COMP 250 - Homework #5
Due on December 3rd 2013, 23:59

Web search-engine or Sudoku (100 points)

For this assignment, you have the choice between two possible projects.
You should do only *one* of the two.

Project #1: Web search-engine

For this final programming homework, we are going to write a mini-Google program that will (i) explore a portion of the web, (ii) build an index of the words contained in each web site of the web, (iii) analyze the structure of the internet graph to establish which web sites should be considered authorities, (iv) use this analysis to answer simple Google searches where a query word is entered by the user and you return the most relevant web sites available. Although we are only going to be dealing with a very small subset of the whole web (we will only consider a subset of the web sites on the www.cs.mcgill.ca domain), the tools you will develop are essentially the ones used at Google to answer actual queries.

Needless to say that this programming is somewhat more substantial than those you had to do in the first four assignments. You will NOT be able to complete this project if you start too late! Still, your final solution will still be relatively simple, and I will guide you step by step.

Start by downloading the Java classes at http://www.cs.mcgill.ca/~blanchem/250/hw5

The tools:

directedGraph class
I am providing you with a directedGraph class that represents directed graphs using the adjacency-list data structure seen in class. You will use this class to represent the mini-internet we will work with. The vertices of the graph will be labeled with Strings corresponding to the URLs of the web pages. A hash table is used to store a set of pairs (vertex, list-of-adjacent-vertices), where list-of-adjacent-vertices is a LinkedList of Strings. The class allows the following operations on the graph:

```
void addVertex(String v)              // Adds a new vertex to the graph.
void addEdge(String v, String w)      // Adds an edge between two existing vertices
LinkedList getVertices()              // Returns a LinkedList of all vertices in the graph
LinkedList getNeighbors(String v)     // Returns a LinkedList containing the neighbors
                                         of vertex v
LinkedList getEdgesInto(String v)     // Returns the list of vertices that have edges
                                         toward vertex v
```

```
int getOutDegree(String v)                // Returns the number of edges going out of v
boolean getVisited(String v)              // Returns true if the vertex v has been visited
void setVisited(String v, boolean b)      // Sets the “labeled” field of vertex v to value b
double getPageRank(String v)              // Returns the pageRank of v
void setPageRank(String v, double pr)     // Sets the pageRank of v to pr
```

A complete description of each method is available in the directedGraph.java file. You should not need to modify this class at all (but you can if you want).

htmlParsing class
This class has static methods to read the content of the web page at a given URL and to extract information from it. It has two static methods that you will need to use: getContent(String url) returns a LinkedList of Strings corresponding to the set of words in the web page located at the given URL. You will need to use this method during your graph traversal to build your word index. getLinks(String url) returns a LinkedList of Strings containing all the hyperlinks going out of the given URL.
The class also has other methods that you will most likely not need. You should not need to modify this class at all.

searchEngine class
The searchEngine class is the one you will need to work on. It contains two importnat members: “directedGraph internet” is the internet graph we will be working on. The graph is initially empty, and it will be your job to add vertices and edges to represent an internet graph. “HashMap wordIndex” will be used to store the list of URLs containing a particular word. It will contain a set of pairs (String word, LinkedList urls).

HashMap class (part of the standard Java distribution)
To keep an index of which web sites contain which words, we will use the java HashMap class. A HashMap is an implementation of a dictionary. You will use words as keys in that dictionary. The data associated with a given word will be the list of web sites that contain that word. You will find a complete description of the HashMap class at http://docs.oracle.com/javase/6/docs/api/

Notice that the get(String key) method returns the information associated with a given key, so you can write something like:
LinkedList<String> myList = wordIndex.get(“hello”)).
HashMap are extensively used in the directedGraph class, so you can have a look at that code to figure how things work.

LinkedList class (part of the standard java distribution)
See http://docs.oracle.com/javase/6/docs/api/ .

Iterator class
You will often need to step through a LinkedList to do some processing on every piece of data in the list. A good way to do that is to use an object of the class Iterator, as follows:
LinkedList<String> content = htmlParsing.getContent(“http://www.cs.mcgill.ca”);

```
Iterator<String> i = content.iterator();
while ( i.hasNext() ) {
        String s = i.next();
        // Do some processing on s
        System.out.println(s);
}
```

You will need to implement the following methods of the searchEngine class:

void traverseInternet(String url): This method will do a graph traversal of the internet, starting at the given url. You can use either a depth-first search or a breadth-first search, and you can make it either recursive or non-recursive. For each new url visited, you will need to (i) update the internet graph by adding the appropriate vertex and edges and (ii) update the wordIndex to add every word in the url to the index.

void computePageRanks(): This method will compute the pageRank of each vertex of the graph, using the technique seen in class and described below. This method will only be called after the traverseInternet method has been called.

String getBestURL(String query): This method will have to return the most relevant web site for a particular single-word query. The URL returned must be the one with the highest pageRank score containing the query. This method is only going to be called after the computePageRanks method has been called.

