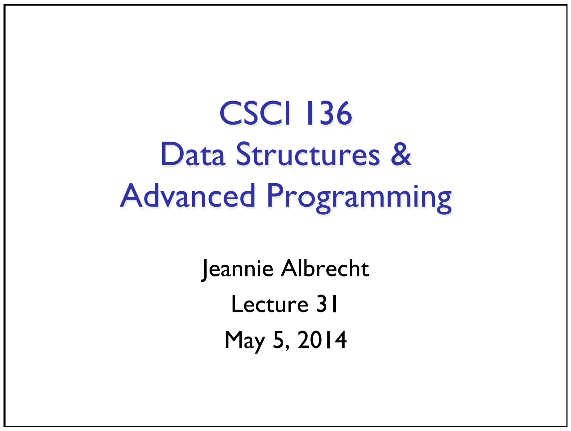
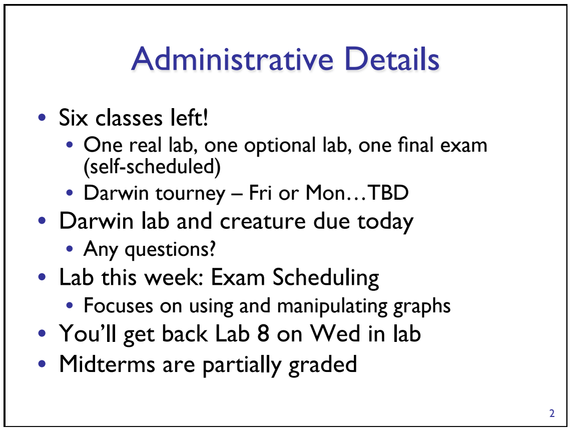


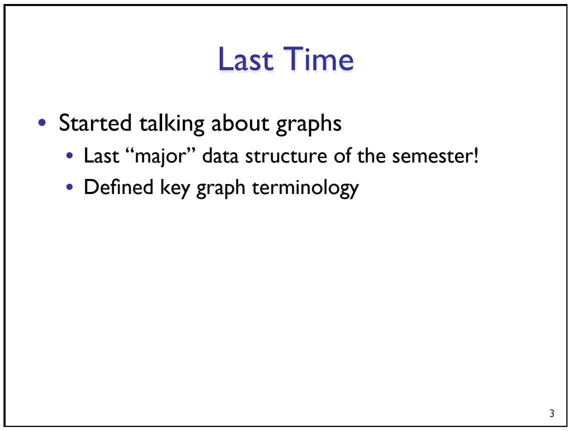
CSCI 136
Data Structures &
Advanced Programming

Jeannie Albrecht
Lecture 31
May 5, 2014



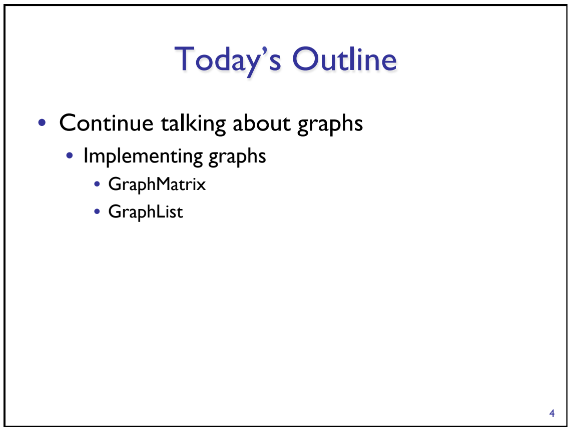
Administrative Details

- Six classes left!
  - One real lab, one optional lab, one final exam (self-scheduled)
  - Darwin tourney – Fri or Mon…TBD
- Darwin lab and creature due today
  - Any questions?
- Lab this week: Exam Scheduling
  - Focuses on using and manipulating graphs
- You'll get back Lab 8 on Wed in lab
- Midterms are partially graded



