CS 541 Artificial Intelligence

Programming Assignment 1

- **Deepa Varghese**

I] Three heuristics used:

- Manhattan distance: it provides the distance in aspects of horizontal and vertical with the respect to the goal state point location which can be calculated for two points as: $| (x_2 - x_1) - (y_2 - y_1) |$
- Euclidean distance: gives the straight-line distance using the formula for two points as shown below: $\sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$
- Misplaced tiles: here for every input it checks with the goal state position of that element and then outputs the number of required changes.

NOTE: the solution paths are printed in the reverse order

II] Manhattan Distance:

Best First Search	**A* Algorithm**
Initial State 1: [1, 2, 3, 4, 5, 6, 7, 'b', 8] Solution Path: [1, 2, 3, 4, 5, 6, 7, 'b', 8] [1, 2, 3, 4, 5, 6, 7, 8, 'b'] steps: 2	Initial State 1: [1, 2, 3, 4, 5, 6, 7, 'b', 8] Solution Path: [1, 2, 3, 4, 5, 6, 7, 8, 'b'] [1, 2, 3, 4, 5, 6, 7, 'b', 8] steps: 2
Initial State 2: [8, 1, 3, 4, 'b', 2, 7, 6, 5] Solution Path: [1, 2, 3, 4, 5, 6, 7, 8, 'b'] [1, 2, 3, 4, 5, 'b', 7, 8, 6] [1, 2, 3, 4, 'b', 5, 7, 8, 6] [1, 2, 3, 4, 8, 5, 7, 'b', 6] [1, 2, 3, 4, 8, 5, 'b', 7, 6] [1, 2, 3, 'b', 8, 5, 4, 7, 6] [1, 2, 3, 8, 'b', 5, 4, 7, 6] [1, 'b', 3, 8, 2, 5, 4, 7, 6] ['b', 1, 3, 8, 2, 5, 4, 7, 6] [8, 1, 3, 'b', 2, 5, 4, 7, 6] [8, 1, 3, 4, 2, 5, 'b', 7, 6] [8, 1, 3, 4, 2, 5, 7, 'b', 6] [8, 1, 3, 4, 2, 5, 7, 6, 'b'] [8, 1, 3, 4, 2, 'b', 7, 6, 5] [8, 1, 3, 4, 'b', 2, 7, 6, 5] steps: 15	Initial State 2: [8, 1, 3, 4, 'b', 2, 7, 6, 5] Solution Path: [1, 2, 3, 4, 5, 6, 7, 8, 'b'] [1, 2, 3, 4, 5, 'b', 7, 8, 6] [1, 2, 3, 4, 'b', 5, 7, 8, 6] [1, 2, 3, 4, 8, 5, 7, 'b', 6] [1, 2, 3, 4, 8, 5, 'b', 7, 6] [1, 2, 3, 'b', 8, 5, 4, 7, 6] [1, 2, 3, 8, 'b', 5, 4, 7, 6] [1, 'b', 3, 8, 2, 5, 4, 7, 6] ['b', 1, 3, 8, 2, 5, 4, 7, 6] [8, 1, 3, 'b', 2, 5, 4, 7, 6] [8, 1, 3, 4, 2, 5, 'b', 7, 6] [8, 1, 3, 4, 2, 5, 7, 'b', 6] [8, 1, 3, 4, 2, 5, 7, 6, 'b'] [8, 1, 3, 4, 2, 'b', 7, 6, 5] [8, 1, 3, 4, 'b', 2, 7, 6, 5] steps: 15
Initial State 3: [7, 1, 3, 4, 'b', 2, 5, 6, 8] Solution Path: [1, 2, 3, 4, 5, 6, 7, 8, 'b'] [1, 2, 3, 4, 5, 6, 7, 'b', 8] [1, 2, 3, 4, 5, 6, 'b', 7, 8]	Initial State 3: [7, 1, 3, 4, 'b', 2, 5, 6, 8] Solution Path: [1, 2, 3, 4, 5, 6, 7, 8, 'b'] [1, 2, 3, 4, 5, 6, 7, 'b', 8] [1, 2, 3, 4, 'b', 6, 7, 5, 8]

