UNIVERSITY OF CALOOCAN CITY
COMPUTER ENGINEERING DEPARTMENT

Data Structure and Algorithm

Laboratory Activity No. 12

Graph Searching Algorithm

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I. Objectives

Introduction

Depth-First Search (DFS)

- Explores as far as possible along each branch before backtracking
- Uses stack data structure (either explicitly or via recursion)
- Time Complexity: O(V + E)
- Space Complexity: O(V)

Breadth-First Search (BFS)

- Explores all neighbors at current depth before moving deeper
- Uses queue data structure
- Time Complexity: O(V + E)
- Space Complexity: O(V)

This laboratory activity aims to implement the principles and techniques in:

- Understand and implement Depth-First Search (DFS) and Breadth-First Search (BFS) algorithms
- Compare the traversal order and behavior of both algorithms
- Analyze time and space complexity differences

II. Methods

- Copy and run the Python source codes.
- If there is an algorithm error/s, debug the source codes.
- Save these source codes to your GitHub.
- Show the output

1. Graph Implementation

```
from collections import deque
import time

class Graph:
    def __init__(self):
        self.adj_list = {}

    def add_vertex(self, vertex):
        if vertex not in self.adj_list:
            self.adj_list[vertex] = []

    def add_edge(self, vertex1, vertex2, directed=False):
        self.add_vertex(vertex1)
        self.add_vertex(vertex2)

        self.adj_list[vertex1].append(vertex2)
        if not directed:
            self.adj_list[vertex2].append(vertex1)
    def display(self):
        for vertex, neighbors in self.adj_list.items():
            print(f"{vertex}: {neighbors}")
```

2. DFS Implementation

```
def dfs_recursive(graph, start, visited=None, path=None):
    if visited is None:
        visited = set()
    if path is None:
        path = []

    visited.add(start)
    path.append(start)
    print(f"Visiting: {start}")

    for neighbor in graph.adj_list[start]:
        if neighbor not in visited:
            dfs_recursive(graph, neighbor, visited, path)

    return path

def dfs_iterative(graph, start):
    visited = set()
    stack = [start]
    path = []

    print("DFS Iterative Traversal:")
    while stack:
        vertex = stack.pop()
        if vertex not in visited:
            visited.add(vertex)
            path.append(vertex)
            print(f"Visiting: {vertex}")

            # Add neighbors in reverse order for same behavior as recursive
            for neighbor in reversed(graph.adj_list[vertex]):
                if neighbor not in visited:
                    stack.append(neighbor)
    return path
```

3. BFS Implementation

```
def bfs(graph, start):
    visited = set()
    queue = deque([start])
    path = []

    print("BFS Traversal:")
    while queue:
        vertex = queue.popleft()
        if vertex not in visited:
            visited.add(vertex)
            path.append(vertex)
            print(f"Visiting: {vertex}")
            for neighbor in graph.adj_list[vertex]:
                if neighbor not in visited:
                    queue.append(neighbor)

        return path
```

