Intelligent Systems	
Project 1	
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8-puzzle Formulation

The 8-puzzle problem is a puzzle played on a 3-by-3 grid with 8 square blocks labelled 1 - 8 and a blank square. The goal is to rearrange the blocks in the initial state so that they are in the order specified by goal state. The blocks are permitted to slide horizontally or vertically into the blank square.

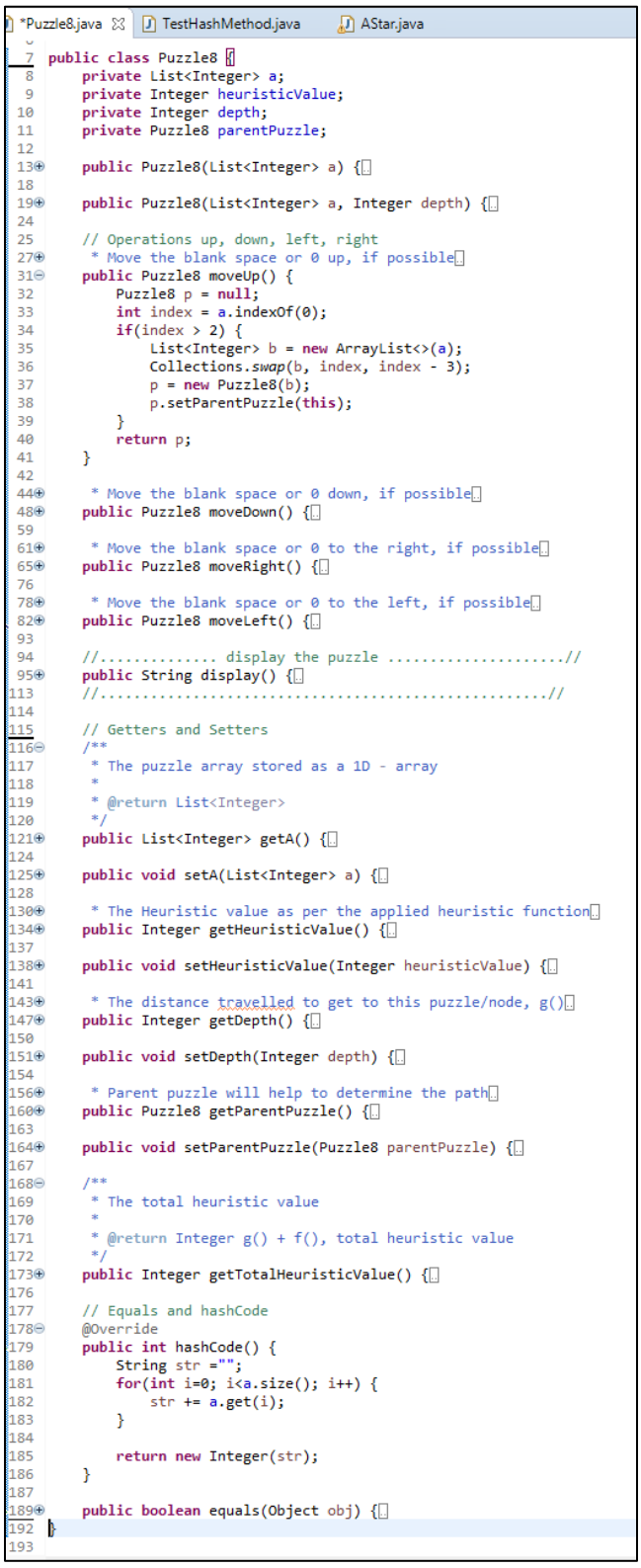
A* algorithm is a state space search algorithm which integrates characteristics of uniform-cost search and heuristic-based search to proficiently find the optimally efficient path.

The A* algorithm aims at using the heuristic as well as the distance travelled so far, combined to select the nodes from the fringe. For 8 puzzle problem, it uses two types of heuristic to find the shortest path to goal state i.e.

- Number of misplaced tiles: The count of tiles that are not present in its desired positions.
- Manhattan distance: It is the linear distance the tile must cover from the initial position to reach the goal position.

The below code aims at implementing A* algorithm using the above-defined heuristic functions to find the optimal path from user provided initial state to user provided goal state.

