Yan Zhen, Yifan Yao

CSE 3521

Homework #3

1. successor function and goal test function

```
 1 2 3
 4 5 6
   7 8
Action:
Move 4 down
Resultant state:
 1 2 3
   5 6
 4 8 7
-----------
Action:
Move 8 left
Resultant state:
 1 2 3
 4 5 6
 8   7
-----------
Number of expanded states is 1
(as expected).

 1 2 3
 4 5 6
 8   7
State IS NOT goal state
Number of evaluated states is 1
(as expected).

 1 2 3
 8   4
 7 6 5
State IS goal state
Number of evaluated states is 1
(as expected).
```

2. Test functions

```
 1   3
 4 2 5
 8 7 6
Action:
Move 6 down
Resultant state:
 1 2 3
 4 5
 8 7 6
-----------
Action:
Move 7 right
Resultant state:
 1 2 3
 4 5 6
 8   7
-----------
Number of expanded states is 1
(as expected).

 1 2 3
 4   5
 8 7 6
Action:
Move 2 down
Resultant state:
 1   3
 4 2 5
 8 7 6
-----------
Action:
Move 7 up

Resultant state:
 1 2 3
 4 7 5
 8   6
-----------
Action:
Move 4 right

Resultant state:
 1 2 3
   4 5
 8 7 6
-----------
Action:
Move 5 left

Resultant state:
 1 2 3
 4 5
 8 7 6
-----------
Number of expanded states is 1
(as expected).
```

The function is capable to recognize all two, three, and four potential successors. Plus, the test we ran before (with only two

successors), the function passed all scenarios.

3. breadth-first search

```
Number of states evaluated=705
Number of states expanded=420
Path length=11
-----------
 1 2 3
 4 5 6
   8 7
-----------
Move 8 left
-----------
 1 2 3
 4 5 6
 8   7
-----------
Move 7 left
-----------
 1 2 3
 4 5 6
 8 7
-----------
Move 6 down
-----------
 1 2 3
 4 5
 8 7 6
-----------
Move 5 right
-----------
 1 2 3
 4   5
 8 7 6
-----------
Move 4 right
-----------
 1 2 3
   4 5
 8 7 6
-----------
Move 8 up
-----------
 1 2 3
 8 4 5
   7 6
-----------
Move 7 left
-----------
 1 2 3
 8 4 5
 7   6
-----------
Move 6 left
-----------
 1 2 3
 8 4 5
 7 6
-----------
Move 5 down
-----------
 1 2 3
 8 4
 7 6 5
-----------
Move 4 right
-----------
 1 2 3
 8   4
 7 6 5

Number of states evaluated=11
Number of states expanded=10
Path length=6
-----------
Jug 1 volume: 7
Jug 2 volume: 0
-----------
Pour 3gal from Jug 1 into Jug 2
-----------
Jug 1 volume: 4
Jug 2 volume: 3
-----------
Empty Jug 2
-----------
Jug 1 volume: 4
Jug 2 volume: 0
-----------
Pour 3gal from Jug 1 into Jug 2
-----------
Jug 1 volume: 1
Jug 2 volume: 3
-----------
Empty Jug 2
-----------
Jug 1 volume: 1
Jug 2 volume: 0
-----------
Pour 1gal from Jug 1 into Jug 2
-----------
Jug 1 volume: 0
Jug 2 volume: 1

Number of states evaluated=6
```

```
Number of states expanded=5
Path length=4
-----------
Robot Left
Left dirt: 1
Right dirt: 1
-----------
Vaccuum: Left dirt 1 -> 0
-----------
Robot Left
Left dirt: 0
Right dirt: 1
-----------
Move right
-----------
Robot Right
Left dirt: 0
Right dirt: 1
-----------
Vaccuum: Right dirt 1 -> 0
-----------
Robot Right
Left dirt: 0
Right dirt: 0
```

4. depth-limited search

```
Number of states evaluated=643
Number of states expanded=643
-----------
No solution found!
```

