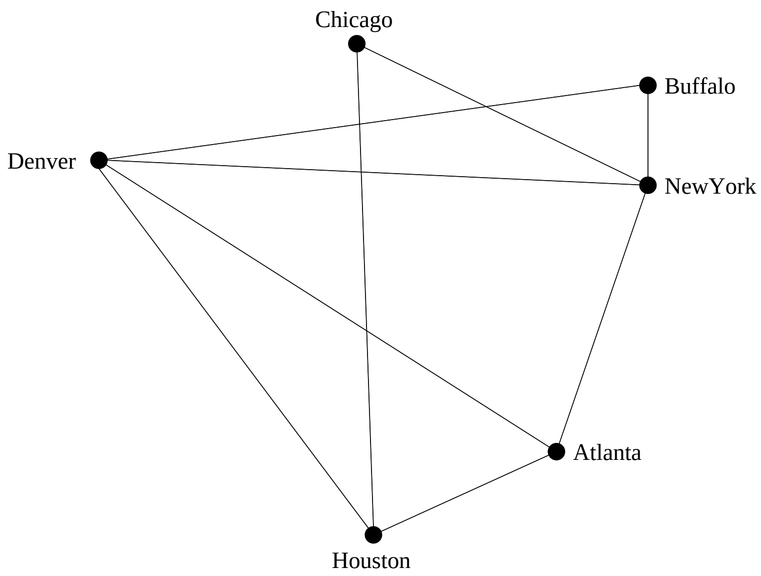
22C:21 Project 2

Due date and time: See submission schedule below.

Introduction. In this project you will implement several versions of a class that implements the graph data structure and write a program that tests and evaluates this class. A *graph* is a structure that consists of *vertices*, pairs of which are connected by *edges*. For example, here is a graph that might represent flight connections among a few American cities. The nodes (cities) are shown as points and the edges connecting pairs of cities (flight connections) are shown as straight line segments.



A graph can model all kinds of real-life structures. In addition to transport connections, graphs are used extensively to model circuits etched on a computer chip, organization of large corporations, networks of computers, the world wide web, evolution of species, states in games of strategy, etc. Often, a graph allows us to abstract the essential features of the underlying structure and to reason about the structure more precisely. Chapter 15 in your textbook deals with graphs, but you don't have to read the chapter to complete this project.

The `MyGraph` interface. In this project, you will start with an interface called `MyGraph` (to avoid confusion with the `Graph` interface provided by Bailey), create an abstract class called `MyAbstractGraph` that implements `MyGraph`, and then create two regular classes, `MyMatrixGraph` and `MyListGraph` that extend `MyAbstractGraph`.

The `MyGraph` interface is given below.

```
public interface MyGraph
{
        public void addVertex(Object v);
        public void addEdge(Object u, Object v);
        public void deleteVertex(Object v);
        public void deleteEdge(Object u, Object v);
```

```
        public Vector getVectices();
        public Matrix getEdges();
        public Vector getNeighbors(Object v);

        public int numberOfVertices();
        public int numberOfEdges();

        public boolean areNeighbors(Object u, Object v);
        public Vector depthFirstTraversal();
}
```

With the exception of the last function, the names of the functions in the above interface are fairly self-explanatory. Anyway, here is a brief description of each of the functions mentioned above.

`void addVertex(Object v)` Add a vertex v to this graph. If v already exists in G, then this function does nothing.

`void addEdge(Object u, Object v)` Add an edge between vertex u and vertex v to this graph. If there is already an edge between u and v, then this function does nothing. If either of the vertices u and v do not exist in this graph, then the function throws an exception.

`void deleteVertex(Object v)` Delete the vertex v from this graph. If v does not exist in this graph, then this function does nothing.

`void deleteEdge(Object u, Object v)` Delete the edge between u and v from this graph. If this edge does not exist in this graph then the function does nothing. If either of the vertices u and v do not exist in this graph, then the function throws an exception.

`Vector getVectices()` Return a `Vector` of vertices of this graph, in no particular order.

`Matrix getEdges()` Return a `Matrix` of edges of this graph, in no particular order. The returned `Matrix` has two rows and as many columns as the number of edges of the graph. Each column of the `Matrix` contains the two end-vertices of an edge.

`Vector getNeighbors(Object v)` Return a `Vector` of neighboring vertices of the vertex v, in no particular order.

`int numberOfVertices()` Return the number of vertices in this graph.

`int numberOfEdges()` Return the number of edges in this graph.

`boolean areNeighbors(Object u, Object v)` Return `true` if there is an edge between vertices u and v in the graph. Return `false` otherwise. Throw an exception if either u and v does not exist in this graph.

`Vector depthFirstTraversal()` Return a `Vector` of objects of type `SinglyLinkedListElement` that represents a depth-first traversal of the graph. More details in class.

