SWE 4x **Übung zu Softwareentwicklung mit mit modernen Plattformen 4** **SS 2022, Übung 04**

Abgabe elektronisch bis Sa 8 Uhr in der KW 18

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Beispiel	L Lösungsidee	I Implementierung	T Tests	S = L+I+T	Multiplikator	S*M
a	☒☒☒	☒☒☒☒	☒☒☒	10	2	20
b	☒☒☒	☒☒☒☒	☒☒☒	10	3	30
c	☒☒☒	☒☒☒☒	☒☒☒	10	3	30
d	☒☒☒	☒☒☒☒	☒☒☒	10	2	20
					Summe	**100**

1. Verschiebepuzzle

1.1. Board

1.1.1. Lösungsidee

Als Datenstruktur für das Board wurde eine ArrayList gewählt. Zusätzlich zum Array wird auch noch die Größe des Spielfeldes (3 oder 4) gespeichert. Um die zweidimensionalen Koordinaten in eindimensionale Koordinaten umzurechnen, gibt es eine Hilfsfunktion. In der Klasse biete ich zwei Konstruktoren an. Einer nimmt nur eine Size und initialisiert damit ein gelöstes Board. Der zweite Konstruktor kann eine Liste aufnehmen und daraus das Board generieren.

Die meisten weiteren geforderten Methoden sind eigentlich mit sehr einfachen Algorithmen zu lösen. Nur zu den folgenden möchte ich Kommentare machen.

Copy: um das Board zu kopieren rufe ich den Konstruktor (mit der size vom originalen Board) auf. Dadurch wird ein neues Board mit eigenem Array angelegt. Dann kopiere ich die Werte vom originalen Board in das neu erstellte Board (das ja zu Beginn als sortiertes Board initialisiert wird).

IsSolveable: Diese Funktion habe ich eingeführt, um zu überprüfen, ob ein Spielbrett lösbar ist oder nicht. Glücklicherweise kann man schon vor man das Puzzle löst feststellen, ob es lösbar ist. Dazu muss man sich die Anzahl der nötigen Vertauschungen ansehen. Bei einem Board mit ungerader Größe muss die Anzahl der Vertauschungen gerade sein. Bei einem Board mit gerade Größe muss man zusätzlich zur Anzahl der Vertauschungen auch noch die Reihennummer der leeren Zelle berücksichtigen. Wenn die Summe dieser beiden Werte ungerade ist, ist das Board lösbar.[1]

[1] https://www.cs.princeton.edu/courses/archive/spring19/cos226/assignments/8puzzle/specification.php

