CS1027

ASSIGNMENT 2

Computer Science Fundamentals II

This assignment is due on Thursday, March 4th, 2021 by 11:55pm.
See the bottom of this document for submission details.

Learning Outcomes

To gain experience with

- Solving problems with the stack data type
- The design of algorithms in pseudocode and their implementations in Java
- Handling exceptions

Introduction

Valentines Day is fast approaching, and the hero of our story, Cupid, is trying his best to spread some platonic love and friendship in these gloomy times. If you didn't know, Cupid is an archer, and archers often prefer staying still and spending their time taking good shots with their bow. Cupid is no different in this regard, but he's heard you've been learning about stacks and algorithm design and was wondering if you could help him simulate some scenarios so that he's in tip-top shape (He hasn't been getting out much with the pandemic). He also understands that your assignment isn't due until the 4th of March, but he's happy to have it for future years anyways.

You are given a map that describes Cupid and the targets for his arrows, which is divided into rectangular cells to simplify the task of computing the required path. There are different types of map cells:

- The starting point that Cupid wants to use
- Map cells where the target is located,
- Map cells indicating roadblocks or other barriers
- Map cells containing pathways. There are 3 types of pathways:
    - Cross paths. A cross path located in cell L can be used to interconnect all the neighbouring map cells of L. A cell L has at most 4 neighbouring cells that we denote as the north, south, east, and west neighbours. The cross path can be used to interconnect all neighbours of L;
    - Vertical paths. A vertical path can be used to connect the north and south neighbours of a map cell; and
    - Horizontal paths. A horizontal path can be used to connect the east and west neighbours of a map cell.

Figure 1 shows an example of a map divided into cells.

Each map cell has up to 4 neighbouring cells indexed from 0 to 3.

Given a cell, the north neighbouring cell has index 0 and the remaining neighbouring cells are indexed in clockwise order. For example, in Figure 1 the neighbouring cells of cell 8 are indexed from 0 to 3 as follows: neighbour with index 0 is cell 1, neighbour with index 1 is cell 9, neighbour with index 2 is cell 13, and neighbour with index 3 is cell 7.

Some cells have fewer than 4 neighbours and the indices of these neighbours might not be consecutive numbers; for example, cell 4 in Figure 1 has 2 neighbours indexed 1 and 2 (no 0 or 3 neighbours).

A path from Cupid (cell number 12 in the figure) to a target (cell number 0) is the following: 12, 7, 2, 1, 0. A path from Cupid to another target (cell number 4) is the following: 12, 7, 2, 3, 4. Note that in some other maps, cells will be inaccessible because they are walls, or because the path is horizontal and the only way is vertical, or vice versa.

Valid Paths

When looking for a path the program must satisfy the following conditions:

- The path can go from Cupid, a cross path cell, or a target cell to the following neighbouring cells:
  - A target cell,
  - A cross path cell,
  - The north cell or the south cell, if such a cell is a vertical path, or
  - The east cell or the west cell, if such a cell is a horizontal path.

- The path can go from a vertical path cell to the following neighbouring cells:
  - The north cell or the south cell, if such a cell is either Cupid, a cross path cell, a target cell, or a vertical path cell.
- The path can go from a horizontal path cell to the following neighbouring cells:
  - The east cell or the west cell, if such a cell is either Cupid, a cross path cell, a target cell, or a horizontal path cell.

