| Experiment **#11** | | Student ID | |
|---|---|---|---|
| Date | | Student Name | [@KLWKS_BOT] THANOS |

**Experiment Title: To implement programs on problem solving using Graph Algorithms.**

**Aim/Objective:** To understand the concept and implementation of programs on Graph Algorithms-based Problems.

**Description:** The students will understand DFS , BFS, Single Source Shortest Path and All-Pairs Shortest path algorithms. Students will gain experience in implementing these algorithms and applying them to solve real-world problems.

**Pre-Requisites:**

**Knowledge:** Before beginning this lab, students should have a foundational understanding of:

- The concepts of DFS , BFS,Single Source Shortest Path, and All-Pairs Shortest path algorithms.
- Mathematical Background: Logarithmic complexity analysis for tree operations.
- Understanding of height-balanced properties.

**Tools:** Code Blocks/Eclipse IDE.

**Pre-Lab:**

1. Write a program to find the shortest path from a starting point (e.g., a person's location) to the nearest exit in a building represented as a grid using BFS.

- **Procedure/Program:**

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

#define MAX 100

typedef struct {
   int x, y;
} Point;

typedef struct {
   Point points[MAX];
   int front, rear;
} Queue;
```

```
void initQueue(Queue *q) {
   q->front = 0;
   q->rear = 0;
}

bool isEmpty(Queue *q) {
   return q->front == q->rear;
}

void enqueue(Queue *q, Point p) {
   q->points[q->rear++] = p;
}

Point dequeue(Queue *q) {
   return q->points[q->front++];
}

int bfs(int grid[MAX][MAX], int n, int m, Point start) {
   int directions[4][2] = {{0, 1}, {1, 0}, {0, -1}, {-1, 0}};
   bool visited[MAX][MAX] = {false};
   Queue q;
   initQueue(&q);
   enqueue(&q, start);
   visited[start.x][start.y] = true;
   int distance = 0;

   while (!isEmpty(&q)) {
      int size = q.rear - q.front;
      for (int i = 0; i < size; i++) {
         Point current = dequeue(&q);
         if (grid[current.x][current.y] == 2) {
            return distance;
         }
         for (int j = 0; j < 4; j++) {
            int newX = current.x + directions[j][0];
            int newY = current.y + directions[j][1];
```

```
            if (newX >= 0 && newX < n && newY >= 0 && newY < m &&
                grid[newX][newY] != 1 && !visited[newX][newY]) {
                visited[newX][newY] = true;
                enqueue(&q, (Point){newX, newY});
            }
        }
    }
    distance++;
  }
  return -1;
}

int main() {
  int grid[MAX][MAX] = {
    {0, 0, 1, 0, 2},
    {0, 1, 0, 0, 0},
    {0, 0, 0, 1, 0},
    {1, 0, 1, 0, 0},
    {0, 0, 0, 0, 0}
  };
  Point start = {0, 0};
  int n = 5, m = 5;
  int result = bfs(grid, n, m, start);
  if (result != -1) {
    printf("Shortest path to exit is: %d\n", result);
  } else {
    printf("No exit found.\n");
  }
  return 0;
}
```

- **Data and Results:**

## Data

A grid represents a building with obstacles and exits.

## Result

Shortest path to the nearest exit is determined using BFS.

- **Analysis and Inferences:**

## Analysis

Breadth-first search explores paths layer-by-layer, ensuring shortest route.

## Inferences

BFS efficiently finds the shortest exit path in grid-based environments.

**In-Lab:**

1. You are given a connected, undirected graph representing a network of cities. Each edge represents a road between two cities with a given cost. Write a program to find the Minimum Spanning Tree (MST), which connects all cities with the minimum total cost.

- **Procedure/Program**:

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

#define MAX 100
#define INF 99999

int graph[MAX][MAX], parent[MAX], key[MAX], visited[MAX];
int numVertices;

void primMST() {
   for (int i = 0; i < numVertices; i++) {
      key[i] = INF;
      visited[i] = 0;
   }
   key[0] = 0;
   parent[0] = -1;

   for (int count = 0; count < numVertices - 1; count++) {
      int minKey = INF, minIndex;
      for (int v = 0; v < numVertices; v++) {
         if (!visited[v] && key[v] < minKey) {
```

```
                minKey = key[v];
                minIndex = v;
            }
        }
        visited[minIndex] = 1;

        for (int v = 0; v < numVertices; v++) {
            if (graph[minIndex][v] && !visited[v] && graph[minIndex][v] < key[v]) {
                parent[v] = minIndex;
                key[v] = graph[minIndex][v];
            }
        }
    }
}

void printMST() {
    printf("Edge \tWeight\n");
    for (int i = 1; i < numVertices; i++) {
        printf("%d - %d \t%d\n", parent[i], i, graph[i][parent[i]]);
    }
}

int main() {
    numVertices = 5;



    int exampleGraph[5][5] = {
```

```
    {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}
  };

  for (int i = 0; i < numVertices; i++) {
    for (int j = 0; j < numVertices; j++) {
      graph[i][j] = exampleGraph[i][j];
    }
  }

  primMST();
  printMST();

  return 0;
}
```

