CS 470

Artificial Intelligence

Programming Project 2 Part 2  
Road Warrior Route Solving

Presented by

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1. For my approach for my solution was to call my go function to decide which algorithm to run because I decided to separate all my different algorithms into different functions, but I quickly found that almost all my algorithms are very similar, but the only thing that changed was my insert function. The main reason for this was because my insert function would handle how we inserted into the open list and how we handle duplicates differently for each algorithm. My insert function for the breadth search algorithm adds all the nodes it takes into the end of the open list and keeps all existing nodes in the open list and discards the duplicates. My insert function for the depth search algorithm adds all the nodes it takes into the front of the list and for any duplicates it replaces them with new node no matter what. My insert function for the best search algorithm adds all the nodes it takes in order meaning it creates a priority list of the smallest node value to the front and largest to the back and it keeps the better of duplicates nodes when comparing their values or g(n) function. My insert function for A\* is very similar to my best function where creates a priority list, but the list is prioritized by the f(n) function which is f(n) = g(n) + h(n) where h(n) is my hSLD. It also takes in the better of the two duplicates according to the f(n).
2. My heuristic function takes in a single node and then it will calculate the hSLD for all the goal nodes that we have. It calculates the hSLD using the formula for distance between 2 points on graph making it valid and consistent because every single hSLD is calculated the same way. Since my heuristic function is acceptable for all given nodes in a graph with a goal node set then it must be admissible. It is also consistent in the same way that it use the same formula when calculating and hSLD. I can guarantee that my A\* search is optimal because it is using the same calculations and the best rough estimation for all node paths to the goal node.
3. The difference between the algorithms is how it handles space. Breadth search algorithm is great for goals that aren’t very deep inside of tree or the goal node isn’t super far away from the start node. Depth search is useful when there is a node all the way down one path but could be an issue when there is a super long path that it has to go down and the goal node is all the way on the other side of the tree. Best search algorithm is useful when we are looking for a greedy approach where are just trying to find the goal node in the shortest amount of distance possible but could end up going down the wrong path if the goal node is far away. A\* search is the most optimal when trying to find the shortest path because it is estimating the distance the whole time to find the most optimal path.

**5 Different Start and Goal Combinations for 30Node:**

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|  | | Breadth | Depth |
| Start = V  Goal = AD | | Search total of 9 out of total of 30 in graph  Ended at Node: AD with path cost: 815  Path ( 3 ): ['V', 'AE', 'AD']  Frontier size: Average= 8.0 Max size = 8  Depth of Search: Average= 4.0 ;Max Depth = 2  Order of Node Expansion: [V,AA,AE,E,J,AC,C,U,AD,] | Search total of 18 out of total of 30 in graph  Ended at Node: AD with path cost: 4619  Path ( 18 ): ['V', 'AA', 'AC', 'F', 'A', 'G', 'H', 'N', 'M', 'B', 'AB', 'D', 'I', 'K', 'R', 'J', 'AE', 'AD']  Frontier size: Average= 1.5 Max size = 8  Depth of Search: Average= 0.7058823529411765 ;Max Depth = 17  Order of Node Expansion: [V,AA,AC,F,A,G,H,N,M,B,AB,D,I,K,R,J,AE,AD,] |
| Start = J  Goal = R | | Search total of 5 out of total of 30 in graph  Ended at Node: R with path cost: 305  Path ( 2 ): ['J', 'R']  Frontier size: Average= 8.0 Max size = 3  Depth of Search: Average= 8.0 ;Max Depth = 1  Order of Node Expansion: [J,AE,E,P,R,] | Search total of 22 out of total of 30 in graph  Ended at Node: R with path cost: 4195  Path ( 21 ): ['J', 'AE', 'AD', 'B', 'AB', 'D', 'I', 'K', 'A', 'F', 'AC', 'AA', 'C', 'E', 'Y', 'L', 'Q', 'O', 'S', 'P', 'R']  Frontier size: Average= 0.6428571428571429 Max size = 14  Depth of Search: Average= 0.45 ;Max Depth = 20  Order of Node Expansion: [J,AE,AD,B,AB,D,I,K,A,F,AC,AA,C,E,V,Y,L,Q,O,S,P,R,] |
| Start = P  Goal = AE | | Search total of 6 out of total of 30 in graph  Ended at Node: AE with path cost: 631  Path ( 3 ): ['P', 'J', 'AE']  Frontier size: Average= 10.0 Max size = 3  Depth of Search: Average= 5.0 ;Max Depth = 2  Order of Node Expansion: [P,J,R,S,Y,AE,] | Search total of 3 out of total of 30 in graph  Ended at Node: AE with path cost: 631  Path ( 3 ): ['P', 'J', 'AE']  Frontier size: Average= 0.875 Max size = 8  Depth of Search: Average= 3.5 ;Max Depth = 2  Order of Node Expansion: [P,J,AE,] |
| Start: AB Goal: M | | Search total of 7 out of total of 30 in graph  Ended at Node: M with path cost: 694  Path ( 3 ): ['AB', 'B', 'M']  Frontier size: Average= 6.0 Max size = 6  Depth of Search: Average= 3.0 ;Max Depth = 2  Order of Node Expansion: [AB,B,D,I,T,AD,M,] | Search total of 14 out of total of 30 in graph  Ended at Node: M with path cost: 4034  Path ( 14 ): ['AB', 'B', 'AD', 'AE', 'J', 'E', 'AA', 'AC', 'F', 'A', 'G', 'H', 'N', 'M']  Frontier size: Average= 1.875 Max size = 8  Depth of Search: Average= 1.1538461538461537 ;Max Depth = 13  Order of Node Expansion: [AB,B,AD,AE,J,E,AA,AC,F,A,G,H,N,M,] |
| Start: F Goal: D | | Search total of 19 out of total of 30 in graph  Ended at Node: D with path cost: 674  Path ( 4 ): ['F', 'A', 'K', 'D']  Frontier size: Average= 0.5714285714285714 Max size = 14  Depth of Search: Average= 2.6666666666666665 ;Max Depth = 3  Order of Node Expansion: [F,A,AC,H,L,N,Q,X,G,K,AA,U,C,Y,M,W,O,S,D,] | Search total of 15 out of total of 30 in graph  Ended at Node: D with path cost: 3796  Path ( 15 ): ['F', 'A', 'G', 'H', 'N', 'AC', 'AA', 'C', 'E', 'J', 'AE', 'AD', 'B', 'AB', 'D']  Frontier size: Average= 1.0 Max size = 14  Depth of Search: Average= 1.0 ;Max Depth = 14  Order of Node Expansion: [F,A,G,H,N,AC,AA,C,E,J,AE,AD,B,AB,D,] |
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| Best | | | A\*x |
|  | Search total of 24 out of total of 30 in graph  Ended at Node: AD with path cost: 815  Path ( 3 ): ['V', 'AE', 'AD']  Frontier size: Average= 0.75 Max size = 8  Depth of Search: Average= 1.2 ;Max Depth = 5  Order of Node Expansion: [V,E,J,Y,C,AA,L,Q,P,S,U,O,X,R,AE,AC,F,A,T,I,K,H,AB,AD,] | | Search total of 3 out of total of 30 in graph  Ended at Node: AD with path cost: 815  Path ( 3 ): ['V', 'AE', 'AD']  Frontier size: Average= 0.625 Max size = 8  Depth of Search: Average= 2.5 ;Max Depth = 2  Order of Node Expansion: [V,AE,AD,] |
| Start = V  Goal = AD | Search total of 6 out of total of 30 in graph  Ended at Node: R with path cost: 305  Path ( 2 ): ['J', 'R']  Frontier size: Average= 0.6428571428571429 Max size = 14  Depth of Search: Average= 4.5 ;Max Depth = 2  Order of Node Expansion: [J,P,S,Y,V,R,] | | Search total of 2 out of total of 30 in graph  Ended at Node: R with path cost: 305  Path ( 2 ): ['J', 'R']  Frontier size: Average= 0.5 Max size = 14  Depth of Search: Average= 7.0 ;Max Depth = 1  Order of Node Expansion: [J,R,] |
| Start = J  Goal = R | Search total of 25 out of total of 30 in graph  Ended at Node: AE with path cost: 631  Path ( 3 ): ['P', 'J', 'AE']  Frontier size: Average= 0.75 Max size = 8  Depth of Search: Average= 1.2 ;Max Depth = 5  Order of Node Expansion: [P,S,O,R,Y,J,Q,L,X,T,I,K,A,C,E,AB,F,U,V,AA,G,D,H,B,AE,] | | Search total of 3 out of total of 30 in graph  Ended at Node: AE with path cost: 631  Path ( 3 ): ['P', 'J', 'AE']  Frontier size: Average= 0.875 Max size = 8  Depth of Search: Average= 3.5 ;Max Depth = 2  Order of Node Expansion: [P,J,AE,] |
| Start = P  Goal = AE | Search total of 20 out of total of 30 in graph  Ended at Node: M with path cost: 584  Path ( 3 ): ['AB', 'D', 'M']  Frontier size: Average= 1.0 Max size = 8  Depth of Search: Average= 2.0 ;Max Depth = 4  Order of Node Expansion: [AB,I,T,D,K,B,R,G,X,A,P,W,S,AE,J,O,Q,H,F,M,] | | Search total of 3 out of total of 30 in graph  Ended at Node: M with path cost: 584  Path ( 3 ): ['AB', 'D', 'M']  Frontier size: Average= 0.75 Max size = 8  Depth of Search: Average= 3.0 ;Max Depth = 2  Order of Node Expansion: [AB,D,M,] |
| Start: AB Goal: M | Search total of 24 out of total of 30 in graph  Ended at Node: D with path cost: 618  Path ( 4 ): ['F', 'X', 'K', 'D']  Frontier size: Average= 0.42857142857142855 Max size = 14  Depth of Search: Average= 1.5 ;Max Depth = 4  Order of Node Expansion: [F,H,X,N,L,A,Q,AC,Y,O,S,G,K,C,U,P,I,AA,E,W,R,AB,J,D,] | | Search total of 4 out of total of 30 in graph  Ended at Node: D with path cost: 674  Path ( 4 ): ['F', 'A', 'K', 'D']  Frontier size: Average= 0.7857142857142857 Max size = 14  Depth of Search: Average= 3.6666666666666665 ;Max Depth = 3  Order of Node Expansion: [F,A,K,D,] |