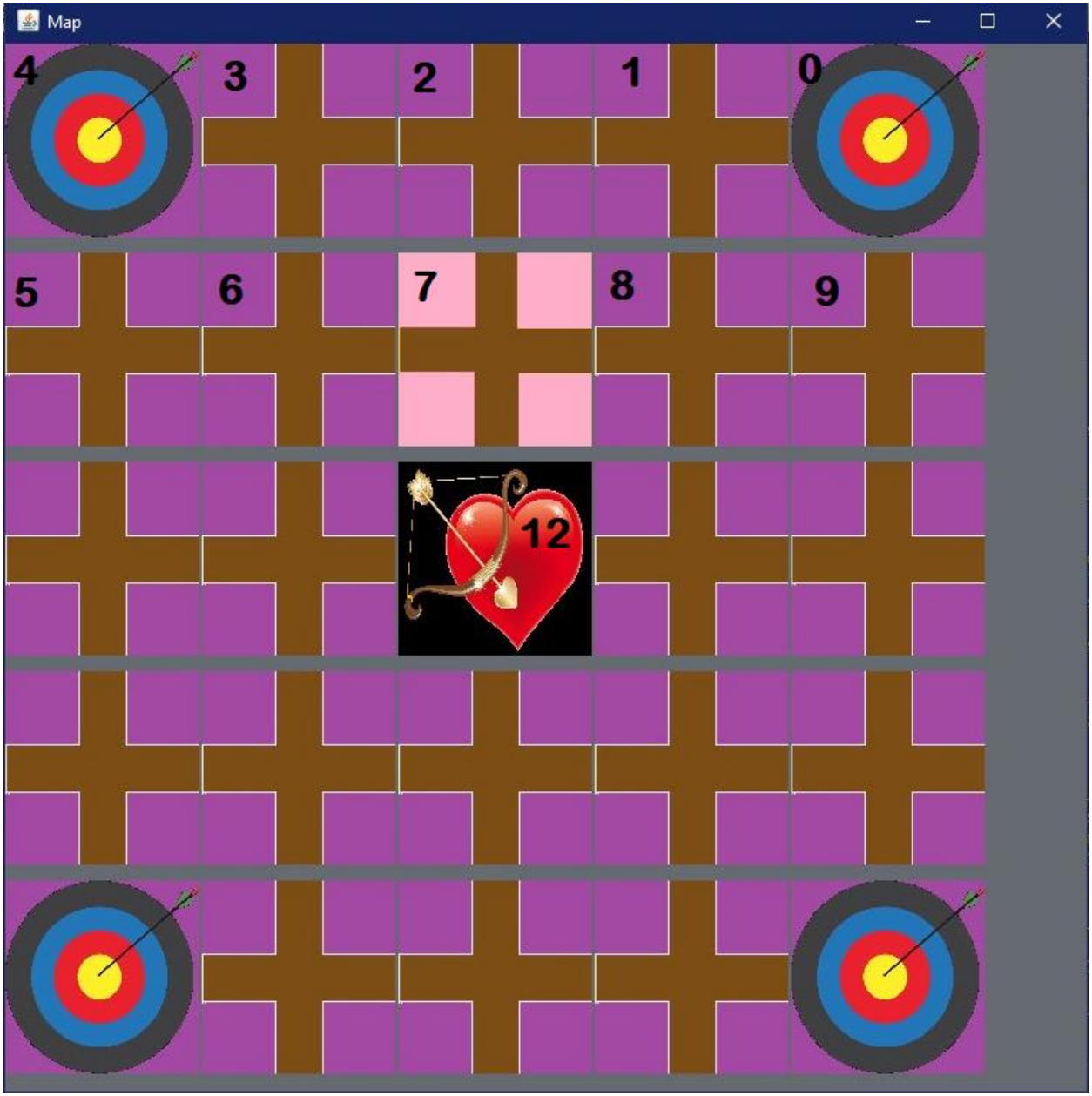


Figure 1. A sample of one of Cupid's maps represented as a grid of cells

Limitation:
If while looking for a path the program finds that from the current cell there are several choices as to which adjacent cell to use to continue the path, your program must select the next cell for the path in the following manner:

- An object in motion in motion will stay in motion unless acted on by an unbalanced force. The arrows will continue in the same direction they were heading if the path is available.
- The program prefers a target cell over the other cells.
- If there is no target cell adjacent to the current cell, then the program must prefer the cross path cell over the other cells; and
- If there is no cross-path cell, then the program chooses the smallest indexed cell that
- satisfies the conditions described above.
- While Cupid's arrows are magic, they are only so magical. The arrows Cupid uses can backtrack up to 3 times before they are unable to do so again.
- Cupid's arrows can only turn so much as well. Keep track of the inertia of the arrow by tracking how many times it has traveled in the same direction. After it has taken 3 steps in the same direction, it can no longer turn. For simplicity, it may take 2 steps and turn as many times as needed for the pathfinding.
- **Importantly**, Cupid will only shoot an arrow down the same path once.
- Cupid's arrows should stop when they hit a target, and the stack should be popped until empty.
- The distance Cupid can shoot an arrow is configurable and provided as an argument to the program.
- Lastly, Cupid fires arrows one at a time.