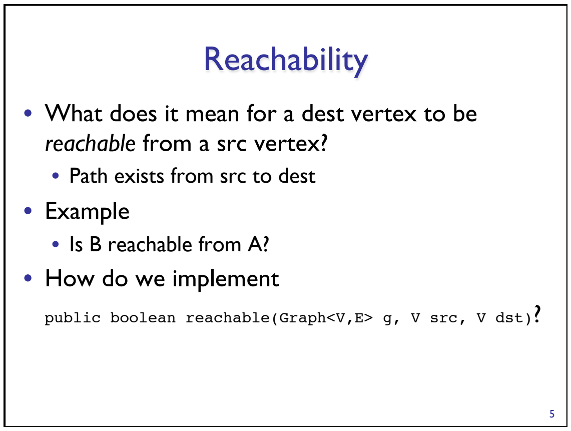
Last Time

- Started talking about graphs
  - Last "major" data structure of the semester!
  - Defined key graph terminology



Today's Outline

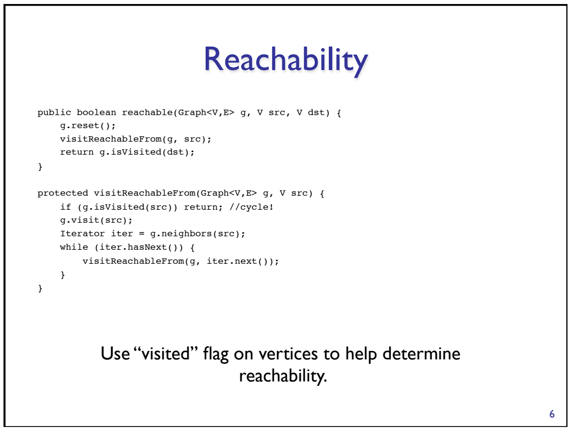
- Continue talking about graphs
  - Implementing graphs
    - GraphMatrix
    - GraphList



Reachability

- What does it mean for a dest vertex to be *reachable* from a src vertex?
  - Path exists from src to dest
- Example
  - Is B reachable from A?
- How do we implement

`public boolean reachable(Graph<V,E> g, V src, V dst)`?



Reachability

```
public boolean reachable(Graph<V,E> g, V src, V dst) {
    g.reset();
    visitReachableFrom(g, src);
    return g.isVisited(dst);
}

protected visitReachableFrom(Graph<V,E> g, V src) {
    if (g.isVisited(src)) return; //cycle!
    g.visit(src);
    Iterator iter = g.neighbors(src);
    while (iter.hasNext()) {
        visitReachableFrom(g, iter.next());
    }
}
```

Use "visited" flag on vertices to help determine reachability.

Implementing Graphs: Graph Interface

- You'll gain a better understanding of the Graph interface in lab this week
- What is it used for?
  1. Creating graphs
  2. Adding nodes/edges
  3. Testing connectivity
  4. Traversing nodes/edges (iterators)

Graph Interface Methods

- void add(V vtx), V remove(V vtx)
  - Add/remove vertex to graph
- void addEdge(V vtx1, V vtx2, E edgeLabel), E removeEdge(V vtx1, V vtx2)
  - Add/remove edge between vtx1 and vtx2
- boolean containsEdge(V vtx1, V vtx2)
  - Returns true iff there is an edge between vtx1 and vtx2
- Edge<V,E> getEdge(V vtx1, V vtx2)
  - Returns edge between vtx1 and vtx2
- void clear()
  - Remove all nodes (and edges) from graph

Graph Interface Methods

- boolean visit(V vertexLabel)
  - Mark vertex as "visited" and return *previous* value of visited flag
- void visitEdge(Edge<V,E> e)
  - Mark edge as "visited"
- boolean isVisited(V vtx), boolean isVisitedEdge(Edge<V,E> e)
  - Returns true iff vertex/edge has been visited
- Iterator<V> neighbors(V vtx1)
  - Get iterator for all neighbors to vtx1
  - For directed graphs, out-edges only
- Iterator<V> iterator()
  - Get vertex iterator
- void reset()
  - Remove visited flags for all nodes/edges

Edge Class

- Graph *edges* are defined in their own public class
  - `Edge<V,E>(    V vtx1, V vtx2,`
    `                E label, boolean directed)`
  - Construct a (possibly directed) edge between two labeled vertices (vtx1->vtx2)
- Useful methods:

```
label(), here(), there()
setLabel(), isVisited(), isDirected()
```

