VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB REPORT
on

Analysis and Design of Algorithms

Submitted by

Rishabh Kumar (1BM22CS221)

in partial fulfillment for the award of the degree of
BACHELOR OF ENGINEERING
in
COMPUTER SCIENCE AND ENGINEERING

B.M.S. COLLEGE OF ENGINEERING
(Autonomous Institution under VTU)
BENGALURU-560019

April-2024 to August-2024

B. M. S. College of Engineering,

Bull Temple Road, Bangalore 560019

(Affiliated to Visvesvaraya Technological University, Belgaum)

Department of Computer Science and Engineering

CERTIFICATE

This is to certify that the Lab work entitled “**Analysis and Design of Algorithms**” carried out by **Rishabh Kumar (1BM22CS221),** who is bonafide student of **B.M.S. College of Engineering.** It is in partial fulfillment for the award of **Bachelor of Engineering in Computer Science and Engineering** of the Visvesvaraya Technological University, Belgaum during the academic semester April-2024 to August-2024. The Lab report has been approved as it satisfies the academic requirements in respect of an **Analysis and Design of Algorithms (23CS4PCADA)** work prescribed for the said degree.

Madhavi R P	Dr. Jyothi S Nayak
Assistant Professor	Professor and Head
Department of CSE	Department of CSE
BMSCE, Bengaluru	BMSCE, Bengaluru

Index Sheet

	Leet Code.	
11	Find Minimum Cost Spanning Tree of a given undirected graph using Prim's algorithm. Find Minimum Cost Spanning Tree of a given undirected graph using Kruskal's algorithm.	21
12	Implement Fractional Knapsack using Greedy technique.	22
13	From a given vertex in a weighted connected graph, find shortest paths to other vertices using Dijkstra's algorithm.	24
14	Implement "N-Queens Problem" using Backtracking.	25

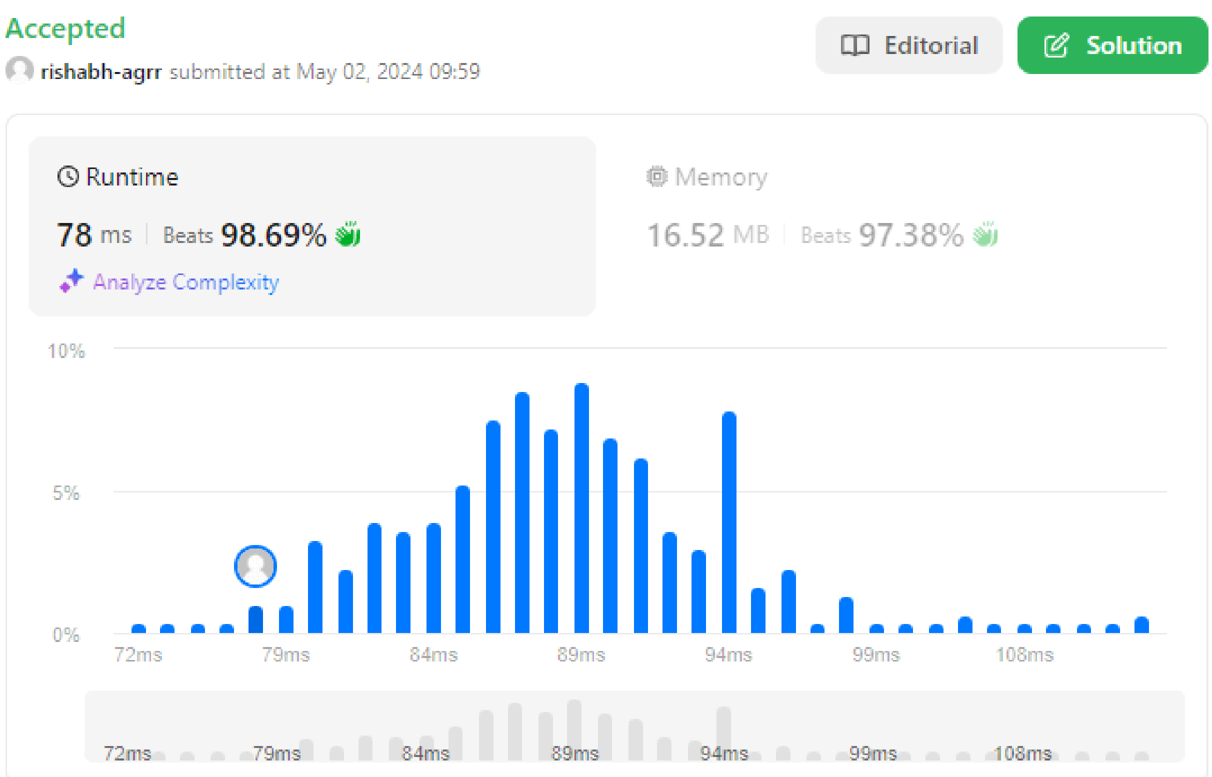
Course Outcome

CO1	Analyze time complexity of Recursive and Non-recursive algorithms using asymptotic notations.
CO2	Apply various design techniques for the given problem.
CO3	Apply the knowledge of complexity classes P, NP, and NP-Complete and prove certain problems are NP-Complete
CO4	Design efficient algorithms and conduct practical experiments to solve problems.