1.1.2. Quellcode

```
//file Board.java

package at.fhooe.swe4.slidingpuzzle;

import com.sun.xml.internal.ws.api.model.wsdl.WSDLOutput;

import java.util.*;

import static java.lang.Math.abs;

public class Board implements Comparable<Board> {
  private final List board;
  private int size;

  /**
   * Calculcates the array index for a given row and column (row and column start with 1)
   * @param row = input row
   * @param col = input column
   * @return = array index for this row and column
   */
  private int getArrayIndex(int row, int col) {
    if(row < 1 || row > size || col < 1 || col > size) {
      throw new ArrayIndexOutOfBoundsException("indices must be > 0 and <= size");
    }
    int nRow = row-1;
    int nCol = col-1;

    return nRow*size+nCol;
  }

  /**
   * Constructor for board. Initializes board 1 to n*n-1. Last position of array (n|n) holds 0 cell.
   * Size must be 3 or 4. If other size is chosen board will be initialized with size 3
   * @param size = size of board (for a 3x3 board enter 3 and NOT 9)
   */
  public Board(int size) {
    int saveSize = size;
    if((size != 3) && (size != 4)) {
      System.out.println("Only size 3 or 4 allowed. Board was initialized with size = 3");
      saveSize = 3;
    }
    board = new ArrayList<Integer>(saveSize*saveSize);
    for(int i = 0; i < saveSize*saveSize; i++) {
      board.add(i,i+1);
    }

    board.set(saveSize*saveSize-1, 0);

    this.size = saveSize;
  }

  /**
   * Constructor taking a one dimensional list as start board
   * @param boardInput = list representing start baord
   * @param size = size of board (for a 3x3 board enter 3 and NOT 9)
   */
  public Board(List boardInput, int size) {
    board = new ArrayList<Integer>();
    board.addAll(boardInput);
    this.size = size;
  }


  /**
   * @return string representation of board
   */
  @Override
  public String toString() {
    StringBuilder sb = new StringBuilder();
    for(int row = 1; row <= size; row++) {
      for(int col = 1; col <= size; col++) {
        sb.append(board.get(getArrayIndex(row, col)));
        sb.append("\t");
      }
      sb.append("\n");
    }
    return sb.toString();
  }

  /**
```

```java
     * checks if boards have the same configuration (board and size are considered)
     * @param other = the other board
     * @return = true if this and other are the same, else false
     */
    public boolean equals(Object other) {
      if (this == other) return true;
      if(other == null || getClass() != other.getClass()) return false;

      Board o = (Board)other;
      return board.equals(o.board) &&
              size == o.size;
    }

    /**
     * @return hashCode for board (considering board and size)
     */
    @Override
    public int hashCode() {
      return Objects.hash(board, size);
    }

    /**
     * @param other the object to be compared.
     * @return < 1 if this is smaller than other; 0 if they are the same, >1 if this is larger than oterh
     */
    public int compareTo(Board other) {
      if (size < other.size) {
        return -1;
      }
      else if (size == other.size) {
        return 0;
      } else
        return 1;
    }

    /**
     * Gets the value of a certain tile
     * @param i = row of tile
     * @param j = column of tile
     * @return = number of tile at position i|j
     * throws InvalidBoardIndexException if i or j are < 1 or > size
```

```
   */
  public int getTile(int i, int j) {
    if(i < 1 || i > size || j < 1 || j > size) {
      throw new InvalidBoardIndexException(i,j,size);
    }

    Integer val = (Integer) board.get(getArrayIndex(i,j));
    return val;
  }

  /**
   * Sets a tile to input number
   * @param i = row of tile to be set
   * @param j = column of tile to be set
   * @param number = value which should be set on position i|j
   * throws InvalidBoardIndexException if i or j are < 1 or > size
   * throws InvalidTileNumberException if number < 1 or > size*size-1
   */
  public void setTile(int i, int j, int number) {
    if(i < 1 || i > size || j < 1 || j > size) {
      throw new InvalidBoardIndexException(i,j,size);
    }

    if(number < 0 || number > size*size-1) {
      throw new InvalidTileNumberException(number, size);
    }

    int aIndex = getArrayIndex(i,j);
    board.set(aIndex, number);
  }

  /**
   * Sets a certain position to 0 (it could be possible to set several tiles to 0 with this method)
   * @param i = row of tile which should be set to 0
   * @param j = column of tile which should be set to 0
   * throws InvalidBoardIndexException if i or j are < 1 or > size
   */
  public void setEmptyTile(int i, int j) {
    if(i < 1 || i > size || j < 1 || j > size) {
      throw new InvalidBoardIndexException(i,j,size);
    }
    setTile(i,j,0);
  }


  /**
   * @return row number of empty tile (rows start with 1)
   */
  public int getEmptyTileRow() {
    int retVal = -1;
    for(int row = 1; row <= size; row++) {
      for(int col = 1; col <= size; col++) {
        int curVal = getTile(row, col);
        if(curVal == 0) {
          retVal = row;
        }
      }
    }
    return retVal;
  }

  /**
   * @return column number of empty tile (columns start with 1)
   */
  public int getEmptyTileColumn() {
    int retVal = -1;
    for(int row = 1; row <= size; row++) {
      for(int col = 1; col <= size; col++) {
        int curVal = getTile(row, col);
        if(curVal == 0) {
          retVal = col;
        }
      }
    }
    return retVal;
  }

  /**
   * @return number of rows / columns
   */
  public int size() {
    return size;
  }

  // Überprüft, ob Position der Kacheln konsistent ist.

  /**
   * checks if a board is valid.
   * @return true if all numbers from 0 to size-1 is once in board (irrespective of order)
   */
  public boolean isValid() {
    ArrayList<Integer> copy = new ArrayList<>();
    copy.addAll(board);
    Collections.sort(copy);

    for(int i = 0; i < size*size; i++) {
      int curVal = (Integer) copy.get(i);
      if(curVal != i) {
        return false;
      }
    }
    return true;
  }

  /**
   * Makes a deep copy of the board and returns the new board
   * @return the copied board
   */
  public Board copy() {
    Board copy = new Board(size);
    for(int i = 0; i < size*size; i++) {
      copy.board.set(i, board.get(i));