Program Structure



```
*Puzzle8.java   TestHashMethod.java   AStar.java
 7  public class Puzzle8 {
 8      private List<Integer> a;
 9      private Integer heuristicValue;
10      private Integer depth;
11      private Puzzle8 parentPuzzle;
12
13      public Puzzle8(List<Integer> a) {
18
19      public Puzzle8(List<Integer> a, Integer depth) {
24
25      // Operations up, down, left, right
27       * Move the blank space or 0 up, if possible
31      public Puzzle8 moveUp() {
32          Puzzle8 p = null;
33          int index = a.indexOf(0);
34          if(index > 2) {
35              List<Integer> b = new ArrayList<>(a);
36              Collections.swap(b, index, index - 3);
37              p = new Puzzle8(b);
38              p.setParentPuzzle(this);
39          }
40          return p;
41      }
42
44       * Move the blank space or 0 down, if possible
48      public Puzzle8 moveDown() {
59
61       * Move the blank space or 0 to the right, if possible
65      public Puzzle8 moveRight() {
76
78       * Move the blank space or 0 to the left, if possible
82      public Puzzle8 moveLeft() {
93
94      //.............. display the puzzle ....................//
95      public String display() {
113     //.....................................................//
114
115     // Getters and Setters
116     /**
117      * The puzzle array stored as a 1D - array
118      *
119      * @return List<Integer>
120      */
121     public List<Integer> getA() {
124
125     public void setA(List<Integer> a) {
128
130      * The Heuristic value as per the applied heuristic function
134     public Integer getHeuristicValue() {
137
138     public void setHeuristicValue(Integer heuristicValue) {
141
143      * The distance travelled to get to this puzzle/node, g()
147     public Integer getDepth() {
150
151     public void setDepth(Integer depth) {
154
156      * Parent puzzle will help to determine the path
160     public Puzzle8 getParentPuzzle() {
163
164     public void setParentPuzzle(Puzzle8 parentPuzzle) {
167
168     /**
169      * The total heuristic value
170      *
171      * @return Integer g() + f(), total heuristic value
172      */
173     public Integer getTotalHeuristicValue() {
176
177     // Equals and hashCode
178     @Override
179     public int hashCode() {
180         String str ="";
181         for(int i=0; i<a.size(); i++) {
182             str += a.get(i);
183         }
184
185         return new Integer(str);
186     }
187
189     public boolean equals(Object obj) {
192 }
193
```

1. An **instance** of class 'Puzzle8' stores a particular **state**, along with its heuristic value (h), the distance/depth travelled (g) to get to that state and the parent 'Puzzle8'.
2. The array 'a' defines the number arrangement as a 1D array.
   e.g. a= {1, 2, 3, 4, 5, 6, 7, 8, 0}
   implies $\begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & - \end{bmatrix}$
3. '**hashCode'** method returns '**hash**' of every state, which would be unique for each state of all 9! i.e. 362880 combinations possible (Checked using **TestHashMethod.java**). This value will be used to store states that were already **visited** in the A-star algorithm, rather than storing the whole 'Puzzle8' object or the array
4. 'equals' method uses 'hashCode' rather than comparing for every array element
5. **Operations** include moving blank space - **up**, **down**, **right** or **left**. The operation will return a new instance of 'Puzzle8', which would have the parent as the current instance
6. Correct logic is applied for each of the operations while dealing with a 1D representation
7. E.g. Up operation swaps the 'blank' at (position) with the element at (position – 3)
8. If the operation is not possible, null is returned

Puzzle8.java | TestHashMethod.java | AStar.java

```java
package project;

import java.util.ArrayList;

public class AStar {

    List<Integer> initial;
    List<Integer> goal;
    private List<Puzzle8> fringe;
    private Set<Integer> visited;

    public AStar(List<Integer> initial, List<Integer> goal) {
        super();
        this.initial = initial;
        this.goal = goal;
        Puzzle8 puzzle = new Puzzle8(initial);
        this.fringe = new ArrayList<>();
        this.visited = new HashSet<>();
        insertPuzzleNode(puzzle, 0);
    }
```