ADA Week-1

(Q) LeetCode – 448 - Find all disappeared numbers in an array

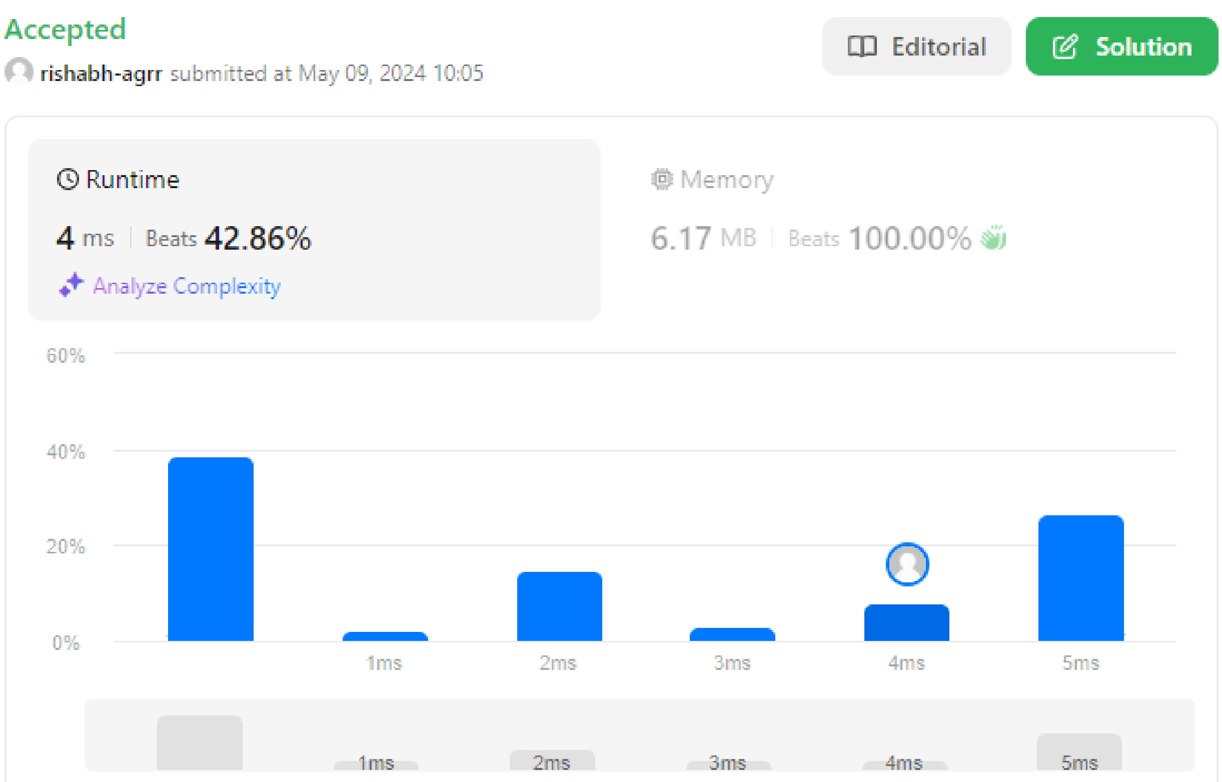
```
int* findDisappearedNumbers(int* nums, int numsSize, int* returnSize) {
    int temp = 0;
    for (int index = 0; index < numsSize; ++index) {
        temp = abs(nums[index]) - 1;
        nums[temp] = abs(nums[temp]) * -1;
    }
    int insert_index = 0;
    *returnSize = 0;
    for (int index = 0; index < numsSize; ++index) {
        if (nums[index] > 0) {
            ++*returnSize;
            nums[insert_index++] = index + 1;
        }
    }
    return nums;
}
```



