CSM6120 - 8 puzzle solver

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***Abstract*—The abstract goes here.**

I. Introduction

IN this report the created solution to the 8 puzzle solver will be discussed.

II. Structure

The overall structure can be seen in the UML diagram, found in appendix A though C. In this section the structure of the program will be explained and the different classes and their uses analysed. Detailed description of the most important methods will be given, but for reference to all methods and theirs uses please refer to the JavaDoc in appendix **ADD JAVADOC AS APPENDIX**.
The structure of this section is as follows: for every package used in the program the use of the package as well as the classes inside it is given followed by a section about the justification of the design choices.

A. The csm6120 Package

This package holds the Main class, aswell as the *State* and *FileManager classes*.
The class diagram for this can be found in Appendix A on page 4.
This package acts as entry point to the program where the input files are read and where the *State* class is located.

1) Main: The Main class is the entrance to the program.
The main method takes command line arguments such as the path to the start state and goal state of the puzzle(in .txt files) and a string which specifies what algorithm to use.
It creates instances of the FileManager object and State objects and calls the algorithm chosen by the user.

2) State: The State class holds variables and methods to manipulate and represent each state of the puzzle, that is the tile placement of the puzzle.
The tiles are interpreted as a simple arrayList, this has been done in order to make manipulating the array easier.
The class holds methods to switch 2 given tiles(done based on their index in the arrayList) as well as other common methods such as getters and methods to compare a state object to another.
These methods are used in the other algorithms incorporated in the program.

3) FileManager: The FileManager class holds methods to read input from a file, converts the strings into integers and then save it to the integer ArrayList in a State object.
The main class instantiates a single FileManager object and than uses it to read the input files provided by the user.

4) Justification: The idea for the *csm6120 Package* was to have the methods which manipulate the input files all in one place. It was considered to move the State class to the *SearchTree* package, but considering it holds such a central role in the program the decision fell against it.
The FileManager class was created in order to have a separate class to handle input files, this was done in order to follow object orientated design structures.

B. The SearchTree Package

This package holds classes which represent and generate the search tree.
The UML diagram for this can be found in appendix B on page 5

1) TreeNode: Objects of the TreeNode class represent nodes of the search tree.
Every TreeNode holds a State object as well as 2 linkedLists. One linkedList holding the children of one particular node, the other for holding its siblings.
The class has methods to add, get and remove nodes from those lists, as well as common methods such as returning if a list is empty.

2) Graph: The graph is used to generate the next step of the graph, by expanding all possible children from a particular TreeNode object and than add them to the linkedlist of children of said TreeNode object.
The nextStep method of this class checks where the empty tile is in a given TreeNode object, based on that it calls one of three possible functions which generate the children of the object.

3) Justification: The idea was to have all classes which represent or manipulate the nodes of the search tree in a single package. It was also decided to only have a class for the nodes of the tree and representing the connections to its children using a internal linkedList rather than having a separate edge class which only links 2 nodes together. The reason this was done was for simplicity: using linkedList methods like adding and returning makes it easier considering every node has a very limited, maximum of 4, number of possible children.

C. SearchAlgorithm Package

This package holds all search algorithms implemented in the program, as well as all supporting classes needed for them.
The UML diagram for this package can be seen in appendix C on page 6.

In general all the search algorithms are build up much the same way, they take 2 parameters: a start and goal State object, these States are than used to create the first node of the search tree, the goal state gets saved in the current search algorithm object and is used to check if the goal state of the puzzle has been reached.
The algorithms use the classes from the SearchTree package(see section II-B) to generate the search tree.
At the beginning of each algorithm it is checked if the start state is equal the goal state, this might be a rare occurrence but a useful functionality non the less.
All algorithms also hold a list of all previous expanded nodes, which all new generated nodes are checked against in order to prevent infinity loops. That already visited nodes are created again is because the children to each node are generated without knowledge if such a node has been created before, so infinity loops would be created relatively early on in the search trees.

1) Breadth-First search: This class holds the breadth-first search algorithm.
This algorithm works using a first-come first served queue.

2) Depth-First search: This class holds the depth-first search algorithm.
It is in its structure very similar to the breadth-first search algorithm, however uses a last-in first-out stack.

3) Greedy Best-First search: This class holds the greedy best-first search algorithm.
It is in its structure very like the breadth-first or depth-first algorithms, however uses a priority queue. In the priority queue the elements are sorted according to its *natural ordering*, meaning from lower to higher numbers.
That way the treeNode which is closer to the goal state will be checked next. The priority queue uses the stateComparator class to sort its elements.