**5 Different Start/Goal Combinations for 30Node:**

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|  | Breadth | Depth |
| Start: O Goal: G | Search total of 23 out of total of 30 in graph  Ended at Node: G with path cost: 1534  Path ( 5 ): ['O', 'AC', 'A', 'AB', 'G']  Frontier size: Average= 0.6 Max size = 10  Depth of Search: Average= 1.5 ;Max Depth = 4  Order of Node Expansion: [O,AC,F,M,N,S,A,AD,L,AE,R,AB,K,Q,X,D,J,AA,H,W,B,Y,G,] | Search total of 5 out of total of 30 in graph  Ended at Node: G with path cost: 1534  Path ( 5 ): ['O', 'AC', 'A', 'AB', 'G']  Frontier size: Average= 1.1 Max size = 10  Depth of Search: Average= 2.75 ;Max Depth = 4  Order of Node Expansion: [O,AC,A,AB,G,] |
| Start: H Goal: Q | Start Node: H ; Goal Node(s): [Q,]  Search total of 29 out of total of 30 in graph  Ended at Node: Q with path cost: 1412  Path ( 5 ): ['H', 'AA', 'W', 'G', 'Q']  Frontier size: Average= 0.16666666666666666 Max size = 12  Depth of Search: Average= 0.5 ;Max Depth = 4  Order of Node Expansion: [H,AA,AE,C,E,R,Y,W,F,S,I,V,P,U,B,J,L,N,G,O,T,AB,K,D,AC,AD,M,X,Q,] | Search total of 10 out of total of 30 in graph  Ended at Node: Q with path cost: 3252  Path ( 10 ): ['H', 'AA', 'AE', 'F', 'O', 'AC', 'A', 'AB', 'G', 'Q']  Frontier size: Average= 1.1666666666666667 Max size = 12  Depth of Search: Average= 1.5555555555555556 ;Max Depth = 9  Order of Node Expansion: [H,AA,AE,F,O,AC,A,AB,G,Q,] |
| Start: Q Goal: T | Search total of 9 out of total of 30 in graph  Ended at Node: T with path cost: 933  Path ( 3 ): ['Q', 'AB', 'T']  Frontier size: Average= 1.6666666666666667 Max size = 6  Depth of Search: Average= 5.0 ;Max Depth = 2  Order of Node Expansion: [Q,A,AB,G,AC,AD,K,P,T,] | Search total of 5 out of total of 30 in graph  Ended at Node: T with path cost: 1794  Path ( 5 ): ['Q', 'A', 'AB', 'G', 'T']  Frontier size: Average= 1.0 Max size = 6  Depth of Search: Average= 1.5 ;Max Depth = 4  Order of Node Expansion: [Q,A,AB,G,T,] |
| Start: AB Goal: R | Search total of 27 out of total of 30 in graph  Ended at Node: R with path cost: 1445  Path ( 5 ): ['AB', 'A', 'AC', 'L', 'R']  Frontier size: Average= 0.3333333333333333 Max size = 12  Depth of Search: Average= 1.0 ;Max Depth = 4  Order of Node Expansion: [AB,A,G,K,P,Q,T,AC,AD,W,D,U,X,E,V,L,M,O,AA,AE,C,J,B,Y,H,I,R,] | Search total of 9 out of total of 30 in graph  Ended at Node: R with path cost: 2005  Path ( 9 ): ['AB', 'A', 'AC', 'AD', 'K', 'D', 'J', 'B', 'R']  Frontier size: Average= 0.9166666666666666 Max size = 12  Depth of Search: Average= 1.375 ;Max Depth = 8  Order of Node Expansion: [AB,A,AC,AD,K,D,J,B,R,] |
| Start: N Goal: AB | Search total of 23 out of total of 30 in graph  Ended at Node: AB with path cost: 1129  Path ( 5 ): ['N', 'M', 'AC', 'A', 'AB']  Frontier size: Average= 0.875 Max size = 8  Depth of Search: Average= 1.75 ;Max Depth = 4  Order of Node Expansion: [N,M,O,R,S,AC,L,F,AE,B,H,J,Y,A,AD,D,X,AA,W,U,C,E,AB,] | Search total of 5 out of total of 30 in graph  Ended at Node: AB with path cost: 1129  Path ( 5 ): ['N', 'M', 'AC', 'A', 'AB']  Frontier size: Average= 1.0 Max size = 8  Depth of Search: Average= 2.0 ;Max Depth = 4  Order of Node Expansion: [N,M,AC,A,AB,] |

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|  | Best | A\* |
| Start: O Goal: G | Search total of 29 out of total of 30 in graph  Ended at Node: G with path cost: 1223  Path ( 8 ): ['O', 'N', 'R', 'B', 'U', 'P', 'T', 'G']  Frontier size: Average= 0.2 Max size = 10  Depth of Search: Average= 0.2857142857142857 ;Max Depth = 7  Order of Node Expansion: [O,N,F,M,S,AC,R,L,B,J,Y,X,AE,H,U,D,AD,E,K,P,AA,C,A,V,AB,T,I,W,G,] | Search total of 10 out of total of 30 in graph  Ended at Node: G with path cost: 1322  Path ( 8 ): ['O', 'M', 'L', 'J', 'U', 'P', 'T', 'G']  Frontier size: Average= 1.5 Max size = 10  Depth of Search: Average= 2.142857142857143 ;Max Depth = 7  Order of Node Expansion: [O,M,L,J,U,P,V,I,T,G,] |
| Start: H Goal: Q | Search total of 30 out of total of 30 in graph  Ended at Node: Q with path cost: 1175  Path ( 6 ): ['H', 'E', 'V', 'T', 'G', 'Q']  Frontier size: Average= 0.08333333333333333 Max size = 12  Depth of Search: Average= 0.2 ;Max Depth = 5  Order of Node Expansion: [H,Y,E,AA,C,R,B,U,J,AE,V,P,I,D,K,T,X,W,L,N,S,AB,AD,M,F,G,A,O,AC,Q,] | Search total of 5 out of total of 30 in graph  Ended at Node: Q with path cost: 1416  Path ( 5 ): ['H', 'C', 'W', 'G', 'Q']  Frontier size: Average= 0.8333333333333334 Max size = 12  Depth of Search: Average= 2.5 ;Max Depth = 4  Order of Node Expansion: [H,C,W,G,Q,] |
| Start: Q Goal: T | Search total of 4 out of total of 30 in graph  Ended at Node: T with path cost: 732  Path ( 3 ): ['Q', 'G', 'T']  Frontier size: Average= 0.8333333333333334 Max size = 6  Depth of Search: Average= 2.5 ;Max Depth = 2  Order of Node Expansion: [Q,G,AB,T,] | Search total of 3 out of total of 30 in graph  Ended at Node: T with path cost: 933  Path ( 3 ): ['Q', 'AB', 'T']  Frontier size: Average= 0.8333333333333334 Max size = 6  Depth of Search: Average= 2.5 ;Max Depth = 2  Order of Node Expansion: [Q,AB,T,] |
| Start: AB Goal: R | Search total of 18 out of total of 30 in graph  Ended at Node: R with path cost: 537  Path ( 5 ): ['AB', 'K', 'U', 'B', 'R']  Frontier size: Average= 0.5833333333333334 Max size = 12  Depth of Search: Average= 1.75 ;Max Depth = 4  Order of Node Expansion: [AB,K,A,T,P,D,U,V,AD,E,X,J,G,I,B,Y,C,R,] | Search total of 5 out of total of 30 in graph  Ended at Node: R with path cost: 537  Path ( 5 ): ['AB', 'K', 'U', 'B', 'R']  Frontier size: Average= 1.0 Max size = 12  Depth of Search: Average= 3.0 ;Max Depth = 4  Order of Node Expansion: [AB,K,U,B,R,] |
| Start: N Goal: AB | Search total of 25 out of total of 30 in graph  Ended at Node: AB with path cost: 871  Path ( 6 ): ['N', 'R', 'B', 'U', 'K', 'AB']  Frontier size: Average= 0.625 Max size = 8  Depth of Search: Average= 1.0 ;Max Depth = 5  Order of Node Expansion: [N,M,O,S,AC,F,R,L,B,J,Y,X,H,U,D,AD,E,AE,K,P,AA,C,A,V,AB,] | Search total of 6 out of total of 30 in graph  Ended at Node: AB with path cost: 934  Path ( 6 ): ['N', 'R', 'J', 'U', 'P', 'AB']  Frontier size: Average= 1.75 Max size = 8  Depth of Search: Average= 2.8 ;Max Depth = 5  Order of Node Expansion: [N,R,J,U,P,AB,] |

