**COMPARISON OF VARIOUS PATHFINDER ALGORITHMS' EXPERIMENTAL PERFORMANCE USING DIFFERENT DATASETS**

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**Abstract**

In this project, we have compared 5 different pathfinder algorithms according to their system’s time, efficiency and energy cost. We used C++ for our experiment. For our testing phase, we used 2 different computers to compare the results of the algorithms.

We used 5 different pathfinder algorithms which are A\*, Dijkstra's Algorithm, BFS (Breadth- First Algorithm), DFS (Depth-First Algorithm) and Random algorithm. We also measured our data sets in two different operation systems: MacBook and Windows according to system’s time and energy consumption to see the difference in two different architectures.

At the end, some graphics are prepared to show which algorithm is most suitable in which condition.

**Table of Contents:**

1.Introduction

1.1 Report Context

1.2 Project Purpose & Context

1.3 Motivation

1.4 Outline

2.Background

2.1 BFS (Breadth First Search) Algorithm  
  
2.2 DFS (Depth First Search) Algorithm  
  
2.3 Dijkstra’s Search Algorithm  
  
2.4 A\* Search Algorithm

3. Methods/Design

3.1 Random Algorithm.

3.2 Creating the labyrinth

3.3 Testing Environment

4.Results/Data

5.Analysis

6.Project Evaluation

7.Conclusions

References

# 1. Introduction

**1.1 Report Context**

This final project report is prepared for our “BLG374E-Technical Communication for Computer Engineers” course semester project to the course teacher.

**1.2 Project Purpose & Context**

This project’s aim is to compare 5 different pathfinder algorithms and compare them to understand which algorithm is more suitable in which condition. We want to help people choose the most suitable pathfinder algorithm and encourage future projects on pathfinding algorithms. This project also includes some results of datasets (testing environment) and some graphical data.

**1.3 Motivation**

Pathfinding is an important subject since finding a traversable path between two nodes is important nowadays. In general, computers do this very easily but finding the more efficient way is important. That is why comparing those algorithms according to energy usage or time is important.

**1.4 Outline**

In this report, there is an “Introduction” section where the project value and motivation is mentioned, a “Background” section where some informations about pathfinding algorithms are discussed, a “Methods/Design”section where testing environment and experiments are explained in detail, a “Results/Data” section where the results and graphics are illustrated according to the obtained results, an “Analysis” section where those results are analyzed, a “Project Evaluation” section and a “Conclusion”.

**2. Background**

**2.1 BFS (Breadth First Search) Algorithm**  
Breadth First Search (BFS) is a search algorithm that checks parents or root first, then checks child nodes to find nodes which provides necessary condition or conditions. An adaptation of this algorithm to pathfinding is to convert available paths to a tree which has costs when moving node to node. After that shortest path can be calculated searching each node for total cost to get there. Algorithm's complexity is O (bd) at worst case because breadth-first search must travel all the nodes and if you consider an average case, half of the nodes which has depth of d, needs to be searched so complexity is still O (bd). [Korf 1985]  
  
 **2.2 DFS (Depth First Search) Algorithm**  
Depth- First Search(DFS) is an algorithm that searches graphs or trees. It has the method of checking the child nodes first, then the parent(root)nodes. It has the method of going as deep as it possibly can, that’s why it’ called depth-first search. Algorithm’s complexity is O (bd) at worst case (for implicit graphs with branching factor b and depth d). [Massachusetts Institute of Technology, 2017]

2.3 **Dijkstra’s Search Algorithm**  
Dijkstra’s pathfinding algorithm starts from the starting point, by marking infinite every distance from the starting point, which means that those other points have not been visited yet. Initially, the starting point is marked zero and after marking the starting point, other distances between other nodes are labeled iteratively (after the starting point other points will be visited), when a closest distance is found, the distance is updated. When visiting all the nodes and updating all the distance between those nodes are terminated, the shortest path is found. Algorithm’s complexity is O (E + |v |log| v|) where E is the number of edges and v is the number of vertices. [Cornell University, 2017]  
  
**2.4** **A\* Search Algorithm**  
A\* estimates pretty well its route to the destination point. Let’s assume that n is our destination point. A\* uses the function f(n) = g(n) + h(n) to find its way from starting point to the destination point with the least cost. g(n) is the complete cost calculated from the starting point to the arrived point and h(n) is the approximate cost from the starting distance to the destination point n. Using g(n) and h(n) A\* finds and chooses its optimal route in every step taking account to f(n). [Patel, 2017]

**3. Methods/Design**

**3.1 Random Algorithm**

This algorithm used as a control group rather than a competitor. Its pure aim is to travel around the maze randomly, without considering anything until a path is found.