[1, 2, 3, 'b', 5, 6, 4, 7, 8] [1, 2, 3, 5, 'b', 6, 4, 7, 8] [1, 'b', 3, 5, 2, 6, 4, 7, 8] ['b', 1, 3, 5, 2, 6, 4, 7, 8] [5, 1, 3, 'b', 2, 6, 4, 7, 8] [5, 1, 3, 4, 2, 6, 'b', 7, 8] [5, 1, 3, 4, 2, 6, 7, 'b', 8] [5, 1, 3, 4, 2, 6, 7, 8, 'b'] [5, 1, 3, 4, 2, 'b', 7, 8, 6] [5, 1, 3, 4, 'b', 2, 7, 8, 6] [5, 1, 3, 'b', 4, 2, 7, 8, 6] ['b', 1, 3, 5, 4, 2, 7, 8, 6] [1, 'b', 3, 5, 4, 2, 7, 8, 6] [1, 3, 'b', 5, 4, 2, 7, 8, 6] [1, 3, 2, 5, 4, 'b', 7, 8, 6] [1, 3, 2, 5, 4, 6, 7, 8, 'b'] [1, 3, 2, 5, 4, 6, 7, 'b', 8] [1, 3, 2, 5, 'b', 6, 7, 4, 8] [1, 3, 2, 'b', 5, 6, 7, 4, 8] [1, 3, 2, 7, 5, 6, 'b', 4, 8] [1, 3, 2, 7, 5, 6, 4, 'b', 8] [1, 3, 2, 7, 'b', 6, 4, 5, 8] [1, 3, 2, 7, 6, 'b', 4, 5, 8] [1, 3, 'b', 7, 6, 2, 4, 5, 8] [1, 'b', 3, 7, 6, 2, 4, 5, 8] ['b', 1, 3, 7, 6, 2, 4, 5, 8] [7, 1, 3, 'b', 6, 2, 4, 5, 8] [7, 1, 3, 4, 6, 2, 'b', 5, 8] [7, 1, 3, 4, 6, 2, 5, 'b', 8] [7, 1, 3, 4, 'b', 2, 5, 6, 8] steps: 33	[1, 'b', 3, 4, 2, 6, 7, 5, 8] [1, 3, 'b', 4, 2, 6, 7, 5, 8] [1, 3, 6, 4, 2, 'b', 7, 5, 8] [1, 3, 6, 4, 'b', 2, 7, 5, 8] [1, 3, 6, 'b', 4, 2, 7, 5, 8] [1, 3, 6, 7, 4, 2, 'b', 5, 8] [1, 3, 6, 7, 4, 2, 5, 'b', 8] [1, 3, 6, 7, 4, 2, 5, 8, 'b'] [1, 3, 6, 7, 4, 'b', 5, 8, 2] [1, 3, 'b', 7, 4, 6, 5, 8, 2] [1, 'b', 3, 7, 4, 6, 5, 8, 2] ['b', 1, 3, 7, 4, 6, 5, 8, 2] [7, 1, 3, 'b', 4, 6, 5, 8, 2] [7, 1, 3, 4, 'b', 6, 5, 8, 2] [7, 1, 3, 4, 6, 'b', 5, 8, 2] [7, 1, 3, 4, 6, 2, 5, 8, 'b'] [7, 1, 3, 4, 6, 2, 5, 'b', 8] [7, 1, 3, 4, 'b', 2, 5, 6, 8] steps: 21
Initial State 4: [1, 6, 3, 4, 'b', 2, 5, 7, 8] Solution Path: [1, 2, 3, 4, 5, 6, 7, 8, 'b'] [1, 2, 3, 4, 5, 6, 7, 'b', 8] [1, 2, 3, 4, 5, 6, 'b', 7, 8] [1, 2, 3, 'b', 5, 6, 4, 7, 8] [1, 2, 3, 5, 'b', 6, 4, 7, 8] [1, 'b', 3, 5, 2, 6, 4, 7, 8] ['b', 1, 3, 5, 2, 6, 4, 7, 8] [5, 1, 3, 'b', 2, 6, 4, 7, 8] [5, 1, 3, 4, 2, 6, 'b', 7, 8] [5, 1, 3, 4, 2, 6, 7, 'b', 8] [5, 1, 3, 4, 2, 6, 7, 8, 'b'] [5, 1, 3, 4, 2, 'b', 7, 8, 6] [5, 1, 3, 4, 'b', 2, 7, 8, 6] [5, 1, 3, 'b', 4, 2, 7, 8, 6] ['b', 1, 3, 5, 4, 2, 7, 8, 6] [1, 'b', 3, 5, 4, 2, 7, 8, 6]	Initial State 4: [1, 6, 3, 4, 'b', 2, 5, 7, 8] Solution Path: [1, 2, 3, 4, 5, 6, 7, 8, 'b'] [1, 2, 3, 4, 5, 'b', 7, 8, 6] [1, 2, 'b', 4, 5, 3, 7, 8, 6] [1, 'b', 2, 4, 5, 3, 7, 8, 6] ['b', 1, 2, 4, 5, 3, 7, 8, 6] [4, 1, 2, 'b', 5, 3, 7, 8, 6] [4, 1, 2, 5, 'b', 3, 7, 8, 6] [4, 1, 2, 5, 3, 'b', 7, 8, 6] [4, 1, 2, 5, 3, 6, 7, 8, 'b'] [4, 1, 2, 5, 3, 6, 7, 'b', 8] [4, 1, 2, 5, 3, 6, 'b', 7, 8] [4, 1, 2, 'b', 3, 6, 5, 7, 8] ['b', 1, 2, 4, 3, 6, 5, 7, 8] [1, 'b', 2, 4, 3, 6, 5, 7, 8] [1, 3, 2, 4, 'b', 6, 5, 7, 8] [1, 3, 2, 4, 6, 'b', 5, 7, 8]

[1, 3, 'b', 5, 4, 2, 7, 8, 6] [1, 3, 2, 5, 4, 'b', 7, 8, 6] [1, 3, 2, 5, 4, 6, 7, 8, 'b'] [1, 3, 2, 5, 4, 6, 7, 'b', 8] [1, 3, 2, 5, 'b', 6, 7, 4, 8] [1, 'b', 2, 5, 3, 6, 7, 4, 8] [1, 2, 'b', 5, 3, 6, 7, 4, 8] [1, 2, 6, 5, 3, 'b', 7, 4, 8] [1, 2, 6, 5, 'b', 3, 7, 4, 8] [1, 2, 6, 5, 4, 3, 7, 'b', 8] [1, 2, 6, 5, 4, 3, 'b', 7, 8] [1, 2, 6, 'b', 4, 3, 5, 7, 8] [1, 2, 6, 4, 'b', 3, 5, 7, 8] [1, 'b', 6, 4, 2, 3, 5, 7, 8] [1, 6, 'b', 4, 2, 3, 5, 7, 8] [1, 6, 3, 4, 2, 'b', 5, 7, 8] [1, 6, 3, 4, 'b', 2, 5, 7, 8] steps: 33	[1, 3, 'b', 4, 6, 2, 5, 7, 8] [1, 'b', 3, 4, 6, 2, 5, 7, 8] [1, 6, 3, 4, 'b', 2, 5, 7, 8] steps: 19
Initial State 5: [1, 2, 3, 4, 5, 6, 'b', 7, 8] Solution Path: [1, 2, 3, 4, 5, 6, 7, 8, 'b'] [1, 2, 3, 4, 5, 6, 7, 'b', 8] [1, 2, 3, 4, 5, 6, 'b', 7, 8] steps: 3	Initial State 5: [1, 2, 3, 4, 5, 6, 'b', 7, 8] Solution Path: [1, 2, 3, 4, 5, 6, 7, 8, 'b'] [1, 2, 3, 4, 5, 6, 7, 'b', 8] [1, 2, 3, 4, 5, 6, 'b', 7, 8] steps: 3
Average: (2+15+33+33+3)/5 = 17.2	Average: (2+15+21+19+3)/5 = 12