ADA Week-2

(Q) LeetCode – 103 - Binary Tree ZigZag level Order Traversal

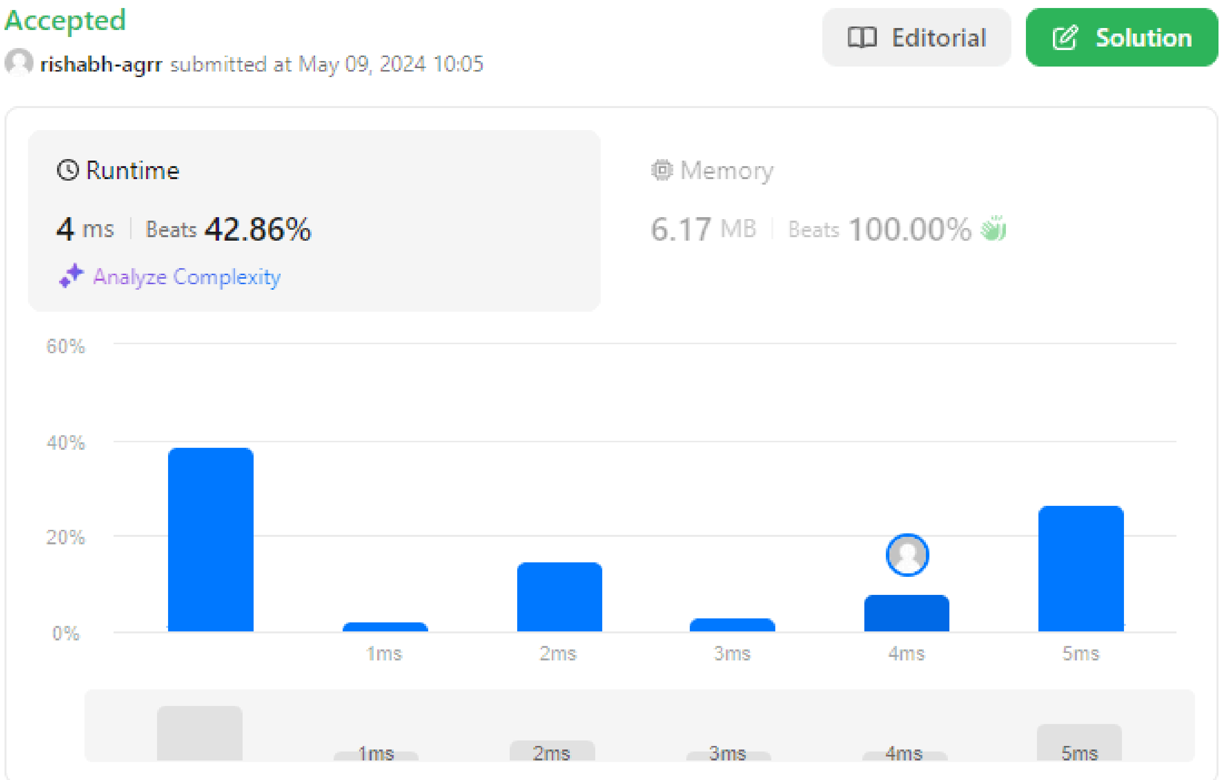
```
int** zigzagLevelOrder(struct TreeNode* root, int* returnSize, int** returnColumnSizes) {
    int th = funheight(root);
    int** ret = (int**)calloc(th, sizeof(int*));
    *returnSize = th;
    (*returnColumnSizes) = (int*)calloc(th, sizeof(int));
    for(int i= 0;i<th; i++){
        int cnt = 0;
        ret[i] = (int*)calloc(1<<i, sizeof(int));
        if(i%2){//odd
            funR(root, i, ret[i], &cnt);
        }else{
            funL(root, i, ret[i], &cnt);
        }
        (*returnColumnSizes)[i] = cnt;
    }
    return ret;
}
```



ADA Week-3

(Q) LeetCode – 897 - Increasing Order Search Tree

```
struct TreeNode *createNode(int val)
{
    struct TreeNode *n = malloc(sizeof(struct TreeNode));
    n->val = val;
    n->left = NULL;
    n->right = NULL;

    return n;
}

void fillRightTree(struct TreeNode **tree, struct TreeNode *node)
{
    if (!node)
    {
        return;
    }

    fillRightTree(tree, node->left);
    (*tree)->right = createNode(node->val);
    *tree = (*tree)->right;
    fillRightTree(tree, node->right);
}

struct TreeNode* increasingBST(struct TreeNode* root) {
    struct TreeNode *dummyRoot = createNode(0);
    struct TreeNode *newTree = dummyRoot;

    fillRightTree(&newTree, root);

    struct TreeNode *rightTreeRoot = dummyRoot->right;
    free(dummyRoot);  // Free the dummy root

    return rightTreeRoot;
}
```



ADA Week - 4

(Q) A program to implement Topological Sort Order

```
// topological sort

#include <stdio.h>
#include <stdlib.h>

#define MAX_VERTICES 100

// Adjacency list node
struct Node {
    int vertex;
    struct Node* next;
};

// Graph with adjacency list representation
```

```
struct Graph {
    int numVertices;
    struct Node** adjList;
    int* inDegree;
};

// Function to create a new node
struct Node* createNode(int v) {
    struct Node* newNode = (struct Node*)malloc(sizeof(struct Node));
    newNode->vertex = v;
    newNode->next = NULL;
    return newNode;
}

// Function to create a graph with 'V' vertices
struct Graph* createGraph(int V) {
    struct Graph* graph = (struct Graph*)malloc(sizeof(struct Graph));
    graph->numVertices = V;
    graph->adjList = (struct Node**)malloc(V * sizeof(struct Node*));
    graph->inDegree = (int*)malloc(V * sizeof(int));

    for (int i = 0; i < V; i++) {
        graph->adjList[i] = NULL;
        graph->inDegree[i] = 0;
    }

    return graph;
}

// Function to add an edge to the graph
void addEdge(struct Graph* graph, int src, int dest) {
    struct Node* newNode = createNode(dest);
    newNode->next = graph->adjList[src];
    graph->adjList[src] = newNode;

    graph->inDegree[dest]++;
}

// Function to perform Kahn's algorithm for topological sorting
void topologicalSortKahn(struct Graph* graph) {
    int V = graph->numVertices;
    int* inDegree = graph->inDegree;

    // Initialize a queue for Kahn's algorithm
    int queue[MAX_VERTICES];
    int front = 0, rear = 0;

    // Enqueue vertices with in-degree 0
    for (int i = 0; i < V; i++) {
        if (inDegree[i] == 0)
            queue[rear++] = i;
    }

    int count = 0; // Count of visited vertices
```

```
    // Initialize topological order
    int topologicalOrder[V];

    while (front < rear) {
        int u = queue[front++];
        topologicalOrder[count++] = u;

        // Iterate through all adjacent vertices of u
        struct Node* temp = graph->adjList[u];
        while (temp != NULL) {
            int v = temp->vertex;
            // Decrease in-degree of adjacent vertex
            inDegree[v]--;

            // If in-degree becomes 0, add to queue
            if (inDegree[v] == 0)
                queue[rear++] = v;

            temp = temp->next;
        }
    }

    // Check if there was a cycle
    if (count != V) {
        printf("Graph has a cycle!\n");
        return;
    }

    // Print topological order
    printf("Topological Sort (Kahn's Algorithm): ");
    for (int i = 0; i < V; i++)
        printf("%d ", topologicalOrder[i]);
    printf("\n");
}

// Function to perform Depth-First Search (DFS)
void DFS(struct Graph* graph, int v, int visited[], int* index, int topologicalOrder[]) {
    visited[v] = 1;

    // Recur for all the vertices adjacent to this vertex
    struct Node* temp = graph->adjList[v];
    while (temp != NULL) {
        if (!visited[temp->vertex])
            DFS(graph, temp->vertex, visited, index, topologicalOrder);
        temp = temp->next;
    }

    // Store the vertex in the topological order
    topologicalOrder[*index] = v;
    (*index)--;
}

// Function to perform topological sorting using DFS
```

```
void topologicalSortDFS(struct Graph* graph) {
    int V = graph->numVertices;
    int* visited = (int*)malloc(V * sizeof(int));
    int topologicalOrder[V];
    int index = V - 1;

    // Initialize all vertices as not visited
    for (int i = 0; i < V; i++)
        visited[i] = 0;

    // Perform DFS for each unvisited vertex
    for (int i = 0; i < V; i++) {
        if (!visited[i])
            DFS(graph, i, visited, &index, topologicalOrder);
    }

    // Print topological order
    printf("Topological Sort (DFS Algorithm): ");
    for (int i = 0; i < V; i++)
        printf("%d ", topologicalOrder[i]);
    printf("\n");

    free(visited);
}

// Main function
int main() {
    int V = 6;
    struct Graph* graph = createGraph(V);

    addEdge(graph, 5, 2);
    addEdge(graph, 5, 0);
    addEdge(graph, 4, 0);
    addEdge(graph, 4, 1);
    addEdge(graph, 2, 3);
    addEdge(graph, 3, 1);

    printf("Graph:\n");
    for (int i = 0; i < V; i++) {
        struct Node* temp = graph->adjList[i];
        printf("Vertex %d: ", i);
        while (temp != NULL) {
            printf("%d ", temp->vertex);
            temp = temp->next;
        }
        printf("\n");
    }

    topologicalSortKahn(graph);
    topologicalSortDFS(graph);

    return 0;
}
```

