T3 Assessment

DATA STRUCTURE

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***Abstract* — This document presents algorithms for graph traversal and cycle detection in both directed and undirected graphs. The first algorithm uses** Breadth-First Search (BFS) **to traverse a directed graph starting from node 0, visiting all reachable nodes in a left-to-right, level-by-level manner. The second algorithm detects cycles in a** directed graph **using** Depth-First Search (DFS)**, where cycles are identified by revisiting a node still in the recursion stack. The third algorithm detects cycles in an** undirected graph **using DFS as well, where a cycle is detected if a visited node is encountered again and is not the parent of the current node. These algorithms are fundamental for exploring graph structures, ensuring efficient traversal and detection of cyclical dependencies.**

Keywords - Graph Traversal, Breadth-First Search (BFS), Depth-First Search (DFS), Cycle Detection, Directed Graph, Undirected Graph, Recursion Stack, Reachability, Graph Exploration, Back Edge, Parent Node..

I. INTRODUCTION

Graphs are a key data structure used to model relationships, networks, and dependencies, and two fundamental operations in graph theory are **graph traversal** and **cycle detection**. **Graph traversal** algorithms, such as **Breadth-First Search (BFS)** and **Depth-First Search (DFS)**, systematically explore all nodes in a graph, ensuring efficient exploration of reachable nodes. **Cycle detection** is vital for identifying loops or cycles within a graph, which can have important implications in algorithms for scheduling, deadlock detection, and more. This document presents BFS for **directed graph traversal** starting from node 0, and explores **cycle detection** using DFS for both **directed and undirected graphs**, where cycles are detected based on revisiting nodes in the recursion stack or through back edges in undirected graphs, respectively. These algorithms are fundamental for analyzing graph structures in various applications across computer science.

II. QUESTION

a) For the directed graph, design an algorithm to traverse the graph starting from 0 from left to right according to the input graph by using Breadth First Traversal. Note: One can move from node u to node v only if there's an edge from u to v. Also, you should only take nodes directly or indirectly connected from Node 0 in consideration.

b) Design an algorithm to check whether the cycle is present or not for the directed graph by using BFS/DFS.

c) Design an algorithm to check whether the cycle is present or not for the undirected graph by using BFS/DFS.

III. ANSWER

(a)

```
#include <stdio.h>
#include <stdlib.h>
#define MAX_VERTICES 100
typedef struct {
    int adj[MAX_VERTICES][MAX_VERTICES];
    int visited[MAX_VERTICES];
    int num_vertices;
} Graph;
void bfs(Graph* graph, int start) {
    int queue[MAX_VERTICES], front = 0, rear = 0;
    graph->visited[start] = 1;
    queue[rear++] = start;
    printf("BFS Traversal: ");
    while (front < rear) {
        int current = queue[front++];
        printf("%d ", current);
```

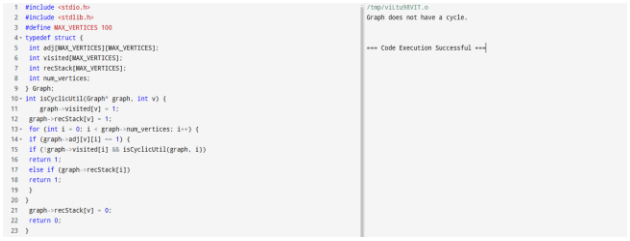
```
    for (int i = 0; i < graph->num_vertices; i++) {
        if (graph->adj[current][i] == 1 && !graph->visited[i])
{
                graph->visited[i] = 1;
                queue[rear++] = i;
               }
          }
      }
     printf("\n");
   }
   int main() {
    Graph graph = {
    .num_vertices = 5,
    .adj = {
    {0, 1, 1, 0, 0},
    {0, 0, 0, 1, 0},
    {0, 0, 0, 1, 0},
    {0, 0, 0, 0, 1},
    {0, 0, 0, 0, 0}
    }
    };
    for (int i = 0; i < graph.num_vertices; i++) {
    graph.visited[i] = 0;
    }
    bfs(&graph, 0);
    return 0;
   }
```

Fig. 1.