    }
    return copy;
  }

  /**
   * Checks if a board is solvable
   * @return true if it is solvable, otherwise false
   */
  public boolean isSolvable() {
    int inversions = 0;
    for(int i = 0; i < board.size() - 1; i++) {
      for(int j = i + 1; j < board.size(); j++)
        if((Integer) board.get(i) > (Integer) board.get(j)) inversions++;
      if((Integer) board.get(i) == 0 && i % 2 == 1) inversions++;
    }

    /*
      If size is odd, then number of inversions must be even for board to be solvable.
      If size is even, then number of inversions+row_number_of_empty_cell (starting with 1) must be odd for board to be
solvable.
    */
    if (size % 2 == 1) {
      return (inversions % 2 == 0);
    } else {
      int blankRow = getEmptyTileRow();
      int test = inversions+blankRow-1;
      return (test % 2 == 1);
    }
  }

  /**
   * Shuffles a board but guarantees that it is still solvable
   */
  public void shuffle() {

    Collections.shuffle(board);
    while(!this.isSolvable()) {
      Collections.shuffle(board);
    }
  }

  /**
   * Checks if a tile is a neighbour of the tile containing 0
   * @param row = row to be checked
   * @param col = column to be checked
   * @return true if the cell is a neighbour of the empty cell otherwise false
   * throws InvalidBoardIndexException if row or colum < 1 or > size
   */
  private boolean isNeighbourOfEmptyField(int row, int col) {
    if(row < 1 || row > size || col < 1 || col > size) {
      throw new InvalidBoardIndexException(row,col,size);
    }

    int rowEmpty = getEmptyTileRow();
    int colEmpty = getEmptyTileColumn();

    int rowOffset = row-rowEmpty;
    int colOffset = col-colEmpty;

    if((abs(rowOffset) == 0 && abs(colOffset) == 1) ||
            (abs(rowOffset) == 1 && abs(colOffset) == 0)) {
      return true;
    } else {
      return false;
    }
  }

  /**
   * Moves empty tile to this position. In fact the empty tile and the chosen tile will be exchanged.
   * Only works if empty tile and inputted tile are neighbours. Otherwise IllegalMoveException will be thrown
   * @param row = row which should be set to 0
   * @param col = column which should be set to 0
   */
  public void move(int row, int col) {
    int rowEmpty = getEmptyTileRow();
    int colEmpty = getEmptyTileColumn();

    if((row < 1 || row > size || col < 1 || col > size)
              || (!isNeighbourOfEmptyField(row, col))) {
      throw new IllegalMoveException(row, col, rowEmpty, colEmpty);
    }

    int temp = getTile(row, col);
    setTile(row, col, 0);
    setTile(rowEmpty, colEmpty, temp);
  }

  /**
   * Moves the empty tile to the left
   * throws IllegalMoveExcpetion if the column of the empty tile is already 1
   */
```

```java
public void moveLeft() {
  int rowEmpty = getEmptyTileRow();
  int colEmpty = getEmptyTileColumn();

  if(colEmpty < 2) {
    throw new IllegalMoveException(rowEmpty, colEmpty-1, rowEmpty, colEmpty);
  } else {
    move(rowEmpty, colEmpty-1);
  }
}

/**
 * Moves the empty tile to the right
 * throws IllegalMoveExcpetion if the column of the empty tile is already the same as size
 */
public void moveRight() {
  int rowEmpty = getEmptyTileRow();
  int colEmpty = getEmptyTileColumn();

  if(colEmpty > size-1) {
    throw new IllegalMoveException(rowEmpty, colEmpty+1, rowEmpty, colEmpty);
  } else {
    move(rowEmpty, colEmpty+1);
  }
}

/**
 * Moves the empty tile up
 * throws IllegalMoveExcpetion if the row of the empty tile is already 1
 */
public void moveUp() {
  int rowEmpty = getEmptyTileRow();
  int colEmpty = getEmptyTileColumn();

  if(rowEmpty < 2) {
    throw new IllegalMoveException(rowEmpty-1, colEmpty, rowEmpty, colEmpty);
  } else {
    move(rowEmpty-1, colEmpty);
  }
}
```

```
/**
 * Moves the empty tile down
 * throws IllegalMoveExcpetion if the row of the empty tile is already the same as size
 */
public void moveDown() {
  int rowEmpty = getEmptyTileRow();
  int colEmpty = getEmptyTileColumn();

  if(rowEmpty > size-1) {
    throw new IllegalMoveException(rowEmpty+1, colEmpty, rowEmpty, colEmpty);
  } else {
    move(rowEmpty+1, colEmpty);
  }
}

/**
 * Peeks and returns potential new row number of empty tile if move would be made
 * @param m = the move to be made (up or down)
 * @return the row number of empty tile if move is made
 */
int getNewRowAfterMove(Move m) {
  int rowEmpty = getEmptyTileRow();
  int rowTo = rowEmpty;

  switch(m) {
    case DOWN:
      rowTo += 1;
      break;
    case UP:
      rowTo -= 1;
      break;
  }
  return rowTo;
}
```

```java
/**
 * Peeks and returns potential new column number of empty tile if move would be made
 * @param m = the move to be made (left or right)
 * @return the column number of empty tile if move is made
 */
int getNewColAfterMove(Move m) {
  int colEmpty = getEmptyTileColumn();
  int colTo = colEmpty;

  switch(m) {
    case LEFT:
      colTo -= 1;
      break;
    case RIGHT:
      colTo += 1;
      break;
  }
  return colTo;
}

/**
 * Performs a sequence of move operations
 * @param moves = a list of moves
 * throw IllegalMOveException if the move can't be made because the empty tile cannot be moved in this direction anymore
 */
public void makeMoves(List<Move> moves) {
  for(int i = 0; i < moves.size(); i++) {
    Move m = moves.get(i);

    int newRow = getNewRowAfterMove(m);
    int newCol = getNewColAfterMove(m);

    if ((newRow < 1 || newRow > size || newCol < 1 || newCol > size) || (!isNeighbourOfEmptyField(newRow, newCol))) {
      throw new IllegalMoveException(newRow, newCol, getEmptyTileRow(), getEmptyTileColumn());
    }

    switch (m) {
      case UP:
        moveUp();
        break;
      case DOWN:
          moveDown();
          break;
        case LEFT:
          moveLeft();
          break;
        case RIGHT:
          moveRight();
          break;
      }
    }
  }

  /**
   * checks if a board is solved (means it is sorted but the 0 is on the last position)
   * @return true if board is solved
   */
  public boolean isSolved() {
    for(int i = 0, shouldVal = 1; i < size*size-1; i++, shouldVal++) {
      Integer isVal = (Integer)board.get(i);
      if(shouldVal != isVal) {
        return false;
      }
    }
    int last = (Integer) board.get(size*size-1);
    return last == 0;
  }
}
```

