Assignment 1

1 Objective

Gain more experience using Java generics, inheritance and interfaces.

2 Marking

This assignment will be graded of of 30 marks, 10 based on the quality of the code and 20 based on the functionality of the code.

It is worth 8% of your final grade.

The submission deadline is June 30, 2016, 11:50pm.

You can work in groups of two if desired. In this case, please declare your group.

Late submission policy: 1% penalty for each hour up to 24 hours. No submissions will be accepted after 11:50pm of July 1, 2016.

3 How to submit your work

1. By now your svn repository will contain a new directory called A1. It contains the starter code for this exercise.
2. If you prefer to work in group, make sure to sign up for a group by Friday, June 17. In case you sign up for a group, please create a text file named A1.txt that contains a single line with the following format:

   `group_id,cdf_name_1,cdf_name_2`

   where `group_id` is the group you have signed up for and `cdf_name_1, cdf_name_2` are the cdf names of the group members.
3. I will create group A1 folders and load the starter code for the groups by Saturday, June 18. After this date no new groups can be formed. You have to work individually.
4. To submit your work, add and commit your changes to your repository (those who are working in groups, should submit at their group repo; those who work individually, should submit at their individual repo).

   Do **not** commit the files and directories generated by Eclipse, such as `bin, doc, .project`, etc. Marks will be deducted if you submit these.
5. Your work willbe evaluated for functionality, style and coding quality.

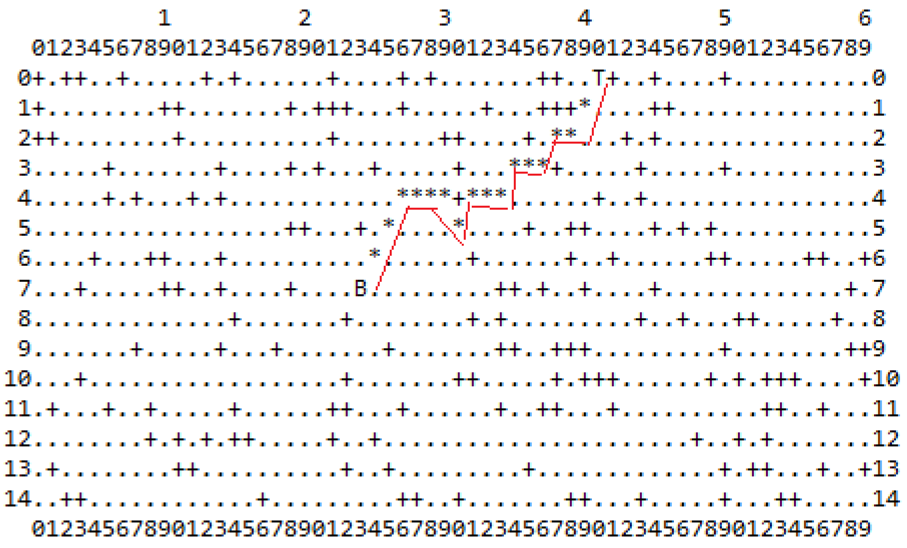
4 The Redbeard Treasure Hunt Game

The famous pirate Redbeard master ship sunk in 17-th century in the Sea Of 1000 Islands after a fierce battle with Bluebeard's ship. The sunken ship contains a large bounty. You are navigating the Sea Of 1000 Islands in your ship provided with modern technology. The Sea Of 1000 Islands has been mapped into a grid where a navigable square is denoted by a dot ("."), and a square that belongs to one of many islands is denoted by a "+".

You have a number of sonar devices. If you drop a sonar device from your ship, if the treasure is in the range of sonar, the device will give you the grid coordinates of the treasure. Once you have the coordinates, your AI engine will run a clever algorithm, called A-star search algorithm, that is capable of plotting the shortest way from the current position of your ship to the detected treasure avoiding the obstacles (in this case, the obstacles are the numerous islands).

