Assignment

**A\* Algorithm for Solving Modified N Puzzle Problem**

Comparison report on using Manhattan Distance and Misplace Tiles as Heuristic Function

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**Introduction**

The standard n-puzzle problem is modified to have two empty locations (instead of one) allowing one to pick any one tile adjacent to any one of the two empty locations and move it to the adjacent empty location. The task here is similar to the standard N-puzzle problem, for a given starting configuration needs to rearrange the tiles by moving them into the empty locations as necessary to end up in a given goal configuration.

To solve this problem A\* search algorithm is used. For the calculation of heuristic cost, the following two heuristic functions are used.

* Manhattan distance of a tile from the current configuration to the goal configuration.
* Number of misplaced tiles compared to the goal configuration.

Since both heuristic functions are admissible, the solution is optimal in both cases. In this report, the efficiency of both heuristic functions is compared according to the number of nodes checked to obtain the solution.

**Basic Analysis**

In this experiment, 100 configurations pairs with varying grid sizes between 5 and 20 were generated. The goal configuration is generated for a start configuration by performing 30 random moves in the start configuration. Due to the limited computational power, modified n-puzzle solve function is terminated if it failed to run within 1 minute of time. So, the data used are related only to the configurations which can solve within 1 minute time constrain.

|  |  |  |
| --- | --- | --- |
|  | **Iterations in Manhattan Heuristic A\*** | **Iterations in Misplaced Heuristic A\*** |
| **Mean** | 112.35 | 436.49 |
| **Standard Deviation** | 152.41658 | 889.10825 |
| **Min** | 838 | 5226 |
| **Max** | 5 | 5 |

**Paired t-test**

* H0 = 0 = A\* search with Manhattan distance heuristic function and Misplaced tile heuristic function is equal.
* HA = A\* search with Manhattan distance heuristic function and Misplaced tile heuristic function is not equal.
* degree of freedom = 100 -1 = 99

Calculations in paired t-test.

(Considered Misplaced – Manhattan for each raw data)

* Mean: 324.14
* Standard Deviation: 774.16551
* Standard Error of Mean: 77.41655
* T- value: 4.18695

Let significance value α = 0.05  
tcritical ~ 1.98 < 4.18695  
Though reject the null hypothesis.  
  
So, Manhattan heuristic function perform better than Misplaced heuristic function for solving  
Modified N puzzle problem.

**Annex: Raw Data**

|  |  |  |  |
| --- | --- | --- | --- |
| # | N x N size | Manhattan Cost | Misplaced Cost |
| 1 | 5 | 41 | 99 |
| 2 | 5 | 273 | 448 |
| 3 | 5 | 821 | 1920 |
| 4 | 5 | 30 | 41 |
| 5 | 5 | 97 | 279 |
| 6 | 5 | 36 | 125 |
| 7 | 5 | 71 | 122 |
| 8 | 5 | 37 | 132 |
| 9 | 5 | 35 | 118 |
| 10 | 5 | 367 | 3543 |
| 11 | 5 | 12 | 12 |
| 12 | 5 | 100 | 343 |
| 13 | 5 | 24 | 24 |
| 14 | 5 | 7 | 12 |
| 15 | 5 | 57 | 110 |
| 16 | 5 | 61 | 370 |
| 17 | 5 | 16 | 16 |
| 18 | 5 | 40 | 40 |
| 19 | 5 | 45 | 71 |
| 20 | 5 | 447 | 1391 |
| 21 | 5 | 20 | 20 |
| 22 | 5 | 50 | 376 |
| 23 | 5 | 18 | 18 |
| 24 | 5 | 72 | 144 |
| 25 | 5 | 49 | 535 |
| 26 | 5 | 50 | 50 |
| 27 | 5 | 38 | 44 |
| 28 | 5 | 58 | 78 |
| 29 | 5 | 49 | 73 |
| 30 | 5 | 11 | 14 |
| 31 | 5 | 94 | 212 |
| 32 | 5 | 63 | 79 |
| 33 | 5 | 27 | 87 |
| 34 | 5 | 12 | 14 |
| 35 | 5 | 64 | 130 |
| 36 | 5 | 112 | 930 |
| 37 | 5 | 16 | 16 |
| 38 | 5 | 46 | 107 |
| 39 | 5 | 5 | 5 |
| 40 | 5 | 20 | 20 |
| 41 | 5 | 20 | 20 |
| 42 | 5 | 314 | 505 |
| 43 | 5 | 73 | 224 |
| 44 | 5 | 495 | 5226 |
| 45 | 5 | 33 | 33 |
| 46 | 5 | 42 | 42 |
| 47 | 5 | 64 | 233 |
| 48 | 5 | 117 | 406 |
| 49 | 5 | 80 | 150 |
| 50 | 5 | 40 | 40 |
| 51 | 6 | 838 | 2662 |
| 52 | 6 | 154 | 1455 |
| 53 | 6 | 89 | 858 |
| 54 | 6 | 33 | 56 |
| 55 | 6 | 63 | 63 |
| 56 | 6 | 48 | 193 |
| 57 | 6 | 188 | 663 |
| 58 | 6 | 26 | 35 |
| 59 | 6 | 20 | 20 |
| 60 | 6 | 32 | 32 |
| 61 | 7 | 18 | 18 |
| 62 | 7 | 22 | 37 |
| 63 | 7 | 8 | 8 |
| 64 | 7 | 329 | 863 |
| 65 | 7 | 77 | 77 |
| 66 | 7 | 448 | 3830 |
| 67 | 7 | 104 | 290 |
| 68 | 7 | 39 | 138 |
| 69 | 7 | 14 | 14 |
| 70 | 7 | 36 | 93 |
| 71 | 8 | 76 | 104 |
| 72 | 8 | 49 | 49 |
| 73 | 8 | 21 | 21 |
| 74 | 8 | 91 | 152 |
| 75 | 8 | 56 | 56 |
| 76 | 8 | 287 | 956 |
| 77 | 8 | 42 | 185 |
| 78 | 8 | 40 | 40 |
| 79 | 8 | 261 | 903 |
| 80 | 8 | 427 | 3700 |
| 81 | 9 | 67 | 160 |
| 82 | 9 | 143 | 955 |
| 83 | 9 | 75 | 328 |
| 84 | 9 | 189 | 495 |
| 85 | 9 | 24 | 24 |
| 86 | 10 | 121 | 314 |
| 87 | 10 | 153 | 294 |
| 88 | 10 | 505 | 2387 |
| 89 | 10 | 208 | 294 |
| 90 | 10 | 32 | 32 |
| 91 | 11 | 49 | 46 |
| 92 | 12 | 112 | 239 |
| 93 | 13 | 225 | 536 |
| 94 | 14 | 134 | 260 |
| 95 | 15 | 96 | 96 |
| 96 | 16 | 16 | 39 |
| 97 | 17 | 90 | 119 |
| 98 | 18 | 117 | 117 |
| 99 | 19 | 45 | 45 |
| 100 | 20 | 140 | 248 |