

Arrays & Strings

Stores data elements based on an sequential, most commonly 0 based, index.

Time Complexity

- **Indexing:** Linear array: $O(1)$, Dynamic array: $O(1)$
- **Search:** Linear array: $O(n)$, Dynamic array: $O(n)$
- **Optimized Search:** Linear array: $O(\log n)$, Dynamic array: $O(\log n)$
- **Insertion:** Linear array: n/a, Dynamic array: $O(n)$

Bonus:

- `type[] name = {val1, val2, ...}`
- `Arrays.sort(arr) ->  $O(n \log(n))$`
- `Collections.sort(list) ->  $O(n \log(n))$`
- `int digit = '4' - '0' -> 4`
- `String s = String.valueOf('e') -> "e"`
- `(int) 'a' -> 97 (ASCII)`
- `new String(char[] arr) ['a','e'] -> "ae"`
- `(char) ('a' + 1) -> 'b'`
- `Character.isLetterOrDigit(char) -> true/false`
- `new ArrayList<>(anotherList); -> list w/ items`
- `StringBuilder.append(char||String)`

Linked List

Stores data with nodes that point to other nodes.

Time Complexity

- **Indexing:** $O(n)$
- **Search:** $O(n)$
- **Optimized Search:** $O(n)$
- **Append:** $O(1)$
- **Prepend:** $O(1)$
- **Insertion:** $O(n)$

HashTable

Stores data with key-value pairs.

Time Complexity

- **Indexing:** $O(1)$
- **Search:** $O(1)$
- **Insertion:** $O(1)$

Bonus:

- `{1, -1, 0, 2, -2}` into map
- `HashMap {-1, 0, 2, 1, -2} -> any order`
- `LinkedHashMap {1, -1, 0, 2, -2} -> insertion order`
- `TreeMap {-2, -1, 0, 1, 2} -> sorted`
- Set doesn't allow duplicates.
- `map.getOrDefaultValue(key, default value)`

Stack/Queue/Deque

Stack	Queue	Deque	Heap
Last In First Out	First In Last Out	Provides first/last	Ascending Order
<code>push(val)</code>	<code>offer(val)</code>	<code>offer(val)</code>	<code>offer(val)</code>
<code>pop()</code>	<code>poll()</code>	<code>poll()</code>	<code>poll()</code>
<code>peek()</code>	<code>peek()</code>	<code>peek()</code>	<code>peek()</code>

Implementation in Java:

- `Stack<E> stack = new Stack();`
- `Queue<E> queue = new LinkedList();`
- `Deque<E> deque = new LinkedList();`
- `PriorityQueue<E> pq = new PriorityQueue();`

DFS & BFS Big O Notation

	Time	Space
DFS	$O(E+V)$	$O(\text{Height})$
BFS	$O(E+V)$	$O(\text{Length})$

V & E -> where V is the number of vertices and E is the number of edges.

Height -> where h is the maximum height of the tree.

Length -> where l is the maximum number of nodes in a single level.

DFS vs BFS

DFS	BFS
• Better when target is closer to Source.	• Better when target is far from Source.
• Stack -> LIFO	• Queue -> FIFO
• Preorder, Inorder, Postorder Search	• Level Order Search
• Goes deep	• Goes wide
• Recursive	• Iterative
• Fast	• Slow

BFS Impl for Graph

```
public boolean connected(int[][] graph, int start,
int end) {
    Set<Integer> visited = new HashSet<>();
    Queue<Integer> toVisit = new LinkedList<>();
    ();
    toVisit.add(start);
    while (!toVisit.isEmpty()) {
        int curr = toVisit.poll();
        if (visited.contains(curr)) continue;
        if (curr == end) return true;
        for (int i : graph[curr]) {
            toVisit.add(i);
        }
        visited.add(curr);
    }
    return false;
}
```

DFS Impl for Graph

```
public boolean connected(int[][] graph, int start,
int end) {
    Set<Integer> visited = new HashSet<>();
    return connected(graph, start, end, visited);
}

private boolean connected(int[][] graph, int start,
int end, Set<Integer> visited) {
    if (start == end) return true;
    if (visited.contains(start)) return false;
    visited.add(start);
    for (int i : graph[start]) {
        if (connected(graph, i, end, visited)) {
            return true;
        }
    }
    return false;
}
```

DFS Impl for Graph (cont)

```
>}
```

BFS Impl. for Level-order Tree Traversal

```
private void printLevelOrder(TreeNode root) {
    Queue<TreeNode> queue = new LinkedList<>();
    ();
    queue.offer(root);
    while (!queue.isEmpty()) {
        TreeNode tempNode = queue.poll();
        print(tempNode.data + " ");

        add left child
        if (tempNode.left != null) {
            queue.offer(tempNode.left);
        }

        add right child
        if (tempNode.right != null) {
            queue.offer(tempNode.right);
        }
    }
}
```

DFS Impl. for In-order Tree Traversal

```
private void inorder(TreeNode root) {
    if (root == null)
        return;
    // Traverse left
    inorder(root.left);
    // Traverse root
    print(root.data + " ");
    // Traverse right
    inorder(root.right);
}
```

Dynamic Programming

- Dynamic programming is the technique of storing repeated computations in memory, rather than recomputing them every time you need them.
- The ultimate goal of this process is to improve runtime.
- Dynamic programming allows you to use more space to take less time.

