Wikipedia Path Search

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Abstract

The goal of this application is to find one of the shortest paths to get from one Wikipedia page to another Wikipedia page. The edges are is determined by hyperlinks on the page. The application will return one of the shortest paths using the specified algorithm.

Introduction

The overall objective of our project is to examine different path finding algorithms. Website navigation is important to user experience. When users navigate through a web application, it is intuitive to have relevant pages linked. Wikipedia is a popular website that links sources to other web pages. Many people use Wikipedia for causal research. With more efficient algorithms, it would be easier and faster to search for paths between these pages. Some applications of this problem is website page ranking and user analysis. Page ranking analyzes how popular or important a web page is by ranking it to other web pages. One major application that utilizes page ranking are search engine results. With page ranking, the Wikipedia pages can be examined on which web pages are most frequently visited and the popularity of the links within the page. They can also be examined on how many clicks does it usually take from one user to navigate to another page or which path do users usually take. Other possible analysis can be of how easy it is to find a page and how closely one article term/name relates to another. Analyzing with time can also be done with examining how long it usually takes one user to get to another page as well as what the the fastest way to get from one page to another.

From the dataset we used, it's sources show that it uses the Floyd-Warshall algorithm. The algorithm calculates all the shortest paths between all pairs of vertices.

One issue with the approaches above is the time and space complexity. From the dataset, they used Floyd-Warshall algorithm, which requires at least $O(n^2)$ data for the table and takes $O(n^3)$ for time complexity. The dataset is large with 4604 nodes, 119882 edges, and an average in and out degree of 26.0387. Since the dataset is large, it requires a lot of time and resources. Another issue with this problem is that it is an uninformed search which comes with limitations. Being an uninformed search, it cannot use knowledge for the searching process and cannot utilize many heuristics. There is no way to guarantee that a heuristics can under estimate. Uninformed searches are slower than informed searches because of this.

We would turn to algorithms that that only find one path at a time. In addition, we chose algorithms that don't have require a n by n matrix. This would lower the space required since we are only focusing how to get from a to b and ignoring everything else. Only the path from the source to the target is needed. In addition it would take less time, this is because it doesn't have to make more checks to determine if other things fail.

The baseline to problem is applying the depth first search (DFS) to the graph. This algorithm doesn't guarantee that it would return the shortest path. However, it is a easy to understand and popular algorithm which is why we chose it as our baseline model. We turned to different methods and improvements to depth first search.

Most of our initial ideas at relied on heuristics. We had thought of using BFS with layered detection and/or branch and bound. We had also thought of using best first search, A* with tree adaptive A* or iterative deepening. However, because the problem is an uninformed search, there wasn't a way to define consistent heuristics that wouldn't overestimate the estimated distance. We realized that the problem is an uninformed search and our initial ideas pertained to informed search. With this realization, we were not able to utilize heuristics available to informed searches, and it caused a lot of our initial ideas to be dropped. We then tried to implement the Floyd-Warshall algorithm ourselves. However, that results in a large amount of space needed for the matrix to store the cost of paths and is not efficient. Additionally, we ruled out Dijkstra's algorithm because it also creates a large matrix to store the cost of paths. Our dataset has a large number of nodes and edges which would not make this feasible to implement. If we were to use either Floyd-Warshall or Dijkstra, it would produce a matrix with over 4,600 * 4,600 elements.

Outcome:

1. We implemented a Wikipedia path finder to examine the different algorithms for path finding
2. Compared different path finding algorithms for uninformed search
3. Explore algorithms that were discussed in lecture that we didn't do in our assignments

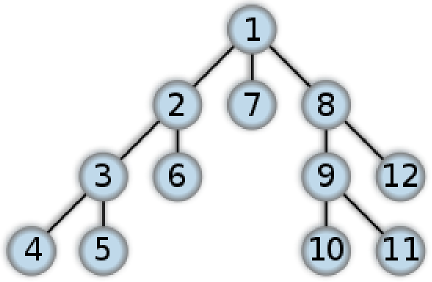
Your Task

The program takes in the source article name and the target article name from the user via the terminal. In addition, it takes an additional argument which the user can specify a file path to write the output to. The program then would write to an output file the path from $starting\_article$ to $ending\_article$. The output also details the time in millisecond (ms) and the number of nodes explored to calculate that shortest path.