Provided files

The following is a list of files provided to you for this assignment. You do not need alter these files in any way and should assume we will mark them with unmodified ones. Studying these will help improve your understanding of Java.

- Map.java – This class represents the map of the neighbourhood, including Cupid's starting location and the target houses. The public methods from this class you might use include:
    - *Map (String inputFile) throws InvalidMapException, FileNotFoundException, IOException*. This method reads the input file and displays the map on the screen. An *InvalidMapException* is thrown if the *inputFile* has the wrong format.
    - *MapCell getStart()*. Returns a *MapCell* object for the cell that Cupid starts in.
    - *Int quiverSize()*. Returns the number of targets that can fit in Cupid's quiver.
    - **Note:** Lines 45-47 set the delay times for showing the path. You may wish to enable line 47 when testing many maps to have it go quicker.

- MapCell.java – This class represents the cells of the map. Objects of this class are created inside the class *Map* when its constructor reads the map file. The methods that you might use from this class are:

    - *MapCell neighbourCell(int i) throws InvalidNeighbourIndexException*. As explained in Section 1, each cell of the map has up to four neighbouring cells, indexed from 0 to 3. This method returns either a *MapCell* object representing the i-th neighbour of the current cell or null if such a neighbour does not exist. Remember that if a cell has fewer than 4 neighbouring cells, these neighbours do not necessarily need to appear at consecutive index values. So, it might be, for example, that *this.getNeighbour(2)* is null, but *this.getNeighbour(i)* for all other values of i are not null. An *InvalidNeighbourIndexException* exception is thrown if the value of the parameter i is negative or larger than 3.

    - boolean methods: *isBlocked(), isCrossPath(), isVerticalPath(), isHorizontalPath(), isCupid(), isTarget(),* return true if this *MapCell* object represents a cell corresponding to a blocked path, a cross path, a vertical path, a horizontal path, Cupid, or a target respectively.
    - *boolean isMarked()* returns true if this MapCell object represents a cell that has been marked as *inStack* or *outOfStack.*
    - *void markInStack()* marks this *MapCell* object as *inStack.*
    - *void markOutStack()* marks this *MapCell* object as *outOfStack.*

- Other classes provided:
    - *ArrayStackADT.java, CellColors.java, CellComponent.java, InvalidNeighbourIndexException.java, CellLayout.java, InvalidMapException.java, IllegalArgumentException.java.*

Classes to implement

A description of the classes that you are required to implement for full marks in this assignment are given below. You may implement more classes if you want; you must submit the code for these with your assignment.

In all these classes, you may implement more private (helper) methods as desired, but you may **not** implement more public methods. You may **not** add static methods or instance variables. Penalties will be applied if you implement these.

ASSIGNMENT 2

For this assignment, you may not use Java's *Stack* class, although reading and understanding the code there may help you better understand stacks. You also may not use any other pre-made Java collections libraries. The data structure required for this assignment is an array, described below:

ArrayStack.java

This class implements a stack using an array. The header for this class must be this:

public class ArrayStack<T> implements ArrayStackADT<T>

This class will have the following private instance variables:

- T[] stack.
  - This array stores the data items of the stack.

- int top.
  - This variable stores the position of the last data item in the stack. In the constructor this variable must be initialized to -1, this means the stack is empty.
  - Note that this is different from the way in which the variable top is used in the lecture notes.

This class will have the following **public static** variable:

- public static String sequence;
  - Used for tracking the arrow path.