If the sonar device detects nothing, you can navigate in any direction you like (north, south, east, west, north-east, north-west, south-east, south-west) one navigable square at a time. You can move as many squares as you like. Whenever you feel like it, you drop another sonar. And so on until the treasure has been found, or you run out of the sonars. Please note once a sonar has been dropped, it is not recoverable. The goal of the game is to find the treasure and plot the navigation route to the treasure. If you run out of the sonar devices before finding the treasure, you lose the game.

A copy of the map, including the plotted trip to the treasure, is shown below. The dots indicate navigable squares, the "+" signs indicate obstacles, the letter "B" indicates the position of the ship, the letter "T" indicates the position of the treasure. The sequence of "*" signs indicates the path plotted by the A-star search algorithm. The jagged red line just follows the "*" symbols to emphasize the path.



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            1         2         3         4         5         6
  012345678901234567890123456789012345678901234567890123456789
 0+.++..+.....+.+......+....+.+.......++..T+..+....+..........0
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 3.....+.......+....+.+...+.....+...***+.....+.....+..........3
 4.....+.+...+.+............****+***......+..+................4
 5..................++...+.*....*....+..++....+.+.+...........5
 6....+...++...+..........*......+......+..+......++.....++..+6
 7...+.....++..+....+....B.........++.+..+....+.............+.7
 8..............+.......+........+.+.........+..+...++.....+..8
 9.......+.....+...+.......+.......++..+++.........+........++9
10...+..................+.......++.....+.+++......+.+.+++....+10
11.+...+..+.....+......++...+......+..++...+..........++..+...11
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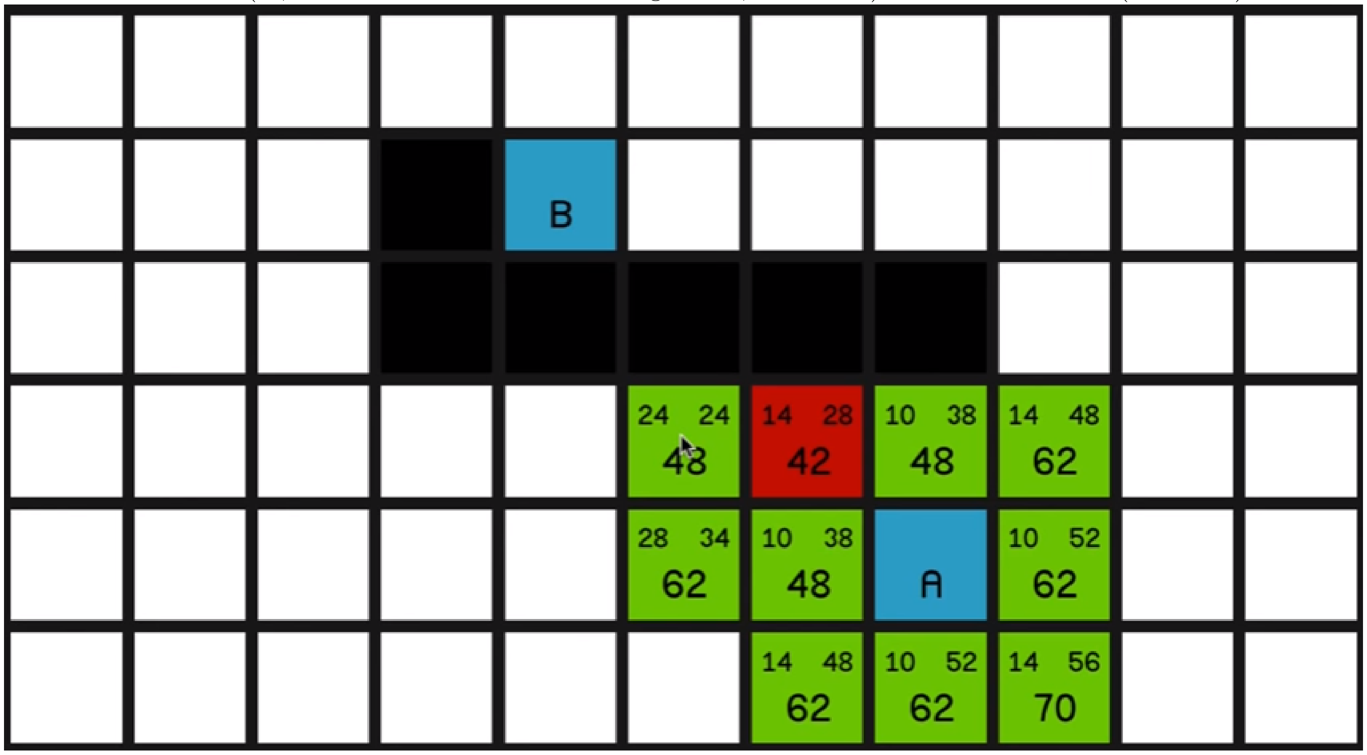