Example Graph/Edge Usage

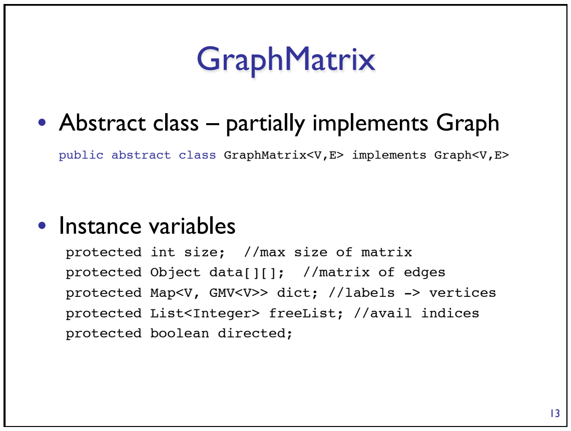
- You'll see one example in lab this week…
- For our map with edge labels:

SF
1468
Dallas

```
Graph<String,Integer> g =
   new GraphMatrixDirected<String, Integer>();
g.add(“SF”);
g.add(“Dallas”);
g.addEdge(“SF”, “Dallas”, new Integer(1468));
…
Edge<String, Integer> SFtoDallas = g.getEdge(“SF”, “Dallas”);
int dist = (SFtoDallas.label()).intValue();
```

Representing Graphs

- Two options
  - Option 1: GraphMatrix (Directed and Undirected)
  - Option 2: GraphList (Directed and Undirected)
- We're going to look at GraphMatrix first
  - Represent graph as a vertex *adjacency matrix*
- Challenge: How to represent vertices and edges?
  - Solution: Maintain a *dictionary* that translates a "normal" vertex label into an index in matrix



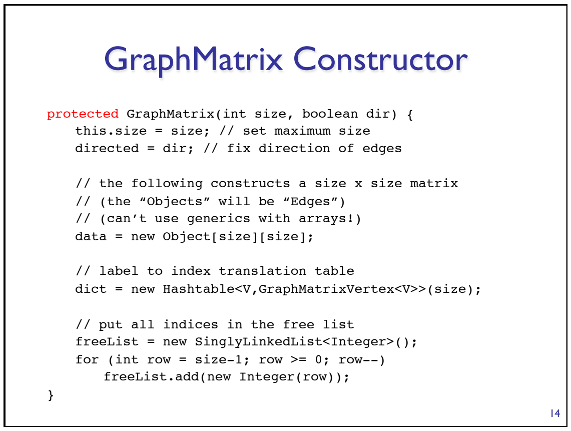
GraphMatrix

- Abstract class – partially implements Graph

```
public abstract class GraphMatrix<V,E> implements Graph<V,E>
```

- Instance variables

```
protected int size;  //max size of matrix
protected Object data[][];  //matrix of edges
protected Map<V, GMV<V>> dict; //labels -> vertices
protected List<Integer> freeList; //avail indices
protected boolean directed;
```



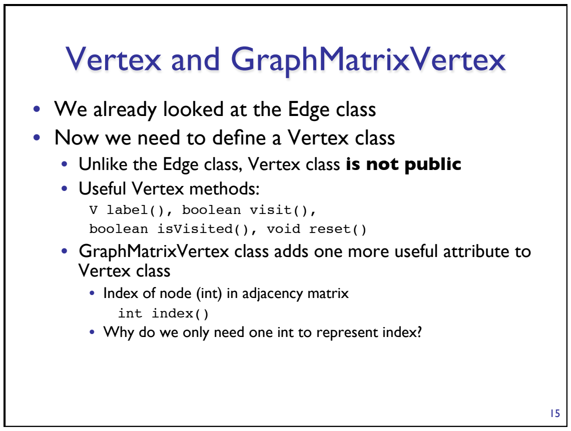
GraphMatrix Constructor

```
protected GraphMatrix(int size, boolean dir) {
    this.size = size; // set maximum size
    directed = dir; // fix direction of edges

    // the following constructs a size x size matrix
    // (the “Objects” will be “Edges”)
    // (can’t use generics with arrays!)
    data = new Object[size][size];

    // label to index translation table
    dict = new Hashtable<V,GraphMatrixVertex<V>>(size);

    // put all indices in the free list
    freeList = new SinglyLinkedList<Integer>();
    for (int row = size-1; row >= 0; row--)
        freeList.add(new Integer(row));
}
```