This class needs to provide the following public methods:

- ArrayStack()
  - Creates an empty stack.
  - The default initial capacity of the array used to store the items of the stack is 14 (for Valentine's day)

- ArrayStack(int initialCapacity).
  - Creates an empty stack using an array of length equal to the value of the parameter.

- void push(T dataItem)
  - Adds dataItem to the top of the stack. If the array storing the data items is full, you will increase its capacity as follows:
    - If the capacity of the array is smaller than 50, then the capacity of the array will be increased by 10.

- Otherwise, the capacity of the array will increase by doubling the initial size. So, if, for example, the size of the array is 225 and the array is full, when a new item is added the size of the array will increase to 450.

At the end of this method, add the following. This is used in TestSearch to make sure you are following a correct path:

```
if (dataItem instanceof MapCell) {
        sequence += "push" + ((MapCell)dataItem).getIdentifier();
    }
    else {
        sequence += "push" + dataItem.toString();
    }
```

- T pop() throws EmptyStackException
  - Removes and returns the data item at the top of the stack. An EmptyStackException is thrown if the stack is empty.
  - If after removing a data item from the stack the number of data items remaining is smaller than one fourth of the length of the array you need to shrink the size of the array by one half, to a minimum of 14;
  - To do this create a new array of size equal to half of the size (to a minimum of 14) of the original array and copy the data items there.
  - For example, if the stack is stored in an array of size 100 and it contains 25 data items, after performing a pop operation the stack will contain only 24 data items. Since 24 < 100/4 then the size of the array will be reduced to 50. When creating an EmptyStackException an appropriate String message must be passed as parameter.

At the end of pop(), add the following lines:

```
if (result instanceof MapCell) {
        sequence += "pop" + ((MapCell)result).getIdentifier();
    }
    else {
        sequence += "pop" + result.toString();
    }
```

- T peek() throws EmptyStackException.
  - Returns the data item at the top of the stack without removing it. An EmptyStackException is thrown if the stack is empty.

- boolean isEmpty().
  - Returns true if the stack is empty and returns false otherwise.

- int size()
  - Returns the number of data items in the stack.

- int length()
  - Returns the capacity of the array stack.

- String toString()
  - Returns a String representation of the stack of the form:
    "Stack: elem1, elem2, ..." where element i is a String representation of the i-th element of the stack.
  - If, for example, the stack is stored in an array called s, then element 1 is s[0].toString(), element 2 is s[1].toString(), and so on.

You can implement other methods in this class, if you want to, but they must be declared as private.

StartSearch.java

This class will have the following **private** instance variable

- Map targetMap;
- This variable will reference the object representing the map where Cupid and the targets are located. This variable must be initialized in the constructor for the class, as described below.
- int numArrows, for how many arrows Cupid has fired so far. Compare this to the quiverSize from the Map.
- int inertia, which is used for tracking how many times an arrow has travelled in the same direction. It should start at 0 and increase everytime an arrow moves in the same direction.
- int direction, which is used for tracking the direction of the arrow. 0 is north, 1 is east, 2 is south, 3 is west. (Or Up, Right, Down, Left, respectively)

You must implement the following methods in this class:

- StartSearch(String filename)
  - This is the constructor for the class. It receives as input the name of the file containing the description of the map. In this method you must create an object of the class Map (described in the provided files) passing as parameter the given input file; this will display the map on the screen.
  - Read them if you want to know the format of the input files.
- static void main(String[] args).
  - This method will first create an object of the class *StartSearch* using the constuctor *StartSearch(args[0]).*
  - *Args[0]* will be the name of a map file, *args[1]* will be the number of cells that the arrow can travel before it falls to the ground.
  - If and only if a size argument is provided, your algorithm should count how many targets can be found in a path that is at most *args[1]* long with the number of arrows determined by the map.
  - When you run the program, you will pass as command line arguments the name of the input file (see following section after Java classes), and the number of cells that Cupid can hit from his starting point to find target along with the number of arrows.
  - Your main method then will try to find a path from Cupid to the targets according to the restrictions specified above.
  - The algorithm that looks for a path from the initial cell to the destinations must use a stack and it cannot be recursive.
  - Suggestions on how to look for this path are given in the next section. The code provided to you will show the path selected by the algorithm as it tries to reach the target cells, so you can visually verify if your program works.
  - The main method should exit by printing out the number of targets found given the restrictions above (maximum arrow length, maximum number of arrows, Cupid won't shoot down the same path twice.