III] Euclidean Distance:

Best First Search	**A* Algorithm**
Initial State 1: [1, 2, 3, 4, 5, 6, 7, 'b', 8] Solution Path: [1, 2, 3, 4, 5, 6, 7, 'b', 8] [1, 2, 3, 4, 5, 6, 7, 8, 'b'] steps: 2	Initial State 1: [1, 2, 3, 4, 5, 6, 7, 'b', 8] Solution Path: [1, 2, 3, 4, 5, 6, 7, 8, 'b'] [1, 2, 3, 4, 5, 6, 7, 'b', 8] steps: 2
Initial State 2: [8, 1, 3, 4, 'b', 2, 7, 6, 5] Solution Path: [1, 2, 3, 4, 5, 6, 7, 8, 'b'] [1, 2, 3, 4, 5, 6, 7, 'b', 8] [1, 2, 3, 4, 'b', 6, 7, 5, 8] [1, 'b', 3, 4, 2, 6, 7, 5, 8] [1, 3, 'b', 4, 2, 6, 7, 5, 8] [1, 3, 6, 4, 2, 'b', 7, 5, 8] [1, 3, 6, 4, 'b', 2, 7, 5, 8] [1, 3, 6, 4, 5, 2, 7, 'b', 8] [1, 3, 6, 4, 5, 2, 7, 8, 'b'] [1, 3, 6, 4, 5, 'b', 7, 8, 2] [1, 3, 'b', 4, 5, 6, 7, 8, 2] [1, 'b', 3, 4, 5, 6, 7, 8, 2]	Initial State 2: [8, 1, 3, 4, 'b', 2, 7, 6, 5] Solution Path: [1, 2, 3, 4, 5, 6, 7, 8, 'b'] [1, 2, 3, 4, 5, 6, 7, 8, 'b'] [1, 2, 3, 4, 5, 'b', 7, 8, 6] [1, 2, 3, 4, 'b', 5, 7, 8, 6] [1, 2, 3, 4, 8, 5, 7, 'b', 6] [1, 2, 3, 4, 8, 5, 'b', 7, 6] [1, 2, 3, 'b', 8, 5, 4, 7, 6] [1, 2, 3, 8, 'b', 5, 4, 7, 6] [1, 'b', 3, 8, 2, 5, 4, 7, 6] ['b', 1, 3, 8, 2, 5, 4, 7, 6] [8, 1, 3, 'b', 2, 5, 4, 7, 6] [8, 1, 3, 4, 2, 5, 'b', 7, 6]