5. iterative-deepening search

```
Number of states evaluated=2657
Number of states expanded=2656
Path length=11
-----------
 1 2 3
 4 5 6
   8 7
-----------
Move 8 left
-----------
 1 2 3
 4 5 6
 8 7
-----------
Move 7 left
-----------
 1 2 3
 4 5 6
 8 7
-----------
Move 6 down
-----------
 1 2 3
 4 5
 8 7 6
-----------
Move 5 right
-----------
 1 2 3
 4   5
 8 7 6
-----------
Move 4 right
-----------
 1 2 3
   4 5
 8 7 6
-----------
Move 8 up
-----------
 1 2 3
 8 4 5
   7 6
-----------
Move 7 left
-----------
 1 2 3
 8 4 5
 7 6
-----------
Move 6 left
-----------
 1 2 3
 8 4 5
 7 6
-----------
Move 5 down
-----------
 1 2 3
 8 4
 7 6 5
-----------
Move 4 right
-----------
 1 2 3
 8   4
 7 6 5
```

6. A* search algorithm

```
Number of states evaluated=29
Number of states expanded=15
Path length=11
-----------
 1 2 3
```

```
 4 5 6
   8 7
-----------
Move 8 left
-----------
 1 2 3
 4 5 6
 8 7
-----------
Move 7 left
-----------
 1 2 3
 4 5 6
 8 7
-----------
Move 6 down
-----------
 1 2 3
 4 5
 8 7 6
-----------
Move 5 right
-----------
 1 2 3
 4   5
 8 7 6
-----------
Move 4 right
-----------
 1 2 3
   4 5
 8 7 6
-----------
Move 8 up
-----------
 1 2 3
 8 4 5
   7 6
-----------
Move 7 left
-----------
 1 2 3
 8 4 5
 7 6
-----------
Move 6 left
-----------
 1 2 3
 8 4 5
 7 6
-----------
Move 5 down
-----------
 1 2 3
 8 4
 7 6 5
-----------
Move 4 right
-----------
 1 2 3
 8   4
 7 6 5
```

7. See Below

    a. Configuration 1, Breadth-first Search

```
Number of states
evaluated=53335
Number of states
expanded=36835
Path length=21
-----------
 1 2
 4 3 6
 5 8 7
-----------
Move 2 right
-----------
 1   2
 4 3 6
 5 8 7
-----------
Move 1 right
-----------
   1 2
 4 3 6
 5 8 7
-----------
Move 4 up
-----------
 4 1 2
   3 6
 5 8 7
-----------
Move 5 up
-----------
 4 1 2
 5 3 6
   8 7
-----------
Move 8 left
-----------
 4 1 2
 5 3 6
 8   7
```

```
-----------
Move 7 left
-----------
 4 1 2
 5 3 6
 8 7
-----------
Move 6 down
-----------
 4 1 2
 5 3
 8 7 6
-----------
Move 3 right
-----------
 4 1 2
 5   3
 8 7 6
-----------
Move 5 right
-----------
 4 1 2
   5 3
 8 7 6
-----------
Move 4 down
-----------
   1 2
 4 5 3
 8 7 6
-----------
Move 1 left
-----------
 1   2
 4 5 3
 8 7 6
-----------
Move 2 left
-----------
 1 2
 4 5 3
 8 7 6
-----------
Move 3 up
-----------
 1 2 3
 4 5
 8 7 6
-----------
Move 5 right
-----------
 1 2 3
 4   5
 8 7 6
-----------
Move 4 right
-----------
 1 2 3
   4 5
 8 7 6
-----------
Move 8 up
-----------
 1 2 3
 8 4 5
   7 6
-----------
Move 7 left
-----------
 1 2 3
 8 4 5
 7   6
-----------
Move 6 left
-----------
 1 2 3
 8 4 5
 7 6
-----------
Move 5 down
-----------
 1 2 3
 8 4
 7 6 5
-----------
Move 4 right
-----------
 1 2 3
 8   4
 7 6 5
```