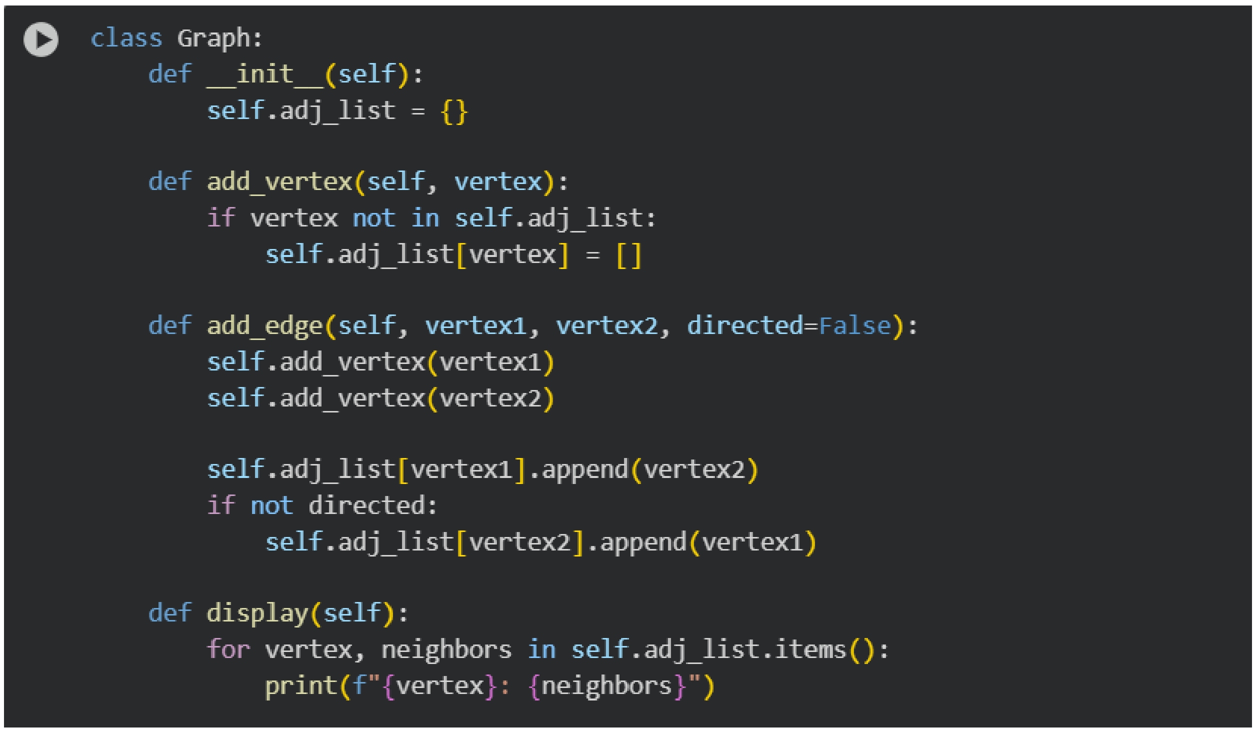
Questions:

1. When would you prefer DFS over BFS and vice versa?
2. What is the space complexity difference between DFS and BFS?
3. How does the traversal order differ between DFS and BFS?
4. When does DFS recursive fail compared to DFS iterative?