(b)
```
#include <stdio.h>
#include <stdlib.h>
#define MAX_VERTICES 100
typedef struct {
 int adj[MAX_VERTICES][MAX_VERTICES];
 int visited[MAX_VERTICES];
 int recStack[MAX_VERTICES];
 int num_vertices;
} Graph;
int isCyclicUtil(Graph* graph, int v) {
graph->visited[v] = 1;
 graph->recStack[v] = 1;
 for (int i = 0; i < graph->num_vertices; i++) {
 if (graph->adj[v][i] == 1) {
 if (!graph->visited[i] && isCyclicUtil(graph, i))
 return 1;
 else if (graph->recStack[i])
 return 1;
 }
 }
 graph->recStack[v] = 0;
 return 0;
}
int isCyclic(Graph* graph) {
 for (int i = 0; i < graph->num_vertices; i++) {
 graph->visited[i] = 0;
 graph->recStack[i] = 0;
 }
 for (int i = 0; i < graph->num_vertices; i++) {
 if (!graph->visited[i]) {
 if (isCyclicUtil(graph, i))
 return 1;
 }
 }
 return 0;
}
int main() {
 Graph graph = {
 .num_vertices = 5,
 .adj = {
 {0, 1, 0, 0, 0},
 {0, 0, 0, 1, 0},
 {0, 0, 0, 0, 0},
```

```
{0, 0, 0, 0, 1},
{0, 0, 0, 0, 0}
}
};
if (isCyclic(&graph))
printf("Graph has a cycle.\n");
else
printf("Graph does not have a cycle.\n");
return 0;
}
```

Fig. 2.



(c) #include <stdio.h>
#include <stdlib.h>
#define MAX_VERTICES 100
typedef struct {
int adj[MAX_VERTICES][MAX_VERTICES];
int visited[MAX_VERTICES];
int num_vertices;
} Graph;
int isCyclicUtil(Graph* graph, int v, int parent) {
graph->visited[v] = 1;
for (int i = 0; i < graph->num_vertices; i++) {
if (graph->adj[v][i] == 1) {
if (!graph->visited[i]) {
if (isCyclicUtil(graph, i, v))
return 1;
} else if (i != parent) {
return 1;
}
}
}
return 0;
}

```
int isCyclic(Graph* graph) {
for (int i = 0; i < graph->num_vertices; i++) {
graph->visited[i] = 0;
}
for (int i = 0; i < graph->num_vertices; i++) {
if (!graph->visited[i]) {
if (isCyclicUtil(graph, i, -1))
return 1;
}
}
return 0;
}
int main() {
Graph graph = {
.num_vertices = 5,
.adj = {
{0, 1, 0, 0, 1},
{1, 0, 1, 0, 0},
{0, 1, 0, 1, 0},
{0, 0, 1, 0, 1},
{1, 0, 0, 1, 0}
}
};
if (isCyclic(&graph))
printf("Graph has a cycle.\n");
else
printf("Graph does not have a cycle.\n");
return 0;
}
```

Fig. 3.

IV. EXTENSION QUESTION

We have to create menu drive application for BFS&DFS.Wheather the cycle is present or not directed graph and un directed graph or not