[1, 5, 3, 4, 'b', 6, 7, 8, 2] [1, 5, 3, 4, 8, 6, 7, 'b', 2] [1, 5, 3, 4, 8, 6, 'b', 7, 2] [1, 5, 3, 'b', 8, 6, 4, 7, 2] [1, 5, 3, 8, 'b', 6, 4, 7, 2] [1, 'b', 3, 8, 5, 6, 4, 7, 2] ['b', 1, 3, 8, 5, 6, 4, 7, 2] [8, 1, 3, 'b', 5, 6, 4, 7, 2] [8, 1, 3, 4, 5, 6, 'b', 7, 2] [8, 1, 3, 4, 5, 6, 7, 'b', 2] [8, 1, 3, 4, 5, 6, 7, 2, 'b'] [8, 1, 3, 4, 5, 'b', 7, 2, 6] [8, 1, 3, 4, 'b', 5, 7, 2, 6] [8, 1, 3, 4, 2, 5, 7, 'b', 6] [8, 1, 3, 4, 2, 5, 7, 6, 'b'] [8, 1, 3, 4, 2, 'b', 7, 6, 5] [8, 1, 3, 4, 'b', 2, 7, 6, 5] steps: 29	[8, 1, 3, 4, 2, 5, 7, 'b', 6] [8, 1, 3, 4, 2, 5, 7, 6, 'b'] [8, 1, 3, 4, 2, 'b', 7, 6, 5] [8, 1, 3, 4, 'b', 2, 7, 6, 5] steps: 15
Initial State 3: [7, 1, 3, 4, 'b', 2, 5, 6, 8] Solution Path: [1, 2, 3, 4, 5, 6, 7, 8, 'b'] [1, 2, 3, 4, 5, 'b', 7, 8, 6] [1, 2, 3, 4, 'b', 5, 7, 8, 6] [1, 2, 3, 'b', 4, 5, 7, 8, 6] ['b', 2, 3, 1, 4, 5, 7, 8, 6] [2, 'b', 3, 1, 4, 5, 7, 8, 6] [2, 4, 3, 1, 'b', 5, 7, 8, 6] [2, 4, 3, 1, 5, 'b', 7, 8, 6] [2, 4, 'b', 1, 5, 3, 7, 8, 6] [2, 'b', 4, 1, 5, 3, 7, 8, 6] ['b', 2, 4, 1, 5, 3, 7, 8, 6] [1, 2, 4, 'b', 5, 3, 7, 8, 6] [1, 2, 4, 5, 'b', 3, 7, 8, 6] [1, 'b', 4, 5, 2, 3, 7, 8, 6] [1, 4, 'b', 5, 2, 3, 7, 8, 6] [1, 4, 3, 5, 2, 'b', 7, 8, 6] [1, 4, 3, 5, 'b', 2, 7, 8, 6] [1, 'b', 3, 5, 4, 2, 7, 8, 6] [1, 3, 'b', 5, 4, 2, 7, 8, 6] [1, 3, 2, 5, 4, 'b', 7, 8, 6] [1, 3, 2, 5, 4, 6, 7, 8, 'b'] [1, 3, 2, 5, 4, 6, 7, 'b', 8] [1, 3, 2, 5, 'b', 6, 7, 4, 8] [1, 'b', 2, 5, 3, 6, 7, 4, 8] [1, 2, 'b', 5, 3, 6, 7, 4, 8] [1, 2, 6, 5, 3, 'b', 7, 4, 8] [1, 2, 6, 5, 'b', 3, 7, 4, 8] [1, 'b', 6, 5, 2, 3, 7, 4, 8] [1, 6, 'b', 5, 2, 3, 7, 4, 8]	Initial State 3: [7, 1, 3, 4, 'b', 2, 5, 6, 8] Solution Path: [1, 2, 3, 4, 5, 6, 7, 8, 'b'] [1, 2, 3, 4, 5, 6, 7, 'b', 8] [1, 2, 3, 4, 'b', 6, 7, 5, 8] [1, 'b', 3, 4, 2, 6, 7, 5, 8] [1, 3, 'b', 4, 2, 6, 7, 5, 8] [1, 3, 6, 4, 2, 'b', 7, 5, 8] [1, 3, 6, 4, 'b', 2, 7, 5, 8] [1, 3, 6, 'b', 4, 2, 7, 5, 8] [1, 3, 6, 7, 4, 2, 'b', 5, 8] [1, 3, 6, 7, 4, 2, 5, 'b', 8] [1, 3, 6, 7, 4, 2, 5, 8, 'b'] [1, 3, 6, 7, 4, 'b', 5, 8, 2] [1, 3, 'b', 7, 4, 6, 5, 8, 2] [1, 'b', 3, 7, 4, 6, 5, 8, 2] ['b', 1, 3, 7, 4, 6, 5, 8, 2] [7, 1, 3, 'b', 4, 6, 5, 8, 2] [7, 1, 3, 4, 'b', 6, 5, 8, 2] [7, 1, 3, 4, 6, 'b', 5, 8, 2] [7, 1, 3, 4, 6, 2, 5, 8, 'b'] [7, 1, 3, 4, 6, 2, 5, 'b', 8] [7, 1, 3, 4, 'b', 2, 5, 6, 8] steps: 21

[1, 6, 3, 5, 2, 'b', 7, 4, 8] [1, 6, 3, 5, 'b', 2, 7, 4, 8] [1, 6, 3, 5, 4, 2, 7, 'b', 8] [1, 6, 3, 5, 4, 2, 7, 8, 'b'] [1, 6, 3, 5, 4, 'b', 7, 8, 2] [1, 6, 'b', 5, 4, 3, 7, 8, 2] [1, 'b', 6, 5, 4, 3, 7, 8, 2] [1, 4, 6, 5, 'b', 3, 7, 8, 2] [1, 4, 6, 'b', 5, 3, 7, 8, 2] ['b', 4, 6, 1, 5, 3, 7, 8, 2] [4, 'b', 6, 1, 5, 3, 7, 8, 2] [4, 6, 'b', 1, 5, 3, 7, 8, 2] [4, 6, 3, 1, 5, 'b', 7, 8, 2] [4, 6, 3, 1, 'b', 5, 7, 8, 2] [4, 'b', 3, 1, 6, 5, 7, 8, 2] ['b', 4, 3, 1, 6, 5, 7, 8, 2] [1, 4, 3, 'b', 6, 5, 7, 8, 2] [1, 4, 3, 6, 'b', 5, 7, 8, 2] [1, 4, 3, 6, 5, 'b', 7, 8, 2] [1, 4, 3, 6, 5, 2, 7, 8, 'b'] [1, 4, 3, 6, 5, 2, 7, 'b', 8] [1, 4, 3, 6, 'b', 2, 7, 5, 8] [1, 4, 3, 'b', 6, 2, 7, 5, 8] [1, 4, 3, 7, 6, 2, 'b', 5, 8] [1, 4, 3, 7, 6, 2, 5, 'b', 8] [1, 4, 3, 7, 6, 2, 5, 8, 'b'] [1, 4, 3, 7, 6, 'b', 5, 8, 2] [1, 4, 3, 7, 'b', 6, 5, 8, 2] [1, 'b', 3, 7, 4, 6, 5, 8, 2] ['b', 1, 3, 7, 4, 6, 5, 8, 2] [7, 1, 3, 'b', 4, 6, 5, 8, 2] [7, 1, 3, 4, 'b', 6, 5, 8, 2] [7, 1, 3, 4, 6, 'b', 5, 8, 2] [7, 1, 3, 4, 6, 2, 5, 8, 'b'] [7, 1, 3, 4, 6, 2, 5, 'b', 8] [7, 1, 3, 4, 'b', 2, 5, 6, 8] steps: 65	
Initial State 4: [1, 6, 3, 4, 'b', 2, 5, 7, 8] Solution Path: [1, 2, 3, 4, 5, 6, 7, 8, 'b'] [1, 2, 3, 4, 5, 'b', 7, 8, 6] [1, 2, 3, 4, 'b', 5, 7, 8, 6] [1, 2, 3, 'b', 4, 5, 7, 8, 6] ['b', 2, 3, 1, 4, 5, 7, 8, 6] [2, 'b', 3, 1, 4, 5, 7, 8, 6] [2, 4, 3, 1, 'b', 5, 7, 8, 6] [2, 4, 3, 1, 5, 'b', 7, 8, 6] [2, 4, 'b', 1, 5, 3, 7, 8, 6] [2, 'b', 4, 1, 5, 3, 7, 8, 6]	Initial State 4: [1, 6, 3, 4, 'b', 2, 5, 7, 8] Solution Path: [1, 2, 3, 4, 5, 6, 7, 8, 'b'] [1, 2, 3, 4, 5, 'b', 7, 8, 6] [1, 2, 'b', 4, 5, 3, 7, 8, 6] [1, 'b', 2, 4, 5, 3, 7, 8, 6] ['b', 1, 2, 4, 5, 3, 7, 8, 6] [4, 1, 2, 'b', 5, 3, 7, 8, 6] [4, 1, 2, 5, 'b', 3, 7, 8, 6] [4, 1, 2, 5, 3, 'b', 7, 8, 6] [4, 1, 2, 5, 3, 6, 7, 8, 'b'] [4, 1, 2, 5, 3, 6, 7, 'b', 8]