- MapCell nextCell(MapCell cell).
  - The parameter is the current cell.
  - This method returns the best cell to continue the path from the current one, as specified early in the limitations.
  - Refer to those priorities when coding this section.
  - If several unmarked cells are adjacent to the current one and can be selected as part of the path (**remember** the arrow will stay on the same path first), then this method must return one of them in the following order:
    - A target cell

        - A cross path cell.
        - If there are several possible cross path cells, then the one with the smallest index is returned.
        - A vertical path cell or a horizontal path cell with smallest index
        - Read the description of the class MapCell below to learn how to get the index of a neighbouring cell.
        - If there are no unmarked cells adjacent to the current one that can be used to continue the path, this method returns null.
    - Your program must catch any exceptions that are thrown by the provided code.
    - For each exception caught, an appropriate message must be printed.
    - The message must explain what caused the exception to be thrown.

You can write more methods in this class but they must be declared as private.

Algorithm for Computing a Path

Below is a description for an algorithm that will look for a path for Cupid to the targets. It will be helpful to understand the algorithm deeply before attempting to implement it. There are better algorithms for finding targets given a maximum path length, but they may not pass all the tests. Implement the algorithm as described to make sure your code passes the test cases.

You must use a stack to keep track of which cells are in the path, and it cannot be recursive. Writing your algorithm in pseudocode will make coding it in Java easier and is helpful to show to the TAs and the instructors if you need help.

- Initialize the number of found targets to 0.
- Create a stack based on the command line inputs
- Get the start cell (Cupid) using the methods of the supplied class Map.
- Push the starting cell into the stack and mark the cell as inStack.
- You will use methods of the class MapCell to mark a cell.
- While the stack is not empty and Cupid has arrows left, and the arrow path length has not been reached, perform the following steps:
    - Peek at the top of the stack to get the current cell.
    - Find the next unmarked neighbouring cell (use method nextCell from class StartSearch to do this).
    - If one exists:
        - Push the neighbouring cell into the stack and mark it as inStack.
        - (If max path length given) Increase the path length counter
        - If the best neighbouring cell is a target, increase the number of targets hit
    - Otherwise, since there are no unmarked neighbouring cells that can be added to the path, pop the top cell (and increase the path length counter) from the stack.
- While the stack is not empty perform the following:

- Pop the top cell from the stack.
- When popping cells adjacent to Cupid, mark as out of stack.

Your program must print a message indicating how many targets were hit
Note that your algorithm does not need to find the shortest path from Cupid to all the targets, or even the shortest path with the pathing restraints.