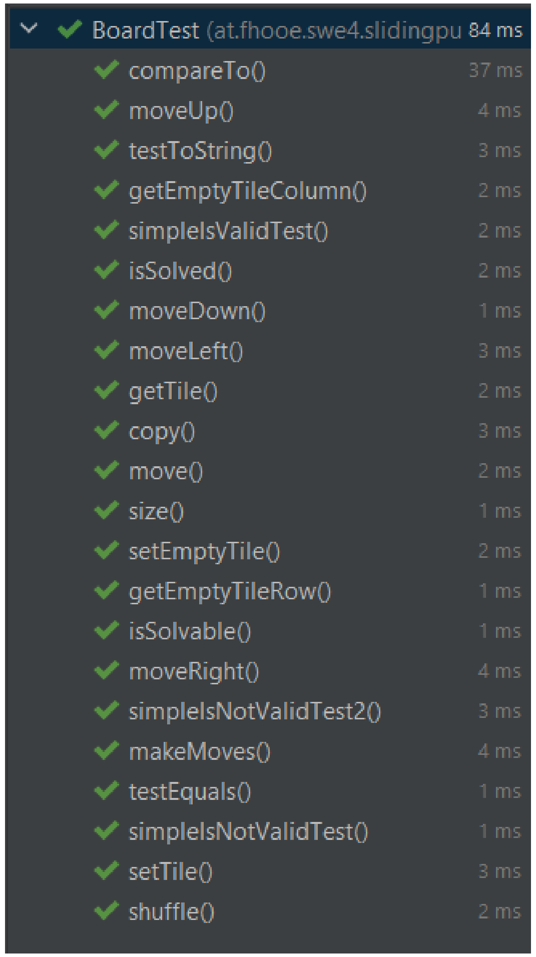
1.1.3. Tests

```java
//file BoardTest.java

package at.fhooe.swe4.slidingpuzzle;

import org.junit.jupiter.api.AfterEach;
import org.junit.jupiter.api.BeforeEach;
import org.junit.jupiter.api.Test;
import org.junit.jupiter.api.TestClassOrder;

import java.util.Arrays;
import java.util.List;

import static org.junit.jupiter.api.Assertions.*;

public class BoardTest {

  private Board board;

  @BeforeEach
  void setUp() {
    board = new Board(3);
  }

  @AfterEach
  void tearDown() { board = null; }

  @Test
  public void simpleIsValidTest() {
    Board board;
    try {
      board = new Board(3);
      board.setTile(1, 1, 1);
      board.setTile(1, 2, 2);
      board.setTile(1, 3, 3);
      board.setTile(2, 1, 4);
      board.setTile(2, 2, 5);
      board.setTile(2, 3, 6);
      board.setTile(3, 1, 7);
      board.setTile(3, 2, 8);
      board.setTile(3, 3, 0);
      assertTrue(board.isValid());
    } catch (BoardException e) {
      fail("BoardException not expected.");
    }
  }

  @Test
  public void simpleIsNotValidTest() {
    Board board;
    try {
      board = new Board(3);
      board.setTile(1, 1, 1);
      board.setTile(1, 2, 2);
      board.setTile(1, 3, 3);
      board.setTile(2, 1, 4);
      board.setTile(2, 2, 5);
      board.setTile(2, 3, 6);
      board.setTile(3, 1, 7);
      board.setTile(3, 2, 1);
      board.setTile(3, 3, 0);

      assertTrue(! board.isValid());
    } catch (BoardException e) {
      fail("BoardException not expected.");
    }
  }

  @Test
  public void simpleIsNotValidTest2() {
    Board board;
    try {
      board = new Board(3);
      board.setTile(1, 1, 8);
      board.setTile(1, 2, 2);
      board.setTile(1, 3, 0);
      board.setTile(2, 1, 7);
      board.setTile(2, 2, 5);
      board.setTile(2, 3, 4);
      board.setTile(3, 1, 3);
      board.setTile(3, 2, 1);
      board.setTile(3, 3, 6);

      assertTrue(board.isValid());
    } catch (BoardException e) {
      fail("BoardException not expected.");
    }
  }

  @Test
  void testToString() {
    assertEquals("1\t2\t3\t\n4\t5\t6\t\n7\t8\t0\t\n", board.toString());
  }

  @Test
  void testEquals() {
    Board b2 = new Board(3);
    assertEquals(board,b2);

    b2.setTile(2,1,7);
    assertNotEquals(board,b2);
  }

  @Test
  void compareTo() {
    Board b2 = new Board(3);
    Board b3 = new Board(4);
    Board b4 = new Board(8);

    assertEquals(0, board.compareTo(b2));
    assertEquals(-1, board.compareTo(b3));
    assertEquals(1, b3.compareTo(board));
    assertEquals(0, board.compareTo(b4));
  }

  @Test
  void getTile() {
    assertThrows(InvalidBoardIndexException.class, () -> board.getTile(2,7));
    assertEquals(0, board.getTile(3,3));
    assertEquals(1, board.getTile(1,1));
    assertEquals(5, board.getTile(2,2));
  }
```

```java
@Test
void setTile() {
  assertEquals(6, board.getTile(2,3));
  board.setTile(2,3,7);
  assertEquals(7, board.getTile(2,3));

  assertThrows(InvalidBoardIndexException.class, () -> board.setTile(4,5, 4));
  assertThrows(InvalidTileNumberException.class, () -> board.setTile(1,3, 99));
}


@Test
void setEmptyTile() {
  assertEquals(0, board.getTile(3,3));
  assertNotEquals(0, board.getTile(1,2));
  board.setEmptyTile(1,2);
  assertEquals(0, board.getTile(1,2));

}

@Test
void getEmptyTileRow() {
  assertEquals(3, board.getEmptyTileRow());
  board.setEmptyTile(1,2);
  board.setTile(3,3, 2);
  assertEquals(1, board.getEmptyTileRow());
}

@Test
void getEmptyTileColumn() {
  assertEquals(3, board.getEmptyTileColumn());
  board.setEmptyTile(1,2);
  board.setTile(3,3, 2);
  assertEquals(2, board.getEmptyTileColumn());
}

@Test
void size() {
  assertEquals(3, board.size());
  assertFalse(board.size() != 3);
}

@Test
void copy() {
  Board b2 = board.copy();
  assertEquals(b2, board);

  b2.setTile(1,3, 6);
  assertNotEquals(b2, board);

  assertTrue(board.getTile(1,3) == 3);
  assertTrue(b2.getTile(1,3) == 6);
  assertFalse(board.getTile(1,3) == 6);
  assertFalse(b2.getTile(1,3) == 3);
}

@Test
void isSolvable() {
  List<Integer> a1 = Arrays.asList(0,5,2,1,8,3,4,7,6);
  List<Integer> a2 = Arrays.asList(4,1,2,5,8,3,7,0,6);
  Board b2 = new Board(a1,3);
  Board b3 = new Board(a2,3);
  assertTrue(b2.isSolvable());
  assertTrue(b3.isSolvable());

  List<Integer> a3 = Arrays.asList(1,2,3,4,5,6,8,7,0);
  List<Integer> a4 = Arrays.asList(1,5,0,3,2,8,4,6,7);
  Board b4 = new Board(a3,3);
  Board b5 = new Board(a4,3);
  assertFalse(b4.isSolvable());
  assertFalse(b5.isSolvable());
}

@Test
void shuffle() {
  assertEquals("1\t2\t3\t\n4\t5\t6\t\n7\t8\t0\t\n", board.toString());
  board.shuffle();
  assertNotEquals("1\t2\t3\t\n4\t5\t6\t\n7\t8\t0\t\n", board.toString(),board.toString());
  assertTrue(board.isSolvable());
  assertTrue(board.isValid());
}
```

```
@Test
void move() {
    board.move(3,2);
    assertEquals(0, board.getTile(3,2));
    assertEquals(8, board.getTile(3,3));

    //index must be valid
    assertThrows(IllegalMoveException.class, () -> board.move(2,7));

    //index must be neighbour of empty field (currently 3|2)
    assertThrows(IllegalMoveException.class, () -> board.move(1,2));

    board.move(2,2);
    assertEquals(0, board.getTile(2,2));
    assertEquals(5, board.getTile(3,2));
}

@Test
void moveLeft() {
  board.moveLeft();
  assertEquals(0, board.getTile(3,2));
  assertEquals(8, board.getTile(3,3));

  board.moveLeft();
  assertEquals(0, board.getTile(3,1));
  assertEquals(7, board.getTile(3,2));
  assertEquals(8, board.getTile(3,3));

  //now can't move any further
  assertThrows(IllegalMoveException.class, () -> board.moveLeft());
}

@Test
void moveRight() {
  //set start position of empty field
  board.moveLeft();
  board.moveLeft();
  board.moveUp();

  assertEquals(0, board.getTile(2,1));
```

```
    assertEquals(8, board.getTile(3,3));

    board.moveRight();
    assertEquals(5, board.getTile(2,1));
    assertEquals(0, board.getTile(2,2));

    board.moveRight();
    assertEquals(5, board.getTile(2,1));
    assertEquals(6, board.getTile(2,2));
    assertEquals(0, board.getTile(2,3));

    //now can't move any further
    assertThrows(IllegalMoveException.class, () -> board.moveRight());
  }

  @Test
  void moveUp() {
    board.moveUp();
    assertEquals(0, board.getTile(2,3));
    assertEquals(6, board.getTile(3,3));

    board.moveUp();
    assertEquals(6, board.getTile(3,3));
    assertEquals(3, board.getTile(2,3));
    assertEquals(0, board.getTile(1,3));

    //now can't move any further
    assertThrows(IllegalMoveException.class, () -> board.moveUp());
  }

  @Test
  void moveDown() {
      //set start position of empty field
    board.moveUp();
    board.moveUp();
    board.moveLeft();

    assertEquals(0, board.getTile(1,2));
    assertEquals(6, board.getTile(3,3));

    board.moveDown();
    assertEquals(5, board.getTile(1,2));
    assertEquals(0, board.getTile(2,2));

    board.moveDown();
    assertEquals(5, board.getTile(1,2));
    assertEquals(8, board.getTile(2,2));
    assertEquals(0, board.getTile(3,2));

    //now can't move any further
    assertThrows(IllegalMoveException.class, () -> board.moveDown());
  }

  @Test
  void makeMoves() {
    board.moveLeft();
    board.moveLeft();
    board.moveUp();
    board.moveUp();
    board.moveRight();
    board.moveRight();

    Board b1 = new Board(3);
    List<Move> m = Arrays.asList(Move.LEFT, Move.LEFT, Move.UP, Move.UP, Move.RIGHT, Move.RIGHT);
    b1.makeMoves(m);
    assertEquals(0, b1.getTile(1,3));

    assertEquals(board, b1);
  }

  @Test
  void isSolved() {
    assertTrue(board.isSolved());
    board.moveLeft();
    board.moveUp();
    assertFalse(board.isSolved());
  }
}
```



```
BoardTest (at.fhooe.swe4.slidingpu 84 ms
  compareTo()               37 ms
  moveUp()                   4 ms
  testToString()             3 ms
  getEmptyTileColumn()       2 ms
  simpleIsValidTest()        2 ms
  isSolved()                 2 ms
  moveDown()                 1 ms
  moveLeft()                 3 ms
  getTile()                  2 ms
  copy()                     3 ms
  move()                     2 ms
  size()                     1 ms
  setEmptyTile()             2 ms
  getEmptyTileRow()          1 ms
  isSolvable()               1 ms
  moveRight()                4 ms
  simpleIsNotValidTest2()    3 ms
  makeMoves()                4 ms
  testEquals()               1 ms
  simpleIsNotValidTest()     1 ms
  setTile()                  3 ms
  shuffle()                  2 ms
```

