + h2)** where h1 and h2 represents the height of the tree

```
// returns the value of the leaf, or -1 if empty
int getLeaf(stack<TreeNode*>& tree) {
    // tree is a reference, we will always pop an element from it
    while(!tree.empty()) {
        // get the top element from the stack
        TreeNode* node = tree.top();
        // already visited, so remove from stack
        tree.pop();
        // is this a leaf?
        if (!node->left && !node->right) {
            // yes, return the value
            return node->val;
        }
        // push the right FIRST to the stack
        if (node->right) tree.push(node->right);
        // left should be on top of the stack
        if (node->left) tree.push(node->left);
    }
    return -1;
}
```

```
bool leafSimilar(TreeNode* root1, TreeNode* root2) {
    // initialize the stacks, add root1 and root2
    std::stack<TreeNode*> leftTree, rightTree;
    leftTree.push(root1);
    rightTree.push(root2);

    while(true) {
        // get the leaves to compare
        int leaf1 = getLeaf(leftTree);
        int leaf2 = getLeaf(rightTree);
        // exit immediately if one leaf is different
        if (leaf1 != leaf2) return false;
        // stop when there are no leaves left
        if (leaf1 == -1 || leaf2 == -1) break;
    }
    return true;
}
```

Problem – 1448. Count Good Nodes in Binary Tree

Easy

LeetCode leetcode.com/problems/count-good-nodes-in-binary-tree

Problem Statement

- You are given a binary tree and have to find "**good**" **nodes**
- A **good node** is a **node** where the values in the path are always than the **node**
- The **root node** is always a **good node**
- Example:

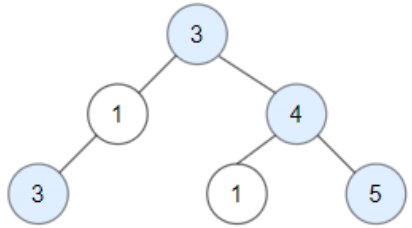
  - root 3 is a good node

  left side:

  - left **leaf 1** is not a good node because **1 < 3**
  - **leaf 3** is a good node because **3 > 1** and **3 == 3**

  right side:

  - **leaf 4** is a good node because **4 > 3**
  - **leaf 1** is not a good node because **1 < 4**
  - **leaf 5** is a good node because **5 > 4 > 3**



Solution – Count Good Nodes in Binary Tree

Easy

LeetCode leetcode.com/problems/count-good-nodes-in-binary-tree

Solution

- ...

Code – Count Good Nodes in Binary Tree

Easy

LeetCode leetcode.com/problems/count-good-nodes-in-binary-tree

Code

Time: **O(n + m)** where n and m are the numbers of nodes for trees 1 and 2 Space: **O(h1 + h2)** where h1 and h2 represents the height of the tree

```
// returns the value of the leaf, or -1 if empty
int getLeaf(stack<TreeNode*>& tree) {
    // tree is a reference, we will always pop an element from it
    while(!tree.empty()) {
        // get the top element from the stack
        TreeNode* node = tree.top();
        // already visited, so remove from stack
        tree.pop();
        // is this a leaf?
        if (!node->left && !node->right) {
            // yes, return the value
            return node->val;
        }
        // push the right FIRST to the stack
        if (node->right) tree.push(node->right);
        // left should be on top of the stack
        if (node->left) tree.push(node->left);
    }
    return -1;
}
```

```
bool leafSimilar(TreeNode* root1, TreeNode* root2) {
    // initialize the stacks, add root1 and root2
    std::stack<TreeNode*> leftTree, rightTree;
    leftTree.push(root1);
    rightTree.push(root2);

    while(true) {
        // get the leaves to compare
        int leaf1 = getLeaf(leftTree);
        int leaf2 = getLeaf(rightTree);
        // exit immediately if one leaf is different
        if (leaf1 != leaf2) return false;
        // stop when there are no leaves left
        if (leaf1 == -1 || leaf2 == -1) break;
    }
    return true;
}
```

INTERVAL

greedy strategy: sort by the end time

Because ending earlier gives **more room** for future intervals. It’s a classic greedy trick: choose the interval that **frees up time** as quickly as possible.