Baseline Model(s)

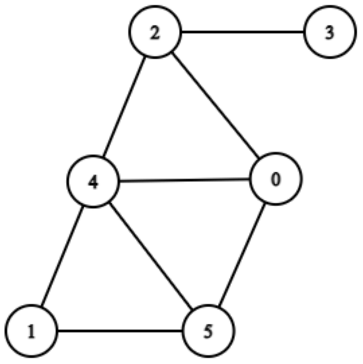
Our baseline system uses depth first search. Depth first search utilizes a stack to store the nodes that need to be explored. It also contains a list of all the items that were already explored. This guarantees that the traversal does not enter a loop. While the stack isn't empty, the algorithm examines the first node in the stack and then adds it to the explored list. Afterwards, it checks if that node was the target. If it is not, it will add all the children/neighbors of the current node to the stack.

The figure below shows the order of nodes for the graph traversal.



The Issues

The main problem with depth first search is that it isn't optimal. In other words, if there is a shorter path with another node, it won't catch it first. This would result in a path that is a longer than the shortest. In the figure below, it shows a case where depth first search isn't optimal.



Suppose that in the figure above, start is 0 and goal is 1 and the list of adjacent are in numerical order. If the program is optimal, it would choose [0, 4, 1] or [0, 5, 1]. Since the adjacent nodes are stored in numerical value, the path returned would be [0, 2, 4, 1]. This is a smaller scale example, but for out dataset that can be a difference of 3 nodes to all 4,604 nodes.

Your Approach

Breadth First Search:

Unlike depth first search, breadth first search is guaranteed to be optimal. That means it will always return the shortest path if the path exists. In the algorithm's code it has a queue, visited list, and parents list. The queue stores node that need to be explored. The visited list stores all the nodes that have been explored to prevent the code from looping and revisiting. While there are elements in the queue, it would check if that node is equal to the target. If not, it will put all the adjacent/neighboring nodes into the queue. The parents list is utilized to return the path that was taken.
This guarantees optimality because it makes sure that you check all the nodes of that length before it goes to the next one.

Iterative Deepening Depth First Search:

Iterative deepening depth first search is a combination of depth first search and breadth first search. It takes the good things from both searches. It takes the space efficiency of depth first search and the time complexity of breath first search.
Iterative deepening depth first search calls a helper function that recursively calls itself. It checks if there the depth is 0 (Iterative deepening depth first search limits the depth of the search). If not, it goes through all the adjacent/neighboring nodes of the current node that hasn't been visited and then is added to the node of visited. It recursively calls itself for each adjacent node. With each iteration where it does not find a solution, the depth increases by 1.

Bidirectional Search:

For bidirectional search, it utilizes two breadth first searches, one on each ends. One search starts on the source node while the other search starts on the target node. The idea of this search is that both search would have to travel $n/2$ nodes

and meet in the middle. Each search has its own queue, visited, and parent variables. For both searches, the queue keeps track of the nodes that will be explored next. Similar to the previous algorithms mentioned, for each search we have an visited list to prevent looping and revisiting.
While both queues aren't empty, it would pop elements from their respective queue. If the node element that is popped from the first queue isn't the target or in the other queue, it would add all it's adjacent/neighboring nodes in it's respective queue. The same happens for the second queue.

Evaluation

State the purpose of your evaluation. How should one evaluate a system for your task. What are the questions to ask?

We evaluated the system based on completeness, time complexity, space complexity and number of nodes expanded. When evaluating search strategies these are taken to account. With completeness we aim to find the shortest possible path. Time complexity, space complexity and number of nodes are used to measure performance/efficiency for speed and resource usage.

Dataset Details

We obtained the dataset from Stanford University's Stanford Network Analysis Project (SNAP) dataset collection. We are working with the Wikipedia navigation paths[1]
This data two files that we utilized. The articles.tsv file includes all the Wikipedia article titles separated by a new line. The links.tsv file includes the edges for the Wikipedia articles, each edge is represented with 2 article names, which represent which one article page linking to another article page. The links are formatted such that the source_article tab target_article. Each link is also separated by new line.
The dataset has 4604 articles (nodes) and 11,9882 links (edges). There is an average of approximately 26 edges leaving and entering a node on average.