b. Configuration 1, Iterative Deepening Search

```
Number of states
evaluated=594689
Number of states
expanded=594688
Path length=21
-----------
 1 2
 4 3 6
 5 8 7
-----------
Move 2 right
-----------
```

```
 1   2
 4 3 6
 5 8 7
-----------
Move 1 right
-----------
   1 2
 4 3 6
 5 8 7
-----------
Move 4 up
-----------
 4 1 2
   3 6
 5 8 7
-----------
Move 5 up
-----------
 4 1 2
 5 3 6
   8 7
-----------
Move 8 left
-----------
 4 1 2
 5 3 6
 8   7
-----------
Move 7 left
-----------
 4 1 2
 5 3 6
 8 7
-----------
Move 6 down
-----------
 4 1 2
 5 3
 8 7 6
-----------
Move 3 right
-----------
 4 1 2
 5   3
 8 7 6
-----------
Move 5 right
-----------
 4 1 2
   5 3
 8 7 6
-----------
Move 4 down
-----------
   1 2
 4 5 3
 8 7 6
-----------
Move 1 left
-----------
 1   2
 4 5 3
 8 7 6
-----------
Move 2 left
-----------
 1 2
 4 5 3
 8 7 6
-----------
Move 3 up
-----------
 1 2 3
 4 5
 8 7 6
-----------
Move 5 right
-----------
 1 2 3
 4   5
 8 7 6
-----------
Move 4 right
-----------
 1 2 3
   4 5
 8 7 6
-----------
Move 8 up
-----------
 1 2 3
 8 4 5
   7 6
-----------
Move 7 left
-----------
 1 2 3
 8 4 5
 7   6
-----------
Move 6 left
-----------
 1 2 3
 8 4 5
 7 6
-----------
```

```
Move 5 down
-----------
 1 2 3
 8 4
 7 6 5
-----------
Move 4 right
-----------
 1 2 3
 8   4
 7 6 5
```

c. Configuration 1, A* Search

```
Number of states
evaluated=646
Number of states
expanded=373
Path length=21
-----------
 1 2
 4 3 6
 5 8 7
-----------
Move 2 right
-----------
 1   2
 4 3 6
 5 8 7
-----------
Move 1 right
-----------
   1 2
 4 3 6
 5 8 7
-----------
Move 4 up
-----------
 4 1 2
   3 6
 5 8 7
-----------
Move 5 up
-----------
 4 1 2
 5 3 6
   8 7
-----------
Move 8 left
-----------
 4 1 2
 5 3 6
 8   7
-----------
Move 7 left
-----------
 4 1 2
 5 3 6
 8 7
-----------
Move 6 down
-----------
 4 1 2
 5 3
 8 7 6
-----------
Move 3 right
-----------
 4 1 2
 5   3
 8 7 6
-----------
Move 5 right
-----------
 4 1 2
   5 3
 8 7 6
-----------
Move 4 down
-----------
   1 2
 4 5 3
 8 7 6
-----------
Move 1 left
-----------
 1   2
 4 5 3
 8 7 6
-----------
Move 2 left
-----------
 1 2
 4 5 3
 8 7 6
-----------
Move 3 up
-----------
 1 2 3
 4 5
 8 7 6
-----------
Move 5 right
-----------
 1 2 3
 4   5
 8 7 6
```

```
-----------
Move 4 right
-----------
 1 2 3
   4 5
 8 7 6
-----------
Move 8 up
-----------
 1 2 3
 8 4 5
   7 6
-----------
Move 7 left
-----------
 1 2 3
 8 4 5
 7   6
-----------
Move 6 left
-----------
 1 2 3
 8 4 5
 7 6
-----------
Move 5 down
-----------
 1 2 3
 8 4
 7 6 5
-----------
Move 4 right
-----------
 1 2 3
 8   4
 7 6 5
```

d. Configuration 1, Depth-limited Search (BFS)

```
Number of states
evaluated=220837
Number of states
expanded=220836
Path length=21
-----------
 1 2
 4 3 6
 5 8 7
-----------
Move 2 right
-----------
 1   2
 4 3 6
 5 8 7
-----------
Move 1 right
-----------
   1 2
 4 3 6
 5 8 7
-----------
Move 4 up
-----------
 4 1 2
   3 6
 5 8 7
-----------
Move 5 up
-----------
 4 1 2
 5 3 6
   8 7
-----------
Move 8 left
-----------
 4 1 2
 5 3 6
 8   7
-----------
Move 7 left
-----------
 4 1 2
 5 3 6
 8 7
-----------
Move 6 down
-----------
 4 1 2
 5 3
 8 7 6
-----------
Move 3 right
-----------
 4 1 2
 5   3
 8 7 6
-----------
Move 5 right
-----------
 4 1 2
   5 3
 8 7 6
-----------
Move 4 down
-----------
```

```
   1 2
 4 5 3
 8 7 6
-----------
Move 1 left
-----------
 1   2
 4 5 3
 8 7 6
-----------
Move 2 left
-----------
 1 2
 4 5 3
 8 7 6
-----------
Move 3 up
-----------
 1 2 3
 4 5
 8 7 6
-----------
Move 5 right
-----------
 1 2 3
 4   5
 8 7 6
-----------
Move 4 right
-----------
 1 2 3
   4 5
 8 7 6
-----------
Move 8 up
-----------
 1 2 3
 8 4 5
   7 6
-----------
Move 7 left
-----------
 1 2 3
 8 4 5
 7   6
-----------
Move 6 left
-----------
 1 2 3
 8 4 5
 7 6
-----------
Move 5 down
-----------
 1 2 3
 8 4
 7 6 5
-----------
Move 4 right
-----------
 1 2 3
 8   4
 7 6 5
```