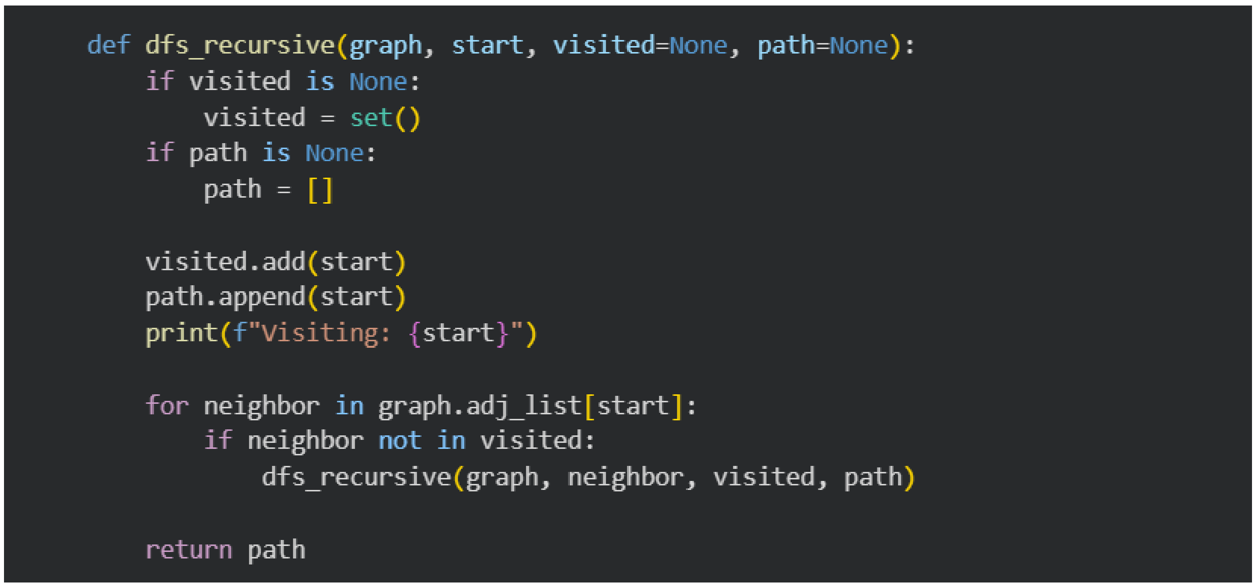
III. Results

Present the visualized procedures done. Also present the results with corresponding data visualizations such as graphs, charts, tables, or image . Please provide insights, commentaries, or explanations regarding the data. If an explanation requires the support of literature such as academic journals, books, magazines, reports, or web articles please cite and reference them using the IEEE format.

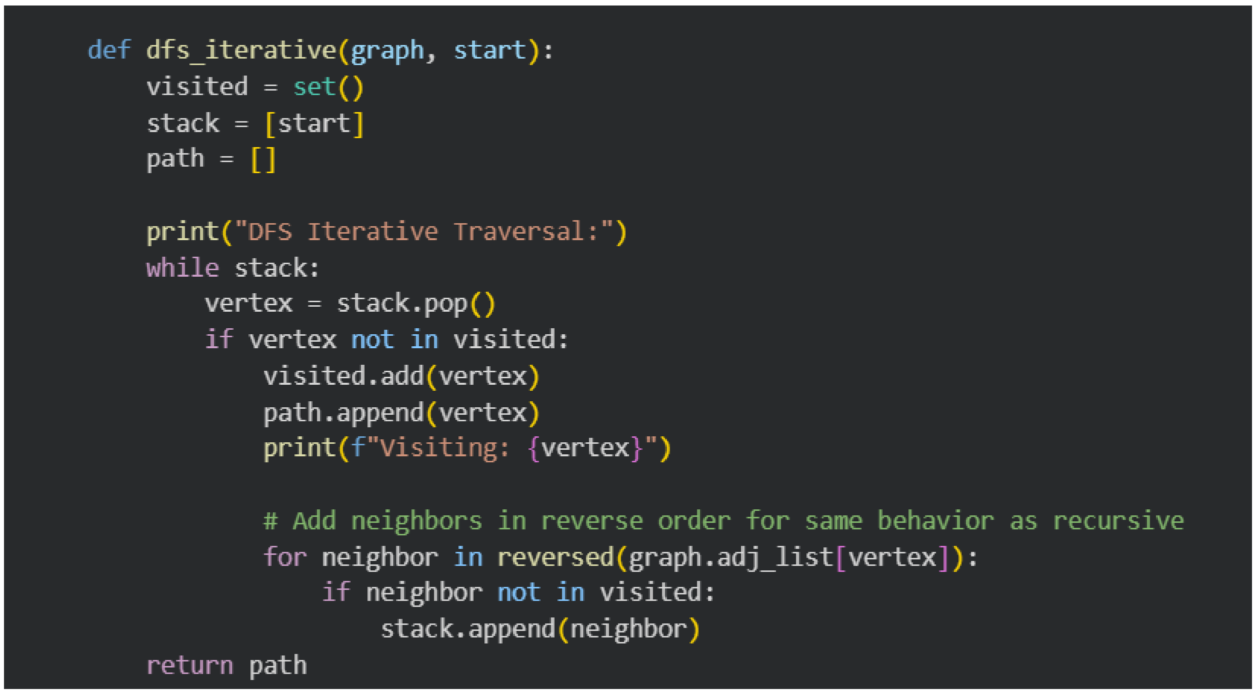
Please take note of the styles on the style ribbon as these would serve as the style format of this laboratory report. The body style is Times New Roman size 12, line spacing: 1.5. Body text should be in Justified alignment, while captions should be center-aligned. Images should be readable and include captions. Please refer to the sample below:



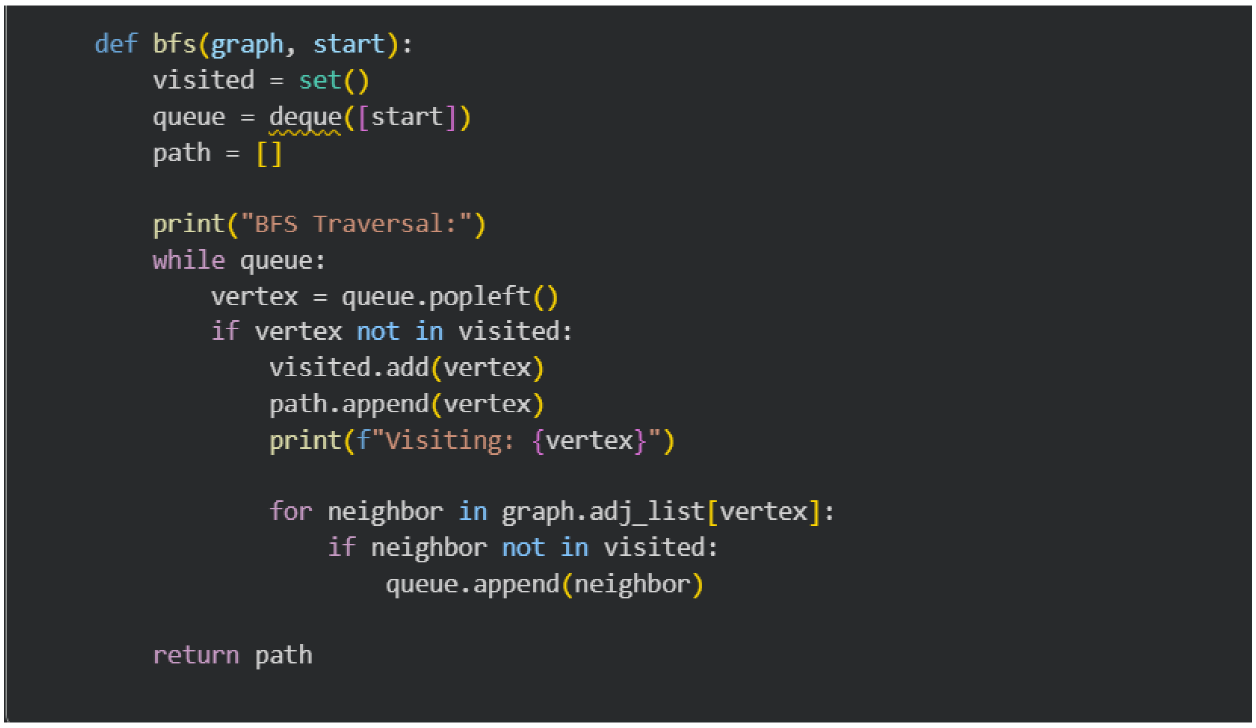
```python
class Graph:
    def __init__(self):
        self.adj_list = {}

    def add_vertex(self, vertex):
        if vertex not in self.adj_list:
            self.adj_list[vertex] = []

    def add_edge(self, vertex1, vertex2, directed=False):
        self.add_vertex(vertex1)
        self.add_vertex(vertex2)

        self.adj_list[vertex1].append(vertex2)
        if not directed:
            self.adj_list[vertex2].append(vertex1)

    def display(self):
        for vertex, neighbors in self.adj_list.items():
            print(f"{vertex}: {neighbors}")
```



```python
def dfs_recursive(graph, start, visited=None, path=None):
    if visited is None:
        visited = set()
    if path is None:
        path = []

    visited.add(start)
    path.append(start)
    print(f"Visiting: {start}")

    for neighbor in graph.adj_list[start]:
        if neighbor not in visited:
            dfs_recursive(graph, neighbor, visited, path)

    return path
```



```python
def dfs_iterative(graph, start):
    visited = set()
    stack = [start]
    path = []

    print("DFS Iterative Traversal:")
    while stack:
        vertex = stack.pop()
        if vertex not in visited:
            visited.add(vertex)
            path.append(vertex)
            print(f"Visiting: {vertex}")

            # Add neighbors in reverse order for same behavior as recursive
            for neighbor in reversed(graph.adj_list[vertex]):
                if neighbor not in visited:
                    stack.append(neighbor)
    return path
```



```
def bfs(graph, start):
    visited = set()
    queue = deque([start])
    path = []

    print("BFS Traversal:")
    while queue:
        vertex = queue.popleft()
        if vertex not in visited:
            visited.add(vertex)
            path.append(vertex)
            print(f"Visiting: {vertex}")

            for neighbor in graph.adj_list[vertex]:
                if neighbor not in visited:
                    queue.append(neighbor)

    return path
```