**3.2 Creating the labyrinth**

The labyrinth that we tested the pathfinding algorithms is a 2D maze. An algorithm is implemented to create a random maze with size of 50x50 and these labyrinths have different characteristics such as crooked, flat and crooked combined with flatmazes with one input – output and one input – multiple outputs.

**3.3 Testing Environment**

Algorithms implemented tested on two different test systems which gave similar results. Specifications of the systems tested are listed below:

* Apple MacBook Pro (Mid 2015) - will be referred as PC1
  + CPU
    - 2,8 GHz Intel Core i7 4980HQ
    - L1: 32KB/32KB
    - L2: 256KB
    - L3: 6MB
  + Battery
    - Max. Battery Cap: 8,755 mAh
    - Cur. Battery Cap: 8,095 mAh
    - Cur. Battery Health: 92%
    - \*Battery Consumption in 1 min:
      * Avg. 14,2 mAh
      * Avg. 0,159 mWh
    - \*\*Battery Cycle: 228
* Asus n550jk cn167d - -will be referred as PC2
  + CPU
    - 2,4 GHz Intel Core I7 4700HQ
    - L1: 256KB
    - L2:1024KB
    - L3:6MB
  + Battery
    - Max. Battery Cap: 4,000 mAh
    - Cur. Battery Cap: 2841,9594 mAh
    - Cur. Battery Health: 71%
    - \*Battery Consumption in 1 min:
      * Avg. 32 mAh
      * Avg. 0,473 mWh
    - \*\*Battery Cycle: No data
* ***\* Battery Consumption in* *1 minute:*** *The battery consumption with the default programs running in the OS (Operation System). In addition to that, mouse was plugged in, wi-fi was on and the screen brightness was full in order to get a standard consumption average. It was calculated right after a reboot several times to get the average.*
* ***\*\* Battery Cycle:*** *The charge / discharge cycle in which shows the battery life.*

Algorithms have been implemented by datPATH team in C++. And a testing environment prepared in C++ to get necessary data. Each algorithm tested on ten different map from each category. Categories are crooked maps, flat maps, crooked and flat maps.

Energy consumption has been calculated by unplugging the computer and measuring battery level before and after running the algorithm hundred times on ten different labyrinths, in total thousand times.

**4. Results/Data**

Gathered data from each experiment and statistical values for each maze category given below.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Crooked Map on PC1 | map 1 | map 2 | map 3 | map 4 | map 5 | map 6 | map 7 | map 8 | map 9 | map 10 |
| DFS results | 32 | 18 | 43 | 16 | 8 | 16 | 12 | 15 | 21 | 22 |
| BFS results | 24 | 19 | 17 | 214 | 33 | 19 | 34 | 27 | 20 | 24 |
| A\* results | 230 | 60 | 218 | 218 | 169 | 121 | 167 | 179 | 170 | 126 |
| Dijkstra's results | 187 | 29 | 199 | 167 | 133 | 82 | 137 | 134 | 192 | 81 |
| Random results | 107 | 16 | 100 | 50 | 38 | 27 | 44 | 54 | 72 | 21 |

Table 4.1 Experiment results for crooked map on PC1.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Crooked Map on PC1 | Average | Variance | Standard Deviation | Normalized Variance |
| DFS results | 20,3 | 105,1222222 | 9,392668536 | 11,19194421 |
| BFS results | 43,1 | 3639,655556 | 59,95512725 | 60,70632692 |
| A\* results | 165,8 | 2728,844444 | 47,11687596 | 57,91649784 |
| Dijkstra's results | 134,1 | 3114,988889 | 52,62609783 | 59,19095311 |
| Random results | 52,9 | 985,6555556 | 24,98641606 | 39,4476564 |