['b', 2, 4, 1, 5, 3, 7, 8, 6] [1, 2, 4, 'b', 5, 3, 7, 8, 6] [1, 2, 4, 5, 'b', 3, 7, 8, 6] [1, 'b', 4, 5, 2, 3, 7, 8, 6] [1, 4, 'b', 5, 2, 3, 7, 8, 6] [1, 4, 3, 5, 2, 'b', 7, 8, 6] [1, 4, 3, 5, 'b', 2, 7, 8, 6] [1, 'b', 3, 5, 4, 2, 7, 8, 6] [1, 3, 'b', 5, 4, 2, 7, 8, 6] [1, 3, 2, 5, 4, 'b', 7, 8, 6] [1, 3, 2, 5, 4, 6, 7, 8, 'b'] [1, 3, 2, 5, 4, 6, 7, 'b', 8] [1, 3, 2, 5, 'b', 6, 7, 4, 8] [1, 'b', 2, 5, 3, 6, 7, 4, 8] [1, 2, 'b', 5, 3, 6, 7, 4, 8] [1, 2, 6, 5, 3, 'b', 7, 4, 8] [1, 2, 6, 5, 'b', 3, 7, 4, 8] [1, 2, 6, 5, 4, 3, 7, 'b', 8] [1, 2, 6, 5, 4, 3, 'b', 7, 8] [1, 2, 6, 'b', 4, 3, 5, 7, 8] [1, 2, 6, 4, 'b', 3, 5, 7, 8] [1, 'b', 6, 4, 2, 3, 5, 7, 8] [1, 6, 'b', 4, 2, 3, 5, 7, 8] [1, 6, 3, 4, 2, 'b', 5, 7, 8] [1, 6, 3, 4, 'b', 2, 5, 7, 8] steps: 35	[4, 1, 2, 5, 3, 6, 'b', 7, 8] [4, 1, 2, 'b', 3, 6, 5, 7, 8] ['b', 1, 2, 4, 3, 6, 5, 7, 8] [1, 'b', 2, 4, 3, 6, 5, 7, 8] [1, 3, 2, 4, 'b', 6, 5, 7, 8] [1, 3, 2, 4, 6, 'b', 5, 7, 8] [1, 3, 'b', 4, 6, 2, 5, 7, 8] [1, 'b', 3, 4, 6, 2, 5, 7, 8] [1, 6, 3, 4, 'b', 2, 5, 7, 8] steps: 19
Initial State 5: [1, 2, 3, 4, 5, 6, 'b', 7, 8] Solution Path: [1, 2, 3, 4, 5, 6, 7, 8, 'b'] [1, 2, 3, 4, 5, 6, 7, 'b', 8] [1, 2, 3, 4, 5, 6, 'b', 7, 8] steps: 3	Initial State 5: [1, 2, 3, 4, 5, 6, 'b', 7, 8] Solution Path: [1, 2, 3, 4, 5, 6, 7, 8, 'b'] [1, 2, 3, 4, 5, 6, 7, 'b', 8] [1, 2, 3, 4, 5, 6, 'b', 7, 8] steps: 3
Average: (2+29+65+35+3)/5 = 26.8	Average: (2+15+21+19+3)/5 = 12

IV] Misplaced Tiles:

Best First Search	**A* Algorithm**
Initial State 1: [1, 2, 3, 4, 5, 6, 7, 'b', 8] Solution Path: [1, 2, 3, 4, 5, 6, 7, 'b', 8] [1, 2, 3, 4, 5, 6, 7, 8, 'b'] steps: 2	Initial State 1: [1, 2, 3, 4, 5, 6, 7, 'b', 8] Solution Path: [1, 2, 3, 4, 5, 6, 7, 8, 'b'] [1, 2, 3, 4, 5, 6, 7, 'b', 8] steps: 2
Initial State 2: [8, 1, 3, 4, 'b', 2, 7, 6, 5] Solution Path: [1, 2, 3, 4, 5, 6, 7, 8, 'b'] [1, 2, 3, 4, 5, 6, 7, 'b', 8] [1, 2, 3, 4, 'b', 6, 7, 5, 8] [1, 'b', 3, 4, 2, 6, 7, 5, 8]	Initial State 2: [8, 1, 3, 4, 'b', 2, 7, 6, 5] Solution Path: [1, 2, 3, 4, 5, 6, 7, 8, 'b'] [1, 2, 3, 4, 5, 'b', 7, 8, 6] [1, 2, 3, 4, 'b', 5, 7, 8, 6]