e. Configuration 1, Depth-limited Search (Double BFS)

```
Number of states
evaluated=595536
Number of states
expanded=595535
Path length=41
-----------
 1 2
 4 3 6
 5 8 7
-----------
Move 6 up
-----------
 1 2 6
 4 3
 5 8 7
-----------
Move 6 down
-----------
 1 2
 4 3 6
 5 8 7
-----------
Move 2 right
-----------
 1   2
 4 3 6
 5 8 7
-----------
Move 3 up
-----------
 1 3 2
 4   6
 5 8 7
-----------
Move 8 up
-----------
 1 3 2
 4 8 6
 5   7
```

```
-----------
Move 5 right
-----------
 1 3 2
 4 8 6
   5 7
-----------
Move 4 down
-----------
 1 3 2
   8 6
 4 5 7
-----------
Move 1 down
-----------
   3 2
 1 8 6
 4 5 7
-----------
Move 3 left
-----------
 3   2
 1 8 6
 4 5 7
-----------
Move 8 up
-----------
 3 8 2
 1   6
 4 5 7
-----------
Move 5 up
-----------
 3 8 2
 1 5 6
 4   7
-----------
Move 4 right
-----------
 3 8 2
 1 5 6
   4 7
-----------
Move 1 down
-----------
 3 8 2
   5 6
 1 4 7
-----------
Move 3 down
-----------
   8 2
 3 5 6
 1 4 7
-----------
Move 8 left
-----------
 8   2
 3 5 6
 1 4 7
-----------
Move 5 up
-----------
 8 5 2
 3   6
 1 4 7
-----------
Move 4 up
-----------
 8 5 2
 3 4 6
 1   7
-----------
Move 7 left
-----------
 8 5 2
 3 4 6
 1 7
-----------
Move 6 down
-----------
 8 5 2
 3 4
 1 7 6
-----------
Move 2 down
-----------
 8 5
 3 4 2
 1 7 6
-----------
Move 5 right
-----------
 8   5
 3 4 2
 1 7 6
-----------
Move 4 up
-----------
 8 4 5
 3   2
 1 7 6
-----------
Move 2 left
-----------
 8 4 5
 1 4 7
-----------
```

```
 3 2
 1 7 6
-----------
Move 5 down
-----------
 8 4
 3 2 5
 1 7 6
-----------
Move 4 right
-----------
 8   4
 3 2 5
 1 7 6
-----------
Move 2 up
-----------
 8 2 4
 3   5
 1 7 6
-----------
Move 3 right
-----------
 8 2 4
   3 5
 1 7 6
-----------
Move 8 down
-----------
   2 4
 8 3 5
 1 7 6
-----------
Move 2 left
-----------
 2   4
 8 3 5
 1 7 6
-----------
Move 3 up
-----------
 2 3 4
 8   5
 1 7 6
-----------
Move 8 right
-----------
 2 3 4
   8 5
 1 7 6
-----------
Move 1 up
-----------
```

```
 2 3 4
 1 8 5
   7 6
-----------
Move 7 left
-----------
 2 3 4
 1 8 5
 7   6
-----------
Move 6 left
-----------
 2 3 4
 1 8 5
 7 6
-----------
Move 5 down
-----------
 2 3 4
 1 8
 7 6 5
-----------
Move 4 down
-----------
 2 3
 1 8 4
 7 6 5
-----------
Move 3 right
-----------
 2   3
 1 8 4
 7 6 5
-----------
Move 2 right
-----------
   2 3
 1 8 4
 7 6 5
-----------
Move 1 up
-----------
 1 2 3
   8 4
 7 6 5
-----------
Move 8 left
-----------
 1 2 3
 8   4
 7 6 5
```