Dynamic Programming Patterns

- Minimum (Maximum) Path to Reach a Target

Approach:

Choose minimum (maximum) path among all possible paths before the current state, then add value for the current state.

Formula:

$routes[i] = \min(routes[i-1], routes[i-2], \dots, routes[i-k]) + cost[i]$

- Distinct Ways

Approach:

Choose minimum (maximum) path among all possible paths before the current state, then add value for the current state.

Formula:

$routes[i] = routes[i-1] + routes[i-2], \dots, + routes[i-k]$

- Merging Intervals

Approach:

Find all optimal solutions for every interval and return the best possible answer

Formula:

$dp[i][j] = dp[i][k] + result[k] + dp[k+1][j]$

- DP on Strings

Approach:

Compare 2 chars of String or 2 Strings. Do whatever you do. Return.

Formula:

if $s1[i-1] == s2[j-1]$ then $dp[i][j] = //code$.

Else $dp[i][j] = //code$

- Decision Making

Approach:

If you decide to choose the current value use the previous result where the value was ignored; vice-versa, if you decide to ignore the current value use previous result where value was used.

Formula:

$dp[i][j] = \max(\{dp[i][j], dp[i-1][j] + arr[i], dp[i-1][j-1]\});$

$dp[i][j-1] = \max(\{dp[i][j-1], dp[i-1][j-1] + arr[i], arr[i]\});$

Binary Search Big O Notation

	Time	Space
Binary Search	$O(\log n)$	$O(1)$

Binary Search - Recursive

```
public int binarySearch(int search, int[] array,
int start, int end) {
    int middle = start + ((end - start) / 2);
    if(end < start) {
        return -1;
    }
    if (search == array[ middle]) {
        return middle;
    } else if (search < array[ middle]) {
        return binarySearch (search, array,
start, middle - 1);
    } else {
        return binarySearch (search, array,
middle + 1, end);
    }
}
```

Binary Search - Iterative

```
public int binarySearch(int target, int[] array) {
    int start = 0;
    int end = array.length - 1;
    while (start <= end) {
        int middle = start + ((end - start) /
2);
        if (target == array[ middle]) {
            return target;
        } else if (search < array[ middle]) {
            end = middle - 1;
        } else {
            start = middle + 1;
        }
    }
}
```

Binary Search - Iterative (cont)

```
> }
    return -1;
}
```

Bit Manipulation

Sign Bit 0 -> Positive, 1 -> Negative

AND 0 & 0 -> 0
 0 & 1 -> 0
 1 & 1 -> 1

OR 0 | 0 -> 0
 0 | 1 -> 1
 1 | 1 -> 1

XOR 0 ^ 0 -> 0
 0 ^ 1 -> 1
 1 ^ 1 -> 0

INVERT 0 -> 1
 1 -> 0

Bonus:

• Shifting

- Left Shift

0001 << 0010 (Multiply by 2)

- Right Shift

0010 >> 0001 (Division by 2)

• Count 1's of n, Remove last bit

$n = n \& (n-1);$

• Extract last bit

$n \& -n$ or $n \& \sim(n-1)$ or $n \& (n-1)$

• $n \wedge n \rightarrow 0$

• $n \wedge 0 \rightarrow n$

Sorting Big O Notation

	Best	Average	Space
Merge Sort	$O(n \log(n))$	$O(n \log(n))$	$O(n)$
Heap Sort	$O(n \log(n))$	$O(n \log(n))$	$O(1)$
Quick Sort	$O(n \log(n))$	$O(n \log(n))$	$O(\log(n))$
Insertion Sort	$O(n)$	$O(n^2)$	$O(1)$
Selection Sort	$O(n^2)$	$O(n^2)$	$O(1)$
Bubble Sort	$O(n)$	$O(n^2)$	$O(1)$