1.2. SearchNode

1.2.1. Lösungsidee

Die Klasse SearchNode enthält eine Datenkomponente, die ein Board speichert. Darüber hinaus wird eine Referenz auf den predecessor SearchNode gespeichert sowie die Kosten bis zu dem Knoten und die geschätzten Kosten bis zum Zielzustand.

Im Konstruktor erhält die Klasse ein Board. Hier wird auch gleich die Methode calculateEstimatedCostsToTarget aufgerufen, welche die Kosten bis zur Zielposition berechnet und die Datenkomponente dementsprechend initialisiert. Die Komponenten für den Predecessor und die Kosten vom Start müssen durch Setter gesetzt werden.

Die Kosten bis zum Ziel werden wie beschrieben mit der Manhatten-Distanz berechnet. Dazu gibt es Hilfsfunktionen, die für eine Nummer als Input deren Zielreihe und Spalte berechnen. Durch die Unterschiede zur aktuellen Position lässt sich dadurch die Distanz abschätzen.

In der Methode „toMoves“ hantle ich mich über den Predecessor so lange die Liste nach vorne, bis es keinen Predecessor mehr gibt. In jedem Schritt berechne ich den gemachten Move (entsprechend der Veränderung von Zeile bzw. Spalte). Der Move wird zu einer Liste geaddet. Zum Schluss muss die Liste noch invertiert werden (da ich die Moves ja in verkehrter Reihenfolge geaddet habe).

Die restlichen Methoden dieser Klasse sind hauptsächlich Getter und Setter.

1.2.2. Quellcode

```
//file: SearchNode.java

package at.fhooe.swe4.slidingpuzzle;

import java.util.ArrayList;
import java.util.Collections;
import java.util.List;
import java.util.Objects;

import static java.lang.Math.abs;

public class SearchNode implements Comparable<SearchNode> {

    private Board boardConfig;
    private SearchNode predecessor = null;

    //costs=steps from start position to this current state
    private int costsFromStart;

    //cost from current position to target position
    private int estimatedCostsToTarget;

    /**
     * Constructor taking a board configuration
     * The estimatedCostsToTarget will be calculated automatically
     *      (as it can be calculated from the board configuration)
     *      predecessor and costsFromStart must be "manually" set
     * @param board = input board
     */
    // Suchknoten mit Board-Konfiguration initialisieren.
    public SearchNode(Board board) {
        boardConfig = board;
        estimatedCostsToTarget = calculateEstimatedCostsToTarget();
    }

    /**
     * Getter for board
     * @return board
     */
```

```
public Board getBoard() {
  return boardConfig;
}

/**
 * Getter for predecessor
 * @return predecessor
 */
public SearchNode getPredecessor() {
  return predecessor;
}

/**
 * Setter for predecessor. Sets predecessor to input value
 * @param predecessor
 */
public void setPredecessor(SearchNode predecessor) {
  this.predecessor = predecessor;
}

/**
 * Getter for costsFromStart
 * @return costsFromStart
 */
public int costsFromStart() {
    return costsFromStart;
}


/**
 * Getter for estimatedCostsToTarget
 * @return estimatedCostsToTarget
 */
public int estimatedCostsToTarget() {
    return estimatedCostsToTarget;
}

/**
 * Calculates the target row for a certain number/tile
 * @param number = number for which target row is calculated
 * @return the target row of the input number
```

```
     */
    private int getTargetRow(int number) {
        if(number % boardConfig.size() == 0) {
            return number / boardConfig.size();
        } else {
            return (number / boardConfig.size()) + 1;
        }
    }

    /**
     * Calculates the target column for a certain number/tile
     * @param number = number for which target column is calculated
     * @return the target column of the input number
     */
    private int getTargetCol(int number) {
        if(number % boardConfig.size() == 0) {
            return boardConfig.size();
        } else {
            return number % boardConfig.size();
        }
    }

    /**
     * Calculates the estimatedCostsToTarget using the Manhatten distance
     * @return estimated costs to target
     */
    private int calculateEstimatedCostsToTarget() {
        int heuristic = 0;

        for(int row = 1; row <= boardConfig.size(); row++) {
            for (int col = 1; col <= boardConfig.size(); col++) {
                int curTile = boardConfig.getTile(row, col);
                if (curTile != 0) {
                    heuristic += calculateManhatten(curTile, row, col);
                }
            }
        }
        return heuristic;
    }

    /**
```