**5 Different Start/ Multi Goal Combinations for 30Node:**

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|  | Breadth | Depth |
| Start: O; Goal: G,D,M | Search total of 27 out of total of 30 in graph  Ended at Node: M with path cost: 1140  Path ( 13 ): ['O', 'Q', 'F', 'N', 'O', 'X', 'K', 'O', 'X', 'A', 'G', 'D', 'M']  Frontier size: Average= 0.8333333333333334 Max size = 6  Depth of Search: Average= 1.25 ;Max Depth = 4  Order of Node Expansion: [O,Q,S,X,F,L,Y,P,R,A,K,AC,H,N,C,U,E,J,I,T,G,D,W,AA,M,] | Search total of 30 out of total of 30 in graph  Ended at Node: M with path cost: 5068  Path ( 43 ): ['O', 'Q', 'F', 'A', 'G', 'H', 'N', 'AC', 'AA', 'C', 'E', 'J', 'AE', 'AD', 'B', 'AB', 'D', 'I', 'K', 'W', 'O', 'Q', 'F', 'A', 'G', 'H', 'N', 'AC', 'AA', 'C', 'E', 'J', 'AE', 'AD', 'B', 'AB', 'O', 'Q', 'F', 'A', 'G', 'D', 'M']  Frontier size: Average= 0.5 Max size = 6  Depth of Search: Average= 0.125 ;Max Depth = 24  Order of Node Expansion: [O,Q,F,A,G,H,N,AC,AA,C,E,J,AE,AD,B,AB,D,I,K,R,P,S,Y,L,U,T,W,M,] |
| Start: M  Goal: W, Q, R | Search total of 25 out of total of 30 in graph  Ended at Node: Q with path cost: 1001  Path ( 10 ): ['M', 'N', 'F', 'M', 'B', 'T', 'M', 'W', 'R', 'Q']  Frontier size: Average= 1.0 Max size = 8  Depth of Search: Average= 2.6666666666666665 ;Max Depth = 3  Order of Node Expansion: [M,B,D,N,W,AB,AD,T,I,K,AC,F,G,H,AE,J,R,A,X,AA,U,L,Q,] | Search total of 30 out of total of 30 in graph  Ended at Node: W with path cost: 2903  Path ( 48 ): ['M', 'B', 'AB', 'D', 'I', 'K', 'A', 'F', 'AC', 'N', 'G', 'M', 'B', 'AB', 'D', 'I', 'K', 'A', 'F', 'AC', 'AA', 'C', 'E', 'J', 'AE', 'T', 'R', 'P', 'S', 'O', 'M', 'B', 'AB', 'D', 'I', 'K', 'A', 'F', 'AC', 'AA', 'C', 'E', 'J', 'AE', 'T', 'R', 'Q', 'W']  Frontier size: Average= 0.125 Max size = 8  Depth of Search: Average= 0.047619047619047616 ;Max Depth = 21  Order of Node Expansion: [M,B,AB,D,I,K,A,F,AC,AA,C,E,J,AE,AD,T,R,P,S,O,Q,L,U,Y,X,V,N,G,H,W,] |
| Start: Q Goal: P, AC, L | Search total of 16 out of total of 30 in graph  Ended at Node: P with path cost: 187  Path ( 8 ): ['Q', 'S', 'Q', 'F', 'Q', 'L', 'AC', 'P']  Frontier size: Average= 0.75 Max size = 12  Depth of Search: Average= 4.5 ;Max Depth = 2  Order of Node Expansion: [Q,F,L,O,S,X,Y,A,AC,H,N,C,U,P,] | Search total of 27 out of total of 30 in graph  Ended at Node: L with path cost: 5029  Path ( 50 ): ['Q', 'F', 'A', 'G', 'H', 'N', 'AC', 'AA', 'C', 'E', 'J', 'AE', 'AD', 'B', 'AB', 'D', 'I', 'K', 'R', 'P', 'S', 'Y', 'Q', 'F', 'A', 'G', 'H', 'N', 'AC', 'AA', 'C', 'E', 'J', 'AE', 'AD', 'B', 'AB', 'D', 'I', 'K', 'R', 'Q', 'F', 'A', 'G', 'H', 'N', 'AC', 'P', 'L']  Frontier size: Average= 0.5 Max size = 12  Depth of Search: Average= 0.2727272727272727 ;Max Depth = 22  Order of Node Expansion: [Q,F,A,G,H,N,AC,AA,C,E,J,AE,AD,B,AB,D,I,K,R,P,S,O,X,Y,L,] |
| Start:  P; Goal: Q, AA, V | Search total of 19 out of total of 30 in graph  Ended at Node: AA with path cost: 832  Path ( 10 ): ['P', 'J', 'E', 'P', 'S', 'P', 'J', 'V', 'Q', 'AA']  Frontier size: Average= 1.25 Max size = 8  Depth of Search: Average= 3.3333333333333335 ;Max Depth = 3  Order of Node Expansion: [P,J,R,S,Y,AE,E,T,V,I,K,O,Q,C,L,AD,AA,] | Search total of 21 out of total of 30 in graph  Ended at Node: Q with path cost: 3918  Path ( 47 ): ['P', 'J', 'AE', 'AD', 'B', 'AB', 'D', 'I', 'K', 'A', 'F', 'AC', 'AA', 'C', 'E', 'Y', 'L', 'P', 'J', 'AE', 'AD', 'B', 'AB', 'D', 'I', 'K', 'A', 'F', 'AC', 'AA', 'C', 'E', 'P', 'J', 'AE', 'AD', 'B', 'AB', 'D', 'I', 'K', 'A', 'F', 'AC', 'AA', 'V', 'Q']  Frontier size: Average= 1.375 Max size = 8  Depth of Search: Average= 0.6470588235294118 ;Max Depth = 17  Order of Node Expansion: [P,J,AE,AD,B,AB,D,I,K,A,F,AC,AA,C,E,V,Y,L,Q,] |
| Start: O Goal: C, H, P | Search total of 17 out of total of 30 in graph  Ended at Node: C with path cost: 440  Path ( 11 ): ['O', 'Q', 'L', 'O', 'Q', 'F', 'O', 'S', 'P', 'H', 'C']  Frontier size: Average= 1.8333333333333333 Max size = 6  Depth of Search: Average= 3.6666666666666665 ;Max Depth = 3  Order of Node Expansion: [O,Q,S,X,F,L,Y,P,R,A,K,AC,H,N,C,] | Search total of 23 out of total of 30 in graph  Ended at Node: P with path cost: 4836  Path ( 37 ): ['O', 'Q', 'F', 'A', 'G', 'H', 'N', 'AC', 'AA', 'C', 'E', 'J', 'AE', 'AD', 'B', 'AB', 'D', 'I', 'K', 'R', 'O', 'Q', 'F', 'A', 'G', 'H', 'N', 'AC', 'AA', 'O', 'Q', 'F', 'A', 'G', 'H', 'C', 'P']  Frontier size: Average= 1.6666666666666667 Max size = 6  Depth of Search: Average= 0.5 ;Max Depth = 20  Order of Node Expansion: [O,Q,F,A,G,H,N,AC,AA,C,E,J,AE,AD,B,AB,D,I,K,R,P,] |