4) A star algorithm: This class holds the A star search algorithm.
This algorithm is similar to the greedy best-first algorithm in that it uses a priority queue, but it also uses a more advanced heuristic to decide which nodes to add to the queue in the first place.
This class holds 2 methods, one is the search algorithm in itself, the other is a method used to decide which treeNode object to add to the search queue. This is done using the Manhattan Distance heuristic. In the beginning of the algorithm the Manhattan Distance to the goal state is calculated and saved to a variable.
The addNode method than uses the current treeNode object and the goal State to calculate the Manhattan distance for each of the current treeNode's children. If the calculated Manhattan Distance is equal or less than the one calculated at the beginning of the algorithm the node is added to the search queue. Should the calculated distance be larger the child is discarded.
To calculate the Manhattan Distance the a ManhattanDistance object is used.

5) StateComparator: This class holds the StateComparator method used to compare to states in a priority list. This class implements the *Comparator* interface.
It uses the String representation of a State objects state array to do the comparison.

6) ManhattanDistance: This class holds the methods used to calculate the Manhattan Distance.
During development of an early method to calculate the Manhattan Distance straight from a state array a number of problems have been found. The decision was made that a 2D representation of the array would be more fitting in order to calculate the Manhattan Distance.
However in order to avoid having to refactor all other algorithms the ManhattanDistance class holds methods to change an input arrayList to a simple array and after that to a 2 dimensional array.

The Manhattan Distance is calculated as such:
For each possible number of the puzzle find its index X and Y coordinates for each of the 2 input States. Then compare the X and Y coordinates of both indices and calculate the total difference in tiles.

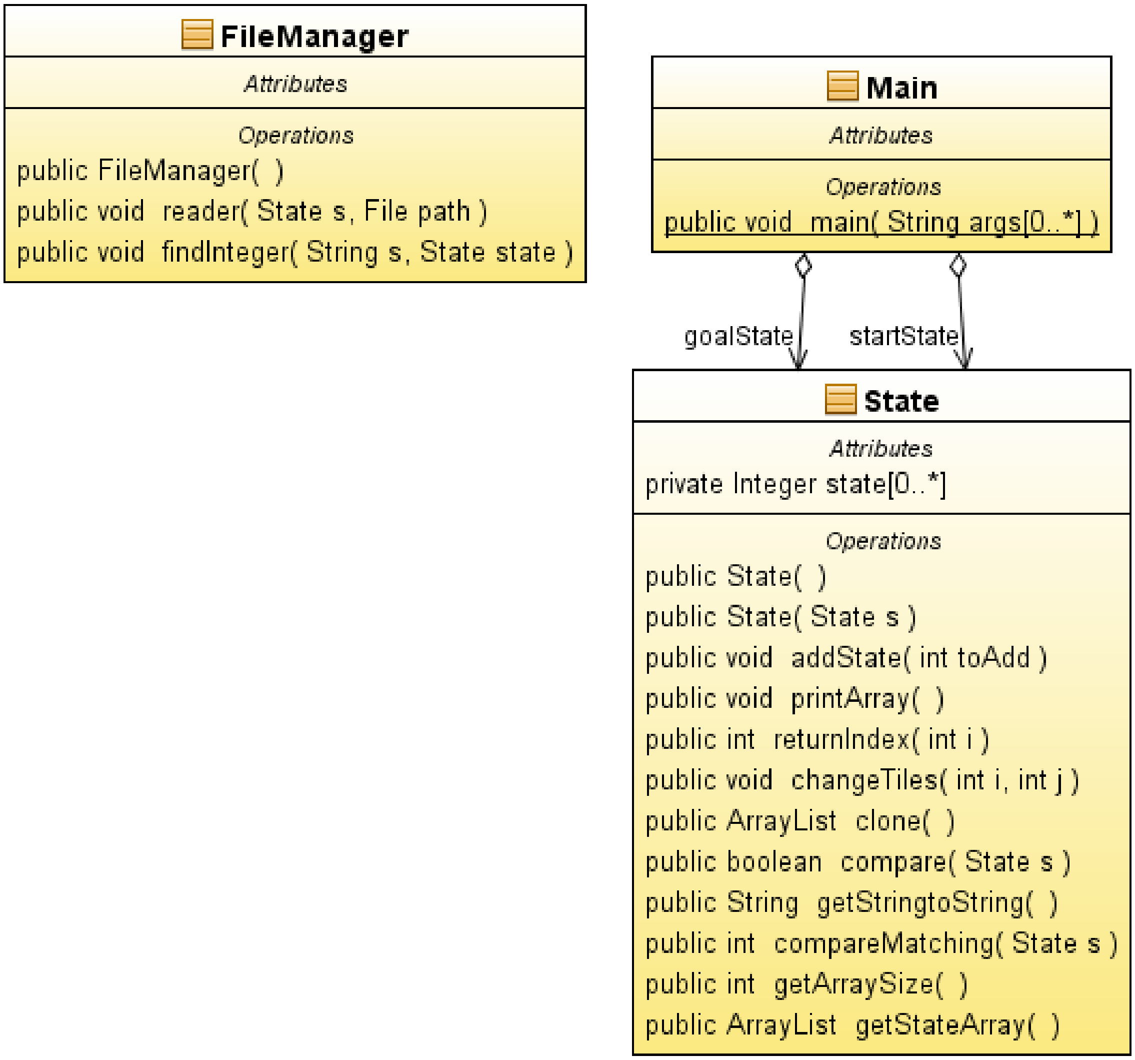
Here 2 things must be nodded:
Depending on if the start State indices minus the goal State indices return a value less than zero or above, the formula gets flipped in order to prevent receiving a negative Manhattan Distance. The code for this is shown below:

```
if (startArray[i][j] == goalArray[i][j]) {
      continue;
} else if (startArray[i][j] - goalArray[i][j]
    < 0) {
      manhattanDistanceSum +=
          Math.abs(x_start - x_goal)
            + Math.abs(y_start - y_goal);
} else if (startArray[i][j] - goalArray[i][j]
    > 0) {
      manhattanDistanceSum += Math.abs(x_goal
          - x_start)
            + Math.abs(y_goal - y_start);
}
```