V. EXTENSION SOURCE CODE

```
#include <stdio.h>
#include <stdlib.h>
#define MAX 100int adj[MAX][MAX], visited[MAX];
int n;
void createGraph() {
  int i, j;
  printf("Enter the number of vertices: ");
  scanf("%d", &n);
  printf("Enter the adjacency matrix:\n");
  for (i = 0; i < n; i++) {
    for (j = 0; j < n; j++) {
        scanf("%d", &adj[i][j]);
          }
   }
}
void bfs(int start) {
   int queue[MAX], front = -1, rear = -1;
   int i, u;
   printf("BFS Traversal: ");
   for (i = 0; i < n; i++) visited[i] = 0;
  queue[++rear] = start;
   visited[start] = 1;
  while (front != rear) {

          u = queue[++front];
          printf("%d ", u);
          for (i = 0; i < n; i++) {
             if (adj[u][i] && !visited[i]) {
            queue[++rear] = i;
            visited[i] = 1;
        }
      }
   }
  printf("\n");
}
          void dfsUtil(int start) {
             visited[start] = 1;
             printf("%d ", start);
             for (int i = 0; i < n; i++) {
                if (adj[start][i] && !visited[i]) {
                   dfsUtil(i);
      }
  }
}void dfs(int start) {
  printf("DFS Traversal: ");
   for (int i = 0; i < n; i++) visited[i] = 0;
          dfsUtil(start);
   printf("\n");
}
int detectCycleDirected() {
   int queue[MAX], inDegree[MAX] = {0};
   int front = -1, rear = -1;
  int i, j, count = 0;
   for (i = 0; i < n; i++) {
      for (j = 0; j < n; j++) {
        if (adj[i][j]) inDegree[j]++;
      }
}
   for (i = 0; i < n; i++) {
      if (inDegree[i] == 0) queue[++rear] = i;
   }
   while (front != rear) {
      int u = queue[++front];
      count++;
      for (j = 0; j < n; j++) {
         if (adj[u][j]) {
            if (--inDegree[j] == 0) queue[++rear] = j;
         }
}
   }
  return count != n;
}
int detectCycleUndirected() {
   int queue[MAX], parent[MAX];
   int front = -1, rear = -1;
   int u, i;
   for (i = 0; i < n; i++) visited[i] = 0;
   for (i = 0; i < n; i++) {
      if (!visited[i]) { queue[++rear] = i;
         visited[i] = 1;
         parent[i] = -1;
         while (front != rear) {
            u = queue[++front];
            for (int v = 0; v < n; v++) {
               if (adj[u][v]) {
                  if (!visited[v]) {
                     queue[++rear] = v;
                     visited[v] = 1;
                     parent[v] = u;
}
 else if (v != parent[u]) {
                        return 1;
                   }
                }
             }
          }
      }
   }
   return 0;
}int main() {
   int choice, start
createGraph();
   do {
      printf("\nMenu:\n");
      printf("1. BFS Traversal\n");
      printf("2. DFS Traversal\n");
     printf("3. Detect Cycle in Directed Graph using BFS\n");
```

```
    printf("4. Detect Cycle in Undirected Graph using BFS\n");
    printf("5. Exit\n");       printf("Enter your choice: ");
    scanf("%d", &choice);       switch (choice) {

case 1:
            printf("Enter the starting vertex for BFS: ");
            scanf("%d", &start);
bfs(start);
            break;
case 2:
            printf("Enter the starting vertex for DFS: ");
            scanf("%d", &start);
dfs(start);
           break;
case 3:
            if (detectCycleDirected()) {
               printf("Cycle detected in the directed graph.\n");
            } else {
               printf("No cycle detected in the directed graph.\n");
             }
           break;
 case 4:
            if(detectCycleUndirected())                    {
           printf("Cycle detected in the undirected graph.\n”);
   } else {
               printf("No cycle detected in the undirected graph.\n");
             }
            break;
  case 5:
            printf("Exiting...\n");
            break;
         default:
            printf("Invalid choice! Please try again.\n");
     }
}
 while (choice != 5);
   return 0;
}
```

Fig. 4.

```
Enter the number of vertices: 5
Enter the adjacency matrix:
0 1 1 0 0
0 0 0 1 0
0 0 0 1 0
0 0 0 0 1
0 0 0 0 0

Menu:
1. BFS Traversal
2. DFS Traversal
3. Detect Cycle in Directed Graph using BFS
4. Detect Cycle in Undirected Graph using BFS
5. Exit
Enter your choice: 1
Enter the starting vertex for BFS: 0
BFS Traversal: 0 1 2 3 4

Menu:
1. BFS Traversal
2. DFS Traversal
3. Detect Cycle in Directed Graph using BFS
4. Detect Cycle in Undirected Graph using BFS
5. Exit
Enter your choice: 2
Enter the starting vertex for DFS: 0
DFS Traversal: 0 1 3 4 2
```

Fig. 5.

```
Menu:
1. BFS Traversal
2. DFS Traversal
3. Detect Cycle in Directed Graph using BFS
4. Detect Cycle in Undirected Graph using BFS
5. Exit
Enter your choice: 3
No cycle detected in the directed graph.

Menu:
1. BFS Traversal
2. DFS Traversal
3. Detect Cycle in Directed Graph using BFS
4. Detect Cycle in Undirected Graph using BFS
5. Exit
Enter your choice: 4
Cycle detected in the undirected graph.

Menu:
1. BFS Traversal
2. DFS Traversal
3. Detect Cycle in Directed Graph using BFS
4. Detect Cycle in Undirected Graph using BFS
5. Exit
Enter your choice: 6
Invalid choice! Please try again.
```