Figure 1 Screenshot of program

If an image is taken from another literature or intellectual property, please cite them accordingly in the caption. Always keep in mind the Honor Code [1] of our course to prevent failure due to academic dishonesty.

ANSWER:

1. When would you prefer DFS over BFS and vice versa?

- **Prefer DFS** when you want to explore a path all the way to the end before backtracking. It is often better for tasks like:
  - Finding a path between two points (like in a maze).
  - Checking if a cycle exists in a graph.
  - Solving puzzles with only one solution (like a sudoku solver).
- **Prefer BFS** when you want to explore nodes level by level, starting from the source. It is better for:
  - Finding the shortest path on an unweighted graph.
  - Finding all nodes within a certain number of "steps" or "levels".
  - Web crawling, where you want to explore links in order of their distance from the start page.

2. What is the space complexity difference between DFS and BFS?

- **DFS** generally has a lower space complexity of **O(h)**, where h is the maximum depth of the graph. It only needs to store a single path from the root to a leaf node in the stack at any time.

- **BFS** has a higher space complexity of **O(w)**, where w is the maximum width of the graph. This is because the queue needs to store all the nodes at the current level before moving to the next, which can be very large for wide graphs.

3. How does the traversal order differ between DFS and BFS?

- **DFS** goes deep first. It starts at the root and explores as far as possible along each branch before backtracking. It's like exploring a single corridor until you hit a dead end, then going back to try the next one.
- **BFS** goes wide first. It visits all the neighbors at the present depth before moving on to nodes at the next depth level. It's like exploring all the rooms on your current floor before going down to the next floor.

4. When does DFS recursive fail compared to DFS iterative?

- **DFS Recursive** can fail with a **stack overflow** error if the graph is very deep. This is because each recursive call adds a new layer to the program's call stack, which has a limited size.
- **DFS Iterative** uses an explicit stack data structure, which is allocated in the heap memory (which is much larger). Therefore, it can handle much deeper graphs without crashing.

IV. Conclusion

In short, use **BFS** to find the shortest path or explore by levels, and use **DFS** to explore deep paths or check for cycles. **BFS** can use more memory on wide graphs, while **DFS** can cause stack overflows on very deep graphs if implemented recursively.

References

[1] Co Arthur O.. “University of Caloocan City Computer Engineering Department Honor Code,” UCC-CpE Departmental Policies, 2020.

[2] GeeksforGeeks. (2023, October 24). *BFS vs DFS for Binary Tree*. https://www.geeksforgeeks.org/bfs-vs-dfs-binary-tree/