Problem – 57. Insert Interval

Medium

LeetCode leetcode.com/problems/insert-interval

Problem Statement

- You are given an array of **intervals,** where **intervals[i] = [$start_i$, end_i]** and **newInterval = [start, end]**
- **newInterval** must be inserted into **intervals**
- Overlapping intervals must be merged
- Example

  intervals = [[1,2],[3,5],[6,7],[8,10],[12,16]] **newInterval** = [4,8]

  Output: [[1,2],[3,10],[12,16]]

Solution – 57. Insert Interval

Medium

LeetCode leetcode.com/problems/insert-interval

Solution

- Sort intervals by the first element (start)
- Initialize **result**
- Solve in three loops:
  1. While there is no overlap with **newInterval**, add to **intervals[i]** to **result**
  2. While it overlaps, merge **newInterval**
  3. While until the end intervals and add the remaining **intervals[i]**

Code – 57. Insert Interval

Medium

LeetCode leetcode.com/problems/insert-interval

Code

Time: **O(n)** Space: **O(n)** where n is the size of intervals

```
vector<vector<int>> insert(vector<vector<int>>& intervals, vector<int>& newInterval) {
    vector<vector<int>> result;
    int tupleIndex = 0;
    int totalTuples = intervals.size();
    // 1. check if it overlaps
    // 1 ------ 2
    //              4 ----- 8
    while (tupleIndex < totalTuples && intervals[tupleIndex][1] < newInterval[0]) {
        result.push_back(intervals[tupleIndex]);
        ++tupleIndex;
    }


    // 2. merge overlap. We already know there is an overlap here,
    // otherwise it should be sorted out in the previous step
    // 3 ---- 5
    //     4 ----- 8
    while (tupleIndex < totalTuples && intervals[tupleIndex][0] <= newInterval[1]) {
        newInterval[0] = min(newInterval[0], intervals[tupleIndex][0]);
        newInterval[1] = max(newInterval[1], intervals[tupleIndex][1]);
        ++tupleIndex;
    }
    result.push_back(newInterval);


    // 3. add remaining parts
    while (tupleIndex < totalTuples) {
        result.push_back(intervals[tupleIndex]);
        ++tupleIndex;
    }
    return result;
}
```

Problem – 56. Merge Intervals

Medium

LeetCode leetcode.com/problems/merge-intervals

Problem Statement

- ...

Solution – 56. Merge Intervals

Medium

LeetCode leetcode.com/problems/merge-intervals

Solution

- ...

Code – 56. Merge Intervals

Medium

LeetCode leetcode.com/problems/merge-intervals

Code

Time: **O(n)** Space: **O(n)**

- ...

Problem – 435. Non-overlapping Intervals

Medium

LeetCode leetcode.com/problems/non-overlapping-intervals

Problem Statement

- ...

Solution – 435. Non-overlapping Intervals

Medium

LeetCode leetcode.com/problems/non-overlapping-intervals

Solution

- ...

Code – 435. Non-overlapping Intervals

Medium

LeetCode leetcode.com/problems/non-overlapping-intervals

Code

Time: **O(n)** Space: **O(n)**

- ...

Problem – number. name

Easy Medium Hard

LeetCode leetcode.com/problems/...

Problem Statement / Solution / Code

Time: **O(n)** Space: **O(n)**

- ...