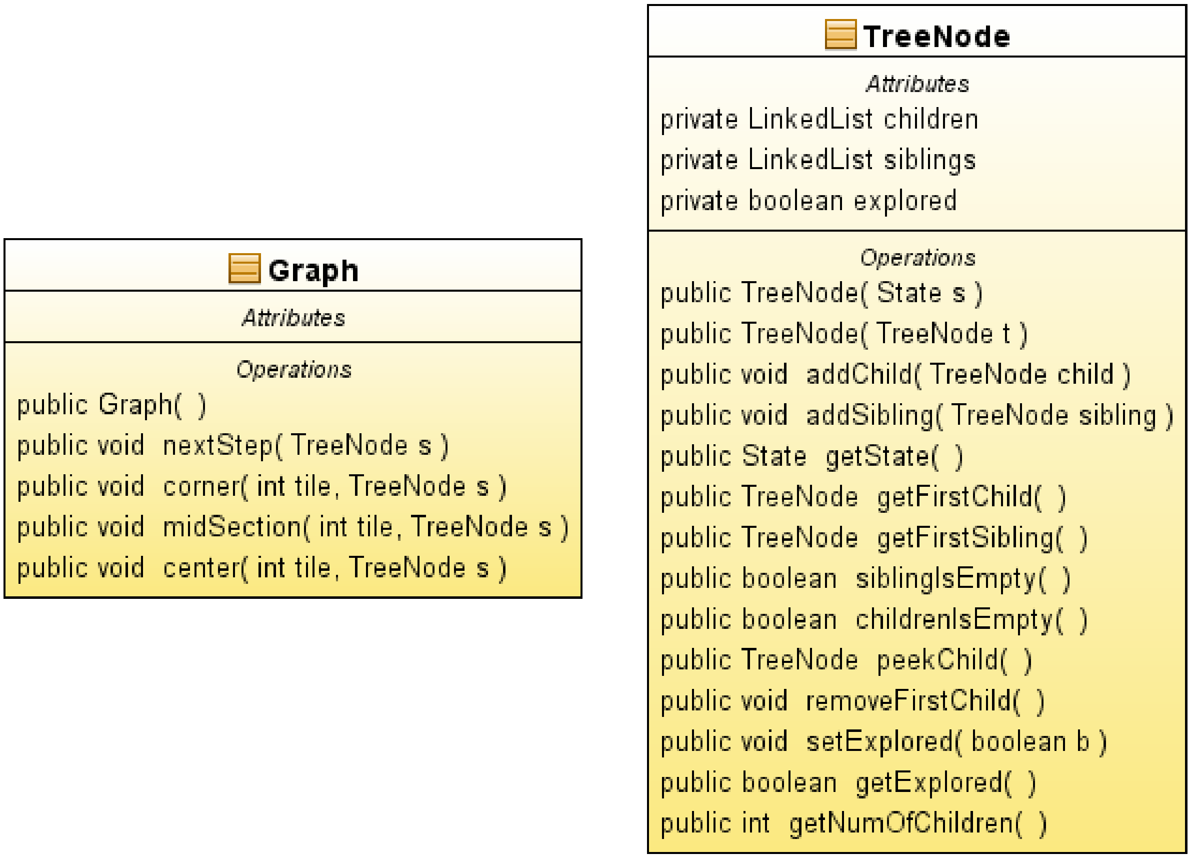
The other important thing to node is that empty/zero tile of the puzzle is ignored in the Manhattan Distance calculation, this is to accommodate the fact that at every iteration 2 tiles are switched.