Evaluation Measures

Baselines

We utilized the basic version of depth first search. The worst case time complexity is $O(V+E) = O(b^d)$ and worst case space complexity is $O(V) = O(bd)$. Where V is the number of nodes visited, E is the number of edges, b is the branching factor (26), d is the depth of the node.

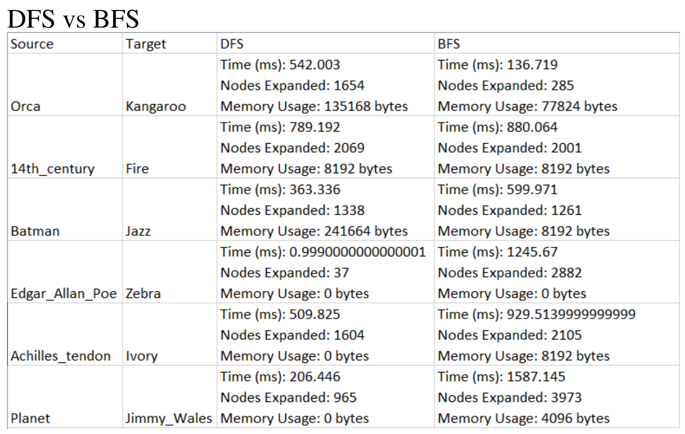
Results

Main results that compares your ideas to the baselines. What does this result tell you?

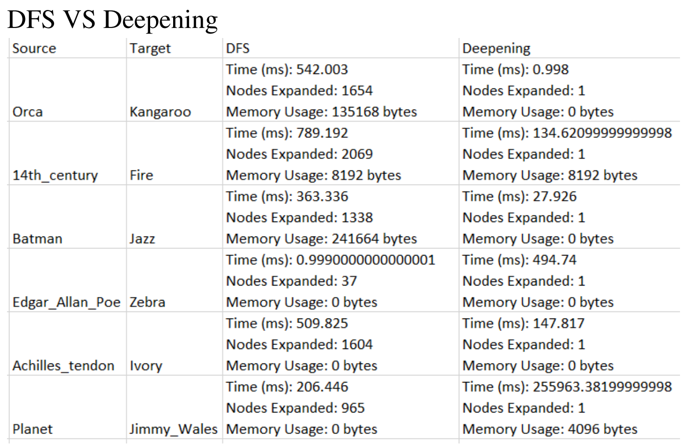
Complexity for different path finding algorithms

	Worst-Case time	Worst-Case space
DFS	$O(\|V\|+\|E\|)$	$O(\|V\|)$
BFS	$O(b^d)$	$O(b^d)$
IDDFS	$O(b^d)$	$O(d)$
Bidirectional	$O(b^d/2)$	$O(b^d)$

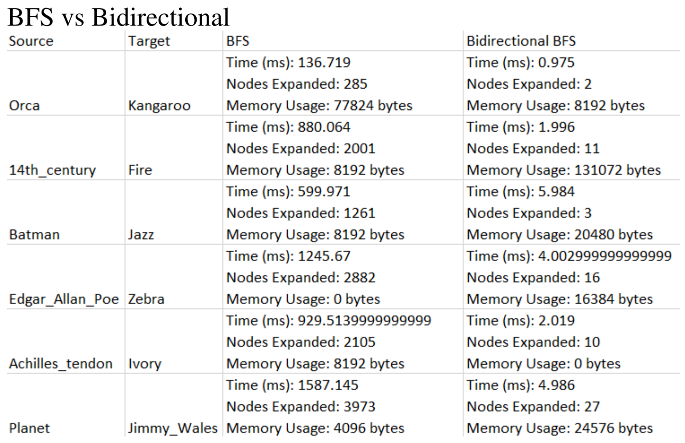
[1]https://snap.stanford.edu/data/wikispeedia.html