LINKED LIST

Problem – Swap Nodes in Pair

Medium

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

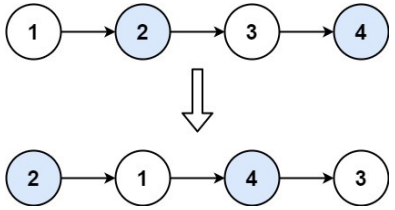
Problem

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

Medium

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

```
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;
}
```

Solution (recursive) – Swap Nodes in Pair

Medium

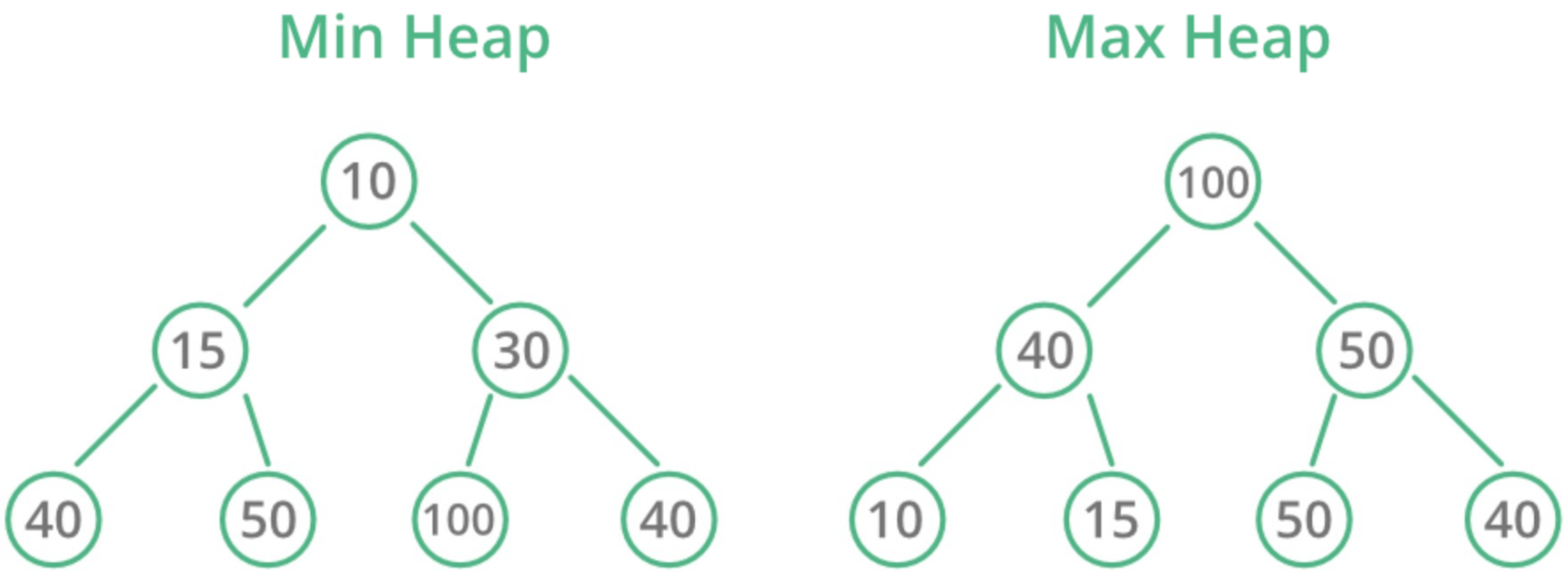
https://leetcode.com/problems/swap-nodes-in-pairs

```
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>>`

```
// 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

Medium

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”

Solution 1 – Kth Largest Element in an Array

Medium

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();
}
```

Solution 2 – Kth Largest Element in an Array

Medium

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 — $O(2^n)$

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

Memoization (Top-Down DP) — O(n)

```
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)

```
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

Easy

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.

Solution – Climbing Stairs

Blind 75

Easy

LeetCode leetcode.com/problems/climbing-stairs

```
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];
}
```

EOF

Tips

Easy Medium Hard

LeetCode leetcode.com/problems/...

Problem Statement / Solution / Code

Time: **O(n)** Space: **O(n)**

- ...

Problem – number. name

Easy Medium Hard

LeetCode leetcode.com/problems/...

Problem Statement / Solution / Code

Time: **O(n)** Space: **O(n)**

- ...