1. 'Astar' class instance will take the **initial** and the **goal** state
2. A '**fringe'** of puzzles will be created, that will include the initial state already present
3. Again, the states are 1D arrays, represented for the 8-puzzle problem, to improve performance by keeping minimal references

```java
    public static void main(String[] args) {

//      Integer[] a1 = {0, 1, 3, 4, 2, 5, 7, 8, 6};Integer[] b1 = {1, 2, 3, 4, 5, 6, 7, 8, 0};
//      Integer[] a1 = {1, 2, 3, 7, 4, 5, 6, 8, 0};Integer[] b1 = {1, 2, 3, 8, 6, 4, 7, 5, 0};
//      Integer[] a1 = {2, 8, 1, 3, 4, 6, 7, 5, 0};Integer[] b1 = {3, 2, 1, 8, 0, 4, 7, 5, 6};
//      List<Integer> a = new ArrayList<>(Arrays.asList(a1));
//      List<Integer> b = new ArrayList<>(Arrays.asList(b1));
//      AStar star = new AStar(a, b);

        List<Integer> a = new ArrayList<>();
        List<Integer> b = new ArrayList<>();

        Scanner src = new Scanner(System.in);

        System.out.println("Add numbers from 0-9 to INITIAL puzzle state serially, separated by SPACE and/or NEW LINE.");
        while(a.size() < 9) {
            Integer n = src.nextInt();
            if(n >= 0 && n < 9 && !a.contains(n)) {
                a.add(n);
            } else {
                System.out.println("Invalid. Add numbers from 0-9.");
            }
        }

        System.out.println("Add numbers from 0-9 to GOAL puzzle state serially.");
        while(b.size() < 9) {
            Integer n = src.nextInt();
            if(n >= 0 && n < 9 && !b.contains(n)) {
                b.add(n);
            } else {
                System.out.println("Invalid. Add numbers from 0-9.");
            }
        }

        AStar star = new AStar(a, b);

        star.runAlgorithm();
        src.close();
    }
}
```

4. User input will be taken as initial and goal state

```java
    /**
     * Insert a new puzzle arrangement in the fringe at the right position,
     * so the fringe stays sorted.
     * Insertion sort technique is used to insert the new puzzle
     *
     */
    private void insertPuzzleNode(Puzzle8 puzzle, int depth) {

        int position = fringe.size();
        Integer heuristicValue = runHeuristic2(puzzle.getA());
        puzzle.setHeuristicValue(heuristicValue);
        puzzle.setDepth(depth);

        for(int i=0; i<fringe.size(); i++) {
            if(puzzle.getTotalHeuristicValue() < fringe.get(i).getTotalHeuristicValue()) {
                position = i;
                break;
            }
        }
        fringe.add(position, puzzle);
    }

    /**
     * Manhattan distance
     * Heuristic function on the 8-puzzle
     *
     */
    public Integer runHeuristic1(List<Integer> a) {
        Integer heuristic = Integer.MAX_VALUE;
        if(a != null) {
            heuristic = 0;
            for(int i=0; i<a.size(); i++) {
                int index = goal.indexOf(a.get(i));
                heuristic += Math.abs(i%3 - index%3) + Math.abs(i/3 - index/3);
            }
        }

        return heuristic;
    }

    /**
     * Missing pieces
     * Heuristic function on the 8-puzzle
     *
     */
    public Integer runHeuristic2(List<Integer> a) {
        Integer heuristic = null;
        if(a != null) {
            heuristic = 0;
            for(int i=0; i<a.size(); i++) {
                if(!a.get(i).equals(goal.get(i))) {
                    heuristic++;
                }
            }
        }

        return heuristic;
    }
```