Calculating pageRanks

We calculate pageRank for each vertex as described in class. Let C(v) be the out-degree of vertex v and let w1...wn be the vertices that have edges pointing toward v:

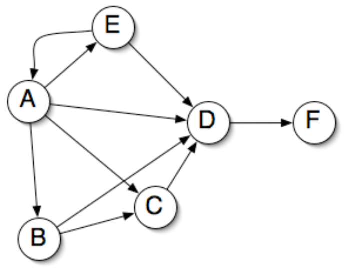
$$PR(v) = 0.5 + 0.5 * (PR(w1)/C(w1) + PR(w2)/C(w2) + ... + PR(wn)/C(wn)$$

For a graph with n vertices, this gives rise to system of n linear equations that can easily be solved iteratively:

```
1) Initialize PR(v) = 1 for all vertices v
2) Repeat until convergence    // 100 iterations should be enough
        For each vertex v do
                PR(v) = formula above
```

Testing your program

To verify that your program is working well, I built a set of six small websites connected as follows:



The content of these sites is as follows :
a.html: Algorithms are fun
b.html: Algorithms are great
c.html: Algorithms are great
d.html: Authority about algorithms
e.html: Algorithms are difficult
f.html: This is a deadend about algorithms

If you start your internetTraversal from the website http://www.cs.mcgill.ca/~blanchem/250/a.html , then your algorithm should learn the graph above.
After computing the pageRank of each site, you should obtain the following numbers:
http://www.cs.mcgill.ca/~blanchem/250/a.html=0.645...
http://www.cs.mcgill.ca/~blanchem/250/b.html=0.580...
http://www.cs.mcgill.ca/~blanchem/250/c.html=0.725...
http://www.cs.mcgill.ca/~blanchem/250/d.html=1.233...
http://www.cs.mcgill.ca/~blanchem/250/e.html=0.580...
http://www.cs.mcgill.ca/~blanchem/250/f.html=1.116...

Thus, on a query “algorithms”, your program should return site D. On query “are”, you should return site C.

When you run your program starting from http://www.cs.mcgill.ca/index.html, here is an example of queries:
Query: “computer” returns http://www.cs.mcgill.ca , p.r. = 8.350
Query: “blanchette” returns http://www.cs.mcgill.ca/people, p.r.= 2.404
Query: “laboratories” should returns http://www.cs.mcgill.ca/about/facilities, p.r.= 0.889
Query: “registration” should return http://www.cs.mcgill.ca/academic/undergrad . p.r. = 1.202
Query: “blabla” should return no site.

Avoiding denial-of-service (DoS) attacks

Suppose you have a bug in your program and during the internetTraversal phase, you have an infinite loop that keeps asking for the content of a given URL. This may be dangerous as it may eventually bring down the web server, in particular if many students had such an infinite loop running. This would be the equivalent of a denial-of-service attack like those that often happen against Microsoft and others: If millions of malicious programs are requesting web pages from the same web server at a very high pace, the web server will be overloaded and may crash.

To prevent this from happening with the cs.mcgill.ca web server, the code given to you will not allow you to call the getContent and getLinks methods more than once on each web page. If you try to access the same web page more than once, you will get an exception saying "Tried to access the following web site more than once…". You must not modify the code in the htmlParsing.

How much work does this represent?
This programming project looks quite complicated but in the end your code will probably take about 150 lines of code. What will take you time is to get used to playing with LinkedList and HashMap. Don't wait until the last moment to ask questions!

Evaluation:

Correctness of internetTraversal:	25%
Correctness of pageRank calculation:	25%
Correctness of best web page reported:	20%
Style, simplicity, reuse, comments:	30%

Project #2: Sudoku solver

A Sudoku is a type of puzzle that has become extremely popular these days. You will find the rules of the Sudoku puzzle at: http://www.sudoku.com/

Your goal is to write a program that will attempt to solve Sudoku puzzles. We are giving you a simple java class to represent a Sudoku puzzle, and to read or write a Sudoku from and to a file. You are asked to write the solve() method, which modifies the Sudoku object on which it is called and should fill all the empty squares in the Sudoku to produce a valid solution.

The code is at: http://www.cs.mcgill.ca/~blanchem/250/hw5/sudoku.html
You will also find there a set of sudoku puzzles, sorted in increasing order of difficulty. To get full credits for this project, your program should be able to solve any 3x3 puzzles in less than 10 seconds of running time.

There are many ways your program could attempt to solve the Sudoku. It is totally up to you to decide which approach to use. I would suggest that you try to solve a few Sudokus manually before trying to write a program. One classical way to approach this kind of problem is to use a backtracking search as described in class for the 8-queens problem. What will determine how quickly your program will find a solution is the criteria you use to decide in what order the backtracking search should be performed. This project is totally open-ended. Use your imagination!

Evaluation

The program succeeds at solving all 3x3 cases correctly in less than 1 minute.	50%
Originality of the solution.	30%
Style and documentation	20%

Sudoku tournament
To identify a winner for the Sudoku tournament, each program will be given one minute to solve each Sudoku puzzle on our computer. The ranking of the programs will be established based on the number of Sudokus it succeeds at solving, from a set of 10 problems ranging from very easy to very difficult. The actual problems that will be used for the tournament will not be released before the tournament, but a set of equally difficult problems will be given for training. To keep the competitive spirit going, teams will have the possibility of using MyCourses to report which problems they are able to solve.

1st place : 20 bonus points
2nd place: 10 bonus points
3rd place: 5 points