Project I - Explanation
COMP 472 NN 2214
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Experiment #1 (Greater Challenge)

Start State: (5 1 4 7 B 6 3 8 2)

5	1	4
7		6
3	8	2

Goal State: (1 2 3 8 B 4 7 6 5)

1	2	3
8		4
7	6	5

	Best First Search		**A* Search**	
Heuristics	**Nodes Explored**	**Solution Path Length**	**Nodes Explored**	**Solution Path Length**
Hamming Distance	1,037	52	4,030	20
Manhattan Distance	237	38	139	20
Permutation Inverse	721	76	310	20
Nilsson's Sequence (Inadmissible)	96	46	377	30

Search Type	**Nodes Explored**	**Solution Path Length**
Depth First Search (DFS)	Recursion limit reached	Recursion limit reached
Breadth First Search (BFS)	48,169	20

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Experiment #2 (Challenge)

Start State: (2 8 3 1 6 4 7 B 5)

2	8	3
1	6	4
7		5

Goal State: (1 2 3 8 B 4 7 6 5)

1	2	3
8		4
7	6	5

	Best First Search		**A* Search**	
Heuristics	**Nodes Explored**	**Solution Path Length**	**Nodes Explored**	**Solution Path Length**
Hamming Distance	7	5	7	5
Manhattan Distance	6	5	6	5
Permutation Inverse	6	5	7	5
Nilsson's Sequence (Inadmissible)	6	5	6	5

Search Type	**Nodes Explored**	**Solution Path Length**
Depth First Search (DFS)	181,417	31
Breadth First Search (BFS)	46	5

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Experiment #3

Start State: (3 8 6 4 5 B 1 7 2)

3	8	6
4	5	
1	7	2

Goal State: (1 2 3 8 B 4 7 6 5)

1	2	3
8		4
7	6	5

	Best First Search		**A* Search**	
Heuristics	**Nodes Explored**	**Solution Path Length**	**Nodes Explored**	**Solution Path Length**
Hamming Distance	133	21	5,501	21
Manhattan Distance	156	21	274	21
Permutation Inverse	398	31	896	21
Nilsson's Sequence (Inadmissible)	34	29	36	21

Search Type	**Nodes Explored**	**Solution Path Length**
Depth First Search (DFS)	Recursion Limit Reached	Recursion Limit Reached
Breadth First Search (BFS)	60,366	21

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Experiment #4

Start State: (1 5 7 6 2 3 8 B 4)

1	5	7
6	2	3
8		4

Goal State: (1 2 3 8 B 4 7 6 5)

1	2	3
8		4
7	6	5

	Best First Search		**A* Search**	
Heuristics	**Nodes Explored**	**Solution Path Length**	**Nodes Explored**	**Solution Path Length**
Hamming Distance	305	35	2,516	19
Manhattan Distance	256	49	252	19
Permutation Inverse	398	33	367	19
Nilsson's Sequence (Inadmissible)	72	37	334	31

Search Type	**Nodes Explored**	**Solution Path Length**
Depth First Search (DFS)	431	419
Breadth First Search (BFS)	38,577	19

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Experiment #5

Start State: (3 8 4 7 5 1 6 2 B)

3	8	4
7	5	1
6	2	

Goal State: (1 2 3 8 B 4 7 6 5)

1	2	3
8		4
7	6	5

	Best First Search		A* Search	
Heuristics	**Nodes Explored**	**Solution Path Length**	**Nodes Explored**	**Solution Path Length**
Hamming Distance	458	36	540	16
Manhattan Distance	22	16	35	16
Permutation Inverse	266	32	113	16
Nilsson's Sequence (Inadmissible)	79	32	190	24

Search Type	**Nodes Explored**	**Solution Path Length**
Depth First Search (DFS)	Recursion Limit Reached	Recursion Limit Reached
Breadth First Search (BFS)	9,847	16

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Overall Results

	Best First Search		A* Search	
Heuristics	**Nodes Explored**	**Solution Path**	**Nodes Explored**	**Solution Path**
Hamming Distance	N_1	$\leq N_1$	M_1	K $(K \leq M_1)$
Manhattan Distance	N_2	$\leq N_2$	M_2	K $(K \leq M_2)$
Permutation Inverse	N_3	$\leq N_3$	M_3	K $(K \leq M_3)$
Nilsson's Sequence (Inadmissible)	N_4	$\leq N_4$	M_4	K* $(K^* \leq M_4)$ $(K^* \geq K)$

After running 5 experiments we can compile the table above with a certain degree of confidence. The experiments run are consistent with prior theoretical knowledge of search algorithms. Mainly in identifying a few keypoints.

- As long as the heuristic chosen is admissible – the A* algorithm will always return the most optimal path from the start node to the goal node.

- Depending on the heuristic, a different amount of nodes can be explored.

- Best first search does not guarantee the most optimal path, but given a good heuristic best first search may give the most optimal path.

- Best first search tends to explore fewer nodes before reaching a solution

- Inadmissible heuristics overestimate the shortest path in the case of an A* algorithm. In doing so an inadmissible heuristic using an A* algorithm does not always return the most optimal path from the start node to the goal node.

- The number of nodes explored are generally smaller in best first searches compared to A* searches. This is because an A* algorithm is in search for the most optimal solution so it must explore more possible nodes and in turn paths.

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Inadmissible Heuristic (Explanation)
Nilsson's Heuristic for 8-puzzle

```
score = distances + 3*(center + 2*successors)
```

Center

If the center tile of the 8 puzzle state does not match the center tile of the goal state then center = 1, else center = 0.

Distances

Sum of Manhattan Distances of the tiles in the 8 puzzle state.

Successors

Traverse state in clockwise order and compare to clockwise traversal of goal state.
Suppose goal state is:

A	B	C
H		D
G	F	E

Suppose current state is:

	A	C
H	B	D
G	F	E

In clockwise arrangement the current state and goal state are given as

Current state: _ACDEFGH
Goal state: ABCDEFGH

the [tile,tile clockwise to it] pairs in the current state are:
[A,C], [C,D], [D,E], [E,F], [F,G], [G,H], [H,_]
([_,A] is not considered)

the "goal" pairs are:
[A,B], [B,C], [C,D], [D,E], [E,F], [F,G], [G,H], [H,A]

There are 2 pairs that do not match the goal pairs:
[A,C], [H,_]

Hence successors = 2

Score = 2 + 3*(1+2*(2)) = 17

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Example

Suppose goal state is:

A	B	C
H		D
G	F	E

Suppose current state is:

A	B	C
	H	D
G	F	E

$h^*(n) = 1$, since tile H needs to move to the left by 1 in order to reach the goal state.

Since the center tile in the current state and goal state do not match, center = 1

With the score formula

```
score = distances + 3*(center + 2*successors)
```

center will be multiplied by 3.

3*1 > 1. Therefore the heuristic value obtained is an overestimate and therefore the Nilsson heuristic is an inadmissible heuristic.