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|  | Best | A\* |
| Start: O; Goal: G,D,M | Search total of 30 out of total of 30 in graph  Ended at Node: M with path cost: 813  Path ( 14 ): ['O', 'X', 'A', 'G', 'W', 'O', 'X', 'K', 'O', 'X', 'A', 'G', 'D', 'M']  Frontier size: Average= 0.3333333333333333 Max size = 6  Depth of Search: Average= 0.4 ;Max Depth = 5  Order of Node Expansion: [O,S,X,Q,P,A,Y,L,R,K,F,J,G,H,I,T,C,U,E,AB,N,AA,W,V,D,AC,B,AE,M,] | Search total of 9 out of total of 30 in graph  Ended at Node: M with path cost: 950  Path ( 13 ): ['O', 'X', 'K', 'D', 'O', 'X', 'K', 'O', 'X', 'A', 'G', 'D', 'M']  Frontier size: Average= 1.8333333333333333 Max size = 6  Depth of Search: Average= 2.75 ;Max Depth = 4  Order of Node Expansion: [O,X,A,G,K,D,M,] |
| Start: M  Goal: W, Q, R | Search total of 19 out of total of 30 in graph  Ended at Node: Q with path cost: 846  Path ( 12 ): ['M', 'W', 'G', 'A', 'X', 'M', 'W', 'K', 'M', 'W', 'R', 'Q']  Frontier size: Average= 1.0 Max size = 8  Depth of Search: Average= 1.6 ;Max Depth = 5  Order of Node Expansion: [M,W,D,G,B,N,K,AB,A,I,X,T,H,F,R,O,Q,] | Search total of 8 out of total of 30 in graph  Ended at Node: Q with path cost: 1073  Path ( 12 ): ['M', 'W', 'K', 'R', 'S', 'M', 'W', 'K', 'M', 'W', 'R', 'Q']  Frontier size: Average= 1.625 Max size = 8  Depth of Search: Average= 2.6 ;Max Depth = 5  Order of Node Expansion: [M,W,K,R,S,Q,] |
| Start: Q Goal: P, AC, L | Search total of 25 out of total of 30 in graph  Ended at Node: AC with path cost: 521  Path ( 9 ): ['Q', 'L', 'U', 'Q', 'S', 'Q', 'L', 'P', 'AC']  Frontier size: Average= 0.5833333333333334 Max size = 12  Depth of Search: Average= 2.3333333333333335 ;Max Depth = 3  Order of Node Expansion: [Q,Y,S,L,O,X,P,F,A,C,U,R,E,K,J,H,AA,G,V,N,I,T,AC,] | Search total of 10 out of total of 30 in graph  Ended at Node: AC with path cost: 916  Path ( 10 ): ['Q', 'Y', 'E', 'AA', 'Q', 'S', 'Q', 'L', 'P', 'AC']  Frontier size: Average= 0.75 Max size = 12  Depth of Search: Average= 2.25 ;Max Depth = 4  Order of Node Expansion: [Q,L,S,P,Y,E,AA,AC,] |
| Start:  P; Goal: Q, AA, V | Search total of 22 out of total of 30 in graph  Ended at Node: AA with path cost: 471  Path ( 10 ): ['P', 'Y', 'C', 'P', 'J', 'P', 'S', 'Q', 'V', 'AA']  Frontier size: Average= 1.125 Max size = 8  Depth of Search: Average= 2.25 ;Max Depth = 4  Order of Node Expansion: [P,S,O,R,Y,J,Q,L,X,T,I,K,A,C,E,AB,F,U,V,AA,] | Search total of 8 out of total of 30 in graph  Ended at Node: AA with path cost: 723  Path ( 11 ): ['P', 'Y', 'E', 'P', 'Y', 'E', 'P', 'Y', 'Q', 'V', 'AA']  Frontier size: Average= 1.25 Max size = 8  Depth of Search: Average= 3.3333333333333335 ;Max Depth = 3  Order of Node Expansion: [P,Y,Q,E,V,AA,] |
| Start: O Goal: C, H, P | Search total of 19 out of total of 30 in graph  Ended at Node: C with path cost: 440  Path ( 11 ): ['O', 'Q', 'L', 'O', 'X', 'A', 'O', 'S', 'P', 'H', 'C']  Frontier size: Average= 1.8333333333333333 Max size = 6  Depth of Search: Average= 3.6666666666666665 ;Max Depth = 3  Order of Node Expansion: [O,S,X,Q,P,A,Y,L,R,K,F,J,G,H,I,T,C,] | Search total of 12 out of total of 30 in graph  Ended at Node: C with path cost: 440  Path ( 11 ): ['O', 'Q', 'L', 'O', 'Q', 'F', 'O', 'S', 'P', 'H', 'C']  Frontier size: Average= 1.8333333333333333 Max size = 6  Depth of Search: Average= 3.6666666666666665 ;Max Depth = 3  Order of Node Expansion: [O,S,P,Q,F,H,N,A,L,C,] |