Table 4.2 Statistical data for crooked map on PC1.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Flat Map on PC1 | map 1 | map 2 | map 3 | map 4 | map 5 | map 6 | map 7 | map 8 | map 9 | map 10 |
| DFS results | 46 | 17 | 17 | 24 | 30 | 32 | 17 | 8 | 11 | 26 |
| BFS results | 30 | 29 | 27 | 43 | 20 | 22 | 33 | 36 | 8 | 19 |
| A\* results | 385 | 331 | 242 | 351 | 264 | 274 | 313 | 325 | 347 | 294 |
| Dijkstra's results | 486 | 294 | 171 | 275 | 214 | 213 | 252 | 280 | 288 | 266 |
| Random results | 104 | 122 | 42 | 94 | 130 | 84 | 96 | 62 | 134 | 72 |

Table 4.3 Experiment results for flat map on PC1.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Flat Map on PC1 | Average | Variance | Standard Deviation | Normalized Variance |
| DFS results | 22,8 | 127,2888889 | 7,799968344 | 16,31915455 |
| BFS results | 26,7 | 98,23333333 | 9,843215373 | 9,979801275 |
| A\* results | 312,6 | 1952,711111 | 36,13281399 | 54,04259717 |
| Dijkstra's results | 273,9 | 7117,211111 | 39,53901027 | 180,0047867 |
| Random results | 94 | 899,5555556 | 29,7860685 | 30,2005468 |

Table 4.3 Statistical data for flat map on PC1.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Crooked & Flat Map on PC1 | map 1 | map 2 | map 3 | map 4 | map 5 | map 6 | map 7 | map 8 | map 9 | map 10 |
| DFS results | 64 | 12 | 13 | 11 | 25 | 6 | 10 | 21 | 21 | 9 |
| BFS results | 23 | 8 | 15 | 17 | 5 | 16 | 18 | 19 | 24 | 9 |
| A\* results | 130 | 34 | 58 | 29 | 40 | 31 | 123 | 215 | 194 | 91 |
| Dijkstra's results | 86 | 18 | 49 | 23 | 26 | 23 | 104 | 192 | 150 | 64 |
| Random results | 125 | 21 | 28 | 11 | 14 | 12 | 82 | 74 | 40 | 67 |

Table 4.4 Experiment results for crooked and flat map on PC1.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Crooked & Flat Map on PC1 | Average | Variance | Standard Deviation | Normalized Variance |
| DFS results | 19,2 | 285,2888889 | 6,124228346 | 46,58364658 |
| BFS results | 15,4 | 39,82222222 | 5,717635702 | 6,964805786 |
| A\* results | 94,5 | 4754,5 | 67,81529017 | 70,10955772 |
| Dijkstra's results | 73,5 | 3567,611111 | 59,56778481 | 59,89161964 |
| Random results | 47,4 | 1459,155556 | 26,75310066 | 54,54154918 |

Table 4.5 Statistical data for crooked and flat map on PC1.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Crooked Map on PC2 | map 1 | map 2 | map 3 | map 4 | map 5 | map 6 | map 7 | map 8 | map 9 | map 10 |
| DFS results | 29 | 14 | 35 | 22 | 16 | 29 | 26 | 27 | 32 | 33 |
| BFS results | 45 | 23 | 35 | 100 | 46 | 36 | 44 | 44 | 36 | 24 |
| A\* results | 261 | 79 | 281 | 286 | 245 | 160 | 231 | 243 | 246 | 158 |
| Dijkstra's results | 221 | 63 | 246 | 263 | 215 | 141 | 205 | 216 | 217 | 144 |
| Random results | 74 | 21 | 53 | 35 | 48 | 41 | 28 | 46 | 56 | 118 |