OUTPUT :-

```
Topological Sort (Kahn's Algorithm): 4 5 2 0 3 1
Topological Sort (DFS Algorithm): 4 0 5 2 3 1
```

ADA Week - 5

(Q) A program to implement and compare selection sort and merge sort.

// selection sort with timings

```
#include <stdio.h>
#include <stdlib.h>
#include <time.h>

// Function to swap two elements
void swap(int* a, int* b) {
    int temp = *a;
    *a = *b;
    *b = temp;
}

// Function to perform Selection Sort
void selectionSort(int arr[], int n) {
    int i, j, min_idx;

    for (i = 0; i < n - 1; i++) {
        min_idx = i;
        for (j = i + 1; j < n; j++) {
            if (arr[j] < arr[min_idx])
                min_idx = j;
        }
        swap(&arr[min_idx], &arr[i]);
    }
}

// Function to generate an array of random integers
void generateRandomArray(int arr[], int n) {
```

```
    for (int i = 0; i < n; i++)
        arr[i] = rand();
}

// Function to measure execution time of selectionSort
double measureSelectionSortTime(int arr[], int n) {
    clock_t start = clock();
    selectionSort(arr, n);
    clock_t end = clock();
    return ((double)(end - start)) / CLOCKS_PER_SEC;
}

// Main function to test Selection Sort with varying input sizes
int main() {
    FILE *fp;
    fp = fopen("selection_sort_time.csv", "w");
    if (fp == NULL) {
        printf("Error opening file.\n");
        return 1;
    }

    fprintf(fp, "Input Size,Time Taken (seconds)\n");

    // Test selection sort with various input sizes
    for (int size = 1000; size <= 10000; size += 1000) {
        int arr[size];
        generateRandomArray(arr, size);

        double time_taken = measureSelectionSortTime(arr, size);
        printf("Input Size: %d, Time Taken: %f seconds\n", size, time_taken);

        fprintf(fp, "%d,%f\n", size, time_taken);
    }

    fclose(fp);
    printf("Data written to selection_sort_time.csv\n");

    return 0;
}




// merge sort with timimngs


#include <stdio.h>
#include <stdlib.h>
#include <time.h>

// Function to merge two subarrays arr[low..mid] and arr[mid+1..high]
void merge(int arr[], int low, int mid, int high) {
    int n1 = mid - low + 1;
    int n2 = high - mid;
```

```
    // Create temporary arrays
    int L[n1], R[n2];

    // Copy data to temporary arrays L[] and R[]
    for (int i = 0; i < n1; i++)
        L[i] = arr[low + i];
    for (int j = 0; j < n2; j++)
        R[j] = arr[mid + 1 + j];

    // Merge the temporary arrays back into arr[low..high]
    int i = 0, j = 0, k = low;
    while (i < n1 && j < n2) {
        if (L[i] <= R[j]) {
            arr[k] = L[i];
            i++;
        } else {
            arr[k] = R[j];
            j++;
        }
        k++;
    }

    // Copy the remaining elements of L[], if any
    while (i < n1) {
        arr[k] = L[i];
        i++;
        k++;
    }

    // Copy the remaining elements of R[], if any
    while (j < n2) {
        arr[k] = R[j];
        j++;
        k++;
    }
}

// Function to perform Merge Sort
void mergeSort(int arr[], int low, int high) {
    if (low < high) {
        int mid = low + (high - low) / 2; // Avoids overflow for large low and high
        mergeSort(arr, low, mid);
        mergeSort(arr, mid + 1, high);
        merge(arr, low, mid, high);
    }
}

// Function to generate an array of random integers
void generateRandomArray(int arr[], int n) {
    for (int i = 0; i < n; i++)
        arr[i] = rand();
}
```

```
// Function to measure execution time of mergeSort
double measureMergeSortTime(int arr[], int n) {
    clock_t start = clock();
    mergeSort(arr, 0, n - 1);
    clock_t end = clock();
    return ((double)(end - start)) / CLOCKS_PER_SEC;
}

// Main function to test Merge Sort with varying input sizes
int main() {
    FILE *fp;
    fp = fopen("merge_sort_time.csv", "w");
    if (fp == NULL) {
        printf("Error opening file.\n");
        return 1;
    }

    fprintf(fp, "Input Size,Time Taken (seconds)\n");

    // Test merge sort with various input sizes
    for (int size = 1000; size <= 10000; size += 1000) {
        int arr[size];
        generateRandomArray(arr, size);

        double time_taken = measureMergeSortTime(arr, size);
        printf("Input Size: %d, Time Taken: %f seconds\n", size, time_taken);

        fprintf(fp, "%d,%f\n", size, time_taken);
    }

    fclose(fp);
    printf("Data written to merge_sort_time.csv\n");

    return 0;
}
```