[1, 3, 'b', 4, 2, 6, 7, 5, 8] [1, 3, 6, 4, 2, 'b', 7, 5, 8] [1, 3, 6, 4, 'b', 2, 7, 5, 8] [1, 3, 6, 4, 5, 2, 7, 'b', 8] [1, 3, 6, 4, 5, 2, 7, 8, 'b'] [1, 3, 6, 4, 5, 'b', 7, 8, 2] [1, 3, 'b', 4, 5, 6, 7, 8, 2] [1, 'b', 3, 4, 5, 6, 7, 8, 2] [1, 5, 3, 4, 'b', 6, 7, 8, 2] [1, 5, 3, 4, 8, 6, 7, 'b', 2] [1, 5, 3, 4, 8, 6, 'b', 7, 2] [1, 5, 3, 'b', 8, 6, 4, 7, 2] [1, 5, 3, 8, 'b', 6, 4, 7, 2] [1, 'b', 3, 8, 5, 6, 4, 7, 2] ['b', 1, 3, 8, 5, 6, 4, 7, 2] [8, 1, 3, 'b', 5, 6, 4, 7, 2] [8, 1, 3, 4, 5, 6, 'b', 7, 2] [8, 1, 3, 4, 5, 6, 7, 'b', 2] [8, 1, 3, 4, 'b', 6, 7, 5, 2] [8, 1, 3, 4, 6, 'b', 7, 5, 2] [8, 1, 3, 4, 6, 2, 7, 5, 'b'] [8, 1, 3, 4, 6, 2, 7, 'b', 5] [8, 1, 3, 4, 'b', 2, 7, 6, 5] steps: 27	[1, 2, 3, 4, 8, 5, 7, 'b', 6] [1, 2, 3, 4, 8, 5, 'b', 7, 6] [1, 2, 3, 'b', 8, 5, 4, 7, 6] [1, 2, 3, 8, 'b', 5, 4, 7, 6] [1, 'b', 3, 8, 2, 5, 4, 7, 6] ['b', 1, 3, 8, 2, 5, 4, 7, 6] [8, 1, 3, 'b', 2, 5, 4, 7, 6] [8, 1, 3, 4, 2, 5, 'b', 7, 6] [8, 1, 3, 4, 2, 5, 7, 'b', 6] [8, 1, 3, 4, 2, 5, 7, 6, 'b'] [8, 1, 3, 4, 2, 'b', 7, 6, 5] [8, 1, 3, 4, 'b', 2, 7, 6, 5] steps: 15
Initial State 3: [7, 1, 3, 4, 'b', 2, 5, 6, 8] Solution Path: [1, 2, 3, 4, 5, 6, 7, 8, 'b'] [1, 2, 3, 4, 5, 6, 7, 'b', 8] [1, 2, 3, 4, 'b', 6, 7, 5, 8] [1, 'b', 3, 4, 2, 6, 7, 5, 8] [1, 3, 'b', 4, 2, 6, 7, 5, 8] [1, 3, 6, 4, 2, 'b', 7, 5, 8] [1, 3, 6, 4, 'b', 2, 7, 5, 8] [1, 3, 6, 4, 5, 2, 7, 'b', 8] [1, 3, 6, 4, 5, 2, 7, 8, 'b'] [1, 3, 6, 4, 5, 'b', 7, 8, 2] [1, 3, 'b', 4, 5, 6, 7, 8, 2] [1, 'b', 3, 4, 5, 6, 7, 8, 2] [1, 5, 3, 4, 'b', 6, 7, 8, 2] [1, 5, 3, 'b', 4, 6, 7, 8, 2] [1, 5, 3, 7, 4, 6, 'b', 8, 2] [1, 5, 3, 7, 4, 6, 8, 'b', 2] [1, 5, 3, 7, 'b', 6, 8, 4, 2] [1, 'b', 3, 7, 5, 6, 8, 4, 2] ['b', 1, 3, 7, 5, 6, 8, 4, 2] [7, 1, 3, 'b', 5, 6, 8, 4, 2] [7, 1, 3, 5, 'b', 6, 8, 4, 2] [7, 1, 3, 5, 4, 6, 8, 'b', 2] [7, 1, 3, 5, 4, 6, 'b', 8, 2]	Initial State 3: [7, 1, 3, 4, 'b', 2, 5, 6, 8] Solution Path: [1, 2, 3, 4, 5, 6, 7, 8, 'b'] [1, 2, 3, 4, 5, 6, 7, 'b', 8] [1, 2, 3, 4, 'b', 6, 7, 5, 8] [1, 'b', 3, 4, 2, 6, 7, 5, 8] [1, 3, 'b', 4, 2, 6, 7, 5, 8] [1, 3, 6, 4, 2, 'b', 7, 5, 8] [1, 3, 6, 4, 'b', 2, 7, 5, 8] [1, 3, 6, 'b', 4, 2, 7, 5, 8] [1, 3, 6, 7, 4, 2, 'b', 5, 8] [1, 3, 6, 7, 4, 2, 5, 'b', 8] [1, 3, 6, 7, 4, 2, 5, 8, 'b'] [1, 3, 6, 7, 4, 'b', 5, 8, 2] [1, 3, 'b', 7, 4, 6, 5, 8, 2] [1, 'b', 3, 7, 4, 6, 5, 8, 2] ['b', 1, 3, 7, 4, 6, 5, 8, 2] [7, 1, 3, 'b', 4, 6, 5, 8, 2] [7, 1, 3, 4, 'b', 6, 5, 8, 2] [7, 1, 3, 4, 6, 'b', 5, 8, 2] [7, 1, 3, 4, 6, 2, 5, 8, 'b'] [7, 1, 3, 4, 6, 2, 5, 'b', 8] [7, 1, 3, 4, 'b', 2, 5, 6, 8] steps: 21