Merge Sort

```
private void mergesort(int low, int high) {
    if (low < high) {
        int middle = low + (high - low) / 2;
        mergesort(low, middle);
        mergesort(middle + 1, high);
        merge(low, middle, high);
    }
}

private void merge(int low, int middle, int high)
{
    for (int i = low; i <= high; i++) {
        helper[i] = numbers[i];
    }
    int i = low;
    int j = middle + 1;
    int k = low;
    while (i <= middle && j <= high) {
        if (helper[i] <= helper[j]) {
            numbers[k] = helper[i];
            i++;
        } else {
            numbers[k] = helper[j];
            j++;
        }
        k++;
    }
    while (i <= middle) {
        numbers[k] = helper[i];
        k++;
        i++;
    }
}
```

Quick Sort

```
private void quicksort(int low, int high) {  
    int i = low, j = high;  
    int pivot = numbers[low + (high-low)/2];  
    while (i <= j) {  
        while (numbers[i] < pivot) {  
            i++;  
        }  
        while (numbers[j] > pivot) {  
            j--;  
        }  
        if (i <= j) {  
            exchange(i, j);  
            i++;  
            j--;  
        }  
    }  
    if (low < j)  
        quicksort(low, j);  
    if (i < high)  
        quicksort(i, high);  
}
```



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Insertion Sort

```
void insertionSort(int arr[]) {
    int n = arr.length;
    for (int i = 1; i < n; ++i) {
        int key = arr[i];
        int j = i - 1;
        while (j >= 0 && arr[j] > key) {
            arr[j + 1] = arr[j];
            j = j - 1;
        }
        arr[j + 1] = key;
    }
}
```

Combinations Backtrack Pattern

- Combination

```
public List<List<Integer>> combinationSum(int[] nums, int target) {
    List<List<Integer>> list = new ArrayList<>();
    Arrays.sort(nums);
    backtrack(list, new ArrayList<>(), nums, target, 0);
    return list;
}

private void backtrack(List<List<Integer>> list, List<Integer> tempList, int[] nums, int remain, int start) {
    if (remain < 0) return;
    else if (remain == 0) list.add(new ArrayList<>(tempList));
    else {
        for (int i = start; i < nums.length; i++) {
            tempList.add(nums[i]);
            // not i + 1 because we can reuse same elements
            backtrack(list, tempList, nums, remain - nums[i], i);
            // not i + 1 because we can reuse same elements
        }
    }
}
```

Combinations Backtrack Pattern (cont)

```
> tempList.remove(tempList.size() - 1);
    }
}
```

Palindrome Backtrack Pattern

- Palindrome Partitioning

```
public List<List<String>> partition(String s) {
    List<List<String>> list = new ArrayList<>();
    backtrack(list, new ArrayList<>(), s, 0);
    return list;
}

public void backtrack(List<List<String>> list, List<String> tempList, String s, int start) {
    if (start == s.length()) {
        list.add(new ArrayList<>(tempList));
    } else {
        for (int i = start; i < s.length(); i++) {
            if (isPalindrome(s, start, i)) {
                tempList.add(s.substring(start, i + 1));
                backtrack(list, tempList, s, i + 1);
                tempList.remove(tempList.size() - 1);
            }
        }
    }
}
```

Subsets Backtrack Pattern

- Subsets

```
public List<List<Integer>> subsets(int[] nums) {
    List<List<Integer>> list = new ArrayList<>();
    Arrays.sort(nums);
    backtrack(list, new ArrayList<>(), nums, 0);
    return list;
}
```

Subsets Backtrack Pattern (cont)

```
> backtrack(list, new ArrayList<>(), nums, 0);
return list;
}
private void backtrack(List<List<Integer>> list, List<Integer>
tempList, int [] nums, int start){
    list.add(new ArrayList<>(tempList));
    for(int i = start; i < nums.length; i++){
        // skip duplicates
        if(i > start && nums[i] == nums[i-1]) continue;
        // skip duplicates
        tempList.add(nums[i]);
        backtrack(list, tempList, nums, i + 1);
        tempList.remove(tempList.size() - 1);
    }
}
```

Permutations Backtrack Pattern (cont)

```
> tempList.add(nums[i]);
backtrack(list, tempList, nums);
tempList.remove(tempList.size() - 1);
}
}
}
```

Permutations Backtrack Pattern

- Permutations

```
public List<List<Integer>> permute(int[] nums)
{
    List<List<Integer>> list = new ArrayList<>();
    // Arrays.sort(nums); // not necessary
    backtrack(list, new ArrayList<>(),
nums);
    return list;
}
private void backtrack(List<List<Integer>>
list, List<Integer> tempList, int [] nums){
    if(tempList.size() == nums.length){
        list.add(new ArrayList<>(tempList));
    } else{
        for(int i = 0; i < nums.length; i++){
            // element already exists, skip
            if(tempList.contains(nums[i])) continue;
            // element already exists, skip
```