Table 4.6 Experiment results for crooked map on PC2.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Crooked Map on PC2 | Average | Variance | Standard Deviation | Normalized Variance |
| DFS results | 26,3 | 49,34444444 | 6,960204339 | 7,089510888 |
| BFS results | 43,3 | 465,1222222 | 21,55841905 | 21,57496897 |
| A\* results | 219 | 4336 | 64,17337627 | 67,56696082 |
| Dijkstra's results | 193,1 | 3581,211111 | 59,03482964 | 60,66268223 |
| Random results | 52 | 761,7777778 | 26,49574855 | 28,75094381 |

Table 4.7 Statistical data for crooked map on PC2.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Flat Map on PC2 | map 1 | map 2 | map 3 | map 4 | map 5 | map 6 | map 7 | map 8 | map 9 | map 10 |
| DFS results | 39 | 24 | 38 | 44 | 43 | 46 | 33 | 15 | 51 | 33 |
| BFS results | 45 | 44 | 33 | 55 | 38 | 41 | 41 | 75 | 36 | 38 |
| A\* results | 432 | 454 | 282 | 464 | 369 | 435 | 363 | 425 | 577 | 334 |
| Dijkstra's results | 366 | 406 | 247 | 411 | 332 | 336 | 325 | 383 | 511 | 308 |
| Random results | 142 | 86 | 87 | 50 | 68 | 71 | 121 | 51 | 59 | 76 |

Table 4.8 Experiment results for flat map on PC2.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Flat Map on PC2 | Average | Variance | Standard Deviation | Normalized Variance |
| DFS results | 36,6 | 116,7111111 | 10,77032961 | 10,83635462 |
| BFS results | 44,6 | 150,4888889 | 12,26658615 | 12,26819647 |
| A\* results | 413,5 | 6666,944444 | 81,39220699 | 81,91133637 |
| Dijkstra's results | 362,5 | 5119,833333 | 71,54244186 | 71,563581 |
| Random results | 81,1 | 891,2111111 | 20,81665999 | 42,81239696 |

Table 4.9 Statistical data for flat map on PC2.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Crooked & Flat Map on PC2 | map 1 | map 2 | map 3 | map 4 | map 5 | map 6 | map 7 | map 8 | map 9 | map 10 |
| DFS results | 26 | 51 | 50 | 34 | 15 | 14 | 26 | 39 | 41 | 20 |
| BFS results | 30 | 16 | 22 | 34 | 18 | 32 | 37 | 35 | 45 | 23 |
| A\* results | 157 | 53 | 97 | 60 | 67 | 63 | 182 | 281 | 282 | 152 |
| Dijkstra's results | 130 | 44 | 84 | 51 | 57 | 55 | 180 | 251 | 244 | 116 |
| Random results | 90 | 14 | 35 | 50 | 19 | 46 | 56 | 100 | 70 | 109 |

Table 4.10 Experiment results for crooked and flat map on PC2.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Crooked & Flat Map on PC2 | Average | Variance | Standard Deviation | Normalized Variance |
| DFS results | 31,6 | 182,9333333 | 13,38139486 | 13,67072232 |
| BFS results | 29,2 | 85,06666667 | 9,218874895 | 9,227445609 |
| A\* results | 139,4 | 7701,6 | 87,54060786 | 87,97745627 |
| Dijkstra's results | 121,2 | 6251,733333 | 79,00742269 | 79,12843023 |
| Random results | 58,9 | 1080,322222 | 30,9986061 | 34,85067098 |

Table 4.11 Statistical data for crooked and flat map on PC2.

Bar graphs are constructed from average values for comparing results.

Figure 1 – Average runtime graph for PC1.

Figure 2 – Average runtime graph for PC2.