**5 Different Start/ Multi Goal Combinations for 30Node:**

|  |  |  |
| --- | --- | --- |
|  | Breadth | Depth |
| Start: R Goal: G,W,Q | Search total of 31 out of total of 30 in graph  Ended at Node: Q with path cost: 1950  Path ( 12 ): ['R', 'AE', 'W', 'G', 'R', 'AE', 'W', 'R', 'AE', 'W', 'G', 'Q']  Frontier size: Average= 0.125 Max size = 16  Depth of Search: Average= 0.5 ;Max Depth = 4  Order of Node Expansion: [R,AE,B,H,J,L,N,S,Y,AA,F,W,U,C,E,D,AC,AD,M,X,O,G,K,P,I,V,A,AB,Q,] | Search total of 23 out of total of 30 in graph  Ended at Node: W with path cost: 3013  Path ( 44 ): ['R', 'AE', 'AA', 'C', 'E', 'H', 'Y', 'B', 'J', 'D', 'K', 'A', 'AB', 'G', 'R', 'AE', 'AA', 'C', 'E', 'H', 'Y', 'B', 'J', 'D', 'K', 'A', 'AB', 'G', 'R', 'AE', 'AA', 'C', 'E', 'H', 'Y', 'B', 'J', 'D', 'K', 'A', 'AB', 'G', 'Q', 'W']  Frontier size: Average= 0.5 Max size = 16  Depth of Search: Average= 0.47058823529411764 ;Max Depth = 17  Order of Node Expansion: [R,AE,AA,C,E,H,Y,B,J,D,K,A,AB,G,Q,T,P,U,V,I,W,] |
| Start: G Goal: AA,L,P | Search total of 26 out of total of 30 in graph  Ended at Node: L with path cost: 1525  Path ( 11 ): ['G', 'AB', 'A', 'AC', 'G', 'W', 'G', 'AB', 'P', 'AA', 'L']  Frontier size: Average= 0.875 Max size = 8  Depth of Search: Average= 1.75 ;Max Depth = 4  Order of Node Expansion: [G,AB,Q,T,W,A,K,P,V,AA,AE,C,AC,AD,D,U,X,E,I,H,F,R,S,L,] | Search total of 28 out of total of 30 in graph  Ended at Node: L with path cost: 3999  Path ( 45 ): ['G', 'AB', 'A', 'AC', 'AD', 'K', 'D', 'J', 'B', 'R', 'AE', 'F', 'O', 'M', 'G', 'AB', 'A', 'AC', 'AD', 'K', 'D', 'J', 'B', 'R', 'AE', 'AA', 'C', 'E', 'H', 'Y', 'U', 'G', 'AB', 'A', 'AC', 'AD', 'K', 'D', 'J', 'B', 'R', 'AE', 'AA', 'P', 'L']  Frontier size: Average= 0.625 Max size = 8  Depth of Search: Average= 0.25 ;Max Depth = 20  Order of Node Expansion: [G,AB,A,AC,AD,K,D,J,B,R,AE,AA,C,E,H,Y,U,P,T,V,I,W,F,O,M,L,] |
| Start: AA Goal: T,M,R | Search total of 27 out of total of 30 in graph  Ended at Node: M with path cost: 1213  Path ( 12 ): ['AA', 'AE', 'F', 'O', 'AA', 'C', 'V', 'AA', 'AE', 'R', 'T', 'M']  Frontier size: Average= 0.75 Max size = 8  Depth of Search: Average= 1.5 ;Max Depth = 4  Order of Node Expansion: [AA,AE,C,H,W,F,R,S,E,I,V,Y,G,O,B,J,L,N,P,U,T,AB,Q,AC,M,] | Search total of 24 out of total of 30 in graph  Ended at Node: M with path cost: 4814  Path ( 44 ): ['AA', 'AE', 'F', 'O', 'AC', 'A', 'AB', 'G', 'T', 'P', 'E', 'C', 'H', 'R', 'B', 'J', 'D', 'K', 'AD', 'L', 'AA', 'AE', 'F', 'O', 'AC', 'A', 'AB', 'G', 'T', 'P', 'E', 'C', 'H', 'AA', 'AE', 'F', 'O', 'AC', 'A', 'AB', 'G', 'T', 'R', 'M']  Frontier size: Average= 1.125 Max size = 8  Depth of Search: Average= 0.45 ;Max Depth = 20  Order of Node Expansion: [AA,AE,F,O,AC,A,AB,G,Q,T,P,E,C,H,R,B,J,D,K,AD,L,M,] |
| Start: M Goal: V, O, AC | Search total of 31 out of total of 30 in graph  Ended at Node: V with path cost: 1416  Path ( 10 ): ['M', 'AC', 'A', 'AB', 'P', 'M', 'M', 'AC', 'O', 'V']  Frontier size: Average= 0.25 Max size = 8  Depth of Search: Average= 0.4 ;Max Depth = 5  Order of Node Expansion: [M,AC,L,N,O,A,AD,D,J,R,X,S,F,AB,K,Q,U,B,AE,H,Y,G,P,T,E,AA,W,C,V,] | Search total of 32 out of total of 30 in graph  Ended at Node: V with path cost: 2438  Path ( 26 ): ['M', 'AC', 'A', 'AB', 'G', 'T', 'P', 'E', 'C', 'I', 'M', 'AC', 'A', 'AB', 'G', 'T', 'P', 'E', 'C', 'AA', 'AE', 'F', 'M', 'AC', 'O', 'V']  Frontier size: Average= 0.125 Max size = 8  Depth of Search: Average= 0.047619047619047616 ;Max Depth = 21  Order of Node Expansion: [M,AC,A,AB,G,Q,T,P,E,C,AA,AE,F,O,N,R,B,J,D,K,AD,L,X,U,Y,H,S,W,I,V,] |
| Start: AC Goal: R,AE,N | Search total of 24 out of total of 30 in graph  Ended at Node: AE with path cost: 995  Path ( 10 ): ['AC', 'L', 'R', 'AC', 'M', 'AC', 'L', 'R', 'N', 'AE']  Frontier size: Average= 0.6 Max size = 10  Depth of Search: Average= 2.0 ;Max Depth = 3  Order of Node Expansion: [AC,A,AD,L,M,O,AB,K,Q,X,D,J,R,N,F,S,G,P,T,U,B,AE,] | Search total of 27 out of total of 30 in graph  Ended at Node: N with path cost: 4903  Path ( 51 ): ['AC', 'A', 'AB', 'G', 'T', 'P', 'E', 'C', 'AA', 'AE', 'F', 'O', 'M', 'L', 'AD', 'K', 'D', 'J', 'B', 'R', 'AC', 'A', 'AB', 'G', 'T', 'P', 'E', 'C', 'AA', 'AE', 'F', 'O', 'M', 'L', 'AD', 'K', 'D', 'J', 'B', 'AC', 'A', 'AB', 'G', 'T', 'P', 'E', 'C', 'AA', 'AE', 'R', 'N']  Frontier size: Average= 0.6 Max size = 10  Depth of Search: Average= 0.2727272727272727 ;Max Depth = 22  Order of Node Expansion: [AC,A,AB,G,Q,T,P,E,C,AA,AE,F,O,M,L,AD,K,D,J,B,R,H,Y,U,N,] |

|  |  |  |
| --- | --- | --- |
|  | Best | A\* |
| Start: R Goal: G,W,Q | Start Node: R ; Goal Node(s): [Q,]  Search total of 32 out of total of 30 in graph  Ended at Node: Q with path cost: 1262  Path ( 16 ): ['R', 'B', 'U', 'K', 'AB', 'R', 'B', 'U', 'P', 'T', 'R', 'H', 'AA', 'W', 'G', 'Q']  Frontier size: Average= 0.0625 Max size = 16  Depth of Search: Average= 0.2 ;Max Depth = 5  Order of Node Expansion: [R,B,J,Y,H,U,D,E,N,S,L,K,X,P,AA,C,AE,M,F,V,O,AD,AB,T,I,AC,A,W,G,Q,] | Search total of 8 out of total of 30 in graph  Ended at Node: Q with path cost: 1624  Path ( 15 ): ['R', 'H', 'C', 'W', 'G', 'R', 'H', 'C', 'W', 'R', 'H', 'C', 'W', 'G', 'Q']  Frontier size: Average= 0.875 Max size = 16  Depth of Search: Average= 2.8 ;Max Depth = 5  Order of Node Expansion: [R,H,C,W,G,Q,] |
| Start: G Goal: AA,L,P | Search total of 25 out of total of 30 in graph  Ended at Node: L with path cost: 821  Path ( 14 ): ['G', 'T', 'P', 'K', 'D', 'G', 'T', 'V', 'C', 'G', 'T', 'P', 'AA', 'L']  Frontier size: Average= 0.625 Max size = 8  Depth of Search: Average= 1.0 ;Max Depth = 5  Order of Node Expansion: [G,T,V,W,P,I,AB,K,E,C,U,Q,D,A,J,Y,H,B,X,AD,AA,R,L,] | Search total of 14 out of total of 30 in graph  Ended at Node: L with path cost: 854  Path ( 15 ): ['G', 'T', 'P', 'U', 'D', 'G', 'T', 'P', 'E', 'H', 'G', 'T', 'P', 'AA', 'L']  Frontier size: Average= 1.625 Max size = 8  Depth of Search: Average= 2.6 ;Max Depth = 5  Order of Node Expansion: [G,T,P,E,H,AA,C,I,AE,U,D,L,] |
| Start: AA Goal: T,M,R | Search total of 27 out of total of 30 in graph  Ended at Node: M with path cost: 800  Path ( 12 ): ['AA', 'H', 'R', 'N', 'AA', 'C', 'V', 'AA', 'H', 'R', 'T', 'M']  Frontier size: Average= 0.75 Max size = 8  Depth of Search: Average= 1.0 ;Max Depth = 6  Order of Node Expansion: [AA,H,C,Y,AE,W,E,V,I,R,B,U,J,T,P,D,K,X,G,AB,L,N,S,AD,M,] | Search total of 11 out of total of 30 in graph  Ended at Node: T with path cost: 2055  Path ( 17 ): ['AA', 'H', 'R', 'N', 'M', 'AC', 'A', 'AB', 'AA', 'H', 'R', 'N', 'AA', 'H', 'R', 'M', 'T']  Frontier size: Average= 2.0 Max size = 8  Depth of Search: Average= 2.0 ;Max Depth = 8  Order of Node Expansion: [AA,H,R,N,M,AC,A,AB,T,] |
| Start: M Goal: V, O, AC | Search total of 27 out of total of 30 in graph  Ended at Node: V with path cost: 874  Path ( 11 ): ['M', 'N', 'R', 'Y', 'E', 'M', 'N', 'M', 'O', 'R', 'V']  Frontier size: Average= 0.75 Max size = 8  Depth of Search: Average= 1.2 ;Max Depth = 5  Order of Node Expansion: [M,N,AC,O,L,S,F,R,X,J,B,D,AD,Y,U,H,K,A,E,P,AE,AA,C,AB,V,] | Search total of 9 out of total of 30 in graph  Ended at Node: V with path cost: 874  Path ( 11 ): ['M', 'N', 'R', 'Y', 'E', 'M', 'N', 'M', 'O', 'R', 'V']  Frontier size: Average= 1.5 Max size = 8  Depth of Search: Average= 2.4 ;Max Depth = 5  Order of Node Expansion: [M,O,N,R,Y,E,V,] |
| Start: AC Goal: R,AE,N | Search total of 27 out of total of 30 in graph  Ended at Node: AE with path cost: 939  Path ( 10 ): ['AC', 'O', 'S', 'AC', 'L', 'AC', 'M', 'N', 'R', 'AE']  Frontier size: Average= 0.6 Max size = 10  Depth of Search: Average= 1.2 ;Max Depth = 5  Order of Node Expansion: [AC,M,L,O,N,X,F,S,J,D,AD,B,U,R,K,A,Y,P,E,H,AB,V,T,C,AE,] | Search total of 7 out of total of 30 in graph  Ended at Node: AE with path cost: 1013  Path ( 12 ): ['AC', 'M', 'N', 'R', 'AC', 'M', 'N', 'AC', 'M', 'N', 'R', 'AE']  Frontier size: Average= 1.0 Max size = 10  Depth of Search: Average= 2.5 ;Max Depth = 4  Order of Node Expansion: [AC,M,N,R,AE,] |