OUTPUT :-

```
Selection Sort:
Input Size: 1000, Time Taken: 0.003555 seconds
Input Size: 2000, Time Taken: 0.011786 seconds
...

Merge Sort:
Input Size: 1000, Time Taken: 0.000083 seconds
Input Size: 2000, Time Taken: 0.000203 seconds
```

ADA Week - 6

(Q) A program to implement Quick Sort.

```
// quick sort


#include <stdio.h>

// Function to swap two elements
void swap(int* a, int* b) {
    int temp = *a;
    *a = *b;
    *b = temp;
}

// Function to partition the array using the last element as pivot
int partition(int arr[], int low, int high) {
    int pivot = arr[high];    // pivot
    int i = (low - 1);  // Index of smaller element

    for (int j = low; j <= high - 1; j++) {
        // If current element is smaller than or equal to pivot
        if (arr[j] <= pivot) {
            i++;    // increment index of smaller element
            swap(&arr[i], &arr[j]);
        }
    }
    swap(&arr[i + 1], &arr[high]);
    return (i + 1);
}

// Function to implement QuickSort
void quickSort(int arr[], int low, int high) {
    if (low < high) {
        // pi is partitioning index, arr[p] is now at right place
        int pi = partition(arr, low, high);

        // Separately sort elements before partition and after partition
        quickSort(arr, low, pi - 1);
        quickSort(arr, pi + 1, high);
    }
}
```

```
// Function to print the array
void printArray(int arr[], int size) {
    for (int i = 0; i < size; i++)
        printf("%d ", arr[i]);
    printf("\n");
}

// Main function to test the QuickSort algorithm
int main() {
    int arr[] = {10, 7, 8, 9, 1, 5};
    int n = sizeof(arr) / sizeof(arr[0]);
    printf("Unsorted array: \n");
    printArray(arr, n);

    quickSort(arr, 0, n - 1);

    printf("Sorted array: \n");
    printArray(arr, n);

    return 0;
}
```

<u>OUTPUT :-</u>

```
Unsorted array:
10 7 8 9 1 5
Sorted array:
1 5 7 8 9 10
```

ADA Week - 7

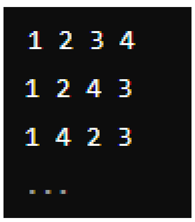
(Q) A program to implement Jhonson-Trotter.

```
#include <stdio.h>
#include <stdbool.h>

#define MAXN 10

int p[MAXN]; // p[i] holds the position of i in the permutation
int dir[MAXN]; // dir[i] = -1 if i is mobile to the left, +1 if mobile to the right

void printPermutation(int n) {
    for (int i = 0; i < n; i++) {
        printf("%d ", p[i]);
    }
    printf("\n");
}

int findLargestMobile(int n) {
```

```
    int mobile = 0;
    int mobileIndex = -1;

    for (int i = 0; i < n; i++) {
        if ((dir[i] == -1 && i > 0 && p[i] > p[i-1]) || // mobile to the left
            (dir[i] == +1 && i < n-1 && p[i] > p[i+1])) { // mobile to the right
            if (p[i] > mobile) {
                mobile = p[i];
                mobileIndex = i;
            }
        }
    }

    return mobileIndex;
}

void swap(int *a, int *b) {
    int temp = *a;
    *a = *b;
    *b = temp;
}

void johnsonTrotter(int n) {
    // Initialize permutation and direction arrays
    for (int i = 0; i < n; i++) {
        p[i] = i + 1; // Initial permutation: 1 2 3 ... n
        dir[i] = -1; // All elements are initially mobile to the left
    }

    // Print the initial permutation
    printPermutation(n);

    // Find the largest mobile integer and swap it
    int mobileIndex = findLargestMobile(n);
    while (mobileIndex != -1) {
        // Swap p[mobileIndex] with the adjacent element it is pointing to
        int nextIndex = mobileIndex + dir[mobileIndex];
        swap(&p[mobileIndex], &p[nextIndex]);

        // Swap corresponding directions
        swap(&dir[mobileIndex], &dir[nextIndex]);

        // Print the new permutation
        printPermutation(n);

        // Update directions of elements greater than the current largest mobile integer
        for (int i = 0; i < n; i++) {
            if (p[i] > p[nextIndex]) {
                dir[i] = -dir[i];
            }
        }

        // Find the next largest mobile integer
        mobileIndex = findLargestMobile(n);
```

```
    }
}

int main() {
    int n;
    printf("Enter the value of n (<= %d): ", MAXN);
    scanf("%d", &n);

    johnsonTrotter(n);

    return 0;
}
```