Energy consumption data measured on PC2 given below.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| |  |  |  | | --- | --- | --- | | BFS on Crooked Map on PC2 | | | | Start | % | 99,2000 | | mWh | 40,5520 | | Finish | % | 97,6000 | | mWh | 39,9000 | | Result | % | 1,6000 | |  | mWh | 0,6520 | | Start | % | 97,4000 | | mWh | 39,7820 | | Finish | % | 95,9000 | | mWh | 39,1000 | | Result | % | 1,5000 | |  | mWh | 0,6820 | | Start | % | 95,9000 | | mWh | 39,1000 | | Finish | % | 94,3000 | | mWh | 38,5090 | | Result | % | 1,6000 | |  | mWh | 0,5910 | |  |  |  | | Average | % | 1,5667 | |  | mWh | 0,6417 | |  |  |  | | Variance | % | 0,0033 | |  | mWh | 0,0022 |   Table 4.12 Energy Consumption of BFS on Crooked Map on PC2. | |  |  |  | | --- | --- | --- | | DFS on Crooked Map on PC2 | | | | Start | % | 83,8000 | | mWh | 34,2320 | | Finish | % | 82,3000 | | mWh | 33,6250 | | Result | % | 1,5000 | |  | mWh | 0,6070 | | Start | % | 82,3000 | | mWh | 33,6250 | | Finish | % | 80,8000 | | mWh | 32,9740 | | Result | % | 1,5000 | |  | mWh | 0,6510 | | Start | % | 80,8000 | | mWh | 32,9740 | | Finish | % | 79,2000 | | mWh | 32,3520 | | Result | % | 1,6000 | |  | mWh | 0,6220 | |  |  |  | | Average | % | 1,5333 | |  | mWh | 0,6267 | |  |  |  | | Variance | % | 0,0033 | |  | mWh | 0,0005 |   Table 4.13 Energy Consumption of DFS on Crooked Map on PC2. | |  |  |  | | --- | --- | --- | | A\* on Crooked Map on PC2 | | | | Start | % | 77,6000 | | mWh | 31,6720 | | Finish | % | 76,2000 | | mWh | 31,1090 | | Result | % | 1,4000 | |  | mWh | 0,5630 | | Start | % | 76,2000 | | mWh | 31,1090 | | Finish | % | 74,8000 | | mWh | 30,4580 | | Result | % | 1,4000 | |  | mWh | 0,6510 | | Start | % | 74,8000 | | mWh | 30,4580 | | Finish | % | 73,3000 | | mWh | 29,8510 | | Result | % | 1,5000 | |  | mWh | 0,6070 | |  |  |  | | Average | % | 1,4333 | |  | mWh | 0,6070 | |  |  |  | | Variance | % | 0,0033 | |  | mWh | 0,0019 |   Table 4.14 Energy consumption of A\* on Crooked Map on PC2. |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| |  |  |  | | --- | --- | --- | | Djikstra on Crooked Map on PC2 | | | | Start | % | 72,8000 | | mWh | 29,7333 | | Finish | % | 71,3000 | | mWh | 29,1260 | | Result | % | 1,5000 | |  | mWh | 0,6073 | | Start | % | 71,3000 | | mWh | 29,1260 | | Finish | % | 66,8000 | | mWh | 27,2610 | | Result | % | 4,5000 | |  | mWh | 1,8650 | | Start | % | 66,9000 | | mWh | 27,2610 | | Finish | % | 65,3000 | | mWh | 26,6630 | | Result | % | 1,6000 | |  | mWh | 0,5980 | |  |  |  | | Average | % | 2,5333 | |  | mWh | 1,0234 | |  |  |  | | Variance | % | 2,9033 | |  | mWh | 0,5312 |   Table 4.15 Energy Consumption of  Djikstra on Crooked Map on PC2. | | |  |  |  | | --- | --- | --- | | Random on Crooked Map on PC2 | | | | Start | % | 64,8000 | | mWh | 26,4320 | | Finish | % | 63,2000 | | mWh | 25,8260 | | Result | % | 1,6000 | |  | mWh | 0,6060 | | Start | % | 63,2000 | | mWh | 25,8260 | | Finish | % | 61,8000 | | mWh | 25,2480 | | Result | % | 1,4000 | |  | mWh | 0,5780 | | Start | % | 61,7000 | | mWh | 25,1740 | | Finish | % | 60,1000 | | mWh | 24,5530 | | Result | % | 1,6000 | |  | mWh | 0,6210 | |  |  |  | | Average | % | 1,5333 | |  | mWh | 0,6017 | |  |  |  | | Variance | % | 0,0133 | |  | mWh | 0,0005 |   Table 4.16 Energy Consumption of  Random on Crooked Map on PC2. | |