14..++............+.........++..+.......++...+.....+...++.....14
  012345678901234567890123456789012345678901234567890123456789
```

5 The A-star path search algorithm

The A-star path search adjoins next cell to the path by chosing a cell that is "open" (see the links below) and satisfies the following condition: the sum of distances of that cell from the origin and the destination must be minimal. The details of the algorithm including the pseudocode can be found on the internet. Here is a couple of recommended links:

- `http://web.mit.edu/eranki/www/tutorials/search/`
- `http://www.policyalmanac.org/games/aStarTutorial.htm`

The next image shows how the actual sum of distances is computed. Please note if we assume one cell has side length one unit, a vertical or horizontal distance from one cell to next is one unit, whereas a diagonal distance (for example from current cell to the cell loacted north-east) is $\sqrt{2}$ or approx. 1.4 units. In order to avoid decimals from or computation, we will multiply everything by 10, so for instance the distance of the cell painted in red is computed as follows: the red cell is one (diagonal) square far from cell labelled "A", that is 14 unit, and two (diagonal) squares from cell labelled "B" therefore 28 units, so its total distance (or, as it is called in the A-star algorithm, its **f-cost**) is 14+28=42 units (as shown).



Please note on each iteration we need the open cell with minimal f-cost (please see the pseudocode in the MIT weblink above). To avoid a costly search on each iteration, we will maintain the list of the open cells using a data structure called **heap** implemented using a complete binary tree stored in an array.

6 Heaps

Heaps are complete binary trees that satisfy these conditions:

1. The smallest value (or highest priority) element sits at the root.
2. Every subtree of a heap is also a heap.

