Department of Mechanical Engineering

ME-620

Fundamentals of Artificial Intelligence

Assignment-1 Report

Submitted by –

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2nd-Sem MTech-Computational Mechanics

Evaluation of Heuristics

Sample solution 1:

Randomly generated instances –

Start State :	Goal State :
8 4 1	4 1 3
5 3 0	0 2 6
2 7 6	7 5 8

Check for solvability –

Start State-	Goal State-
Linear Representation:8,4,1,5,3,0,2,7,6	Linear Representation:4,1,3,0,2,6,7,5,8
Inversions : 8 8 Inversions	Inversions : 4 4 Inversions
4 4 Inversions	1 1 Inversion
1 1 Inversion	3 2 Inversions
5 3 Inversions	0 0 Inversions
3 2 Inversions	2 0 Inversions
0 0 Inversions	6 1 Inversion
2 0 Inversions	7 1 Inversion
7 1 Inversion	5 0 Inversions
6 0 Inversions	8 0 Inversions
Total Inversions 19 – Odd	Total Inversions 9 - Odd

Puzzle is solvable.

Program Output :

```
Heuristic_Variant - Misplaced_Tiles
Generating shortest path...
8 4 1
5 3 0
2 7 6

8 4 1
5 0 3
2 7 6

8 4 1
0 5 3
2 7 6

0 4 1
8 5 3
2 7 6

4 0 1
8 5 3
2 7 6

4 1 0
8 5 3
2 7 6

4 1 3
8 5 0
2 7 6

4 1 3
8 0 5
2 7 6
```

```
4 1 3
0 8 5
2 7 6

4 1 3
2 8 5
0 7 6

4 1 3
2 8 5
7 0 6

4 1 3
2 0 5
7 8 6

4 1 3
2 5 0
7 8 6

4 1 3
2 5 6
7 8 0

4 1 3
2 5 6
7 0 8

4 1 3
2 0 6
7 5 8

4 1 3               Total number of nodes removed from the frontier : 23064
0 2 6               Length of the solution(shortest_path) is : 17
7 5 8               Total running time(seconds) : 3.9177867
```

```
Heuristic_Variant - Manhattan_distance
Generating shortest path...
8 4 1
5 3 0
2 7 6

8 4 1
5 0 3
2 7 6

8 4 1
0 5 3
2 7 6

0 4 1
8 5 3
2 7 6

4 0 1
8 5 3
2 7 6

4 1 0
8 5 3
2 7 6

4 1 3
8 5 0
2 7 6

4 1 3
8 0 5
2 7 6

4 1 3
0 8 5
```

```
2 7 6


4 1 3
2 8 5
0 7 6

4 1 3
2 8 5
7 0 6

4 1 3
2 0 5
7 8 6

4 1 3
2 5 0
7 8 6

4 1 3
2 5 6
7 8 0

4 1 3
2 5 6
7 0 8

4 1 3
2 0 6
7 5 8

4 1 3                    Total number of nodes removed from the frontier : 9497
0 2 6                    Length of the solution(shortest_path) is : 17
7 5 8                    Total running time(seconds) : 0.9389756
```

```
Heuristic_Variant - Linear_Conflicts
Generating shortest path...
8 4 1
5 3 0
2 7 6

8 4 1
5 0 3
2 7 6

8 4 1
0 5 3
2 7 6

0 4 1
8 5 3
2 7 6

4 0 1
8 5 3
2 7 6

4 1 0
8 5 3
2 7 6

4 1 3
8 5 0
2 7 6

4 1 3
8 0 5
2 7 6

4 1 3
0 8 5
```

```
2 7 6


4 1 3
2 8 5
0 7 6


4 1 3
2 8 5
7 0 6


4 1 3
2 0 5
7 8 6


4 1 3
2 5 0
7 8 6


4 1 3
2 5 6
7 8 0


4 1 3
2 5 6
7 0 8


4 1 3
2 0 6
7 5 8


4 1 3               Total number of nodes removed from the frontier : 6462
0 2 6               Length of the solution(shortest_path) is : 17
7 5 8               Total running time(seconds) : 0.6608431
```

Sample solution 2:

Randomly generated instances –

Start State :

0 6 8

7 4 2

3 5 1

Goal State :

0 4 6

7 3 8

5 1 2

Check for solvability –

Start State-

Linear Representation:0,6,8,7,4,2,3,5,1

Inversions : 0 0 Inversions

6 5 Inversions

8 6 Inversion

7 5 Inversions

4 3 Inversions

2 1 Inversion

3 1 Inversion

5 1 Inversion

1 0 Inversions

Total Inversions 22 – Even

Goal State-

Linear Representation:0,4,6,7,3,8,5,1,2

Inversions : 0 0 Inversions

4 3 Inversions

6 4 Inversions

7 4 Inversions

3 2 Inversions

8 3 Inversions

5 2 Inversions

1 0 Inversions

2 0 Inversions

Total Inversions 18 - Even

Puzzle is solvable.