1. Looking at all the data that I generate it would seem a lot of the time that breadth and depth search are very costly when it comes to space and therefore time. When using breadth or depth search most the time it looks like I hit almost every node when looking for the goal node. A\* search is consistent with having the minimum amount of nodes visited and having the minimum cost value to finding the goal node. It would seem that when the goal is close by though it closely represents best or breadth first depending on how close the goal node it the start.
2. A heuristic function that googles maps might actually use to generate routes is probably something that takes in account not only the two nodes or locations on the path but the direction that the location is in like, “N, S, W, E” and all the combinations of those as well. It would then calculate a similar score to what we calculate, but more precise in which way they would need to head. I believe that even though this would run every time and would be very complex it has to make that decision in a split second of where to head. This isn’t even considering that goggle often also estimates how long things would take depending on traffic and sometimes to tries to find a better route if there is a lot of heavy traffic in the area. This could be another thing that is taken into account when google calculates the heuristic function. Google could make this manageable by giving the amount of traffic a rating, so if the traffic hits above a certain rating then it will start to consider other routes.

**Scenario 1: Test Map #1: A very simple map, relatively Sparse:**

**Breadth**

File loaded!

Start = F Goal = D

BREADTH search: from F to D

Exploring Node: F

Inserting new Children: C, J, L,

[ C , 1 , 278 , 384.22 , 662.22],[ J , 1 , 127 , 194.61 , 321.61],[ L , 1 , 277 , 332.96 , 609.96],

Exploring Node: C

Inserting new Children: E, I, K, L,

[ J , 1 , 127 , 194.61 , 321.61],[ L , 1 , 277 , 332.96 , 609.96],[ E , 2 , 571 , 567.61 , 1138.61],[ I , 2 , 569 , 319.62 , 888.62],[ K , 2 , 548 , 596.16 , 1144.16],

Exploring Node: J

Inserting new Children: H, L,

[ L , 1 , 277 , 332.96 , 609.96],[ E , 2 , 571 , 567.61 , 1138.61],[ I , 2 , 569 , 319.62 , 888.62],[ K , 2 , 548 , 596.16 , 1144.16],[ H , 2 , 350 , 121.51 , 471.51],

Exploring Node: L

Inserting new Children:

[ E , 2 , 571 , 567.61 , 1138.61],[ I , 2 , 569 , 319.62 , 888.62],[ K , 2 , 548 , 596.16 , 1144.16],[ H , 2 , 350 , 121.51 , 471.51],

Exploring Node: E

Inserting new Children: A,

[ I , 2 , 569 , 319.62 , 888.62],[ K , 2 , 548 , 596.16 , 1144.16],[ H , 2 , 350 , 121.51 , 471.51],[ A , 3 , 1179 , 183.6 , 1362.6],

Exploring Node: I

Inserting new Children: B, D,

[ K , 2 , 548 , 596.16 , 1144.16],[ H , 2 , 350 , 121.51 , 471.51],[ A , 3 , 1179 , 183.6 , 1362.6],[ B , 3 , 1078 , 268.29 , 1346.29],[ D , 3 , 946 , 0.0 , 946.0],

Exploring Node: K

Inserting new Children:

[ H , 2 , 350 , 121.51 , 471.51],[ A , 3 , 1179 , 183.6 , 1362.6],[ B , 3 , 1078 , 268.29 , 1346.29],[ D , 3 , 946 , 0.0 , 946.0],

Exploring Node: H

Inserting new Children: A, D,

[ A , 3 , 1179 , 183.6 , 1362.6],[ B , 3 , 1078 , 268.29 , 1346.29],[ D , 3 , 946 , 0.0 , 946.0],

Exploring Node: A

Inserting new Children: G,

[ B , 3 , 1078 , 268.29 , 1346.29],[ D , 3 , 946 , 0.0 , 946.0],[ G , 4 , 1306 , 180.69 , 1486.69],

Exploring Node: B

Inserting new Children: D, G,

[ D , 3 , 946 , 0.0 , 946.0],[ G , 4 , 1306 , 180.69 , 1486.69],

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SEARCH SUMMARY STATS:

Search Type: BREADTH Map File: 10test.txt Total Nodes in Graph: 12

Start Node: F ; Goal Node(s): D

Search total of 11 out of total of 12 in graph

Ended at Node: D with path cost: 946

Path ( 4 ): ['F', 'C', 'I', 'D']

Frontier size: Average= 0.5 Max size = 4

Depth of Search: Average= 0.6666666666666666 ;Max Depth = 3

Order of Node Expansion: [F,C,J,L,E,I,K,H,A,B,D,]

Process finished with exit code 0

**Depth:**

File loaded!

Start = F Goal = D

DEPTH search: from F to D

Exploring Node: F

Inserting new Children: C, J, L,

[ C , 1 , 278 , 384.22 , 662.22],[ J , 1 , 127 , 194.61 , 321.61],[ L , 1 , 277 , 332.96 , 609.96],

Exploring Node: C

Inserting new Children: E, I, K, L,

[ E , 2 , 571 , 567.61 , 1138.61],[ I , 2 , 569 , 319.62 , 888.62],[ K , 2 , 548 , 596.16 , 1144.16],[ L , 2 , 412 , 332.96 , 744.96],[ J , 1 , 127 , 194.61 , 321.61],

Exploring Node: E

Inserting new Children: A,

[ A , 3 , 1179 , 183.6 , 1362.6],[ I , 2 , 569 , 319.62 , 888.62],[ K , 2 , 548 , 596.16 , 1144.16],[ L , 2 , 412 , 332.96 , 744.96],[ J , 1 , 127 , 194.61 , 321.61],

Exploring Node: A

Inserting new Children: G, H,

[ G , 4 , 1306 , 180.69 , 1486.69],[ H , 4 , 1251 , 121.51 , 1372.51],[ I , 2 , 569 , 319.62 , 888.62],[ K , 2 , 548 , 596.16 , 1144.16],[ L , 2 , 412 , 332.96 , 744.96],[ J , 1 , 127 , 194.61 , 321.61],

Exploring Node: G

Inserting new Children: B,

[ B , 5 , 1541 , 268.29 , 1809.29],[ H , 4 , 1251 , 121.51 , 1372.51],[ I , 2 , 569 , 319.62 , 888.62],[ K , 2 , 548 , 596.16 , 1144.16],[ L , 2 , 412 , 332.96 , 744.96],[ J , 1 , 127 , 194.61 , 321.61],

Exploring Node: B

Inserting new Children: D, I,

[ D , 6 , 1816 , 0.0 , 1816.0],[ I , 6 , 2050 , 319.62 , 2369.62],[ H , 4 , 1251 , 121.51 , 1372.51],[ K , 2 , 548 , 596.16 , 1144.16],[ L , 2 , 412 , 332.96 , 744.96],[ J , 1 , 127 , 194.61 , 321.61],

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SEARCH SUMMARY STATS:

Search Type: DEPTH Map File: 10test.txt Total Nodes in Graph: 12

Start Node: F ; Goal Node(s): D

Search total of 7 out of total of 12 in graph

Ended at Node: D with path cost: 1816

Path ( 7 ): ['F', 'C', 'E', 'A', 'G', 'B', 'D']

Frontier size: Average= 1.5 Max size = 4

Depth of Search: Average= 1.0 ;Max Depth = 6

Order of Node Expansion: [F,C,E,A,G,B,D,]

Process finished with exit code 0

**Best:**

File loaded!