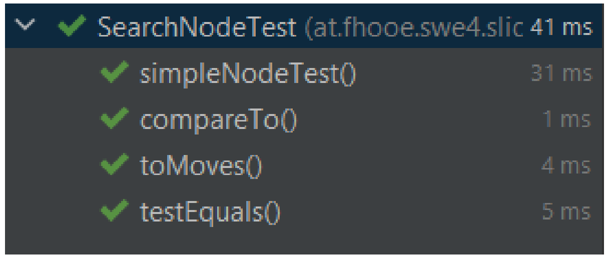
```
     * Calculates for a number and it's current row and column the Manhatten distance to it's target position
     * @param number = number for which distance should be calculated
     * @param currRow = the current row position of the number
     * @param currCol = the current column position of the number
     * @return
     */
    private int calculateManhatten(int number, int currRow, int currCol) {
        int targetRow = getTargetRow(number);
        int targetCol = getTargetCol(number);

        int rowOffset = abs(currRow - targetRow);
        int colOffset = abs(currCol - targetCol);

        return rowOffset+colOffset;
    }

    /**
     * Setter for costsFromStart
     * @param costsFromStart
     */
    public void setCostsFromStart(int costsFromStart) {
      this.costsFromStart = costsFromStart;
    }


    /**
     * @return sum of costsFromStart + estimatedCostsToTarget
     */
    public int estimatedTotalCosts() {
        return costsFromStart + estimatedCostsToTarget;
    }

    /**
     * Compares two nodes based on the boardConfiguration only (doesn't consider cost components of node)
     * @param other = the node with which this node is returned
     * @return true if nodes are the same, othewise false
     */
    public boolean equals(Object other) {
        if (this == other) return true;
        if(other == null || getClass() != other.getClass()) return false;
        SearchNode o = (SearchNode) other;
        return Objects.equals(boardConfig, o.boardConfig);
    }

    /**
     * Compares nodes based on estimated total costs
     * @param other the object to be compared.
     * @return <1 if costs of this node are smaller than other, 0 if costs are the same; 1 if costs of this node are larger
     */
    public int compareTo(SearchNode other) {
      return this.estimatedTotalCosts() - other.estimatedTotalCosts();
    }

    /**
     * Gets a hashcode for a node based on the baordConfiguration (doesn't consider cost components)
     * @return hashcode
     */
    @Override
    public int hashCode() {
        return Objects.hash(boardConfig);
    }

    /**
     * Returns a list of moves that were made from the start board to this current node
     * @return list of moves from start configuration to current configuration
     */
    public List<Move> toMoves() {
      ArrayList<Move> movesUntilHere = new ArrayList<>();
        SearchNode current = this;
        while(current.predecessor != null) {
            Board curBoard = current.boardConfig;
            Board prevBoard = current.predecessor.getBoard();
            Move madeMove = calculateMove(curBoard, prevBoard);
            movesUntilHere.add(madeMove);
            current = current.predecessor;
        }
        Collections.reverse(movesUntilHere);
        return movesUntilHere;
    }

    /**
```

```java
     * Calculates the move that was made between two board configurations
     * @param curBoard the current board configuration
     * @param prevBoard the previous board configuration (starting board before making the move)
     * @return the respective move (left, right, up, down) of null if the boards differ be more than one move
     */
    private Move calculateMove(Board curBoard, Board prevBoard) {
        Move result = null;
        int curBoardRow = curBoard.getEmptyTileRow();
        int curBoardCol = curBoard.getEmptyTileColumn();
        int prevBoardRow = prevBoard.getEmptyTileRow();
        int prevBoardCol = prevBoard.getEmptyTileColumn();

        int verticalMove = curBoardRow - prevBoardRow;
        int horizontalMove = curBoardCol - prevBoardCol;

        if(horizontalMove != 0 && verticalMove != 0) {
            throw new IllegalMoveException(curBoardRow, curBoardCol, prevBoardRow, prevBoardCol);
        }

        //must be left or right move
        if(horizontalMove != 0) {
            if(horizontalMove == 1) {
                result = Move.RIGHT;
            } else if(horizontalMove == -1) {
                result = Move.LEFT;
            }
        }

        //must be up or down move
        if(verticalMove != 0) {
            if(verticalMove == 1) {
                result = Move.DOWN;
            } else if (verticalMove == -1) {
                result = Move.UP;
            }
        }
        return result;
    }

    @Override
    public String toString() {
        return "SearchNode:\n" + boardConfig + "\n" +
                "costs from start: " + costsFromStart + " | " +
                "costs to target: " + estimatedCostsToTarget + "\n";
    }
}
```

1.2.3. Tests

```
//file: SearchNodeTest.java

package at.fhooe.swe4.slidingpuzzle;

import org.junit.jupiter.api.AfterEach;
import org.junit.jupiter.api.BeforeEach;
import org.junit.jupiter.api.Test;

import java.util.ArrayList;
import java.util.Arrays;
import java.util.List;

import static org.junit.jupiter.api.Assertions.*;

public class SearchNodeTest {

  private SearchNode node;
  private Board board = new Board(3);

  @BeforeEach
  void setUp() {
    node = new SearchNode(board);
  }

  @AfterEach
  void tearDown() { node = null; }

  @Test
  public void simpleNodeTest() {
    try {
      Board board = new Board(3);
      board.setTile(1, 1, 1);
      board.setTile(1, 2, 2);
      board.setTile(1, 3, 3);
      board.setTile(2, 1, 4);
      board.setTile(2, 2, 5);
      board.setTile(2, 3, 6);
      board.setTile(3, 1, 7);
      board.setTile(3, 2, 8);
      board.setTile(3, 3, 0);
      SearchNode node = new SearchNode(board);
      assertEquals(0, node.estimatedCostsToTarget());

      board = new Board(3);
      board.setTile(1, 1, 1);
      board.setTile(1, 2, 2);
      board.setTile(1, 3, 3);
      board.setTile(2, 1, 4);
      board.setTile(2, 2, 0);
      board.setTile(2, 3, 6);
      board.setTile(3, 1, 7);
      board.setTile(3, 2, 8);
      board.setTile(3, 3, 5);
      node = new SearchNode(board);
      assertEquals(2, node.estimatedCostsToTarget());

      board = new Board(3);
      board.setTile(1, 1, 1);
      board.setTile(1, 2, 0);
      board.setTile(1, 3, 3);
      board.setTile(2, 1, 4);
      board.setTile(2, 2, 5);
      board.setTile(2, 3, 6);
      board.setTile(3, 1, 7);
      board.setTile(3, 2, 8);
      board.setTile(3, 3, 2);
      node = new SearchNode(board);
      assertEquals(3, node.estimatedCostsToTarget());
    }
    catch (BoardException e) {
      fail("Unexpeced BoardException.");
    }
  }
  @Test
  void testEquals() {
    Board b2 = new Board(3);
    SearchNode n2 = new SearchNode(b2);
    assertEquals(node, n2);

    n2.getBoard().setTile(1,1,4);
    assertNotEquals(node, n2);
  }

  @Test
  void compareTo() {
    Board b2 = new Board(3);
    b2.moveLeft();
    b2.moveUp();
    b2.moveUp();
    SearchNode n2 = new SearchNode(b2);
    n2.setCostsFromStart(20);
    node.setCostsFromStart(20);

    //in n2 changes were made so more changes are needed. The cost of n2 should be higher (considering that the costs from
start are the same
    //20-23;
    assertEquals(-3, node.compareTo(n2));

    node.setCostsFromStart(100);
    //100-23
    assertEquals(77, node.compareTo(n2));
  }

  @Test
  void toMoves() {
    List<Move> moves = Arrays.asList(Move.LEFT, Move.UP, Move.UP, Move.RIGHT, Move.DOWN, Move.DOWN);

    //creating data structure for test
    //allocating some nodes and linking them via predecessor component
    SearchNode current = node;
    SearchNode theNewNode = null;
    for(Move m : moves) {
      Board copiedBoard = current.getBoard().copy();
```

```
        if(m == Move.LEFT) {
          copiedBoard.moveLeft();
        } else if(m == Move.RIGHT) {
          copiedBoard.moveRight();
        } else if (m == Move.UP) {
          copiedBoard.moveUp();
        } else {
          copiedBoard.moveDown();
        }
        theNewNode = new SearchNode(copiedBoard);
        theNewNode.setPredecessor(current);
        current = theNewNode;
      }

      //I'm standing now at "theNewNode". That's the last one in the list (that is linked via predecessors)
      //For this node I'm now calling toMoves to get all previous moves that led to this state
      //The result should be the same as the List "moves" defined in the beginning
      List<Move> madeMoves = theNewNode.toMoves();
      assertEquals(madeMoves, moves);
    }

    /*
    remaining methods are just getter and setters. So I'm not testing them in detail
    */
}
```



```
✓ SearchNodeTest (at.fhooe.swe4.slic 41 ms
    ✓ simpleNodeTest()          31 ms
    ✓ compareTo()                1 ms
    ✓ toMoves()                  4 ms
    ✓ testEquals()               5 ms
```