Program Output :

```
Heuristic_Variant - Misplaced_Tiles
Generating shortest path...
0 6 8
7 4 2
3 5 1

7 6 8
0 4 2
3 5 1

7 6 8
3 4 2
0 5 1

7 6 8
3 4 2
5 0 1

7 6 8
3 4 2
5 1 0

7 6 8
3 4 0
5 1 2

7 6 0
3 4 8
5 1 2

7 0 6
3 4 8
5 1 2
```

```
7 4 6
3 0 8
5 1 2

7 4 6
0 3 8
5 1 2

0 4 6               Total number of nodes removed from the frontier : 45
7 3 8               Length of the solution(shortest_path) is : 11
5 1 2               Total running time(seconds) : 0.0842902


Heuristic_Variant - Manhattan_distance
Generating shortest path...
0 6 8
7 4 2
3 5 1

7 6 8
0 4 2
3 5 1

7 6 8
3 4 2
0 5 1

7 6 8
3 4 2
5 0 1

7 6 8
3 4 2
5 1 0
```

```
7 6 8
3 4 0
5 1 2

7 6 0
3 4 8
5 1 2

7 0 6
3 4 8
5 1 2

7 4 6
3 0 8
5 1 2

7 4 6
0 3 8
5 1 2

0 4 6               Total number of nodes removed from the frontier : 42732
7 3 8               Length of the solution(shortest_path) is : 11
5 1 2               Total running time(seconds) : 9.4001867


Heuristic_Variant - Linear_Conflicts
Generating shortest path...
0 6 8
7 4 2
3 5 1

7 6 8
0 4 2
3 5 1

7 6 8
```

```
3 4 2
0 5 1

7 6 8
3 4 2
5 0 1

7 6 8
3 4 2
5 1 0

7 6 8
3 4 0
5 1 2

7 6 0
3 4 8
5 1 2

7 0 6
3 4 8
5 1 2

7 4 6
3 0 8
5 1 2

7 4 6
0 3 8
5 1 2

0 4 6               Total number of nodes removed from the frontier : 6277
7 3 8               Length of the solution(shortest_path) is : 11
5 1 2               Total running time(seconds) : 0.5266002
```

Analysis & Discussion

Judging from the factor of dominance, when 2 admissible heuristics h1 and h2 are employed in an algorithm, then the necessary condition for h2 to dominate over h1 is –

For all nodes (n) h2(n) >= h1(n)

Using a better heuristic means that we have to expand fewer nodes before the solution is found. Comparing the Misplaced Tiles heuristic with the Manhattan Distance heuristic for the start state-

Sample solution 1 : Misplaced tiles(h1) = 9

Manhattan distance(h2) = 16

Sample solution 2 : Misplaced tiles(h1) = 7

Manhattan distance(h2) = 8

In both the cases, it is clearly evident that h2 > h1. Therefore among these two, Manhattan distance is the preferred heuristic.

However, it must be noted that dominance is not the only criteria that must be considered for the evaluation of heuristics. There is a trade-off involved between the quality of estimate and work done per node in finding the right path. As heuristics get closer to the correct value, we expand fewer nodes but do more computation for determining the heuristic itself.

At the two extremes we thus have the null heuristic(requires least amount of computation) and the exact cost(requiring maximum computation).

Below we can look at the output results –

A*	Sample solution 1			Sample solution 2		
Heuristic name	Nodes removed from frontier	Running time(sec)	Length of solution	Nodes removed from frontier	Running time(sec)	Length of solution
Misplaced Tiles	23064	3.9377	17	45	0.084	11
Manhattan Distance	9497	0.9389	17	42732	9.4	11
Linked Conflicts	6462	0.6608	17	6277	0.5266	11

Looking at the table it is quite evident that the most preferred heuristic for solving the 8-puzzle is the Linked Conflicts heuristic. As the solution path length increases, the other heuristics like Misplaced Tiles take exponentially longer to find the solution, however the

Linked Conflicts heuristic manages to prune down the search tree and therefore still gives solution in reasonably shorter time.