- **Data and Results:**

## Data

Graph with 5 vertices and weighted edges representing city roads.

## Result

Minimum Spanning Tree (MST) found with the least total cost.

- **Analysis and Inferences:**

## Analysis

Prim's algorithm selects edges with the smallest weights efficiently.

## Inferences

MST connects all cities while minimizing the total connection cost.

2. You are given a city map represented as a graph. Write a program to determine if there is a path between two given intersections (nodes). Use Depth-First Search (DFS) or Breadth-First Search (BFS) to solve the problem.

- **Procedure/Program**:

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

#define MAX 100

typedef struct {
    int adj[MAX][MAX];
    int visited[MAX];
    int numNodes;
} Graph;

void initGraph(Graph *g, int nodes) {
    g->numNodes = nodes;
    for (int i = 0; i < nodes; i++) {
        g->visited[i] = 0;
        for (int j = 0; j < nodes; j++) {
            g->adj[i][j] = 0;
        }
    }
}

void addEdge(Graph *g, int src, int dest) {
    g->adj[src][dest] = 1;
    g->adj[dest][src] = 1;
}

void dfs(Graph *g, int node, int target, int *found) {
    g->visited[node] = 1;
    if (node == target) {
        *found = 1;
        return;
```

```
    }
    for (int i = 0; i < g->numNodes; i++) {
        if (g->adj[node][i] && !g->visited[i]) {
            dfs(g, i, target, found);
        }
    }
}

int isPath(Graph *g, int start, int end) {
    int found = 0;
    dfs(g, start, end, &found);
    return found;
}

int main() {
    Graph g;
    initGraph(&g, 5);

    addEdge(&g, 0, 1);
    addEdge(&g, 0, 2);
    addEdge(&g, 1, 3);
    addEdge(&g, 2, 4);

    int start = 0, end = 3;
    if (isPath(&g, start, end)) {
        printf("Path exists between %d and %d\n", start, end);
    } else {
        printf("No path exists between %d and %d\n", start, end);
    }