f. Configuration 2, Breadth-first Search

```
Number of states
evaluated=53335
Number of states
expanded=36835
Path length=21
-----------
 1 2
 4 3 6
 5 8 7
-----------
Move 2 right
-----------
 1   2
 4 3 6
 5 8 7
-----------
Move 1 right
-----------
   1 2
 4 3 6
 5 8 7
-----------
Move 4 up
-----------
 4 1 2
   3 6
 5 8 7
-----------
Move 5 up
-----------
 4 1 2
 5 3 6
   8 7
-----------
Move 8 left
-----------
 4 1 2
 5 3 6
 8   7
-----------
Move 7 left
-----------
 4 1 2
 5 3 6
 8 7
-----------
Move 6 down
-----------
 4 1 2
 5 3
 8 7 6
-----------
Move 3 right
-----------
 4 1 2
 5   3
 8 7 6
-----------
Move 5 right
-----------
 4 1 2
   5 3
 8 7 6
-----------
Move 4 down
-----------
   1 2
 4 5 3
 8 7 6
-----------
Move 1 left
-----------
 1   2
 4 5 3
 8 7 6
-----------
Move 2 left
-----------
 1 2
 4 5 3
 8 7 6
-----------
Move 3 up
-----------
 1 2 3
 4 5
 8 7 6
-----------
Move 5 right
-----------
 1 2 3
 4   5
 8 7 6
-----------
Move 4 right
-----------
 1 2 3
   4 5
 8 7 6
-----------
Move 8 up
-----------
```

```
 1 2 3
 8 4 5
   7 6
-----------
Move 7 left
-----------
 1 2 3
 8 4 5
 7   6
-----------
Move 6 left
-----------
 1 2 3
 8 4 5
 7 6
-----------
Move 5 down
-----------
 1 2 3
 8 4
 7 6 5
-----------
Move 4 right
-----------
 1 2 3
 8   4
 7 6 5
```

g. Configuration 2, Iterative Deepening Search

```
Number of states
evaluated=594689
Number of states
expanded=594688
Path length=21
-----------
 1 2
 4 3 6
 5 8 7
-----------
Move 2 right
-----------
 1   2
 4 3 6
 5 8 7
-----------
Move 1 right
-----------
   1 2
 4 3 6
 5 8 7
-----------
Move 4 up
-----------
 4 1 2
   3 6
 5 8 7
-----------
Move 5 up
-----------
 4 1 2
 5 3 6
   8 7
-----------
Move 8 left
-----------
 4 1 2
 5 3 6
 8   7
-----------
Move 7 left
-----------
 4 1 2
 5 3 6
 8 7
-----------
Move 6 down
-----------
 4 1 2
 5 3
 8 7 6
-----------
Move 3 right
-----------
 4 1 2
 5   3
 8 7 6
-----------
Move 5 right
-----------
 4 1 2
   5 3
 8 7 6
-----------
Move 4 down
-----------
   1 2
 4 5 3
 8 7 6
-----------
Move 1 left
-----------
 1   2
 4 5 3
 8 7 6
```

```
-----------
Move 2 left
-----------
 1 2
 4 5 3
 8 7 6
-----------
Move 3 up
-----------
 1 2 3
 4 5
 8 7 6
-----------
Move 5 right
-----------
 1 2 3
 4   5
 8 7 6
-----------
Move 4 right
-----------
 1 2 3
   4 5
 8 7 6
-----------
Move 8 up
-----------
 1 2 3
 8 4 5
   7 6
-----------
Move 7 left
-----------
 1 2 3
 8 4 5
 7   6
-----------
Move 6 left
-----------
 1 2 3
 8 4 5
 7 6
-----------
Move 5 down
-----------
 1 2 3
 8 4
 7 6 5
-----------
Move 4 right
-----------
 1 2 3
 8   4
 7 6 5
```