The `MyMatrixGraph` and the `MyListGraph` classes. Here I describe two alternate graph representations, the *adjacency matrix* representation and the *adjacency list* representation. You are required to use the adjacency matrix representation in the `MyMatrixGraph` class and the adjacency list representation in the `MyListGraph` class. For this discussion, let us suppose that we have a graph with n vertices. Both representations consist of a `Vector` called `map` that contains the n vertices. The `Vector map` should be viewed as an assignment of distinct IDs in the range 0 through $n-1$ to the n vertices. More specifically, it should be your view that the vertex stored in slot `map[i]` has ID i.

In addition to `map`, the adjacency matrix representation consists of a $n \times n$ boolean matrix, let us call this `M`, such that $M[i, j] = 1$ if there is an edge between the vertex with ID i and the vertex with ID j; otherwise, if there is no edge between the vertex with ID i and the vertex with ID j, then $M[i, j] = 0$. In this project, we are only interested in undirected graphs and so M is symmetric; that is, $M[i, j] = M[j, i]$.

In addition to `map`, the adjacency list representation consists of a `Vector` of size n, let us call this L, each of whose elements is a `DoublyLinkedList` object. The `DoublyLinkedList` object stored at $L[i]$ contains all the neighbors of the vertex with ID i. Note that if vertices withs IDs i and j are adjacent to each other, then i appears in the doubly linked list at $L[j]$ and j appears in the doubly linked list at $L[i]$.

The `MyMatrixGraph` class and the `MyListGraph` class should both contain two counters, let us call these `numVertices` and `numEdges`, to keep track of the number of vertices and the number of edges currently in the graph.

The `MyAbstractGraph` abstract class. The function `depthFirstTraversal` that returns a depth-first traversal of the graph, can be implemented in terms of the rest of the functions in `MyGraph` interface. Hence, this function should be implemented in the `MyAbstractGraph` class and should be inherited by the `MyMatrixGraph` class and the `MyListGraph` class. `depthFirstTraversal` can be implemented by a recursive algorithm, which will be discussed in class.

Testing your implementation. As a test of your implementation, I want you to build a program that plays the *Ladders* game. In this two-player game, one player chooses a starting word and an ending word and the other player constructs a "ladder" between the two words. A ladder is a sequence of words that starts at the starting word, ends at the ending word, and each word in the sequence (except the first) is obtained from the previous word by changing a letter in a single position. For example, suppose the starting word is `flour` and the ending word is `bread`, then a ladder between these two words is: `flour`, `floor`, `flood`, `blood`, `brood`, `broad`, `bread`.

On the course page you will find a link to a file called `words.dat` that contains 5757 five letter English words. This word list comes from *Stanford Graphbase*, a collection of interesting data sets and graph algorithms put together by Donald E. Knuth. The original file can be found at

`ftp://labrea.stanford.edu/pub/sgb`

This word list is the database that your program will use to play the Ladders game.

In this version of the game, the user is always the one providing a pair of words and your program is always the one constructing a ladder between a given pair of words. Your program should start by constructing a graph whose vertices are the five letter words in `words.dat`. There is an edge between a pair of five letter words if one can be obtained from the other by changing a letter in exactly one position. We will call this the *ladders graph* on 5-letter words. After this graph has been constructed, your program should repeatedly prompt the user to enter a pair of 5-letter words. When the user responds by entering two 5-letter words, your program will either (i) output a ladder between the two words or (ii) output a message saying there is no ladder between the two words. Your prompts to the user should be clear and should provide the user the option of quitting your program whenever they want.

Submission Schedule. Your submission is broken up into three parts.

Wednesday, Nov 3rd, 5pm Submit the files `MyGraph.java` and `MyMatrixGraph.java`. The class `MyMatrixGraph` should implement the interface `MyGraph`. `MyMatrixGraph` need not implement `depthFirstTraversal` and therefore can contain just an empty implementation of this function. Create a directory called `project2.1` with these two files in it and submit this directory. This submission is worth 30 points. Our solution will be released soon after the submission deadline.

Monday, Nov 8th Submit the files `MyGraph.java` and `MyListGraph.java`. The class `MyListGraph` should implement the interface `MyGraph`. `MyListGraph` need not implement `depthFirstTraversal` and therefore can contain just an empty implementation of this function. Create a directory called `project2.2` with these two files in it and submit this directory. This submission is worth 30 points. Our solution will be released soon after the submission deadline.

Monday, Nov 15th Submit the following files: `MyGraph.java`, `MyAbstractGraph.java`, `MyMatrixGraph.java`, `MyListGraph.java`, and `Ladders.java`. The `MyAbstractGraph` abstract class should implement the `MyGraph` interface and should contain the implementation of `depthFirstTraversal`. The classes `MyMatrixGraph` and `MyListGraph` should extend `MyAbstractGraph`. This submission is worth 40 points.