    return 0;
}
```

- **Data and Results:**

## Data

Graph with 5 nodes, edges define connectivity between intersections.

## Result

DFS determines if a path exists between two intersections.

- **Analysis and Inferences:**

## Analysis

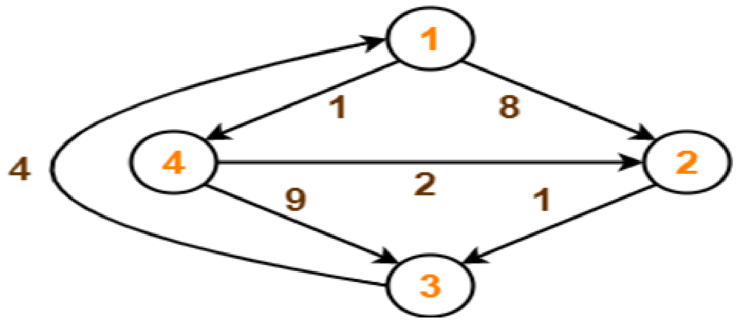
Graph traversal explores connected nodes to check reachability efficiently.

## Inferences

Path existence confirms connectivity; absence indicates graph disconnection.

**Post-Lab:**

Consider the following directed weighted graph and Using Floyd-Warshall Algorithm, find the shortest path distance between every pair of vertices.




- **Procedure/Program**:

**Step-01:**

- Remove all the self loops and parallel edges (keeping the lowest weight edge) from the graph.
- In the given graph, there are neither self edges nor parallel edges.

**Step-02:**

- Write the initial distance matrix.
- It represents the distance between every pair of vertices in the form of given weights.
- For diagonal elements (representing self-loops), distance value = 0.
- For vertices having a direct edge between them, distance value = weight of that edge.
- For vertices having no direct edge between them, distance value = ∞.

Initial distance matrix for the given graph is-

$$D_0 = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \end{array} \begin{array}{c} \begin{array}{cccc} 1 & 2 & 3 & 4 \end{array} \\ \begin{bmatrix} 0 & 8 & \infty & 1 \\ \infty & 0 & 1 & \infty \\ 4 & \infty & 0 & \infty \\ \infty & 2 & 9 & 0 \end{bmatrix} \end{array}$$

## Step-03:

Using Floyd Warshall Algorithm, write the following 4 matrices-

$$D_1 = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \end{array} \begin{array}{c} \begin{array}{cccc} 1 & 2 & 3 & 4 \end{array} \\ \left[\begin{array}{cccc} 0 & 8 & \infty & 1 \\ \infty & 0 & 1 & \infty \\ 4 & 12 & 0 & 5 \\ \infty & 2 & 9 & 0 \end{array}\right] \end{array}$$

$$D_2 = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \end{array} \begin{array}{c} \begin{array}{cccc} 1 & 2 & 3 & 4 \end{array} \\ \left[\begin{array}{cccc} 0 & 8 & 9 & 1 \\ \infty & 0 & 1 & \infty \\ 4 & 12 & 0 & 5 \\ \infty & 2 & 3 & 0 \end{array}\right] \end{array}$$

$$D_3 = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \end{array} \begin{array}{c} \begin{array}{cccc} 1 & 2 & 3 & 4 \end{array} \\ \left[\begin{array}{cccc} 0 & 8 & 9 & 1 \\ 5 & 0 & 1 & 6 \\ 4 & 12 & 0 & 5 \\ 7 & 2 & 3 & 0 \end{array}\right] \end{array}$$

$$D_4 = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \end{array} \begin{array}{c} \begin{array}{cccc} 1 & 2 & 3 & 4 \end{array} \\ \left[\begin{array}{cccc} 0 & 3 & 4 & 1 \\ 5 & 0 & 1 & 6 \\ 4 & 7 & 0 & 5 \\ 7 & 2 & 3 & 0 \end{array}\right] \end{array}$$

- **Data and Results:**

## Data

Graph with weighted edges, vertices, and adjacency matrix representation.

## Result

Final shortest path matrix obtained using Floyd-Warshall algorithm.

- **Analysis and Inferences :**

## Analysis

Each iteration refines shortest paths by considering intermediate vertices.

## Inferences

Algorithm efficiently finds shortest paths between all vertex pairs.

- **Sample VIVA-VOCE Questions (In-Lab):**

1. What is the time complexity of DFS?

- **O(V + E)**, where V is vertices and E is edges.

2. How can BFS be used to find the shortest path in an unweighted graph?

- Uses **level-order traversal**, marking shortest distance from the source.

3. How can you implement Dijkstra’s Algorithm using a priority queue?

- Uses **min-heap** to pick the smallest distance vertex, updating neighbors.

4. What is the Floyd-Warshall Algorithm?

- **Dynamic Programming** approach for **all-pairs shortest paths** in **$O(V^3)$**.

5. How is Prim’s Algorithm different from Kruskal’s Algorithm?

- **Prim’s** grows MST from a node, **Kruskal’s** sorts edges and merges sets.

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| **Evaluator Remark (if Any):** | **Marks Secured ___out of 50** |
| | **Signature of the Evaluator with Date** |

**Evaluator MUST ask Viva-voce prior to signing and posting marks for each experiment.**