5. '**insertPuzzleNode**' inserts every expanded node/state to the fringe
6. '**Insertion sort**' technique is used to determine the right position to insert the new puzzle based on 'totalHeuristic=(g)+(h)'
7. Two heuristic functions are defined, that is called in 'insertPuzzleNode'
8. 'runHeuristic1' is **Manhattan distance** "Formula for 1D array = abs|index%3 - correctIndex%3| + abs|index/3 - correctIndex/3|"
9. 'runHeuristic2' is **Misplaced tiles** The formula for 1D array =(counter++) for every mismatched index

```java
    /**
     * Run the A-star algorithm and display the path
     *
     */
    public void runAlgorithm() {

        int totalExpandedNodes = 0;
        int totalVisitedNodes = 0;
        Puzzle8 puzzle = null;

        while(true) {

            puzzle = fringe.remove(0);
//          puzzle.display();
            if(puzzle.getHeuristicValue().intValue() == 0) {
                break;
            }

            visited.add(puzzle.hashCode());
            totalVisitedNodes++;

            Puzzle8 puzzleUp = puzzle.moveUp();
            Puzzle8 puzzleDown = puzzle.moveDown();
            Puzzle8 puzzleRight = puzzle.moveRight();
            Puzzle8 puzzleLeft = puzzle.moveLeft();

            if(puzzleUp != null && !visited.contains(puzzleUp.hashCode())) {
                totalExpandedNodes++;
                insertPuzzleNode(puzzleUp, puzzle.getDepth() + 1);
            }
            if(puzzleDown != null && !visited.contains(puzzleDown.hashCode())) {
                totalExpandedNodes++;
                insertPuzzleNode(puzzleDown, puzzle.getDepth() + 1);
            }
            if(puzzleRight != null && !visited.contains(puzzleRight.hashCode())) {
                totalExpandedNodes++;
                insertPuzzleNode(puzzleRight, puzzle.getDepth() + 1);
            }
            if(puzzleLeft != null && !visited.contains(puzzleLeft.hashCode())) {
                totalExpandedNodes++;
                insertPuzzleNode(puzzleLeft, puzzle.getDepth() + 1);
            }
        }

        System.out.println("Total Expanded nodes: " + totalExpandedNodes);
        System.out.println("Total Visited nodes: " + totalVisitedNodes);

        StringBuilder builder = new StringBuilder();
        while(puzzle != null) {
            builder.insert(0, puzzle.display());
            puzzle = puzzle.getParentPuzzle();
        }
        System.out.println();
        System.out.print("Path: -");
        System.out.println(builder.toString());
    }

    /**
     * Insert a new puzzle arrangement in the fringe at the right position.
```

Algorithm: -

1. The loop breaks when the '**heuristic value**' equals 0
2. The '**fringe**' is always sorted as the sorting is carried while inserting
3. Hence, the least heuristic node/puzzle is at the 0^{th} index
4. Add its 'hashCode' to the '**visited**' list and increment 'totalVisited' counter
5. If it is not the goal, **expand** to generate more nodes by performing operations – **up**, **down**, **right**, **left**, whichever is possible, and add the generated nodes/puzzles to the fringe by insert operation maintaining the sorting
6. Increment the 'totalExpanded' counter
7. When the loop breaks, the 'puzzle' object will contain the goal state
8. **Trace the complete path by 'parentPuzzle' link**

Sample results for Misplaced Tile Heuristics

Add numbers from 0-9 to INITIAL puzzle state serially, separated by SPACE and/or NEW LINE.

0 1 3 4 2 5 7 8 6

Add numbers from 0-9 to GOAL puzzle state serially.

1 2 3 4 5 6 7 8 0

Total Expanded nodes: 9

Total Visited nodes: 4

Path: -

_ 1 3
4 2 5
7 8 6

1 _ 3
4 2 5
7 8 6

1 2 3
4 _ 5
7 8 6

1 2 3
4 5 _
7 8 6

1 2 3
4 5 6
7 8 _

Process finished with exit code 0

****
****

Add numbers from 0-9 to INITIAL puzzle state serially, separated by SPACE and/or NEW LINE.

1 2 3 7 4 5 6 8 0

Add numbers from 0-9 to GOAL puzzle state serially.

1 2 3 8 6 4 7 5 0

Total Expanded nodes: 43

Total Visited nodes: 23

Path: -

1 2 3
7 4 5
6 8 _

1 2 3
7 4 _
6 8 5

1 2 3
7 _ 4
6 8 5

1 2 3
7 8 4
6 _ 5

1 2 3
7 8 4
_ 6 5

1 2 3
_ 8 4
7 6 5

1 2 3
8 _ 4
7 6 5

1 2 3
8 6 4
7 _ 5

1 2 3
8 6 4
7 5 _

Process finished with exit code 0

****
****

Add numbers from 0-9 to INITIAL puzzle state serially, separated by SPACE and/or NEW LINE.

2 8 1 3 4 6 7 5 0

Add numbers from 0-9 to GOAL puzzle state serially.