h. Configuration 2, A* Search

```
Number of states
evaluated=646
Number of states
expanded=373
Path length=21
-----------
 1 2
 4 3 6
 5 8 7
-----------
Move 2 right
-----------
 1   2
 4 3 6
 5 8 7
-----------
Move 1 right
-----------
   1 2
 4 3 6
 5 8 7
-----------
Move 4 up
-----------
 4 1 2
   3 6
 5 8 7
-----------
Move 5 up
-----------
 4 1 2
 5 3 6
   8 7
-----------
Move 8 left
-----------
 4 1 2
 5 3 6
 8   7
-----------
Move 7 left
-----------
 4 1 2
 5 3 6
 8 7
-----------
Move 6 down
-----------
 4 1 2
 5 3
 7 6 5
```

```
 8 7 6
-----------
Move 3 right
-----------
 4 1 2
 5   3
 8 7 6
-----------
Move 5 right
-----------
 4 1 2
   5 3
 8 7 6
-----------
Move 4 down
-----------
   1 2
 4 5 3
 8 7 6
-----------
Move 1 left
-----------
 1   2
 4 5 3
 8 7 6
-----------
Move 2 left
-----------
 1 2
 4 5 3
 8 7 6
-----------
Move 3 up
-----------
 1 2 3
 4 5
 8 7 6
-----------
Move 5 right
-----------
 1 2 3
 4   5
 8 7 6
-----------
Move 4 right
-----------
 1 2 3
   4 5
 8 7 6
-----------
Move 8 up
-----------
 1 2 3
 8 4 5
   7 6
-----------
Move 7 left
-----------
 1 2 3
 8 4 5
 7   6
-----------
Move 6 left
-----------
 1 2 3
 8 4 5
 7 6
-----------
Move 5 down
-----------
 1 2 3
 8 4
 7 6 5
-----------
Move 4 right
-----------
 1 2 3
 8   4
 7 6 5
```

i. Configuration 2, Depth-limited Search (IDS)

```
Number of states
evaluated=220837
Number of states
expanded=220836
Path length=21
-----------
 1 2
 4 3 6
 5 8 7
-----------
Move 2 right
-----------
 1   2
 4 3 6
 5 8 7
-----------
Move 1 right
-----------
   1 2
 4 3 6
 5 8 7
-----------
Move 4 up
```

```
-----------
 4 1 2
   3 6
 5 8 7
-----------
Move 5 up
-----------
 4 1 2
 5 3 6
   8 7
-----------
Move 8 left
-----------
 4 1 2
 5 3 6
 8   7
-----------
Move 7 left
-----------
 4 1 2
 5 3 6
 8 7
-----------
Move 6 down
-----------
 4 1 2
 5 3
 8 7 6
-----------
Move 3 right
-----------
 4 1 2
 5   3
 8 7 6
-----------
Move 5 right
-----------
 4 1 2
   5 3
 8 7 6
-----------
Move 4 down
-----------
   1 2
 4 5 3
 8 7 6
-----------
Move 1 left
-----------
 1   2
 4 5 3
 8 7 6
-----------
```

```
Move 2 left
-----------
 1 2
 4 5 3
 8 7 6
-----------
Move 3 up
-----------
 1 2 3
 4 5
 8 7 6
-----------
Move 5 right
-----------
 1 2 3
 4   5
 8 7 6
-----------
Move 4 right
-----------
 1 2 3
   4 5
 8 7 6
-----------
Move 8 up
-----------
 1 2 3
 8 4 5
   7 6
-----------
Move 7 left
-----------
 1 2 3
 8 4 5
 7   6
-----------
Move 6 left
-----------
 1 2 3
 8 4 5
 7 6
-----------
Move 5 down
-----------
 1 2 3
 8 4
 7 6 5
-----------
Move 4 right
-----------
 1 2 3
 8   4
 7 6 5
```