<u>OUTPUT :-</u>



(Q) A program to implement String Matching using Brute-Force Technique .

```
#include <stdio.h>
#include <string.h>

void bruteForceSubstringSearch(char *text, char *pattern) {
    int n = strlen(text);
    int m = strlen(pattern);
    int i, j;

    for (i = 0; i <= n - m; i++) {
        for (j = 0; j < m; j++) {
            if (text[i + j] != pattern[j])
                break;
        }
        if (j == m) {
            printf("Pattern found at index %d\n", i);
        }
    }
}

int main() {
    char text[100], pattern[100];

    printf("Enter the main text: ");
    scanf("%s", text);
```

```
    printf("Enter the pattern to search: ");
    scanf("%s", pattern);

    bruteForceSubstringSearch(text, pattern);

    return 0;
}
```

OUTPUT :-

```
Pattern found at index 0
Pattern found at index 4
```

ADA Week - 8

(Q) A program to implement Heap Sort.

```
#include <stdio.h>
#include <stdlib.h>
#include <time.h>

// Function to heapify a subtree rooted at index 'root'
void heapify(int arr[], int n, int root) {
    int largest = root;  // Initialize largest as root
    int left = 2 * root + 1;  // Left child
    int right = 2 * root + 2;  // Right child

    // If left child is larger than root
    if (left < n && arr[left] > arr[largest])
        largest = left;

    // If right child is larger than largest so far
    if (right < n && arr[right] > arr[largest])
        largest = right;

    // If largest is not root
    if (largest != root) {
        // Swap root with largest
        int temp = arr[root];
```

```
        arr[root] = arr[largest];
        arr[largest] = temp;

        // Recursively heapify the affected sub-tree
        heapify(arr, n, largest);
    }
}

// Function to perform Heap Sort
void heapSort(int arr[], int n) {
    // Build heap (rearrange array)
    for (int i = n / 2 - 1; i >= 0; i--)
        heapify(arr, n, i);

    // One by one extract an element from heap
    for (int i = n - 1; i > 0; i--) {
        // Move current root to end
        int temp = arr[0];
        arr[0] = arr[i];
        arr[i] = temp;

        // Call max heapify on the reduced heap
        heapify(arr, i, 0);
    }
}

int main() {
    int N;
    printf("Enter number of elements: ");
    scanf("%d", &N);

    int arr[N];

    printf("Enter %d integers: ", N);
    for (int i = 0; i < N; i++)
        scanf("%d", &arr[i]);

    clock_t start_time = clock();

    heapSort(arr, N);

    clock_t end_time = clock();
    double time_taken = ((double)(end_time - start_time)) / CLOCKS_PER_SEC;

    printf("Sorted array using Heap Sort: ");
    for (int i = 0; i < N; i++)
        printf("%d ", arr[i]);
    printf("\n");

    printf("Time taken: %f seconds\n", time_taken);

    return 0;
}
```

OUTPUT :-

```
Sorted array using Heap Sort: 1 3 5 7 8 9 10
Time taken: 0.000028 seconds
```

(Q) A program to implement Floyd's Algorithm.

```
#include <stdio.h>

#define INF 99999
#define V 4  // Number of vertices in the graph

void printSolution(int dist[][V]) {
    printf("Shortest distances between every pair of vertices:\n");
    for (int i = 0; i < V; i++) {
        for (int j = 0; j < V; j++) {
            if (dist[i][j] == INF)
                printf("%7s", "INF");
            else
                printf("%7d", dist[i][j]);
        }
        printf("\n");
    }
}

void floydWarshall(int graph[][V]) {
    int dist[V][V];

    // Initialize distances to the input graph's distances
    for (int i = 0; i < V; i++)
        for (int j = 0; j < V; j++)
            dist[i][j] = graph[i][j];

    // Update distances by considering all vertices as intermediate vertex one by one
    for (int k = 0; k < V; k++) {
        // Pick all vertices as source one by one
        for (int i = 0; i < V; i++) {
            // Pick all vertices as destination for the above picked source
            for (int j = 0; j < V; j++) {
                // If vertex k is on the shortest path from i to j, then update the value of dist[i][j]
                if (dist[i][k] + dist[k][j] < dist[i][j])
                    dist[i][j] = dist[i][k] + dist[k][j];
            }
        }
    }

    printSolution(dist);
}
```

```
int main() {
    int graph[V][V] = {
        {0, INF, 3, INF},
        {2, 0, INF, INF},
        {INF, 7, 0, 1},
        {6, INF, INF, 0}
    };

    floydWarshall(graph);

    return 0;
}
```