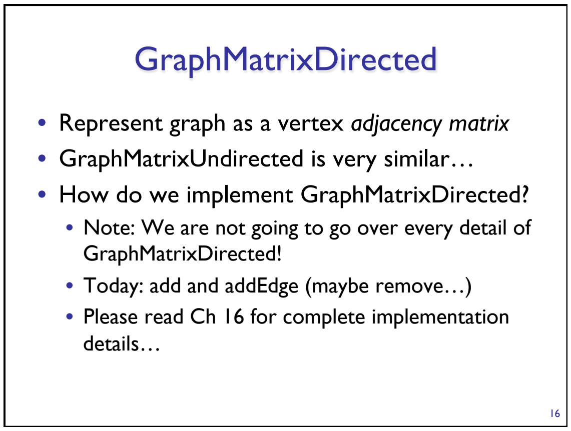


Vertex and GraphMatrixVertex

- We already looked at the Edge class
- Now we need to define a Vertex class
  - Unlike the Edge class, Vertex class **is not public**
  - Useful Vertex methods:

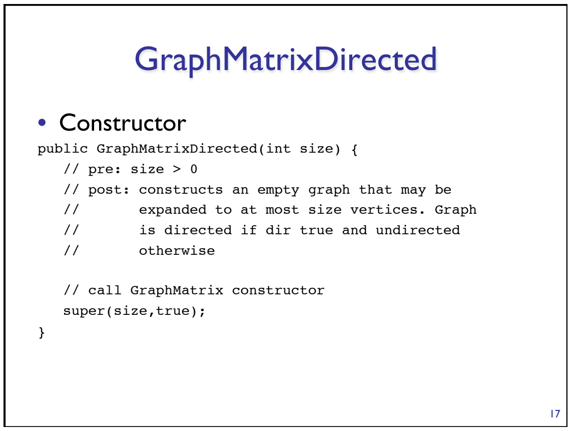
    ```
    V label(), boolean visit(),
    boolean isVisited(), void reset()
    ```
  - GraphMatrixVertex class adds one more useful attribute to Vertex class
    - Index of node (int) in adjacency matrix

      ```
      int index()
      ```
    - Why do we only need one int to represent index?



GraphMatrixDirected

- Represent graph as a vertex *adjacency matrix*
- GraphMatrixUndirected is very similar…
- How do we implement GraphMatrixDirected?
  - Note: We are not going to go over every detail of GraphMatrixDirected!
  - Today: add and addEdge (maybe remove…)
  - Please read Ch 16 for complete implementation details…

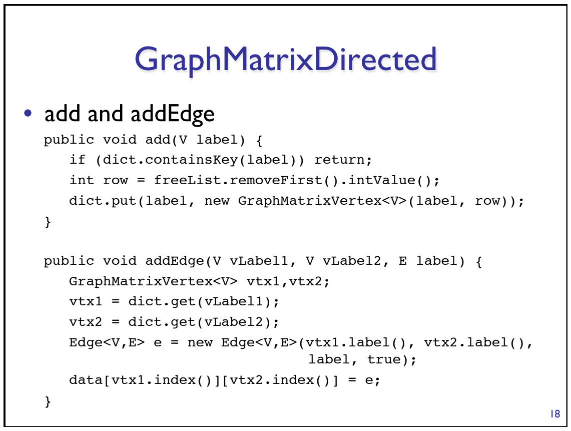


GraphMatrixDirected

- Constructor

```
public GraphMatrixDirected(int size) {
   // pre: size > 0
   // post: constructs an empty graph that may be
   //       expanded to at most size vertices. Graph
   //       is directed if dir true and undirected
   //       otherwise

   // call GraphMatrix constructor
   super(size,true);
}
```



GraphMatrixDirected

- add and addEdge

```
public void add(V label) {
   if (dict.containsKey(label)) return;
   int row = freeList.removeFirst().intValue();
   dict.put(label, new GraphMatrixVertex<V>(label, row));
}

public void addEdge(V vLabel1, V vLabel2, E label) {
   GraphMatrixVertex<V> vtx1,vtx2;
   vtx1 = dict.get(vLabel1);
   vtx2 = dict.get(vLabel2);
   Edge<V,E> e = new Edge<V,E>(vtx1.label(), vtx2.label(),
                               label, true);
   data[vtx1.index()][vtx2.index()] = e;
}
```