[7, 1, 3, 'b', 4, 6, 5, 8, 2] [7, 1, 3, 4, 'b', 6, 5, 8, 2] [7, 1, 3, 4, 6, 'b', 5, 8, 2] [7, 1, 3, 4, 6, 2, 5, 8, 'b'] [7, 1, 3, 4, 6, 2, 5, 'b', 8] [7, 1, 3, 4, 'b', 2, 5, 6, 8] steps: 29	
Initial State 4: [1, 6, 3, 4, 'b', 2, 5, 7, 8] Solution Path: [1, 2, 3, 4, 5, 6, 7, 8, 'b'] [1, 2, 3, 4, 5, 6, 7, 'b', 8] [1, 2, 3, 4, 'b', 6, 7, 5, 8] [1, 'b', 3, 4, 2, 6, 7, 5, 8] [1, 3, 'b', 4, 2, 6, 7, 5, 8] [1, 3, 6, 4, 2, 'b', 7, 5, 8] [1, 3, 6, 4, 'b', 2, 7, 5, 8] [1, 3, 6, 4, 5, 2, 7, 'b', 8] [1, 3, 6, 4, 5, 2, 7, 8, 'b'] [1, 3, 6, 4, 5, 'b', 7, 8, 2] [1, 3, 'b', 4, 5, 6, 7, 8, 2] [1, 'b', 3, 4, 5, 6, 7, 8, 2] [1, 5, 3, 4, 'b', 6, 7, 8, 2] [1, 5, 3, 4, 6, 'b', 7, 8, 2] [1, 5, 'b', 4, 6, 3, 7, 8, 2] [1, 'b', 5, 4, 6, 3, 7, 8, 2] [1, 6, 5, 4, 'b', 3, 7, 8, 2] [1, 6, 5, 'b', 4, 3, 7, 8, 2] ['b', 6, 5, 1, 4, 3, 7, 8, 2] [6, 'b', 5, 1, 4, 3, 7, 8, 2] [6, 5, 'b', 1, 4, 3, 7, 8, 2] [6, 5, 3, 1, 4, 'b', 7, 8, 2] [6, 5, 3, 1, 'b', 4, 7, 8, 2] [6, 'b', 3, 1, 5, 4, 7, 8, 2] ['b', 6, 3, 1, 5, 4, 7, 8, 2] [1, 6, 3, 'b', 5, 4, 7, 8, 2] [1, 6, 3, 5, 'b', 4, 7, 8, 2] [1, 6, 3, 5, 4, 'b', 7, 8, 2] [1, 6, 3, 5, 4, 2, 7, 8, 'b'] [1, 6, 3, 5, 4, 2, 7, 'b', 8] [1, 6, 3, 5, 4, 2, 'b', 7, 8] [1, 6, 3, 'b', 4, 2, 5, 7, 8] [1, 6, 3, 4, 'b', 2, 5, 7, 8] steps: 33	Initial State 4: [1, 6, 3, 4, 'b', 2, 5, 7, 8] Solution Path: [1, 2, 3, 4, 5, 6, 7, 8, 'b'] [1, 2, 3, 4, 5, 'b', 7, 8, 6] [1, 2, 'b', 4, 5, 3, 7, 8, 6] [1, 'b', 2, 4, 5, 3, 7, 8, 6] ['b', 1, 2, 4, 5, 3, 7, 8, 6] [4, 1, 2, 'b', 5, 3, 7, 8, 6] [4, 1, 2, 5, 'b', 3, 7, 8, 6] [4, 1, 2, 5, 3, 'b', 7, 8, 6] [4, 1, 2, 5, 3, 6, 7, 8, 'b'] [4, 1, 2, 5, 3, 6, 7, 'b', 8] [4, 1, 2, 5, 3, 6, 'b', 7, 8] [4, 1, 2, 'b', 3, 6, 5, 7, 8] ['b', 1, 2, 4, 3, 6, 5, 7, 8] [1, 'b', 2, 4, 3, 6, 5, 7, 8] [1, 3, 2, 4, 'b', 6, 5, 7, 8] [1, 3, 2, 4, 6, 'b', 5, 7, 8] [1, 3, 'b', 4, 6, 2, 5, 7, 8] [1, 'b', 3, 4, 6, 2, 5, 7, 8] [1, 6, 3, 4, 'b', 2, 5, 7, 8] steps: 19
Initial State 5: [1, 2, 3, 4, 5, 6, 'b', 7, 8] Solution Path: [1, 2, 3, 4, 5, 6, 7, 8, 'b'] [1, 2, 3, 4, 5, 6, 7, 'b', 8] [1, 2, 3, 4, 5, 6, 'b', 7, 8] steps: 3	Initial State 5: [1, 2, 3, 4, 5, 6, 'b', 7, 8] Solution Path: [1, 2, 3, 4, 5, 6, 7, 8, 'b'] [1, 2, 3, 4, 5, 6, 7, 'b', 8] [1, 2, 3, 4, 5, 6, 'b', 7, 8] steps: 3
Average: (2+27+29+33+3)/5 = 18.8	Average: (2+15+21+19+3)/5 = 12