1.3. SlidingPuzzle

1.3.1. Lösungsidee

Für die closedList verwende ich ein HashSet und kein TreeSet. Ich habe erstens nicht ganz verstanden, warum das sortiert sein müsste. Außerdem hatte ich ziemliche Laufzeitprobleme beim HashSet. Da hat der Test mit den Random 40 Puzzeln bei mir eine Minute gedauert. Eventuell fällt euch (@Tutor/Reviewer) auf, woran das liegen hätte können.

Nachdem die beiden Listen static Klassenkomponenten sind müssen sie bei jedem Aufruf von solve zuerst bereinigt werden. Dann wird ein Knoten erstellt und mit dem übergebenen Board initialisiert. Die Kosten vom Start setze ich für diesen Knoten auf 0. Die estimated costs to target werden im Konstruktor für den Node berechnet. Der Knoten wird der openList hinzugefügt.

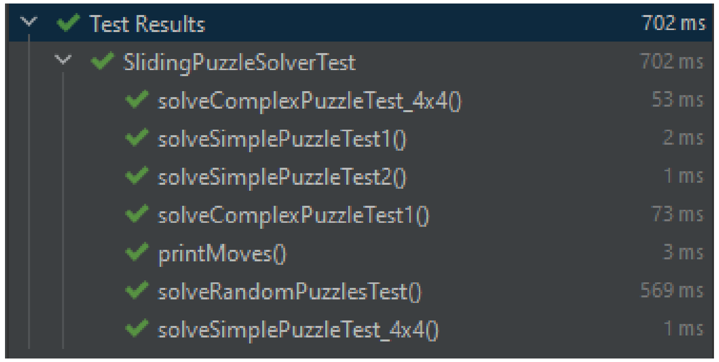
Nun kann die Schleife gestartet werden. Aus der Priority Queue (openList) wird immer der Knoten mit den geringsten Kosten entnommen. Falls dieser Knoten die Lösung darstellt, ist der Algo fertig. Falls nicht, wird der Knoten zur closedList hinzugefügt. Im Anschluss werden die bis zu vier Folgezustände berechnet. Jene Folgezustände, die noch nicht auf der closedList sind, werden zur openList hinzugefügt, um dann in den weiteren Schleifendurchgängen abgearbeitet werden zu können. Ein Update der Knoten in der openList ist in unserem Fall nicht notwendig, da die Kanten keine Gewichte haben (sondern konstant 1 beträgt).

1.3.2. Quellcode

```java
package at.fhooe.swe4.slidingpuzzle;

import java.util.*;

public class SlidingPuzzle {

    private static Queue<SearchNode> openList = new PriorityQueue<>();
    private static Set<SearchNode> closedList = new HashSet<>();

    /**
     * Solves a puzzle and returns a list of moves necessary to solve it
     * @param board the board to be solved
     * @return the list of moves to be made to solve the board
     * throws NoSolutionException
     */
    public static List<Move> solve(Board board) {
        openList.clear();
        closedList.clear();

        if(!board.isSolvable()) {
            throw new NoSolutionException();
        }

        Queue<SearchNode> openList = new PriorityQueue<>();
        Set<SearchNode> closedList = new HashSet<>();

        SearchNode startNode = new SearchNode(board);
        startNode.setPredecessor(null);
        startNode.setCostsFromStart(0);
        openList.add(startNode);

        while(!openList.isEmpty()) {
            SearchNode currentNode = openList.poll();
            if(currentNode.getBoard().isSolved()) {
                return currentNode.toMoves();
            }
            closedList.add(currentNode);

            List<SearchNode> successors = calculateSuccessors(currentNode);
            for(SearchNode succ:successors) {
                if(!closedList.contains(succ)) {
                    openList.add(succ);
                }
            }
        }

        return null;
    }

    /**
     * Makes up to four possible moves from a certain starting point (left, right, up, down)
     * For each new state a node is created and linked to the predecessor
     * @param currentNode = the starting state from which the next possible states are created
     * @return a list of the next states
     */
    private static List<SearchNode> calculateSuccessors(SearchNode currentNode) {
        List<Move> possibleMoves = Arrays.asList(Move.LEFT, Move.RIGHT, Move.UP, Move.DOWN);
        ArrayList<SearchNode> successors = new ArrayList<>();
        for(Move m:possibleMoves) {
            SearchNode nextSuccessor = calculateSuccessor(currentNode, m);
            if(nextSuccessor != null) {
                successors.add(nextSuccessor);
            }
        }
        return successors;
    }

    /**
     * Creates a new node for one particular move (m) based on the current search node
     * @param currentNode = the current state
     * @param m = the move to be made
     * @return a new searchNode with the new board configuration and costs or null if the move can't be made
     */
    private static SearchNode calculateSuccessor(SearchNode currentNode, Move m) {
        Board nextBoard = currentNode.getBoard().copy();
        try {
            switch (m) {
                case RIGHT:
                    nextBoard.moveRight();
                    break;
                case LEFT:
                    nextBoard.moveLeft();
                    break;
                case UP:
                    nextBoard.moveUp();
                    break;
                case DOWN:
                    nextBoard.moveDown();
                    break;
            }

            //estimatedCostsToTarget are set automatically
            SearchNode successorNode = new SearchNode(nextBoard);
            successorNode.setPredecessor(currentNode);
            successorNode.setCostsFromStart(currentNode.costsFromStart()+1);
            return successorNode;
        } catch (IllegalMoveException e){
            return null;
        }
    }

    /**
     * Prints the sequence of boards that result in executing all the moves
     * @param board = the start board
     * @param moves = the list of moves that will be applied to the start board
     */
    public static void printMoves(Board board, List<Move> moves) {
        System.out.println(board.toString());
        for (Move m:moves) {
            switch(m) {
                case DOWN:
                    board.moveDown();
                    break;
                case UP:
                    board.moveUp();
                    break;
                case LEFT:
                    board.moveLeft();
                    break;
                case RIGHT:
                    board.moveRight();
                break;
            }
            System.out.println(board.toString());
        }
    }

}
```