3 2 1 8 0 4 7 5 6

Total Expanded nodes: 14

Total Visited nodes: 7

Path: -

2 8 1

3 4 6

7 5 _

2 8 1

3 4 _

7 5 6

2 8 1

3 _ 4

7 5 6

2 _ 1

3 8 4

7 5 6

_ 2 1

3 8 4

7 5 6

3 2 1

_ 8 4

7 5 6

3 2 1

8 _ 4

7 5 6

Process finished with exit code 0

****
****

Add numbers from 0-9 to INITIAL puzzle state serially, separated by SPACE and/or NEW LINE.

2 8 3 1 6 4 7 0 5

Add numbers from 0-9 to GOAL puzzle state serially.

1 2 3 8 0 4 7 6 5

Total Expanded nodes: 13

Total Visited nodes: 6

Path: -

2 8 3

1 6 4

7 _ 5

2 8 3

1 _ 4

7 6 5

2 _ 3

1 8 4

7 6 5

_ 2 3

1 8 4

7 6 5

1 2 3

_ 8 4

7 6 5

1 2 3

8 _ 4

7 6 5

Process finished with exit code 0

****
****

Add numbers from 0-9 to INITIAL puzzle state serially, separated by SPACE and/or NEW LINE.

8 1 3 4 0 2 7 6 5

Add numbers from 0-9 to GOAL puzzle state serially.

1 2 3 4 5 6 7 8 0

Total Expanded nodes: 555

Total Visited nodes: 338

Path: -

8 1 3
4 _ 2
7 6 5

8 1 3
4 2 _
7 6 5

8 1 3
4 2 5
7 6 _

8 1 3
4 2 5
7 _ 6

8 1 3
4 2 5
_ 7 6

8 1 3
_ 2 5
4 7 6

_ 1 3
8 2 5
4 7 6

1 _ 3
8 2 5
4 7 6

1 2 3
8 _ 5
4 7 6

1 2 3
_ 8 5
4 7 6

1 2 3
4 8 5
_ 7 6

1 2 3
4 8 5
7 _ 6

1 2 3
4 _ 5
7 8 6

1 2 3
4 5 _
7 8 6

1 2 3
4 5 6
7 8 _

Process finished with exit code 0

****
****

Add numbers from 0-9 to INITIAL puzzle state serially, separated by SPACE and/or NEW LINE.

7 2 4 5 0 6 8 3 1

Add numbers from 0-9 to GOAL puzzle state serially.

1 2 3 4 5 6 7 8 0

Total Expanded nodes: 6790

Total Visited nodes: 4286

Path: -

7 2 4
5 _ 6
8 3 1

7 2 4
5 3 6
8 _ 1

7 2 4
5 3 6
8 1 _

7 2 4
5 3 _
8 1 6

7 2 4
5 _ 3
8 1 6

7 2 4
_ 5 3
8 1 6

_ 2 4
7 5 3
8 1 6

2 _ 4
7 5 3
8 1 6

2 4 _
7 5 3
8 1 6

2 4 3
7 5 _
8 1 6

2 4 3
7 _ 5
8 1 6

2 4 3
7 1 5
8 _ 6

2 4 3
7 1 5
_ 8 6

2 4 3
_ 1 5
7 8 6

2 4 3
1 _ 5
7 8 6

2 _ 3
1 4 5
7 8 6

_ 2 3
1 4 5
7 8 6

1 2 3
_ 4 5
7 8 6

1 2 3
4 _ 5
7 8 6

1 2 3
4 5 _
7 8 6

1 2 3
4 5 6
7 8 _

Process finished with exit code 0

****
****

Add numbers from 0-9 to INITIAL puzzle state serially, separated by SPACE and/or NEW LINE.

1 2 0 4 5 3 7 8 6

Add numbers from 0-9 to GOAL puzzle state serially.

1 2 3 4 5 6 7 8 0

Total Expanded nodes: 4

Total Visited nodes: 2

Path: -

1 2 _

4 5 3

7 8 6

1 2 3

4 5 _

7 8 6

1 2 3

4 5 6

7 8 _

Process finished with exit code 0

****
****

Add numbers from 0-9 to INITIAL puzzle state serially, separated by SPACE and/or NEW LINE.

1 2 3 0 4 6 7 5 8

Add numbers from 0-9 to GOAL puzzle state serially.