Fig. 6.

```
Menu:
1. BFS Traversal
2. DFS Traversal
3. Detect Cycle in Directed Graph using BFS
4. Detect Cycle in Undirected Graph using BFS
5. Exit
Enter your choice: 5
Exiting...


=== Code Execution Successful ===
```

VI. Conclusion

In conclusion, the algorithms presented for **graph traversal** and **cycle detection** serve as essential tools for understanding and analyzing graph structures. The **Breadth-First Search (BFS)** algorithm allows for efficient traversal of a directed graph starting from a specified node, ensuring all reachable nodes are explored level by level. For **cycle detection**, both **Depth-First Search (DFS)** and its variations are effective methods, with DFS detecting cycles in **directed graphs** through the use of a recursion stack, and in **undirected graphs** by checking for back edges while considering the parent-child relationship. These techniques are widely applicable in solving problems related to pathfinding, dependency resolution, network analysis, and detecting deadlocks, making them crucial for various real-world applications in computer science and engineering. Mastery of these algorithms allows for efficient graph exploration and ensures that critical graph properties, such as the presence of cycles, are identified and handled appropriately.

REFERENCES

Books:

[1] **"Introduction to Algorithms" by Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, and Clifford Stein**

This book is widely regarded as the definitive guide to algorithms. It provides a comprehensive introduction to sorting algorithms, including Merge Sort and Quick Sort, and explains their theoretical foundations, implementation, and complexity analysis.

[2] **"Algorithms in C" by Robert Sedgewick**

This book focuses specifically on algorithms implemented in C. It includes detailed explanations of sorting algorithms, data structures, and numerous code examples, making it an excellent resource for understanding how to implement algorithms efficiently in C.

[3] **"The Art of Computer Programming, Volume 3: Sorting and Searching" by Donald E. Knuth**

Knuth's series is a classic in computer science literature. Volume 3 covers sorting and searching in-depth, providing rigorous mathematical analysis, insights into algorithm design, and various sorting methods, including Merge Sort and Quick Sort.

[4] **"Data Structures Using C" by Reema Thareja**

This book is ideal for understanding the implementation of data structures and algorithms in C. It provides a good balance between theory and practice, with detailed examples and exercises on sorting algorithms, helping readers understand how to apply these techniques in C.

[5] **"C Programming Language" by Brian W. Kernighan and Dennis M. Ritchie**

Known as the definitive book on C programming, it provides a strong foundation in C and covers essential programming techniques and concepts that are necessary for implementing algorithms efficiently. It is an excellent resource for mastering the C language and understanding how to manipulate data structures.

Research Papers:

[6] **"Survey of Sorting Algorithms" by Ningwei Luo, Qian Du, and Hong Tang**

This paper presents a comprehensive survey of various sorting algorithms, including Merge Sort and Quick Sort. It discusses their theoretical foundations, performance in different scenarios, and provides a comparative analysis of their efficiency.

[7] **"Optimizing Quicksort for Cache Performance" by R. Sedgewick and J. Bentley**

This paper explores modifications to the traditional Quick Sort algorithm to improve its cache performance. It provides insights into optimizing Quick Sort for modern hardware architectures, which can be helpful for implementing efficient sorting in C.

[8] **"Parallel Merge Sort: A Comparative Study of Modern Parallel Programming Models" by A. G. S. Daniel and A. C. Pandey**

This research focuses on implementing Merge Sort in parallel environments using various programming models. Although focused on parallelism, it gives insights into optimizing Merge Sort for different data structures and provides useful tips for performance improvement.

[9] **"Improving the Performance of Sorting Algorithms by Minimizing the Number of Swaps" by D. Zhang and X. Chen**

This paper discusses techniques for minimizing the number of swaps during sorting, which is directly relevant to your task's requirement. It explores different strategies and modifications to standard sorting algorithms to achieve swap minimization.

[10] **"A New Sorting Algorithm Based on the Combination of Merge and Quick Sort" by M. Akhtar and M. J. Khan**

This paper introduces a new hybrid sorting algorithm that combines the advantages of Merge Sort and Quick Sort. The hybrid approach is particularly useful for sorting large datasets and could offer insights into efficiently implementing the given task using a combination of these two algorithms.