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# Introduction

Recursion is a fundamental concept in computer science that involves a function calling itself (Awasthi, 2018). It is a powerful technique that allows for elegant and efficient solutions to a wide range of problems, particularly those that involve data structures like trees and graphs. The Floyd Warshall Algorithm is a classic example of a problem that can be solved using recursion (geeksforgeeks.org, 2022). In this report, I will discuss how I implemented the recursive version of the Floyd Warshall Algorithm and how I tested its performance and accuracy using feature tests, integration tests, and unit tests. I will also explore the practical applications of recursion in various industries, including the London Underground Loop, the Deliveroo App, and streaming services like Netflix and Hulu.

# Data Structure

The Floyd Warshall Algorithm is used to find the shortest path between every pair of vertices in a weighted graph. It is commonly used in network routing protocols and traffic management systems. The algorithm uses a two-dimensional array to represent the graph and a three-dimensional array to store the intermediate vertices in the shortest path. The intermediate vertices are used to recursively compute the shortest path between two vertices. The algorithm has a time complexity of O(V^3), where V is the number of vertices in the graph (Cormen, 2013).

# Implementation

The recursive version of the Floyd Warshall Algorithm involves a base case and a recursive case. The base case is when there are no intermediate vertices, and the distance matrix is already the solution. The recursive case involves iterating over all pairs of vertices and all possible intermediate vertices and updating the distance matrix with the minimum distance. The function then calls itself recursively with the updated distance matrix and the remaining intermediate vertices. The algorithm terminates when there are no more intermediate vertices.

To implement the algorithm, I defined a function `floyd\_warshall\_recursive(graph, dist)` that takes a graph represented as a two-dimensional array and a distance matrix initialized to the graph. The function then recursively computes the shortest path between every pair of vertices using the intermediate vertices.

# Feature Tests

To test the accuracy of the recursive version of the Floyd Warshall Algorithm, I created feature tests that check if the algorithm correctly computes the shortest path between every pair of vertices in a given graph. I used the example graph from the original implementation to test the algorithm. The feature tests involved comparing the output of the recursive algorithm with the output of the original implementation to ensure that they were the same.

# Integration Tests

To test the integration of the recursive algorithm with other parts of the system, I created integration tests that checked if the algorithm worked correctly with different data structures and input formats. For example, I tested if the algorithm could handle graphs represented as adjacency lists or dictionaries, or if the algorithm could handle graphs with negative edge weights.

# Unit Tests

To test the individual components of the recursive algorithm, I created unit tests that checked if each function and loop in the algorithm worked correctly. I used the unittest module in Python (Python Software Foundation, 2023). For example, I tested if the loop that imperated over all pairs of vertices was correctly implemented, or if the function that computed the minimum distance was working correctly. I have also create solution test and ensured it works.

# Performance Tests

To test the performance of the recursive version of the Floyd Warshall Algorithm, I compared its execution time with the execution time of the original implementation. I used the python `timeit` module to measure the execution time of each algorithm with the same input graph. The results showed that the recursive algorithm was slower than the original implementation for large graphs with many vertices and edges (Garey & Johnson, 1979).

# Hypothesis

The difference in performance between the recursive version of the Floyd Warshall Algorithm and the original implementation can be explained by the overhead of the function calls and the creation of new distance matrices for each recursive call. The original implementation uses nested loops to imperate over all pairs of vertices and intermediate vertices, which is more efficient than calling a function recursively for each intermediate vertex.

# Practical Applications



Recursion has many practical applications in various industries. In the London Underground Loop, recursion is used to compute the shortest path between two stations. The algorithm uses a graph to represent the network of stations and tunnels, and recursion is used to find the shortest path between two stations by computing the shortest path between intermediate stations (Kokou Dadzie, 2012). In the Deliveroo App, recursion is used to optimize the delivery routes for riders. The algorithm uses a graph to represent the locations of the riders and the delivery addresses, and recursion is used to find the shortest path between each pair of locations. In streaming services like Netflix and Hulu, recursion is used to recommend new content to users based on their viewing history. The algorithm uses a graph to represent the relationships between different movies and TV shows, and recursion is used to find similar content based on the user's viewing history.

## Imperative and Recursive Methods for the London Underground

The London Underground is one of the oldest and most complex subway systems in the world, with over 270 stations and 11 lines. To find the shortest path between two stations on the Underground, we can use the Floyd Warshall algorithm. In the imperative version of the algorithm, we start with a matrix of distances between each pair of stations and update the matrix using dynamic programming techniques until we have the shortest distance between each pair of stations.

For example, let's say we want to find the shortest path between King's Cross St. Pancras and Waterloo stations. We start with a matrix that represents the distance between each pair of stations:

| | King's Cross St. Pancras | Waterloo |

|---|-------------------------|----------|

| King's Cross St. Pancras | 0 | 2 |

| Waterloo | 2 | 0 |

We then update the matrix using dynamic programming techniques until we have the shortest distance between each pair of stations:

| | King's Cross St. Pancras | Waterloo |

|---|-------------------------|----------|

| King's Cross St. Pancras | 0 | 2 |

| Waterloo | 2 | 0 |

In the recursive version of the algorithm, we define a recursive function that finds the shortest distance between two stations using memoization (interviewcake.com, 2022). The function takes into account the distance between intermediate stations to find the shortest path between the two stations.

For example, let's say we want to find the shortest path between King's Cross St. Pancras and Waterloo stations using the recursive version of the algorithm. We would call the `shortest\_path\_recursive` function with the indices of the two stations:

```

distances = [

[0, 2],

[2, 0]

]

memo = {}

shortest\_distance = shortest\_path\_recursive(0, 1)

print("Short

To further discuss the imperative and recursive methods for the London Underground, we can hypothesize about their performance differences. Based on our implementation and testing of the imperative and recursive versions of the Floyd Warshall algorithm, we can hypothesize that the imperative version will generally be faster and more memory-efficient than the recursive version for large graphs. This is because the imperative version updates a matrix of shortest distances between each pair of vertices in a single pass, while the recursive version may need to re-compute the shortest distance between each pair of vertices multiple times due to the recursive function calls and memoization (interviewcake.com, 2022).

However, for small graphs, the differences in performance between the two versions may be negligible, and the recursive version may be more intuitive and easier to understand than the imperative version.

In the case of the London Underground, the size of the graph may influence the performance of the imperative and recursive methods. If we consider the London Underground graph with over 270 stations and 11 lines, the imperative version may be faster and more memory-efficient due to the large size of the graph. However, for smaller sections of the graph, the recursive version may be more intuitive and easier to understand. Additionally, the use of memoization in the recursive version can improve performance by reducing the number of redundant computations (interviewcake.com, 2022).

# Conclusion

In conclusion, the recursive version of the Floyd Warshall Algorithm is a modified version if the imperative version that uses recursion to divide the graph into smaller subgraphs and solve them recursively. Our feature tests, Integration, performance tests and units test showed that the algorithm is accurate and efficient for small graphs, but less efficient than the imperative version for large graphs. We also explored how recursion software is practically used in different applications such as the London Underground Loop, Deliveroo App, and streaming services like Netflix and Hulu.

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