7) Justification: It can be argued that the methods in the ManhattanDistance class are bad practice, as it would have been better to refactor all previously written algorithm to use 2D arrays rather than converting a State arrayList to a 2D array for every treeNode object.
However this decision was made as the use of a arrayList makes the use of the algorithms though out the program easier, thanks to Java's inbuilt arrayList methods.
Also since all arrayList have a limited size of 8, the computational cost for the conversion is constant and not large.

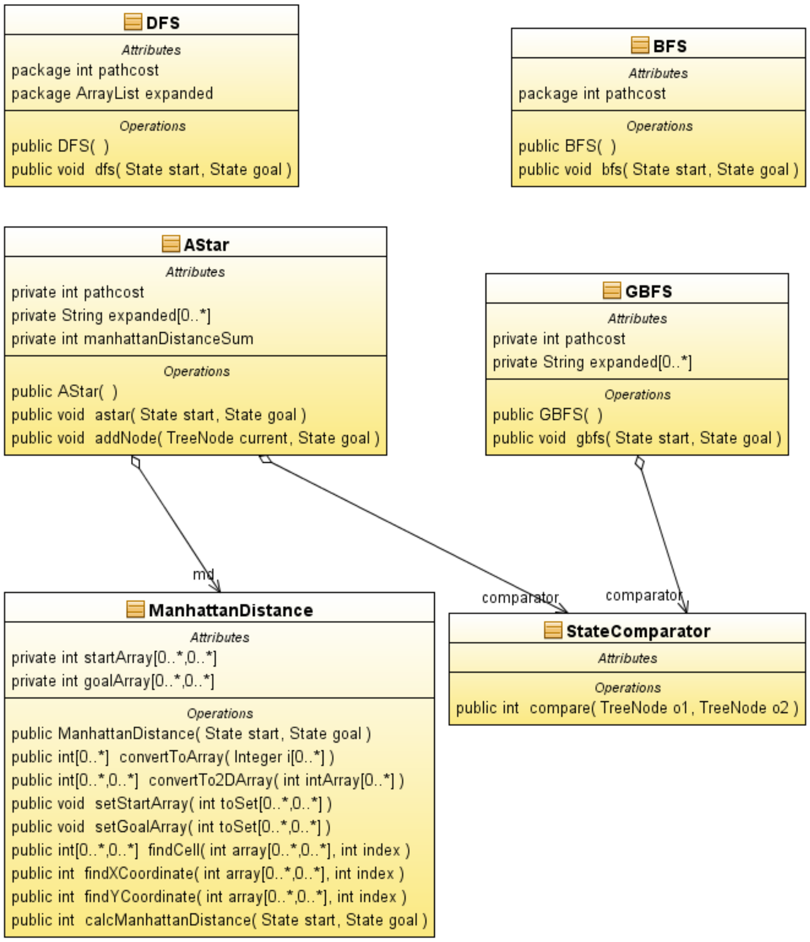
APPENDIX A
CSM1620 PACKAGE UML



APPENDIX B
SEARCHTREE PACKAGE UML



APPENDIX C
SEARCHALGORITHM PACKAGE UML



REFERENCES

[1] H. Kopka and P. W. Daly, *A Guide to LaTeX*, 3rd ed. Harlow, England: Addison-Wesley, 1999.

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Michael Shell Biography text here.

John Doe Biography text here.

Jane Doe Biography text here.