Summary:

If you consider BFS v/s A* algorithms, A* by far performed better than BFS, since it beat the number of steps taken in every example tried, for every heuristic tried.
Then, if you consider how BFS fared against the different types of heuristics used, BFS seems to perform erratically different depending on the heuristic. For BFS, f(n) only depends on h(n), thus the strength of each type of heuristic used is clearly showcased when using BFS. As such, the selection should be made carefully. If we see in the heuristics chosen above, manhattan distance seemed to serve best, followed closely by number of misplaced tiles. Euclidean falls quite a few grades behind. Instinctively, the heuristic that served well is the one that corresponds to the nature of the game. The ability to move a tile only up or down corresponds directly to manhanttan distance.
Now, if you consider A*, the heuristic used on the 5 inputs did not tip the scale in any direction whatsoever. Since A* considers both g(n) and h(n), g(n) i.e. the cost of reaching the current node from the root node seems and h(n) seem to balance each other and present the cheapest path to the goal. Thus making A* the superior algorithm. Therefore, as long as the heuristic is admissible and consistent, A* should be able to give uniformly best results.

Extra Credit: 15 puzzle
NOTE: Ensure that the size of the input and output is the same.
For most of the relatively medium level inputs, the 15 puzzle code couldn't return a solution within the arbitrary number of steps.

I] Manhattan Distance:

Best First Search	**A* Algorithm**
Initial Path 1: [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 'b'] Steps: 2	Initial Path 1: [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 'b'] Steps; 2
Initial Path 2: [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 'b', 13, 14, 15] Steps: 4	Initial Path 2: [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 'b', 13, 14, 15] Steps: 4
Initial Path 3: [15, 2, 3, 'b', 5, 6, 8, 4, 9, 10, 7, 11, 13, 14, 1, 12] Steps: Unreachable	Initial Path 3: [15, 2, 3, 'b', 5, 6, 8, 4, 9, 10, 7, 11, 13, 14, 1, 12] Steps: Unreachable
Initial Path 4: [1, 2, 3, 'b', 5, 6, 8, 4, 9, 10, 7, 11, 13, 14, 15, 12] Steps: 6	Initial Path 4: [1, 2, 3, 'b', 5, 6, 8, 4, 9, 10, 7, 11, 13, 14, 15, 12] Steps: 6
Initial Path 5: ['b', 6, 2, 3, 1, 5, 8, 4, 9, 11, 7, 12, 13, 10, 14, 15] Steps: Unreachable	Initial Path 5: ['b', 6, 2, 3, 1, 5, 8, 4, 9, 11, 7, 12, 13, 10, 14, 15] Steps: Unreachable
Average: 4	Average: 4

II] Euclidean Distance:

Best First Search	**A* Algorithm**
Initial Path 1: [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 'b']	Initial Path 1: [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 'b']

Steps: 2	Steps: 2
Initial Path 2: [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 'b', 13, 14, 15] Steps: 4	Initial Path 2: [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 'b', 13, 14, 15] Steps: 4
Initial Path 3: [15, 2, 3, 'b', 5, 6, 8, 4, 9, 10, 7, 11, 13, 14, 1, 12] Steps: Unreachable	Initial Path 3: [15, 2, 3, 'b', 5, 6, 8, 4, 9, 10, 7, 11, 13, 14, 1, 12] Steps: Unreachable
Initial Path 4: [1, 2, 3, 'b', 5, 6, 8, 4, 9, 10, 7, 11, 13, 14, 15, 12] Steps: 6	Initial Path 4: [1, 2, 3, 'b', 5, 6, 8, 4, 9, 10, 7, 11, 13, 14, 15, 12] Steps: 6
Initial Path 5: ['b', 6, 2, 3, 1, 5, 8, 4, 9, 11, 7, 12, 13, 10, 14, 15] Steps: Unreachable	Initial Path 5: ['b', 6, 2, 3, 1, 5, 8, 4, 9, 11, 7, 12, 13, 10, 14, 15] Steps: Unreachable
Average: 4	Average: 4

III] Misplaced Tiles:

Best First Search	**A* Algorithm**
Initial Path 1: [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 'b'] Steps: 2	Initial Path 1: [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 'b'] Steps: 2
Initial Path 2: [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 'b', 13, 14, 15] Steps: 4	Initial Path 2: [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 'b', 13, 14, 15] Steps: 4
Initial Path 3: [15, 2, 3, 'b', 5, 6, 8, 4, 9, 10, 7, 11, 13, 14, 1, 12] Steps: Unreachable	Initial Path 3: [15, 2, 3, 'b', 5, 6, 8, 4, 9, 10, 7, 11, 13, 14, 1, 12] Steps: Unreachable
Initial Path 4: [1, 2, 3, 'b', 5, 6, 8, 4, 9, 10, 7, 11, 13, 14, 15, 12] Steps: 6	Initial Path 4: [1, 2, 3, 'b', 5, 6, 8, 4, 9, 10, 7, 11, 13, 14, 15, 12] Steps: 6
Initial Path 5: ['b', 6, 2, 3, 1, 5, 8, 4, 9, 11, 7, 12, 13, 10, 14, 15] Steps: Unreachable	Initial Path 5: ['b', 6, 2, 3, 1, 5, 8, 4, 9, 11, 7, 12, 13, 10, 14, 15] Steps: Unreachable
Average: 4	Average: 4