| |  |  |  | | --- | --- | --- | | BFS on Flat Map on PC2 | | | | Start | % | 74,5000 | | mWh | 28,4900 | | Finish | % | 73,1000 | | mWh | 27,9270 | | Result | % | 1,4000 | |  | mWh | 0,5630 | | Start | % | 73,1000 | | mWh | 27,9270 | | Finish | % | 71,5000 | | mWh | 27,3500 | | Result | % | 1,6000 | |  | mWh | 0,5770 | | Start | % | 71,5000 | | mWh | 27,3500 | | Finish | % | 70,3000 | | mWh | 26,8620 | | Result | % | 1,2000 | |  | mWh | 0,4880 | |  |  |  | | Average | % | 1,4000 | |  | mWh | 0,5427 | |  |  |  | | Variance | % | 0,0400 | |  | mWh | 0,0023 |   Table 4.17 Energy Consumption of BFS on Flat Map on PC2. | |  |  |  | | --- | --- | --- | | DFS on Flat Map on PC2 | | | | Start | % | 69,8000 | | mWh | 26,6990 | | Finish | % | 63,6000 | | mWh | 24,3010 | | Result | % | 6,2000 | |  | mWh | 2,3980 | | Start | % | 59,6000 | | mWh | 22,7920 | | Finish | % | 58,3000 | | mWh | 22,3030 | | Result | % | 1,3000 | |  | mWh | 0,4890 | | Start | % | 62,3000 | | mWh | 28,9130 | | Finish | % | 60,7000 | | mWh | 28,2060 | | Result | % | 1,6000 | |  | mWh | 0,7070 | |  |  |  | | Average | % | 3,0333 | |  | mWh | 1,1980 | |  |  |  | | Variance | % | 7,5433 | |  | mWh | 1,0919 |   Table 4.18 Energy Consumption of DFS on Flat Map on PC2. | | |  |  |  | | --- | --- | --- | | A\* on Flat Map on PC2 | | | | Start | % | 57,2000 | | mWh | 21,8590 | | Finish | % | 55,7000 | | mWh | 21,2820 | | Result | % | 1,5000 | |  | mWh | 0,5770 | | Start | % | 55,7000 | | mWh | 21,2820 | | Finish | % | 54,4000 | | mWh | 20,7790 | | Result | % | 1,3000 | |  | mWh | 0,5030 | | Start | % | 54,4000 | | mWh | 20,7790 | | Finish | % | 53,3000 | | mWh | 20,3640 | | Result | % | 1,1000 | |  | mWh | 0,4150 | |  |  |  | | Average | % | 1,3000 | |  | mWh | 0,4983 | |  |  |  | | Variance | % | 0,0400 | |  | mWh | 0,0066 |   Table 4.19 Energy consumption of A\* on Flat Map on PC2. |
| |  |  |  | | --- | --- | --- | | Djikstra on Flat Map on PC2 | | | | Start | % | 52,7000 | | mWh | 20,1420 | | Finish | % | 51,3000 | | mWh | 19,6240 | | Result | % | 1,4000 | |  | mWh | 0,5180 | | Start | % | 51,3000 | | mWh | 19,6240 | | Finish | % | 48,9000 | | mWh | 19,0920 | | Result | % | 2,4000 | |  | mWh | 0,5320 | | Start | % | 48,1000 | | mWh | 18,3960 | | Finish | % | 46,5000 | | mWh | 17,7890 | | Result | % | 1,6000 | |  | mWh | 0,6070 | |  |  |  | | Average | % | 1,8000 | |  | mWh | 0,5523 | |  |  |  | | Variance | % | 0,2800 | |  | mWh | 0,0023 |   Table 4.20 Energy Consumption of  Djikstra on Flat Map on PC2. | | |  |  |  | | --- | --- | --- | | Random on Flat Map on PC2 | | | | Start | % | 46,2000 | | mWh | 17,6560 | | Finish | % | 44,8000 | | mWh | 17,1380 | | Result | % | 1,4000 | |  | mWh | 0,5180 | | Start | % | 44,8000 | | mWh | 17,1380 | | Finish | % | 43,2000 | | mWh | 16,5160 | | Result | % | 1,6000 | |  | mWh | 0,6220 | | Start | % | 43,2000 | | mWh | 16,5160 | | Finish | % | 41,8000 | | mWh | 15,9690 | | Result | % | 1,4000 | |  | mWh | 0,5470 | |  |  |  | | Average | % | 1,4667 | |  | mWh | 0,5623 | |  |  |  | | Variance | % | 0,0133 | |  | mWh | 0,0029 |   Table 4.21 Energy Consumption of  Random on Flat Map on PC2. | |