OUTPUT :-

```
  0     INF     3     INF
  2      0     INF    INF
 INF     7      0      1
  6     INF    INF     0
```

ADA Week - 9

(Q) A program to implement KnapSack using Dynamic Programming.

```
#include <stdio.h>

#define N 4

int max(int a, int b) {
    return (a > b) ? a : b;
}

void knapsack(int weights[], int profits[], int W) {
    int dp[N+1][W+1];

    // Initialize the dp array
    for (int i = 0; i <= N; i++) {
        for (int w = 0; w <= W; w++) {
            if (i == 0 || w == 0)
                dp[i][w] = 0;
```

```
            else if (weights[i-1] <= w)
                dp[i][w] = max(profits[i-1] + dp[i-1][w-weights[i-1]], dp[i-1][w]);
            else
                dp[i][w] = dp[i-1][w];
        }
    }

    // Maximum profit will be in dp[N][W]
    printf("Maximum profit: %d\n", dp[N][W]);

    // To find which items were selected
    int selected[N];
    int i = N, j = W;
    while (i > 0 && j > 0) {
        if (dp[i][j] != dp[i-1][j]) {
            selected[i-1] = 1;
            j -= weights[i-1];
        } else {
            selected[i-1] = 0;
        }
        i--;
    }

    // Display selected items
    printf("Objects selected in knapsack:\n");
    for (int i = 0; i < N; i++) {
        if (selected[i])
            printf("Object %d (Weight: %d, Profit: %d)\n", i + 1, weights[i], profits[i]);
    }
}

int main() {
    int weights[] = {2, 1, 3, 2};
    int profits[] = {12, 10, 20, 15};
    int W = 5; // Knapsack capacity

    knapsack(weights, profits, W);

    return 0;
}
```

<u>OUTPUT :-</u>

```
Maximum profit: 37
Objects selected in knapsack:
Object 1 (Weight: 2, Profit: 12)
Object 3 (Weight: 3, Profit: 20)
Object 4 (Weight: 2, Profit: 15)
```

(Q) A program to implement Prim's Algorithm.

```
#include <stdio.h>
#include <limits.h>

#define V 5 // Number of vertices in the graph

// A utility function to find the vertex with minimum key value,
// from the set of vertices not yet included in MST
int minKey(int key[], bool mstSet[])
{
    int min = INT_MAX, min_index;

    for (int v = 0; v < V; v++)
        if (mstSet[v] == false && key[v] < min)
            min = key[v], min_index = v;

    return min_index;
}

// A utility function to print the constructed MST stored in parent[]
void printMST(int parent[], int graph[V][V])
{
    printf("Edge \tWeight\n");
    for (int i = 1; i < V; i++)
        printf("%d - %d \t%d \n", parent[i], i, graph[i][parent[i]]);
}

// Function to construct and print MST for a graph represented using adjacency matrix representation
void primMST(int graph[V][V])
{
    int parent[V]; // Array to store constructed MST
    int key[V];    // Key values used to pick minimum weight edge in cut
    bool mstSet[V]; // To represent set of vertices not yet included in MST

    // Initialize all keys as INFINITE
    for (int i = 0; i < V; i++)
        key[i] = INT_MAX, mstSet[i] = false;

    // Always include first 0th vertex in MST.
    key[0] = 0;     // Make key 0 so that this vertex is picked as first vertex
    parent[0] = -1; // First node is always root of MST

    // The MST will have V vertices
    for (int count = 0; count < V - 1; count++) {
        // Pick the minimum key vertex from the set of vertices not yet included in MST
        int u = minKey(key, mstSet);

        // Add the picked vertex to the MST Set
        mstSet[u] = true;
```

```
        // Update key value and parent index of the adjacent vertices of the picked vertex.
        // Consider only those vertices which are not yet included in MST
        for (int v = 0; v < V; v++)

            // graph[u][v] is non zero only for adjacent vertices of m
            // mstSet[v] is false for vertices not yet included in MST
            // Update the key only if graph[u][v] is smaller than key[v]
            if (graph[u][v] && mstSet[v] == false && graph[u][v] < key[v])
                parent[v] = u, key[v] = graph[u][v];
    }

    // Print the constructed MST
    printMST(parent, graph);
}

int main()
{
    /* Let us create the following graph
          2    3
        (0)--(1)--(2)
        |   / \   |
       6| 8/   \5 |7
        | /     \ |
        (3)-------(4)
             9          */
    int graph[V][V] = {
        {0, 2, 0, 6, 0},
        {2, 0, 3, 8, 5},
        {0, 3, 0, 0, 7},
        {6, 8, 0, 0, 9},
        {0, 5, 7, 9, 0},
    };

    // Print the solution
    primMST(graph);

    return 0;
}
```