1 2 3 4 5 6 7 8 0

Total Expanded nodes: 8

Total Visited nodes: 3

Path: -

1 2 3

_ 4 6

7 5 8

1 2 3

4 _ 6

7 5 8

1 2 3

4 5 6

7 _ 8

1 2 3

4 5 6

7 8 _

Process finished with exit code 0

****
****

Add numbers from 0-9 to INITIAL puzzle state serially, separated by SPACE and/or NEW LINE.

3 8 2 4 5 6 1 7 0

Add numbers from 0-9 to GOAL puzzle state serially.

1 2 3 4 5 6 7 8 0

Total Expanded nodes: 14780

Total Visited nodes: 9385

Path: -

3 8 2
4 5 6
1 7 _

3 8 2
4 5 _
1 7 6

3 8 2
4 _ 5
1 7 6

3 8 2
_ 4 5
1 7 6

3 8 2
1 4 5
_ 7 6

3 8 2
1 4 5
7 _ 6

3 8 2
1 4 5
7 6 _

3 8 _
1 4 2
7 6 5

3 _ 8
1 4 2
7 6 5

_ 3 8
1 4 2
7 6 5

1 3 8
_ 4 2
7 6 5

1 3 8
4 _ 2
7 6 5

1 3 8
4 2 _
7 6 5

1 3 _
4 2 8
7 6 5

1 _ 3
4 2 8
7 6 5

1 2 3
4 _ 8
7 6 5

1 2 3
4 6 8
7 _ 5

1 2 3
4 6 8
7 5 _

1 2 3
4 6 _
7 5 8

1 2 3
4 _ 6
7 5 8

1 2 3
4 5 6
7 _ 8

1 2 3

4 5 6

7 8 _

Process finished with exit code 0

****
****

Sample Solution for Manhattan distance heuristics

Add numbers from 0-9 to INITIAL puzzle state serially, separated by SPACE and/or NEW LINE.

0 1 3

4 2 5

7 8 6

Add numbers from 0-9 to GOAL puzzle state serially.

1 2 3

4 5 6

7 8 0

Total Expanded nodes: 9

Total Visited nodes: 4

Path: -

_ 1 3

4 2 5

7 8 6

1 _ 3

4 2 5

7 8 6

1 2 3

4 _ 5

7 8 6

1 2 3

4 5 _

7 8 6

1 2 3

4 5 6

7 8 _

Process finished with exit code 0

****
****

Add numbers from 0-9 to INITIAL puzzle state serially, separated by SPACE and/or NEW LINE.

1 2 3

7 4 5

6 8 0

Add numbers from 0-9 to GOAL puzzle state serially.

1 2 3 8 6

4 7 5 0

Total Expanded nodes: 22

Total Visited nodes: 11

Path: -

1 2 3

7 4 5

6 8 _

1 2 3

7 4 _

6 8 5

1 2 3

7 _ 4

6 8 5

1 2 3

7 8 4

6 _ 5

1 2 3

7 8 4

_ 6 5

1 2 3

_ 8 4

7 6 5

1 2 3

8 _ 4

7 6 5

1 2 3

8 6 4

7 _ 5

1 2 3

8 6 4

7 5 _

Process finished with exit code 0

****
****

Add numbers from 0-9 to INITIAL puzzle state serially, separated by SPACE and/or NEW LINE.

2 8 1 3 4 6 7 5 0

Add numbers from 0-9 to GOAL puzzle state serially.

3 2 1 8 0 4 7 5 6

Total Expanded nodes: 12

Total Visited nodes: 6

Path: -

2 8 1
3 4 6
7 5 _

2 8 1
3 4 _
7 5 6

2 8 1
3 _ 4
7 5 6

2 _ 1
3 8 4
7 5 6

_ 2 1
3 8 4
7 5 6

3 2 1
_ 8 4
7 5 6

3 2 1
8 _ 4
7 5 6

Process finished with exit code 0

****
****

Add numbers from 0-9 to INITIAL puzzle state serially, separated by SPACE and/or NEW LINE.

8 1 3 4 0 2 7 6 5

Add numbers from 0-9 to GOAL puzzle state serially.

