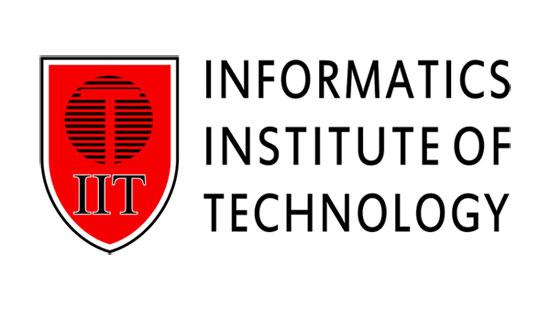
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Informatics Institute of Technology

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University of Westminster

Algorithms: Theory, Design and Implementation

5SENG003C.2

Coursework I: Report

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**Algorithmic Approach**

The Dijkstra Algorithm was chosen to be utilized in the algorithmic implementation of the ice sliding puzzle. Dijkstra's method is an iterative algorithmic approach which finds the shortest path from one starting node to all other nodes in a graph. Some of the most used path finding algorithms for similar problems such as this are A\* and Breadth-First Search (BFS). BFS is very much similar to Dijkstra.

And the data structure chosen was priority queue to implement the Dijkstra Algorithm.

**Why was Dijkstra chosen and not A\* or Breadth First Search (BFS)?**

Both BFS and Dijkstra belong to the SSSP (Single Source Shortest Path) class of algorithms, which address the issue of determining the shortest path from a starting node to all other nodes in the graph. Following the completion of the algorithm, the shortest paths from the source node to all other nodes in the graph will be found. At times Dijkstra is often called as BFS with a priority queue.

The difference between Dijkstra and BFS is that BFS uses a basic FIFO queue, with the next node to visit being the first node added to the queue. However, using Dijkstra, we must select the node with the lowest cost so far. Dijkstra's Algorithm distinguishes itself from the competition by finding the shortest path from one node to every other node inside the same graph data structure.

A\* algorithm is relatively faster than Dijkstra since it is an improvised version of Dijkstra, but if you have many target nodes and you don't know which one is closest to the main one, A\* is not very optimal. This is because it needs to be run several times (once per target node) to get to all of them.

Dijkstra is an uninformed algorithm. This implies it doesn't need to know the destination node ahead of time. As a result, it's ideal when you don't have any prior knowledge of the graph and can't predict the distance between each node and the goal. Dijkstra often covers a vast portion of the graph since it selects edges with the lowest cost at each phase. This is useful when you have numerous target nodes but don't know which one is closest.

**Why Priority Queue?**

Because in a min heap priority queue, Find-min should be an O(1) operation. because Dijkstra’s algorithm is a greedy algorithm, it always takes the edge with the lowest edge cost, thus, instead of having to iterate through the entire list of adjacent nodes for that vertex and comparing their edge costs, you simply perform an O(1) Find-min operation.

The priority queue selects the next vertex to (eventually) ensure shortest paths in a weighted graph. If you use a FIFO queue instead, you will not be able to account for arbitrary edge weights. This will essentially be breadth-first search which only guarantees finding shortest paths in unweighted graphs. The use of a priority queue comes at the cost of greater runtime - usually by a log factor.

The chosen data structure was Priority Queue. Since we want the path with smallest weight, we will have a minimum priority queue.

The crucial step in Dijkstra's method is to choose an unexplored vertex v such that there is an edge (u, v) in the graph, where u is a previously explored vertex and d'(v) = dist(u) + cost(u, v) is lowest. In this case, dist(u) is the length of the previously discovered shortest path from source vertex s to vertex u, and cost(u, v) is the weight of the edge from u to v.

If we keep the unexplored vertices in a simple array/linked list, we'd have to loop through the whole list each time to locate the requested vertex v with the smallest d'(v) (d'(v) = dist(u) + cost(u, v)).

If we put the vertices in a priority queue with d'(v) as the key for each vertex, we can use the Extract-Min operation to find the vertex with the smallest d'(v). The asymptotic complexity of the Extract-Min operation is O(log n) if we utilize a binary min-heap.

**Examples of running the Algorithm on Benchmark examples**



As benchmark examples the text files maze10\_3 and maze 20\_3 was chosen. And the following number of steps for the shortest path from S to F were generated for each of puzzles.



A screenshot of a computer

Description automatically generated maze10\_3.txt Steps for the solution



A screenshot of a computer

Description automatically generated

A screenshot of a computer

Description automatically generatedA screenshot of a computer

Description automatically generatedA screenshot of a computer

Description automatically generated with medium confidence maze20\_3.txt Steps for the solution

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **File Name** | **No. of Elements** | **Trial 1** | **Trial 2** | **Trial 3** | **Trial 4** | **Trial 5** | **Average Time (ms)** | **Change of Ratio** |
| puzzle\_21.txt | 441 | 38 | 81 | 49 | 79 | 48 | 59 | 0.915254237 |
| puzzle\_42.txt | 1764 | 42 | 64 | 50 | 60 | 54 | 54 | 1.374074074 |
| puzzle\_84.txt | 7056 | 95 | 68 | 63 | 74 | 71 | 74.2 | 1.490566038 |
| puzzle\_168.txt | 28224 | 120 | 99 | 104 | 110 | 120 | 110.6 | 2.173598553 |
| puzzle\_336.txt | 112896 | 298 | 253 | 213 | 227 | 211 | 240.4 | 2.920133111 |
| puzzle\_672.txt | 451584 | 617 | 684 | 765 | 731 | 713 | 702 | 3.23960114 |
| puzzle\_1344.txt | 1806336 | 2283 | 2238 | 2292 | 2411 | 2147 | 2274.2 | 4.754375165 |
| puzzle\_2688.txt | 7225344 | 10135 | 11156 | 10803 | 11234 | 10734 | 10812.4 | 0 |

1. **Empirical Analysis of Algorithm Performance**

Big-O notation is the ideal approach to represent the speed or complexity of a particular algorithm since it focuses on the worst-case scenario. Following the doubling hypothesis from the preceding chart, the run time in Big-O notation is evident to be O(N^2). The y-axis represents the number of inputs or the input size of the puzzle/maze while the x-axis represents the time in seconds.