DFS vs BFS

Source	Target	DFS	BFS
Orca	Kangaroo	Time (ms): 542.003 Nodes Expanded: 1654 Memory Usage: 135168 bytes	Time (ms): 136.719 Nodes Expanded: 285 Memory Usage: 77824 bytes
14th_century	Fire	Time (ms): 789.192 Nodes Expanded: 2069 Memory Usage: 8192 bytes	Time (ms): 880.064 Nodes Expanded: 2001 Memory Usage: 8192 bytes
Batman	Jazz	Time (ms): 363.336 Nodes Expanded: 1338 Memory Usage: 241664 bytes	Time (ms): 599.971 Nodes Expanded: 1261 Memory Usage: 8192 bytes
Edgar_Allan_Poe	Zebra	Time (ms): 0.9990000000000001 Nodes Expanded: 37 Memory Usage: 0 bytes	Time (ms): 1245.67 Nodes Expanded: 2882 Memory Usage: 0 bytes
Achilles_tendon	Ivory	Time (ms): 509.825 Nodes Expanded: 1604 Memory Usage: 0 bytes	Time (ms): 929.5139999999999 Nodes Expanded: 2105 Memory Usage: 8192 bytes
Planet	Jimmy_Wales	Time (ms): 206.446 Nodes Expanded: 965 Memory Usage: 0 bytes	Time (ms): 1587.145 Nodes Expanded: 3973 Memory Usage: 4096 bytes


DFS VS Deepening

Source	Target	DFS	Deepening
Orca	Kangaroo	Time (ms): 542.003 Nodes Expanded: 1654 Memory Usage: 135168 bytes	Time (ms): 0.998 Nodes Expanded: 1 Memory Usage: 0 bytes
14th_century	Fire	Time (ms): 789.192 Nodes Expanded: 2069 Memory Usage: 8192 bytes	Time (ms): 134.62099999999998 Nodes Expanded: 1 Memory Usage: 8192 bytes
Batman	Jazz	Time (ms): 363.336 Nodes Expanded: 1338 Memory Usage: 241664 bytes	Time (ms): 27.926 Nodes Expanded: 1 Memory Usage: 0 bytes
Edgar_Allan_Poe	Zebra	Time (ms): 0.9990000000000001 Nodes Expanded: 37 Memory Usage: 0 bytes	Time (ms): 494.74 Nodes Expanded: 1 Memory Usage: 0 bytes
Achilles_tendon	Ivory	Time (ms): 509.825 Nodes Expanded: 1604 Memory Usage: 0 bytes	Time (ms): 147.817 Nodes Expanded: 1 Memory Usage: 0 bytes
Planet	Jimmy_Wales	Time (ms): 206.446 Nodes Expanded: 965 Memory Usage: 0 bytes	Time (ms): 255963.38199999998 Nodes Expanded: 1 Memory Usage: 4096 bytes


BFS vs Bidirectional

Source	Target	BFS	Bidirectional BFS
Orca	Kangaroo	Time (ms): 136.719 Nodes Expanded: 285 Memory Usage: 77824 bytes	Time (ms): 0.975 Nodes Expanded: 2 Memory Usage: 8192 bytes
14th_century	Fire	Time (ms): 880.064 Nodes Expanded: 2001 Memory Usage: 8192 bytes	Time (ms): 1.996 Nodes Expanded: 11 Memory Usage: 131072 bytes
Batman	Jazz	Time (ms): 599.971 Nodes Expanded: 1261 Memory Usage: 8192 bytes	Time (ms): 5.984 Nodes Expanded: 3 Memory Usage: 20480 bytes
Edgar_Allan_Poe	Zebra	Time (ms): 1245.67 Nodes Expanded: 2882 Memory Usage: 0 bytes	Time (ms): 4.002999999999999 Nodes Expanded: 16 Memory Usage: 16384 bytes
Achilles_tendon	Ivory	Time (ms): 929.5139999999999 Nodes Expanded: 2105 Memory Usage: 8192 bytes	Time (ms): 2.019 Nodes Expanded: 10 Memory Usage: 0 bytes
Planet	Jimmy_Wales	Time (ms): 1587.145 Nodes Expanded: 3973 Memory Usage: 4096 bytes	Time (ms): 4.986 Nodes Expanded: 27 Memory Usage: 24576 bytes

Analysis

Heuristics were not able to work with this uninformed search problem, which is mentioned in the introduction for paragraph 5. For error analysis, the ordering of the node's neighbors will effect the node choices in the path. For DFS since the algorithm is not optimal, the code will encounter infinite loops or an extremely long path where it will get stuck.

Code

Github: https://github.com/AnnaZhang2/AI_Final_Project
Note: You cannnot copy and paste the link above, it removes the underscores

Conclusions

What we learned form this project is the different algorithms that can be utilized for an uninformed search. DFS can be improved with iterative deepening. BFS can be improved with bidirectional search. From the results it illustrates the pros and cons of trade offs between the algorithms.

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