1 2 3 4 5 6 7 8 0

Total Expanded nodes: 187

Total Visited nodes: 110

Path: -

8 1 3
4 _ 2
7 6 5

8 1 3
4 2 _
7 6 5

8 1 3
4 2 5
7 6 _

8 1 3
4 2 5
7 _ 6

8 1 3
4 2 5
_ 7 6

8 1 3
_ 2 5
4 7 6

_ 1 3
8 2 5
4 7 6

1 _ 3
8 2 5
4 7 6

1 2 3
8 _ 5
4 7 6

1 2 3
_ 8 5
4 7 6

1 2 3
4 8 5
_ 7 6

1 2 3
4 8 5
7 _ 6

1 2 3

4 _ 5

7 8 6

1 2 3

4 5 _

7 8 6

1 2 3

4 5 6

7 8 _

Process finished with exit code 0

****
****

Add numbers from 0-9 to INITIAL puzzle state serially, separated by SPACE and/or NEW LINE.

2 8 3 1 6 4 7 0 5

Add numbers from 0-9 to GOAL puzzle state serially.

1 2 3 8 0 4 7 6 5

Total Expanded nodes: 11

Total Visited nodes: 5

Path: -

2 8 3

1 6 4

7 _ 5

2 8 3

1 _ 4

7 6 5

2 _ 3

1 8 4

7 6 5

_ 2 3

1 8 4

7 6 5

1 2 3

_ 8 4

7 6 5

1 2 3

8 _ 4

7 6 5

Process finished with exit code 0

****
****

Add numbers from 0-9 to INITIAL puzzle state serially, separated by SPACE and/or NEW LINE.

7 2 4 5 0 6 8 3 1

Add numbers from 0-9 to GOAL puzzle state serially.

1 2 3 4 5 6 7 8 0

Total Expanded nodes: 746

Total Visited nodes: 460

Path: -

7 2 4
5 _ 6
8 3 1

7 2 4
5 3 6
8 _ 1

7 2 4
5 3 6
8 1 _

7 2 4
5 3 _
8 1 6

7 2 4
5 _ 3
8 1 6

7 2 4
_ 5 3
8 1 6

_ 2 4
7 5 3
8 1 6

2 _ 4
7 5 3
8 1 6

2 4 _
7 5 3
8 1 6

2 4 3
7 5 _
8 1 6

2 4 3
7 _ 5
8 1 6

2 4 3
7 1 5
8 _ 6

2 4 3
7 1 5
_ 8 6

2 4 3
_ 1 5
7 8 6

2 4 3
1 _ 5
7 8 6

2 _ 3
1 4 5
7 8 6

_ 2 3
1 4 5
7 8 6

1 2 3
_ 4 5
7 8 6

1 2 3
4 _ 5
7 8 6

1 2 3
4 5 _
7 8 6

1 2 3
4 5 6
7 8 _

Process finished with exit code 0

****
****

Add numbers from 0-9 to INITIAL puzzle state serially, separated by SPACE and/or NEW LINE.

1 2 0 4 5 3 7 8 6

Add numbers from 0-9 to GOAL puzzle state serially.

1 2 3 4 5 6 7 8 0

Total Expanded nodes: 4

Total Visited nodes: 2

Path: -

1 2 _

4 5 3

7 8 6

1 2 3

4 5 _

7 8 6

1 2 3

4 5 6

7 8 _

Process finished with exit code 0

****
****

Add numbers from 0-9 to INITIAL puzzle state serially, separated by SPACE and/or NEW LINE.

1 2 3 0 4 6 7 5 8

Add numbers from 0-9 to GOAL puzzle state serially.

1 2 3 4 5 6 7 8 0

Total Expanded nodes: 8

Total Visited nodes: 3

Path: -

1 2 3

_ 4 6

7 5 8

1 2 3

4 _ 6

7 5 8

1 2 3

4 5 6

7 _ 8

1 2 3

4 5 6

7 8 _

Process finished with exit code 0

****
****

Add numbers from 0-9 to INITIAL puzzle state serially, separated by SPACE and/or NEW LINE.

3 8 2 4 5 6 1 7 0

Add numbers from 0-9 to GOAL puzzle state serially.

1 2 3 4 5 6 7 8 0

Total Expanded nodes: 2881

Total Visited nodes: 1789

Path: -

3 8 2

4 5 6

1 7 _

3 8 2

4 5 _

1 7 6

3 8 2

4 _ 5

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Process finished with exit code 0