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| |  |  |  | | --- | --- | --- | | BFS on Crooked & Flat Map on PC2 | | | | Start | % | 40,3000 | | mWh | 15,4210 | | Finish | % | 39,0000 | | mWh | 14,9180 | | Result | % | 1,3000 | |  | mWh | 0,5030 | | Start | % | 39,0000 | | mWh | 14,9180 | | Finish | % | 37,6000 | | mWh | 14,3700 | | Result | % | 1,4000 | |  | mWh | 0,5480 | | Start | % | 37,6000 | | mWh | 14,3700 | | Finish | % | 36,2000 | | mWh | 13,8520 | | Result | % | 1,4000 | |  | mWh | 0,5180 | |  |  |  | | Average | % | 1,3667 | |  | mWh | 0,5230 | |  |  |  | | Variance | % | 0,0033 | |  | mWh | 0,0005 |   Table 4.22 Energy Consumption of BFS on Crooked & Flat Map on PC2. | |  |  |  | | --- | --- | --- | | DFS on Crooked & Flat Map on PC2 | | | | Start | % | 35,9000 | | mWh | 13,7190 | | Finish | % | 34,3000 | | mWh | 13,1120 | | Result | % | 1,6000 | |  | mWh | 0,6070 | | Start | % | 34,3000 | | mWh | 13,1120 | | Finish | % | 32,8000 | | mWh | 12,5500 | | Result | % | 1,5000 | |  | mWh | 0,5620 | | Start | % | 32,8000 | | mWh | 12,5500 | | Finish | % | 30,9000 | | mWh | 11,8100 | | Result | % | 1,9000 | |  | mWh | 0,7400 | |  |  |  | | Average | % | 1,6667 | |  | mWh | 0,6363 | |  |  |  | | Variance | % | 0,0433 | |  | mWh | 0,0086 |   Table 4.23 Energy Consumption of DFS on Crooked & Flat Map on PC2. | | |  |  |  | | --- | --- | --- | | A\* on Crooked & Flat Map on PC2 | | | | Start | % | 30,0000 | | mWh | 11,4550 | | Finish | % | 28,3000 | | mWh | 10,8330 | | Result | % | 1,7000 | |  | mWh | 0,6220 | | Start | % | 28,3000 | | mWh | 10,8330 | | Finish | % | 27,4000 | | mWh | 10,4930 | | Result | % | 0,9000 | |  | mWh | 0,3400 | | Start | % | 27,4000 | | mWh | 10,4930 | | Finish | % | 25,8000 | | mWh | 9,8560 | | Result | % | 1,6000 | |  | mWh | 0,6370 | |  |  |  | | Average | % | 1,4000 | |  | mWh | 0,5330 | |  |  |  | | Variance | % | 0,1900 | |  | mWh | 0,0280 |   Table 4.24 Energy consumption of A\* on Crooked & Flat Map on PC2. |
| |  |  |  | | --- | --- | --- | | Djikstra on Crooked & Flat Map on PC2 | | | | Start | % | 25,0000 | | mWh | 9,5600 | | Finish | % | 24,1000 | | mWh | 9,2050 | | Result | % | 0,9000 | |  | mWh | 0,3550 | | Start | % | 24,1000 | | mWh | 9,2050 | | Finish | % | 23,9000 | | mWh | 9,1460 | | Result | % | 0,2000 | |  | mWh | 0,0590 | | Start | % | 23,9000 | | mWh | 9,1460 | | Finish | % | 21,6000 | | mWh | 8,2430 | | Result | % | 2,3000 | |  | mWh | 0,9030 | |  |  |  | | Average | % | 1,1333 | |  | mWh | 0,4390 | |  |  |  | | Variance | % | 1,1433 | |  | mWh | 0,1834 |   Table 4.25 Energy Consumption of  Djikstra on Crooked & Flat Map on PC2. | | |  |  |  | | --- | --- | --- | | Random on Crooked & Flat Map on PC2 | | | | Start | % | 20,1000 | | mWh | 7,6660 | | Finish | % | 18,8000 | | mWh | 7,1480 | | Result | % | 1,3000 | |  | mWh | 0,5180 | | Start | % | 18,8000 | | mWh | 7,1480 | | Finish | % | 18,5000 | | mWh | 7,0890 | | Result | % | 0,3000 | |  | mWh | 0,0590 | | Start | % | 18,5000 | | mWh | 7,0890 | | Finish | % | 17,1000 | | mWh | 6,5260 | | Result | % | 1,4000 | |  | mWh | 0,5630 | |  |  |  | | Average | % | 1,0000 | |  | mWh | 0,3800 | |  |  |  | | Variance | % | 0,3700 | |  | mWh | 0,0778 |   Table 4.26 Energy Consumption of  Random on Crooked & Flat Map on PC2. | |