j. Configuration 2, Depth-limited Search (Double IDS)

```
Number of states
evaluated=595536
Number of states
expanded=595535
Path length=41
-----------
 1 2
 4 3 6
 5 8 7
-----------
Move 6 up
-----------
 1 2 6
 4 3
 5 8 7
-----------
Move 6 down
-----------
 1 2
 4 3 6
 5 8 7
-----------
Move 2 right
-----------
 1   2
 4 3 6
 5 8 7
-----------
Move 3 up
-----------
 1 3 2
 4   6
 5 8 7
-----------
Move 8 up
-----------
 1 3 2
 4 8 6
 5   7
-----------
Move 5 right
-----------
 1 3 2
 4 8 6
   5 7
-----------
Move 4 down
-----------
 1 3 2
   8 6
 4 5 7
-----------
Move 1 down
-----------
   3 2
 1 8 6
 4 5 7
-----------
Move 3 left
-----------
 3   2
 1 8 6
 4 5 7
-----------
Move 8 up
-----------
 3 8 2
 1   6
 4 5 7
-----------
Move 5 up
-----------
 3 8 2
 1 5 6
 4   7
-----------
Move 4 right
-----------
 3 8 2
 1 5 6
   4 7
-----------
Move 1 down
-----------
 3 8 2
   5 6
 1 4 7
-----------
Move 3 down
-----------
   8 2
 3 5 6
 1 4 7
-----------
Move 8 left
-----------
 8   2
 3 5 6
 1 4 7
-----------
Move 5 up
-----------
```

```
 8 5 2
 3   6
 1 4 7
-----------
Move 4 up
-----------
 8 5 2
 3 4 6
 1   7
-----------
Move 7 left
-----------
 8 5 2
 3 4 6
 1 7
-----------
Move 6 down
-----------
 8 5 2
 3 4
 1 7 6
-----------
Move 2 down
-----------
 8 5
 3 4 2
 1 7 6
-----------
Move 5 right
-----------
 8   5
 3 4 2
 1 7 6
-----------
Move 4 up
-----------
 8 4 5
 3   2
 1 7 6
-----------
Move 2 left
-----------
 8 4 5
 3 2
 1 7 6
-----------
Move 5 down
-----------
 8 4
 3 2 5
 1 7 6
-----------
Move 4 right
-----------
 8   4
 3 2 5
 1 7 6
-----------
Move 2 up
-----------
 8 2 4
 3   5
 1 7 6
-----------
Move 3 right
-----------
 8 2 4
   3 5
 1 7 6
-----------
Move 8 down
-----------
   2 4
 8 3 5
 1 7 6
-----------
Move 2 left
-----------
 2   4
 8 3 5
 1 7 6
-----------
Move 3 up
-----------
 2 3 4
 8   5
 1 7 6
-----------
Move 8 right
-----------
 2 3 4
   8 5
 1 7 6
-----------
Move 1 up
-----------
 2 3 4
 1 8 5
   7 6
-----------
Move 7 left
-----------
 2 3 4
 1 8 5
 7   6
-----------
```

```
Move 6 left
-----------
 2 3 4
 1 8 5
 7 6
-----------
Move 5 down
-----------
 2 3 4
 1 8
 7 6 5
-----------
Move 4 down
-----------
 2 3
 1 8 4
 7 6 5
-----------
Move 3 right
-----------
 2   3
 1 8 4
 7 6 5
-----------
Move 2 right
-----------
   2 3
 1 8 4
 7 6 5
-----------
Move 1 up
-----------
 1 2 3
   8 4
 7 6 5
-----------
Move 8 left
-----------
 1 2 3
 8   4
 7 6 5
```

The solution matches our expectations because when the number of paths from BFS or IDS means there must be a solution out there can be find for depth-limited search which totally make sense. Also, by restricting the depth of the solution can reduce the number of state evaluation because the algorithm will not generate more path since it has been restricted and it will only be evaluated from existing states. Compare to BFS and IDS, once the path is incorrect, the IDS will also search from all the wrong path no matter the path is doable or not and BFS will go through all states parallelly which is a better solution to find the solution. However, A* performed much better for all of them because it will evaluate the current state and choose the best path.

8. non-trivial board configuration

```
BFS
Number of states
evaluated=16554
Number of states
expanded=10671
Path length=18

IDS
Number of states
evaluated=135184
Number of states
expanded=135183
Path length=18

Depth-limit search (BFS)
Number of states
evaluated=30843
Number of states
expanded=30842
Path length=18

Depth-limit search (Double
BFS)
Number of states
evaluated=13619
Number of states
expanded=13618
```

```
Path length=34

A* (Total Manhattan distance
heuristic)
Number of states
evaluated=281
Number of states expanded=156
Path length=18

A* (Misplaced tiles
heuristic)
Number of states
evaluated=1358
Number of states expanded=771
Path length=18

A* (Simplest heuristic
(h(n)=0))
Number of states
evaluated=14609
Number of states
expanded=9544
Path length=18
```

As we discussed before, A* algorithms have advantages to solve specific problems like 8-puzzle, however, the difference between number of states is occurred by implementations. In conclusion, A* will “never overestimates actual distance to goal” which makes it performed better compared to BFS, IDS (even with the simplest heuristic, the performance is close to BFS which is the best case in uninformed search). In this 8-puzzle problem, we need to misplace some tile to reach the final goal which makes the number of evaluation larger than Manhattan distance which matches our expectations.