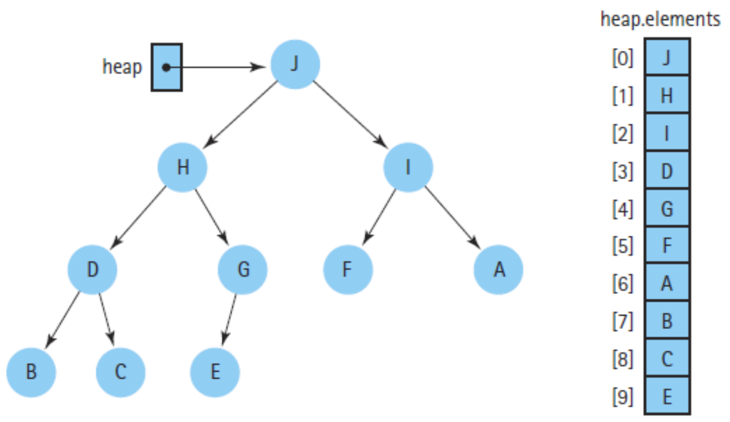
Since a heap is a complete tree, all its levels but the last are complete. The last level may miss some leaves in the rightmost position. An example of a heap is shown in the next image.

Observe that the root (that is the lowest value element - in that case the letter "J" of course assuming the highest value letter of the alphabet is "A" and the lowest value letter of the alphabet is "Z") is mapped (in the implementation) to the lement with index 0 of the array to the right. Its immediate children occupy the cells 1 and 2 of the array. The children of the level 1 occupy elements 3,4,5,6. And so son.

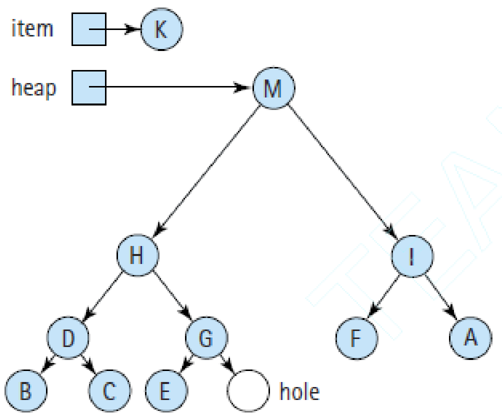
When we use this representation of a binary tree, the following relationships hold for an element at position index:

- If the element is not the root, its parent is at position (index 1) / 2.
- If the element has a left child, the child is at position (index * 2) + 1.
- If the element has a right child, the child it is at position (index * 2) + 2.

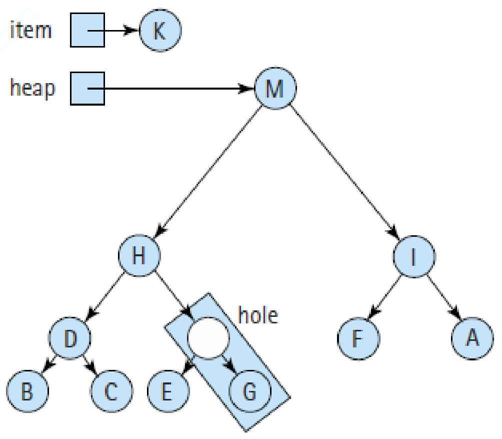
These relationships allow us to efficiently calculate the parent, left child, or right child of any node! And since the tree is complete we do not waste space using the array representation. Time efficiency and space efficiency! We make use of these features in our heap implementation.



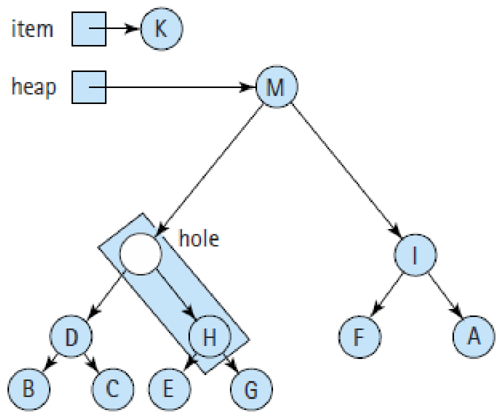
Here is how we add an element to the heap (in this case letter "K"). We add it at the bottom rightmost position, and sort it up (sortUp in the starter code) to the correct position.

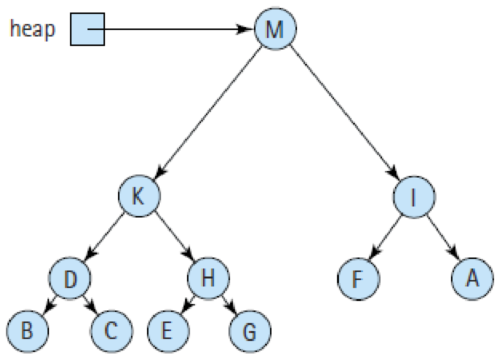


(a) Add K

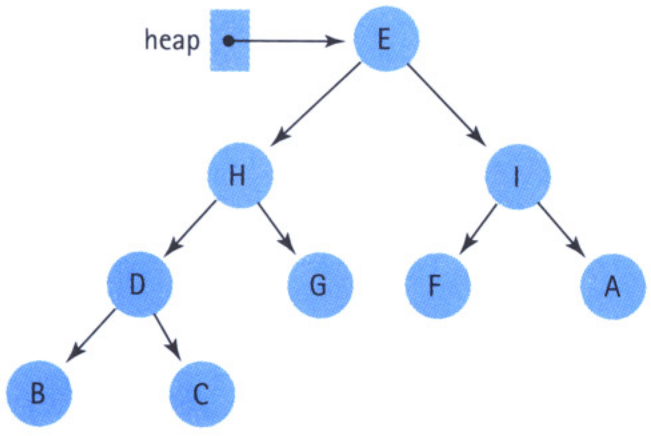


(a) Move hole up

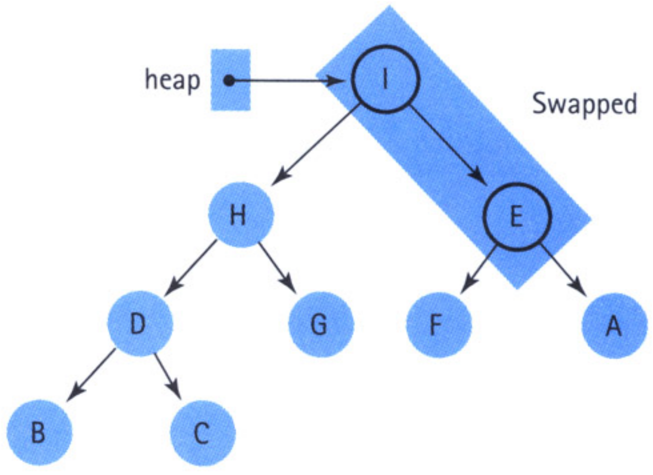




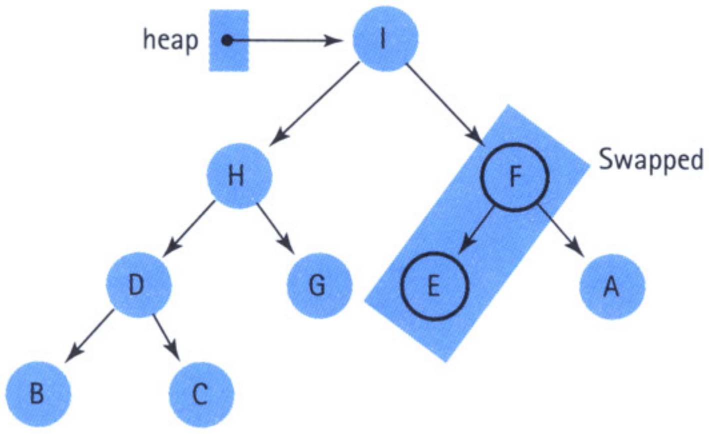