Bar graphs constructed from average energy consumption data in every maze category.

Figure 3 – Average energy consumption graph of algorithms on crooked maze.

Figure 4 – Average energy consumption graph of algorithms on flat maze.

Figure 4 – Average energy consumption graph of algorithms on flat & crooked maze.

**5. Analysis**

Interesting results produced on these experiments. As seen on figure 1 and figure 2 gathered data does not differ on PC1 and PC2. This shows that our methods reliable and stable. Figure 1 and figure 2 shows that A\* algorithm and Dijkstra’s algorithm takes the most time to find a path. Generally, BFS algorithm and DFS algorithm takes the least time to find a path. Figure 1 and figure 2 with table 4.10 and table 4.4 shows that BFS algorithm performs better than DFS algorithm on crooked and flat mazes in terms of runtime. A\* and Dijkstra have a big disadvantage on Flat Mazes according to figure 1 and figure 2. Most interesting result produced by experiments is that even though A\* algorithm and Dijkstra’s algorithm takes the most time, they have a considerably fair amount of energy consumption. More research needed to create a reliable result based on this assumption. Also, this energy consumption can change according to architecture and implementation. For this project, A\* algorithm and Dijkstra’s algorithm’s implementation didn’t include a tree constructed from the map. Implementing a tree constructor might increase performance.

**6. Project Evaluation**

Our project is divided in ten steps. “Labyrinth Implementation”, ”Labyrinth Elimination” and “Testing Tools” are finished at time, but “Implementation of Pathfinding Algorithms”, “Data Analysis” and “Experiments” are finished after the deadlines that we had chosen.

**7. Conclusions**

Presentation phase was actually good, but we could have done more practice. Since mazes created by Random Maze Generator had some problems, we had to edit them by hand. Due to holidays and exams, some planned meetings were missed and we could not catch the schedule that we had planned before.

**References**

CS312 Lecture 20 Dijkstra's Shortest Path Algorithm. (n.d.). Retrieved March 05, 2017, from

[https://www.cs.cornell.edu/courses/cs312/ 2002sp/lectures/lec20/lec20.htm](https://www.cs.cornell.edu/courses/cs312/%202002sp/lectures/lec20/lec20.htm)

MASSACHUSETTS INSTITUTE OF TECHNOLOGY Department of Electrical Engineering and Computer Science 6.034 Artificial Intelligence. (n.d.). Retrieved March 05, 2017, from [**http://www.ai.mit.edu/courses/6.034b/searchcomplex.pdf**](http://www.ai.mit.edu/courses/6.034b/searchcomplex.pdf)

Patel A. 2017. “Amit’s Thoughts on Pathfinding”. Retrieved from:

<http://theory.stanford.edu/~amitp/GameProgramming/index.html>

Richard E. Korf. 1985. Depth-first iterative-deepening: An optimal admissible tree search. Artificial Intelligence, 27 (September 1985), Pages 97-109,

DOI: <http://dx.doi.org/10.1016/0004-3702(85)90084-0>