Implementing Dijkstra's shortest-path algoritm

Preamble

In this assignment, you use your solution to A6 in implementing Dijkstra's shortest-path algorithm. This shortest-path algorithm will then be used in the final project A8. We know your time is limited, so we have cut this assignment to the minimum while still giving you the invaluable experience of implementing the algorithm. Our solution is only 36 lines long. Further, we give you a JUnit testing class, which contains all the test cases you need.

Keep track of how much time you spend on A7; we will ask for it upon submission.

Read this whole document before beginning to code.

We suggest getting this assignment done *well* before the due date so you can study for the prelim and begin thinking about A8.

Collaboration policy and academic integrity

You may do this assignment with one other person. Both members of the group should get on the CMS and do what is required to form a group well before the assignment due date. Both must do something to form the group: one proposes, the other accepts.

People in a group must *work together*. It is against the rules for one person to do some programming on this assignment without the other person sitting nearby and helping. Take turns "driving" —using the keyboard and mouse.

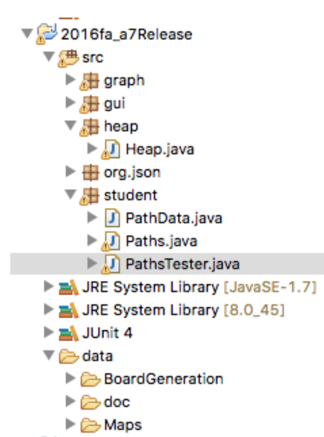
With the exception of your CMS-registered group partner, you may not look at anyone else's code, in any form, or show your code to anyone else (except the course staff), in any form. You may not show or give your code to another student in the class.

Getting help

If you don't know where to start, if you don't understand testing, if you are lost, etc., please SEE SOMEONE IMMEDIATELY —an instructor, a TA, a consultant. Do not wait. A little in-person help can do wonders. See the course homepage for contact information.

The release code

File 2016fa_a7Release.zip is an Eclipse project, which you can most easily import into Eclipse using menu item Open Projects From File System. Here are the steps:



1. Use menu item File --> Open Project From File System
2. In the window that opens:
   select "archive"
   navigate to the downloaded file 2016fa_a7Release.zip
   select it
   click Open
3. If you get a choice of Folders to select, select only the first one, 2016fa_a7Release.zip_expanded
4. Want to change the project name? Use the refactoring tool.

You can, if you want, copy parts individually into a project. But that will require putting JUnit4 o the build path, etc. The project should look like the diagram on the right (your JRE System Libraries may be different).

Replace the code in Heap.java with the code in your Heap.java —or with our solution. Be sure to leave the package statement at the top.

Running the program

Class graph/Main contains method main. To run the program, open class Main in the Eclipse editor, select class Main in the Package Explorer pane, and choose menu item Run -> Run. A GUI will open with a graph. You can get a new randomly-generated graph using menu item Graph -> New Random Map. You can drag the nodes of the graph around to make it easier to see a part of it. The text at the bottom of the window tells you what to do: Click a start node, click an end node, and you will see in red the shortest from start to end(once you complete the assignment). The Piazza A7 FAQs note will contain some seeds that generate fairly small graphs for you to play with.

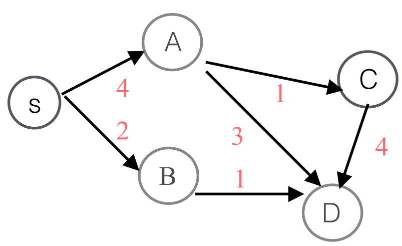
What to do for this assignment

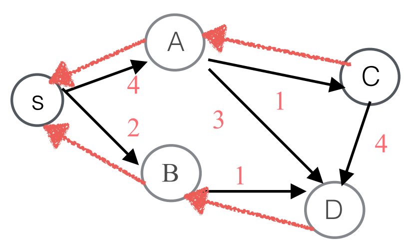
Your job is to implement method Paths.shortestPath. It is marked "TODO". We give you everything else (you can use our Heap.java if you want). The body of that shortestPath contains some comments, which you must follow. Class student.Paths is the only file you have to change and submit.

Backpointers

The basic shortest-path algorithm calculates the shortest path from a start node to an end node. Here, we show, in the context of A7, how to extend the algorithm to also calculate the shortest path itself. Often in programming, we write a basic algorithm and then extend it to produce more information. It's a standard practice/technique.

It is difficult to maintain the shortest path from a start node S to every other node. For example, look at the diagram below and ask yourself: How, in start node S, would you store the shortest paths to all nodes? You would need to store *four* paths, from S to A, to B, to C, and to D. If the graph had 1,000 nodes, you would be storing information for 1,000 paths in S! There *must* be a better way.





We do something else. Look at the diagram to the right. The shortest path from S to D is (S, B, D). Therefore, in node D, store the *back-pointer* on this path, i.e. the *previous* node on this path: B. We show it with a squiggly red arrow. Similarly, the shortest path from S to B is (S, B), so node B contains a *back-pointer* to S.

As one more example, the shortest path from S to C is (S, A, C), so node C contains *back-pointer* A, A contains *back-pointer* S, and S contains null as its back-pointer.

That's it! With only one extra piece of info in each node, a *back-pointer*, we can store all the information needed to give us the path from S to any node, but in reverse. To find the shortest path from S to some node D, we have to use the back-pointers beginning in node D to construct the path. That takes time proportional to the length of the path. Not bad!

The comments at the beginning of function shortestPath describe how to save back pointers as well as the distances of nodes in the settled and frontier sets.

Read this list carefully

1. Implement method Paths.shortestPath. It is marked with "// TODO …". It ***must*** be an implementation of the algorithm given on slide 34 (or so) of lecture 20 that is titled "Final algorithm". The algorithm should be refined to meet the specification and environment in which it is being implemented. See below for more info.

2. The final algorithm in the lecture slides stops when shortest paths to *all* nodes from node *start* have been determined. However, your algorithm should stop as soon as the shortest path from node *start* to node *end* has been determined; once that is known, the method must *not* continue to calculate shortest paths. This is most easily done by putting an appropriate test at the beginning of the main loop body and returning the result if the test is met. If you do not do this, you get a 15-point deduction.

3. The method must return an empty list if there is no path from *start* to *end*. The return statement for this is already included in the method.

4. Your method will not use array L for distances. Instead, a comment at the beginning of the body of Paths.shortestPath explains how to maintain both the backpointer and the distance for each node in the settled and frontier sets.

5. We have provided function Paths.constructPath, which constructs the path from the back-pointers. Use this method, once the desired node has been reached. Study it to see how the path is constructed.

Debugging/testing

6. When testing/debugging, you will want some small maps to work with. For these, try seeds: 7, 16. 1, 6, 19, 18. You can also change constant Graph.GraphGeneration.MAX_NODES to a small number. (GraphGeneration is a static class within class Graph.)

When testing/debugging, you may want to print out the frontier at each iteration. You can easily do this:

```
System.out.println("frontier is: " + frontier);
```

7. You can use the GUI to eyeball how your program is doing. However, we have provided complete test cases in JUnit testing class PathsTester. If your method Paths.shortestPath passes those tests, you can consider the method to be correct. In an item the Piazza A7 FAQs note, we will put an explanation of how our testing works and how we generated the files it uses.

What to do submit

In class Paths, in the comment at the top, put the hours hh and minutes mm that you spent on this assignment. Write a few lines about what you thought about this assignment. Submit on the CMS (only) file Paths.java. We know that your function shortestPath uses class Heap, but we assume you have not changed Heap's behavior by changing its public methods. We will use *our* correct Heap in testing your function.