Command Line Arguments

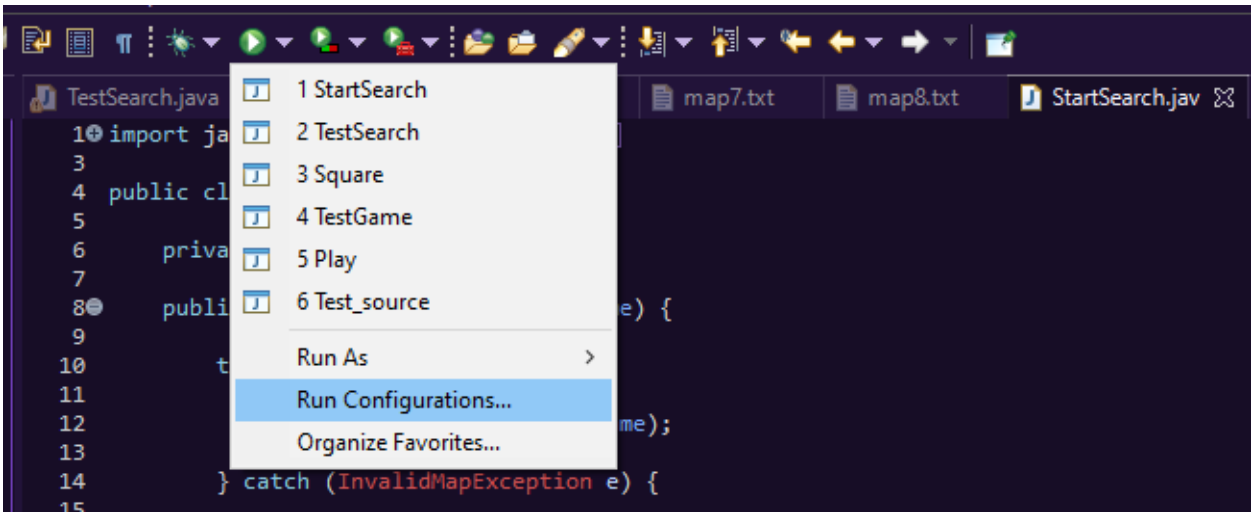
Your program must read the name of the input map file from the command line.
You can run the program with the following command:

java StartSearch nameOfMapFile (optional)maxPathLength

Where nameOfMapFile is the name of the file containing the map, and maxPathLength is the longest path that Cupid's arrow can take to find targets.
You can use the following code to verify that the program was invoked with the correct number of arguments:

```
public class StartSearch {
        public static void main (String[] args) {
                if (args.length < 1) {
                        System.out.println("You must provide the name of the input file");
                        System.exit(0);
                }
                String mapFileName = args[0];
                int maxPathLength = Integer.parseInt(args[1]);
                ...
```

You can access run configurations as follows:

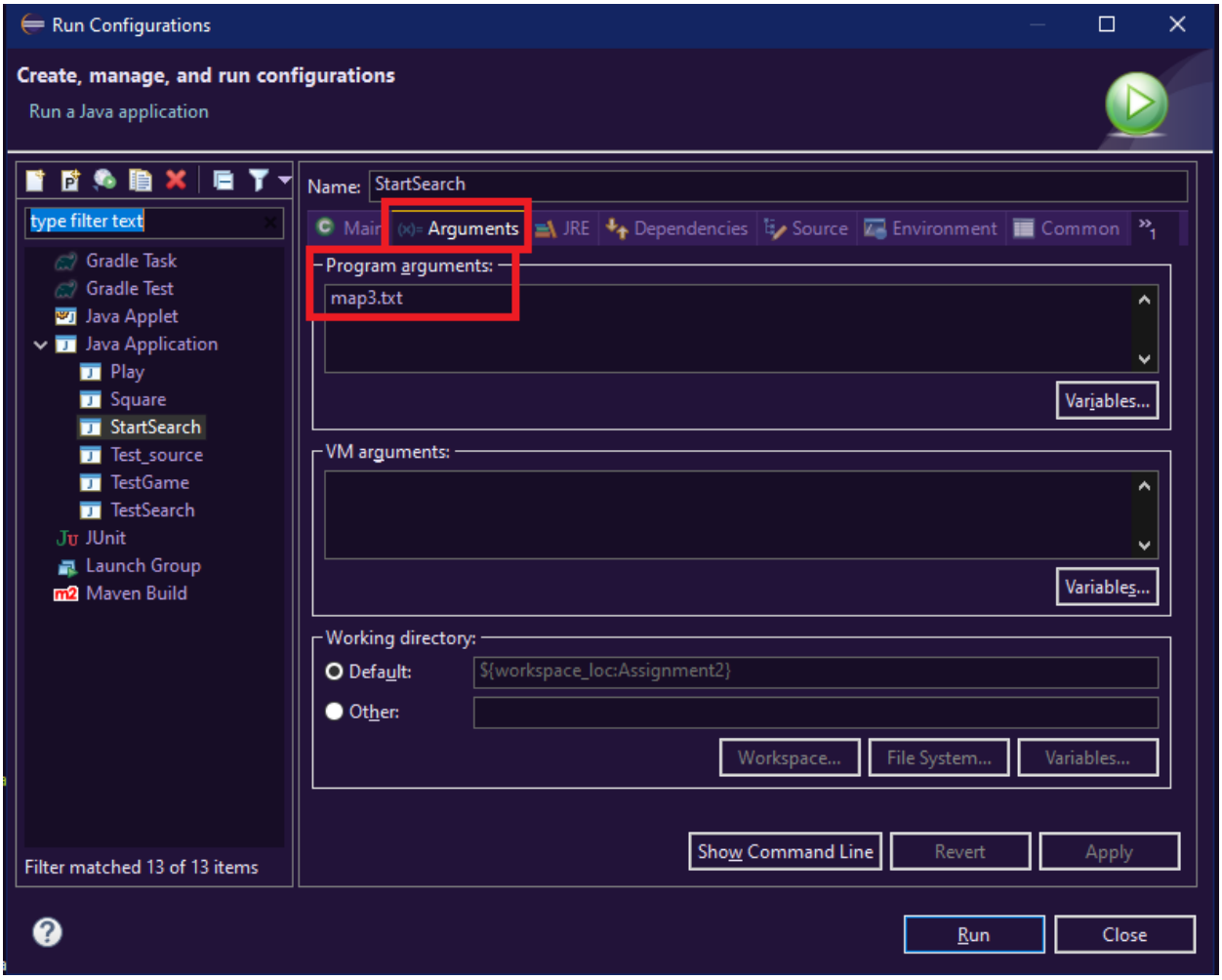


In the text box for 'Program arguments', you can type your arguments in. Ex: map3.txt above, or map3.txt 20 for map 3 with a maximum of 20 steps.

Image Files and Sample Input Files Provided

- You are given several image files that are used by the provided Java code to display the map cells on the screen.
- You are also given several input map files that you can use to test your program.
- In Eclipse put all these files inside your project file in the same folder where the src folder is.
- Do not put them **inside** the src folder as Eclipse will not find them there.

- If your program does not display the map correctly on your monitor, you might need to move these files to another folder, depending on how your installation of Eclipse has been configured.



Marking notes

Marking categories

- Functional specifications
  - Does the program behave according to specifications?
  - Does it produce the correct output and pass all tests?
  - Are the class implemented properly?
  - Are you using appropriate data structures?

- Non-functional specifications
  - Are there Javadocs comments and other comments throughout the code?
  - Are the variables and methods given appropriate, meaningful names?
  - Is the code clean and readable with proper indenting and white-space?
  - Is the code consistent regarding formatting and naming conventions?
- Penalties
  - Lateness: 10% per day
  - Submission error (i.e. missing files, too many files, ZIP, etc.): 5%
  - "package" line at the top of a file: 5%

Remember you must do all the work on your own. Do not copy or even look at the work of another student. All submitted code will be run through cheating-detection software.

Submission (due Thursday, March 4th, 2020 at 11:55pm ET)

Rules

- Please only submit the files specified below. Do not attach other files even if they were part of the assignment.
- Submit the assignment on time. Late submissions will receive a penalty of 10% per day.
- Forgetting to submit is not a valid excuse for submitting late.
- Submissions must be done through Gradescope
- Submitting the files in an incorrect submission page or website will receive a penalty.
- Assignment files are NOT to be emailed to the instructor(s) or TA(s). They will not be marked if sent by email.
- You may re-submit code if your previous submission was not complete or correct, however, re-submissions after the regular assignment deadline will receive a penalty.

Files to submit

- ArrayStack.java
- StartSearch.java
- Any custom classes used.

Grading Criteria

- Total Marks: [20]
- Functional Specifications:
  - [4] ArrayStack.java
  - [4] StartSearch.java

    - [8] Passing Tests
- Non-Functional Specifications:
    - [1] Meaningful variable names, private instance variables
    - [1] Code readability and indentation
    - [2] Code comments