Start = F Goal = D

BEST search: from F to D

Exploring Node: F

Inserting new Children: C, J, L,

[ J , 1 , 127 , 194.61 , 321.61],[ L , 1 , 277 , 332.96 , 609.96],[ C , 1 , 278 , 384.22 , 662.22],

Exploring Node: J

Inserting new Children: H, L,

[ L , 1 , 277 , 332.96 , 609.96],[ C , 1 , 278 , 384.22 , 662.22],[ H , 2 , 350 , 121.51 , 471.51],

Exploring Node: L

Inserting new Children: C,

[ C , 1 , 278 , 384.22 , 662.22],[ H , 2 , 350 , 121.51 , 471.51],

Exploring Node: C

Inserting new Children: E, I, K,

[ H , 2 , 350 , 121.51 , 471.51],[ K , 2 , 548 , 596.16 , 1144.16],[ I , 2 , 569 , 319.62 , 888.62],[ E , 2 , 571 , 567.61 , 1138.61],

Exploring Node: H

Inserting new Children: A, D,

[ A , 3 , 422 , 183.6 , 605.6],[ D , 3 , 485 , 0.0 , 485.0],[ K , 2 , 548 , 596.16 , 1144.16],[ I , 2 , 569 , 319.62 , 888.62],[ E , 2 , 571 , 567.61 , 1138.61],

Exploring Node: A

Inserting new Children: E, G,

[ D , 3 , 485 , 0.0 , 485.0],[ K , 2 , 548 , 596.16 , 1144.16],[ G , 4 , 549 , 180.69 , 729.69],[ I , 2 , 569 , 319.62 , 888.62],[ E , 2 , 571 , 567.61 , 1138.61],

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SEARCH SUMMARY STATS:

Search Type: BEST Map File: 10test.txt Total Nodes in Graph: 12

Start Node: F ; Goal Node(s): D

Search total of 7 out of total of 12 in graph

Ended at Node: D with path cost: 485

Path ( 4 ): ['F', 'J', 'H', 'D']

Frontier size: Average= 1.6666666666666667 Max size = 3

Depth of Search: Average= 1.6666666666666667 ;Max Depth = 3

Order of Node Expansion: [F,J,L,C,H,A,D,]

Process finished with exit code 0

**A\*:**

File loaded!

Start = F Goal = D

A\* search: from F to D

Exploring Node: F

Inserting new Children: C, J, L,

[ J , 1 , 127 , 194.61 , 321.61],[ L , 1 , 277 , 332.96 , 609.96],[ C , 1 , 278 , 384.22 , 662.22],

Exploring Node: J

Inserting new Children: H, L,

[ H , 2 , 350 , 121.51 , 471.51],[ L , 1 , 277 , 332.96 , 609.96],[ C , 1 , 278 , 384.22 , 662.22],

Exploring Node: H

Inserting new Children: A, D,

[ D , 3 , 485 , 0.0 , 485.0],[ A , 3 , 422 , 183.6 , 605.6],[ L , 1 , 277 , 332.96 , 609.96],[ C , 1 , 278 , 384.22 , 662.22],

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SEARCH SUMMARY STATS:

Search Type: A\* Map File: 10test.txt Total Nodes in Graph: 12

Start Node: F ; Goal Node(s): D

Search total of 4 out of total of 12 in graph

Ended at Node: D with path cost: 485

Path ( 4 ): ['F', 'J', 'H', 'D']

Frontier size: Average= 1.3333333333333333 Max size = 3

Depth of Search: Average= 1.3333333333333333 ;Max Depth = 3

Order of Node Expansion: [F,J,H,D,]

Process finished with exit code 0

**Scenario 2.1: Some simple point to point travel:**

**Breadth:**

File loaded!

Start = AG Goal = F

BREADTH search: from AG to F

-------------------------------------------------

SEARCH SUMMARY STATS:

Search Type: BREADTH Map File: 50test.txt Total Nodes in Graph: 50

Start Node: AG ; Goal Node(s): F

Search total of 49 out of total of 50 in graph

Ended at Node: F with path cost: 1272

Path ( 8 ): ['AG', 'V', 'P', 'AP', 'AM', 'L', 'AN', 'F']

Frontier size: Average= 2.0 Max size = 1

Depth of Search: Average= 0.2857142857142857 ;Max Depth = 7

Order of Node Expansion: [AG,C,V,W,Y,AB,AF,AT,G,P,AX,AY,S,AW,N,AP,R,AH,AD,H,AE,AJ,AL,I,B,AU,AM,AQ,AS,K,T,AR,A,E,U,L,AO,AK,O,AI,AA,J,AN,D,M,X,Q,AC,F,]

Process finished with exit code 0

**Depth:**

File loaded!

Start = AG Goal = F

DEPTH search: from AG to F

-------------------------------------------------

SEARCH SUMMARY STATS:

Search Type: DEPTH Map File: 50test.txt Total Nodes in Graph: 50

Start Node: AG ; Goal Node(s): F

Search total of 36 out of total of 50 in graph

Ended at Node: F with path cost: 3224

Path ( 24 ): ['AG', 'C', 'W', 'AX', 'AH', 'AD', 'AM', 'AP', 'P', 'AT', 'V', 'AB', 'G', 'AW', 'B', 'A', 'AU', 'U', 'E', 'AA', 'AI', 'D', 'AV', 'F']

Frontier size: Average= 11.0 Max size = 1

Depth of Search: Average= 0.39285714285714285 ;Max Depth = 28

Order of Node Expansion: [AG,C,W,AX,AH,AD,AM,AP,P,AT,V,AB,AF,G,AW,B,A,AU,N,R,U,E,AA,AI,AR,AL,S,AE,AJ,T,K,I,O,D,AV,F,]

**Best:**

File loaded!

Start = AG Goal = F

BEST search: from AG to F

-------------------------------------------------

SEARCH SUMMARY STATS:

Search Type: BEST Map File: 50test.txt Total Nodes in Graph: 50

Start Node: AG ; Goal Node(s): F

Search total of 47 out of total of 50 in graph

Ended at Node: F with path cost: 1163

Path ( 9 ): ['AG', 'V', 'P', 'R', 'AU', 'U', 'J', 'Q', 'F']

Frontier size: Average= 4.0 Max size = 1

Depth of Search: Average= 0.5 ;Max Depth = 8

Order of Node Expansion: [AG,C,V,AT,G,P,Y,AB,AP,AW,R,N,AH,S,AU,B,AM,W,AX,AF,AD,U,A,AY,I,AE,H,AQ,AS,L,K,E,AJ,J,AO,O,T,AL,AA,Q,AN,AK,AR,X,AI,AC,F,]

Process finished with exit code 0

**A\*:**

File loaded!

Start = AG Goal = F

A\* search: from AG to F

-------------------------------------------------

SEARCH SUMMARY STATS:

Search Type: A\* Map File: 50test.txt Total Nodes in Graph: 50

Start Node: AG ; Goal Node(s): F

Search total of 24 out of total of 50 in graph

Ended at Node: F with path cost: 1163

Path ( 9 ): ['AG', 'V', 'P', 'R', 'AU', 'U', 'J', 'Q', 'F']

Frontier size: Average= 14.0 Max size = 1

Depth of Search: Average= 1.75 ;Max Depth = 8

Order of Node Expansion: [AG,V,G,P,AT,R,AP,AM,AU,N,U,L,AH,AW,Y,J,AQ,Q,B,AB,C,A,AD,F,]

Process finished with exit code 0

**Scenario 2.2: Emergency:**

**Breadth:**

File loaded!

Start = AG Goal = C,AF,AK

BREADTH search: from AG to C, AF, AK

-------------------------------------------------

SEARCH SUMMARY STATS:

Search Type: BREADTH Map File: 50test.txt Total Nodes in Graph: 50

Start Node: AG ; Goal Node(s): [C,AF,AK,]

Search total of 2 out of total of 50 in graph

Ended at Node: C with path cost: 214

Path ( 2 ): ['AG', 'C']

Frontier size: Average= 2.0 Max size = 1

Depth of Search: Average= 2.0 ;Max Depth = 1

Order of Node Expansion: [AG,C,]

-------------------------------------------------

SEARCH SUMMARY STATS:

Search Type: BREADTH Map File: 50test.txt Total Nodes in Graph: 50

Start Node: AG ; Goal Node(s): [AF,AK,]

Search total of 8 out of total of 50 in graph

Ended at Node: AF with path cost: 671

Path ( 5 ): ['AG', 'V', 'AG', 'C', 'AF']

Frontier size: Average= 7.0 Max size = 1

Depth of Search: Average= 3.5 ;Max Depth = 2

Order of Node Expansion: [AG,C,V,W,Y,AB,AF,]

-------------------------------------------------

SEARCH SUMMARY STATS:

Search Type: BREADTH Map File: 50test.txt Total Nodes in Graph: 50

Start Node: AG ; Goal Node(s): [AK,]

Search total of 40 out of total of 50 in graph

Ended at Node: AK with path cost: 1232

Path ( 12 ): ['AG', 'C', 'W', 'AY', 'AD', 'AS', 'AG', 'V', 'AG', 'C', 'AF', 'AK']

Frontier size: Average= 6.0 Max size = 1

Depth of Search: Average= 1.0 ;Max Depth = 6

Order of Node Expansion: [AG,C,V,W,Y,AB,AF,AT,G,P,AX,AY,S,AW,N,AP,R,AH,AD,H,AE,AJ,AL,I,B,AU,AM,AQ,AS,K,T,AR,A,E,U,L,AO,AK,]

Process finished with exit code 0

**Depth:**

File loaded!