Removal of the top element (remember - we only remove the top element - highest priority (in our case lowest f-cost!) is done by substituting it with the rightmost element and then sorting it down. The example below illustrates the removal of topnode "J" (see the first image in the previous page), replacing it by "E" (the rhightmost element in the lowest level) and moving the element "E" down to is right place:



(a)



(b)



(c)

All these manipulations rely on the fact that we are able to **compare** the information stored in the nodes of the heap. That is each node should implement the comparable interface as studied in the lab 4.

7 The starter code

Please study the starter code carefully. It contains a lot of comments explaining many aspects of your coding work. Make sure to implement heap carefuly and use a heap object of this implmentation to maintain the set of open cells.

Each cell of the grid will be represented by a `Node` object. A `Node` object has grid coordinates, and also can be `walkable` or not (that is can be an obstacle or not), it has a parent (that is a prior cell in the A-star path) and can be a member of the A-star path or not, as determined by the A-star algorithm.

The `world` main attribute is a `map` as described above. In order to find and plot the A-star path, we need a heap to maintain the open cells. As such we will implement a heap, where each heap item implements the

`HeapItem` interface.

The `TreasureHunt` class sets up the game. Each game can have the status "STARTED" or "OVER". Once the game is "OVER" we determine if the player won by checking the path. The game can be played from keyboard, however for the purpose of this assignment, we will allow commands of a play session to be read from a text file (a sample has been provided with the starter code). The `GameTest` class is optional -it has been provided in the starter code for your convenience so you can test the game before submitting it.

Make sure to test your work carefuly before submitting! Also make sure to submit the source code only!