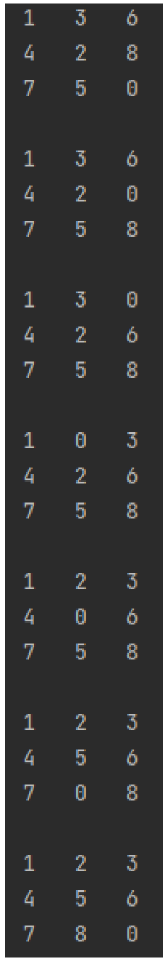
1.3.3. Tests

```
package at.fhooe.swe4.slidingpuzzle;

import static org.junit.jupiter.api.Assertions.assertEquals;
import static org.junit.jupiter.api.Assertions.fail;

import java.util.*;

import org.junit.jupiter.api.Test;

public class SlidingPuzzleSolverTest {

  @Test
  public void solveSimplePuzzleTest1() {
    try {
      Board board = new Board(3);
      board.setTile(1, 1, 1);
      board.setTile(1, 2, 2);
      board.setTile(1, 3, 3);
      board.setTile(2, 1, 4);
      board.setTile(2, 2, 5);
      board.setTile(2, 3, 6);
      board.setTile(3, 1, 7);
      board.setEmptyTile(3, 2);
      board.setTile(3, 3, 8);

      List<Move> moves = SlidingPuzzle.solve(board);
      assertEquals(1, moves.size());
      assertEquals(Move.RIGHT, moves.get(0));
    } catch (NoSolutionException nse) {
      fail("NoSolutionException is not expected.");
    }
  }


  @Test
  public void solveSimplePuzzleTest2() {
    try {
      Board board = new Board(3);
      board.setTile(1, 1, 1);
      board.setTile(1, 2, 2);
      board.setTile(1, 3, 3);
      board.setTile(2, 1, 4);
      board.setTile(2, 2, 5);
      board.setTile(2, 3, 6);
      board.setEmptyTile(3, 1);
      board.setTile(3, 2, 7);
      board.setTile(3, 3, 8);

      List<Move> moves = SlidingPuzzle.solve(board);
      assertEquals(2, moves.size());
      assertEquals(Move.RIGHT, moves.get(0));
      assertEquals(Move.RIGHT, moves.get(1));
    } catch (NoSolutionException nse) {
      fail("NoSolutionException is not expected.");
    }
  }


  @Test
  public void solveComplexPuzzleTest1() {

    try {
      //  8  2  7
      //  1  4  6
      //  3  5  X
      Board board = new Board(3);
      board.setTile(1, 1, 8);
      board.setTile(1, 2, 2);
      board.setTile(1, 3, 7);
      board.setTile(2, 1, 1);
      board.setTile(2, 2, 4);
      board.setTile(2, 3, 6);
      board.setTile(3, 1, 3);
      board.setTile(3, 2, 5);
      board.setEmptyTile(3, 3);

      List<Move> moves = SlidingPuzzle.solve(board);
      board.makeMoves(moves);
      assertEquals(new Board(3), board);
    }
    catch (NoSolutionException nse) {
      fail("NoSolutionException is not expected.");
    }
  }


  @Test
  public void solveRandomPuzzlesTest() {

    for (int k = 0; k < 40; k++) {
      try {
        Board board = new Board(3);
        int n = 1;
        int maxN = board.size() * board.size();
        for (int i = 1; i <= board.size(); i++)
          for (int j = 1; j <= board.size(); j++)
            board.setTile(i, j, (n++) % maxN);

        board.shuffle();
        Board shuffledBoard = board.copy();

        List<Move> moves = SlidingPuzzle.solve(board);
        board.makeMoves(moves);
        assertEquals(new Board(3), board);
        Board freshBoard = new Board(3);
        if(freshBoard != board) {
          shuffledBoard.toString();
        }


      } catch (NoSolutionException nse) {
        fail("NoSolutionException is not expected.");
      }
    }
  }

  @Test
  public void solveSimplePuzzleTest_4x4() {
    try {
      Board board = new Board(4);

      board.moveLeft();

      List<Move> moves = SlidingPuzzle.solve(board);
      assertEquals(1, moves.size());
      assertEquals(Move.RIGHT, moves.get(0));
    }
    catch (NoSolutionException nse) {
      fail("NoSolutionException is not expected.");
    }
  }


  @Test
  public void solveComplexPuzzleTest_4x4() {
    try {
      Board board = new Board(4);

      board.moveLeft();
      board.moveLeft();
      board.moveUp();
      board.moveLeft();
      board.moveUp();
      board.moveUp();
      board.moveRight();
      board.moveDown();
      board.moveLeft();

      List<Move> moves = SlidingPuzzle.solve(board);
      board.makeMoves(moves);
      assertEquals(new Board(4), board);
    }
    catch (NoSolutionException nse) {
      fail("NoSolutionException is not expected.");
    }
  }

  @Test
  void printMoves() {
    Board b = new Board(3);
    List<Move> movesIn = Arrays.asList(Move.LEFT, Move.UP, Move.UP, Move.RIGHT, Move.DOWN, Move.DOWN);
    b.makeMoves(movesIn);
    List<Move> movesOut = SlidingPuzzle.solve(b);
    SlidingPuzzle.printMoves(b,movesOut);

  }
}
```



```
Test Results                          702 ms
  SlidingPuzzleSolverTest             702 ms
    solveComplexPuzzleTest_4x4()       53 ms
    solveSimplePuzzleTest1()            2 ms
    solveSimplePuzzleTest2()            1 ms
    solveComplexPuzzleTest1()          73 ms
    printMoves()                        3 ms
    solveRandomPuzzlesTest()          569 ms
    solveSimplePuzzleTest_4x4()         1 ms
```

Output of printMoves() Test


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

1   3   6
4   2   0
7   5   8

1   3   0
4   2   6
7   5   8

1   0   3
4   2   6
7   5   8

1   2   3
4   0   6
7   5   8

1   2   3
4   5   6
7   0   8

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