Start = AG Goal = C,AF,AK

DEPTH search: from AG to C, AF, AK

-------------------------------------------------

SEARCH SUMMARY STATS:

Search Type: DEPTH Map File: 50test.txt Total Nodes in Graph: 50

Start Node: AG ; Goal Node(s): [C,AF,AK,]

Search total of 2 out of total of 50 in graph

Ended at Node: C with path cost: 214

Path ( 2 ): ['AG', 'C']

Frontier size: Average= 2.0 Max size = 1

Depth of Search: Average= 2.0 ;Max Depth = 1

Order of Node Expansion: [AG,C,]

-------------------------------------------------

SEARCH SUMMARY STATS:

Search Type: DEPTH Map File: 50test.txt Total Nodes in Graph: 50

Start Node: AG ; Goal Node(s): [AF,AK,]

Search total of 14 out of total of 50 in graph

Ended at Node: AF with path cost: 2158

Path ( 15 ): ['AG', 'C', 'W', 'AX', 'AH', 'AD', 'AM', 'AP', 'P', 'AT', 'V', 'AB', 'AG', 'C', 'AF']

Frontier size: Average= 12.0 Max size = 1

Depth of Search: Average= 1.0 ;Max Depth = 12

Order of Node Expansion: [AG,C,W,AX,AH,AD,AM,AP,P,AT,V,AB,AF,]

-------------------------------------------------

SEARCH SUMMARY STATS:

Search Type: DEPTH Map File: 50test.txt Total Nodes in Graph: 50

Start Node: AG ; Goal Node(s): [AK,]

Search total of 42 out of total of 50 in graph

Ended at Node: AK with path cost: 4000

Path ( 43 ): ['AG', 'C', 'W', 'AX', 'AH', 'AD', 'AM', 'AP', 'P', 'AT', 'V', 'AB', 'G', 'AW', 'B', 'A', 'AU', 'U', 'E', 'AA', 'AI', 'D', 'AV', 'F', 'AC', 'AN', 'AO', 'AG', 'C', 'W', 'AX', 'AH', 'AD', 'AM', 'AP', 'P', 'AT', 'V', 'AB', 'AG', 'C', 'AF', 'AK']

Frontier size: Average= 11.0 Max size = 1

Depth of Search: Average= 0.39285714285714285 ;Max Depth = 28

Order of Node Expansion: [AG,C,W,AX,AH,AD,AM,AP,P,AT,V,AB,AF,G,AW,B,A,AU,N,R,U,E,AA,AI,AR,AL,S,AE,AJ,T,K,I,O,D,AV,F,AC,AN,AO,AK,]

Process finished with exit code 0

**Best:**

File loaded!

Start = AG Goal = C,AF,AK

BEST search: from AG to C, AF, AK

-------------------------------------------------

SEARCH SUMMARY STATS:

Search Type: BEST Map File: 50test.txt Total Nodes in Graph: 50

Start Node: AG ; Goal Node(s): [C,AF,AK,]

Search total of 2 out of total of 50 in graph

Ended at Node: C with path cost: 214

Path ( 2 ): ['AG', 'C']

Frontier size: Average= 2.0 Max size = 1

Depth of Search: Average= 2.0 ;Max Depth = 1

Order of Node Expansion: [AG,C,]

-------------------------------------------------

SEARCH SUMMARY STATS:

Search Type: BEST Map File: 50test.txt Total Nodes in Graph: 50

Start Node: AG ; Goal Node(s): [AF,AK,]

Search total of 21 out of total of 50 in graph

Ended at Node: AF with path cost: 671

Path ( 5 ): ['AG', 'V', 'AG', 'C', 'AF']

Frontier size: Average= 11.0 Max size = 1

Depth of Search: Average= 2.75 ;Max Depth = 4

Order of Node Expansion: [AG,C,V,AT,G,P,Y,AB,AP,AW,R,N,AH,S,AU,B,AM,W,AX,AF,]

-------------------------------------------------

SEARCH SUMMARY STATS:

Search Type: BEST Map File: 50test.txt Total Nodes in Graph: 50

Start Node: AG ; Goal Node(s): [AK,]

Search total of 44 out of total of 50 in graph

Ended at Node: AK with path cost: 1060

Path ( 13 ): ['AG', 'V', 'P', 'AP', 'AH', 'AD', 'AS', 'AG', 'V', 'AG', 'C', 'AF', 'AK']

Frontier size: Average= 6.0 Max size = 1

Depth of Search: Average= 0.8571428571428571 ;Max Depth = 7

Order of Node Expansion: [AG,C,V,AT,G,P,Y,AB,AP,AW,R,N,AH,S,AU,B,AM,W,AX,AF,AD,U,A,AY,I,AE,H,AQ,AS,L,K,E,AJ,J,AO,O,T,AL,AA,Q,AN,AK,]

Process finished with exit code 0

**A\*:**

File loaded!

Start = AG Goal = C,AF,AK

A\* search: from AG to C, AF, AK

-------------------------------------------------

SEARCH SUMMARY STATS:

Search Type: A\* Map File: 50test.txt Total Nodes in Graph: 50

Start Node: AG ; Goal Node(s): [C,AF,AK,]

Search total of 2 out of total of 50 in graph

Ended at Node: C with path cost: 214

Path ( 2 ): ['AG', 'C']

Frontier size: Average= 2.0 Max size = 1

Depth of Search: Average= 2.0 ;Max Depth = 1

Order of Node Expansion: [AG,C,]

-------------------------------------------------

SEARCH SUMMARY STATS:

Search Type: A\* Map File: 50test.txt Total Nodes in Graph: 50

Start Node: AG ; Goal Node(s): [AF,AK,]

Search total of 5 out of total of 50 in graph

Ended at Node: AF with path cost: 671

Path ( 5 ): ['AG', 'V', 'AG', 'C', 'AF']

Frontier size: Average= 7.0 Max size = 1

Depth of Search: Average= 3.5 ;Max Depth = 2

Order of Node Expansion: [AG,C,V,AF,]

-------------------------------------------------

SEARCH SUMMARY STATS:

Search Type: A\* Map File: 50test.txt Total Nodes in Graph: 50

Start Node: AG ; Goal Node(s): [AK,]

Search total of 15 out of total of 50 in graph

Ended at Node: AK with path cost: 1386

Path ( 15 ): ['AG', 'V', 'G', 'N', 'R', 'AP', 'AM', 'AQ', 'AO', 'AG', 'V', 'AG', 'C', 'AF', 'AK']

Frontier size: Average= 16.0 Max size = 1

Depth of Search: Average= 1.7777777777777777 ;Max Depth = 9

Order of Node Expansion: [AG,C,V,AF,AB,G,N,R,AP,AM,AQ,AO,AK,]

Process finished with exit code 0

**Scenario 2.2: Emergency Removed AK A\*:**

File loaded!

Start = AG Goal = C,AF

A\* search: from AG to C, AF

-------------------------------------------------

SEARCH SUMMARY STATS:

Search Type: A\* Map File: 50test.txt Total Nodes in Graph: 50

Start Node: AG ; Goal Node(s): [C,AF,]

Search total of 2 out of total of 50 in graph

Ended at Node: C with path cost: 214

Path ( 2 ): ['AG', 'C']

Frontier size: Average= 2.0 Max size = 1

Depth of Search: Average= 2.0 ;Max Depth = 1

Order of Node Expansion: [AG,C,]

-------------------------------------------------

SEARCH SUMMARY STATS:

Search Type: A\* Map File: 50test.txt Total Nodes in Graph: 50

Start Node: AG ; Goal Node(s): [AF,]

Search total of 5 out of total of 50 in graph

Ended at Node: AF with path cost: 671

Path ( 5 ): ['AG', 'V', 'AG', 'C', 'AF']

Frontier size: Average= 7.0 Max size = 1

Depth of Search: Average= 3.5 ;Max Depth = 2

Order of Node Expansion: [AG,C,V,AF,]

Process finished with exit code 0

GRAPH:

My GraphViz for some reason was creating a separate GraphViz for every time that I did something on the GraphViz, I implemented GraphViz working and function how it was supposed to, but for some reason it still continued to do this.