OUTPUT :-

```
Edge    Weight
0 - 1   2
1 - 2   3
0 - 3   6
1 - 4   7
```

ADA Week - 10

(Q) A program to implement Kruskal's Algorithm.

```
#include <stdio.h>
#include <stdlib.h>

// Structure to represent an edge in the graph
struct Edge {
    int src, dest, weight;
};

// Structure to represent a subset for union-find
struct Subset {
    int parent;
    int rank;
};

// Function prototypes
int find(struct Subset subsets[], int i);
void Union(struct Subset subsets[], int x, int y);
int compareEdges(const void* a, const void* b);
void KruskalMST(int V, int E, struct Edge edges[]);

// Function to find the root of a node
int find(struct Subset subsets[], int i) {
    if (subsets[i].parent != i)
        subsets[i].parent = find(subsets, subsets[i].parent);
    return subsets[i].parent;
}

// Function to perform union of two subsets
void Union(struct Subset subsets[], int x, int y) {
    int xroot = find(subsets, x);
    int yroot = find(subsets, y);

    if (subsets[xroot].rank < subsets[yroot].rank)
        subsets[xroot].parent = yroot;
    else if (subsets[xroot].rank > subsets[yroot].rank)
        subsets[yroot].parent = xroot;
    else {
        subsets[yroot].parent = xroot;
        subsets[xroot].rank++;
    }
}

// Comparison function for qsort
int compareEdges(const void* a, const void* b) {
```

```
    struct Edge* edge1 = (struct Edge*)a;
    struct Edge* edge2 = (struct Edge*)b;
    return edge1->weight - edge2->weight;
}

// Function to construct and print MST using Kruskal's algorithm
void KruskalMST(int V, int E, struct Edge edges[]) {
    struct Edge result[V];  // To store the resultant MST
    int e = 0;              // Index variable for result[]
    int i = 0;              // Index variable for sorted edges

    // Step 1: Sort all the edges in non-decreasing order of their weight
    qsort(edges, E, sizeof(edges[0]), compareEdges);

    // Allocate memory for creating V subsets
    struct Subset* subsets = (struct Subset*)malloc(V * sizeof(struct Subset));

    // Create V subsets with single elements
    for (int v = 0; v < V; ++v) {
        subsets[v].parent = v;
        subsets[v].rank = 0;
    }

    // Number of edges to be taken is V-1
    while (e < V - 1 && i < E) {
        // Step 2: Pick the smallest edge. Increment index for next iteration
        struct Edge next_edge = edges[i++];

        int x = find(subsets, next_edge.src);
        int y = find(subsets, next_edge.dest);

        // If including this edge does not cause a cycle, include it
        if (x != y) {
            result[e++] = next_edge;
            Union(subsets, x, y);
        }
    }

    // Print the edges of MST
    printf("Edges in MST:\n");
    for (i = 0; i < e; ++i)
        printf("%d -- %d : %d\n", result[i].src, result[i].dest, result[i].weight);
}

// Driver program to test above functions
int main() {
    int V, E;
    printf("Enter number of vertices and edges: ");
    scanf("%d %d", &V, &E);

    struct Edge edges[E];

    printf("Enter edges (src, dest, weight):\n");
    for (int i = 0; i < E; ++i)
```

```
        scanf("%d %d %d", &edges[i].src, &edges[i].dest, &edges[i].weight);

    KruskalMST(V, E, edges);

    return 0;
}
```

<u>OUTPUT :-</u>

```
Edges in MST:
1 -- 2 : 1
2 -- 3 : 1
3 -- 4 : 3
4 -- 5 : 2
0 -- 1 : 2
```

(Q) A program to implement Djikstra Algorithm .

```
#include <stdio.h>
#include <limits.h>

#define V 6  // Number of vertices in the graph

// Function to find the vertex with the minimum distance value, from the set of vertices
// not yet included in shortest path tree
int minDistance(int dist[], int sptSet[]) {
    int min = INT_MAX, min_index;

    for (int v = 0; v < V; v++) {
        if (sptSet[v] == 0 && dist[v] <= min) {
            min = dist[v];
            min_index = v;
        }
    }

    return min_index;
}

// Function to print the constructed distance array
void printSolution(int dist[]) {
    printf("Vertex \t Distance from Source\n");
```

```
    for (int i = 0; i < V; i++)
        printf("%d \t %d\n", i, dist[i]);
}

// Function that implements Dijkstra's single source shortest path algorithm for a graph
// represented using adjacency matrix representation
void dijkstra(int graph[V][V], int src) {
    int dist[V];     // The output array. dist[i] will hold the shortest distance from src to i

    int sptSet[V];   // sptSet[i] will be 1 if vertex i is included in shortest path tree or shortest distance from src to i is
finalized

    // Initialize all distances as INFINITE and sptSet[] as 0
    for (int i = 0; i < V; i++) {
        dist[i] = INT_MAX;
        sptSet[i] = 0;
    }

    // Distance of source vertex from itself is always 0
    dist[src] = 0;

    // Find shortest path for all vertices
    for (int count = 0; count < V - 1; count++) {
        // Pick the minimum distance vertex from the set of vertices not yet processed.
        // u is always equal to src in the first iteration.
        int u = minDistance(dist, sptSet);

        // Mark the picked vertex as processed
        sptSet[u] = 1;

        // Update dist value of the adjacent vertices of the picked vertex.
        for (int v = 0; v < V; v++) {
            // Update dist[v] only if is not in sptSet, there is an edge from u to v,
            // and total weight of path from src to v through u is smaller than current value of dist[v]
            if (!sptSet[v] && graph[u][v] && dist[u] != INT_MAX && dist[u] + graph[u][v] < dist[v])
                dist[v] = dist[u] + graph[u][v];
        }
    }

    // Print the constructed distance array
    printSolution(dist);
}

// Driver program to test above function
int main() {
    // Example graph represented using adjacency matrix
    int graph[V][V] = {
        {0, 4, 0, 0, 0, 0},
        {4, 0, 8, 0, 0, 0},
        {0, 8, 0, 7, 0, 4},
        {0, 0, 7, 0, 9, 14},
        {0, 0, 0, 9, 0, 10},
        {0, 0, 4, 14, 10, 0}
    };
```

```
    dijkstra(graph, 0);  // Find shortest paths from source vertex 0

    return 0;
}
```

OUTPUT :-

```
Vertex   Distance from Source
0        0
1        4
2        12
3        19
4        21
5        20
```