CSCI 136
Data Structures &
Advanced Programming

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Lecture 30
May 2, 2014

Administrative Details

- Darwin lab
  - Final lab + creature due Monday at noon
  - Any questions/problems?
- How do you infect another creature?
  - Make sure you don't create new creatures…just change the species of an existing one

Last Time (Monday)

- Continued talking about BSTs
- Learned how to add elements to a BST

Today's Outline

- Wrap up binary search trees
- Maybe start talking about Graphs (Ch 16)
  - Learn a bit more about graphs during next lab

Recap: locate

```
protected BT<E> locate(BT<E> top, E value) {
  // pre: top and value are non-null
  // post: returns "highest" node with the desired value,
  //       or node to which value should be added
  E topValue = top.value();
  BT<E> child;
  // found at top: done
  if (topValue.equals(value)) return top;
  // look left if less-than, right if greater-than
  if (ordering.compare(topValue,value) < 0) {
      child = top.right();
  } else {
      child = top.left();
  }
  // if no child there: not in tree, return this node,
  if (child.isEmpty()) { return top; }
  // else keep searching
 else { return locate(child, value); }
}
```

Recap: contains

```
public boolean contains (E value) {
  if (root.isEmpty()) return false;

  BinaryTree<E> node = locate(root, value);
  return node.value().equals(value);
}
```

Recap: add

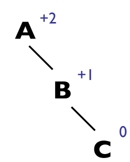
```
public void add(E value) {
  BT<E> newNode = new BT<E>(value);
  if (root.isEmpty()) { root = newNode; }
  else {
   BT<E> node = locate(root,value);
   E nodeValue = node.value();
    // node is either successor or predecessor of newNode
    if (ordering.compare(nodeValue,value) < 0) {
        //locate returned predecessor; add as right child
        node.setRight(newNode);
    } else {  //locate returned successor
      if (!node.left().isEmpty()) {
        // duplicate: if value is in tree, we insert before it
        predecessor(node).setRight(newNode);
      } else {
        node.setLeft(newNode);
      }
    }
  }
  count++;
}
```

Removal

- Removing the root is the hardest
- Let's figure that out first
  - If we figure out how to remove the root, we can remove any element in BST in same way (why?)
- We need to implement:
  - `public E remove(E item)`
  - `protected BT<E> removeTop(BT<E> top)`

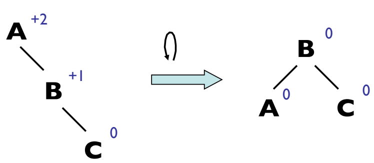
Food for thought…

- Can we design a binary search tree that is always balanced?
- Yes!
- AVL trees
  - Named after its two inventors, G.M. Adelson-Velsky and E.M. Landis, who published a paper about AVL trees in 1962 called "An algorithm for the organization of information"



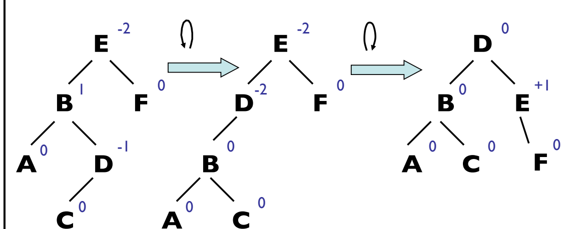
- The balance factor of a node is the *height* of its right subtree minus the height of its left subtree. A node with balance factor 1, 0, or -1 is considered balanced.
- A node with any other balance factor is considered unbalanced and requires rebalancing the tree.

Single Rotation



Unbalanced trees can be rotated to achieve balance.

Double Rotation



Moving on…

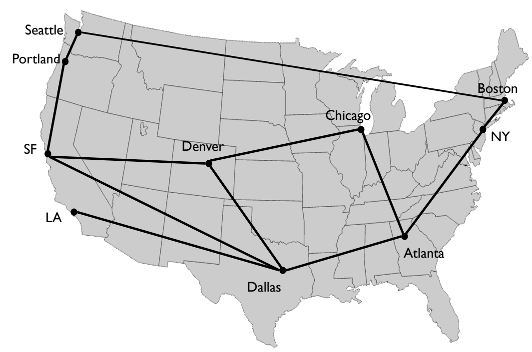
- You won't be tested on AVL trees
- Any questions on BSTs before we move on to graphs?

Introduction to Graphs

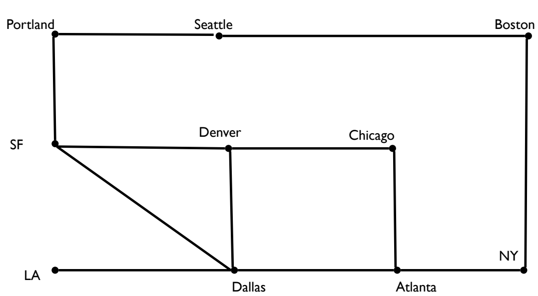
- Types of data structures
  - Basic - Lists/Vectors (no ordering relation)
  - Linear - ordered by insertion
  - Ordered - value ordering
  - Tree - hierarchical ordering
  - BST - value ordering (in a hierarchical fashion)
- Next up: Graphs
  - The most general way to describe relationships between data

Graphs

- Definition
  - A graph is a collection of vertices (nodes) and edges connecting them
- Examples?



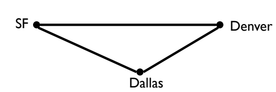
Nodes = cities; Edges = lines connecting cities



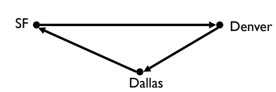
Note: Structure of graph matters, not actual placement of nodes

Types of Graphs

- Undirected
  - All edges are bi-directional

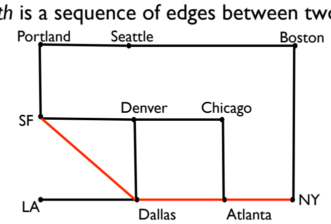


- Directed
  - Edges have a source and destination



Paths

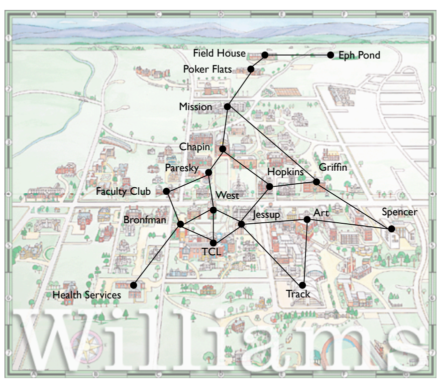
- A *path* is a sequence of edges between two nodes



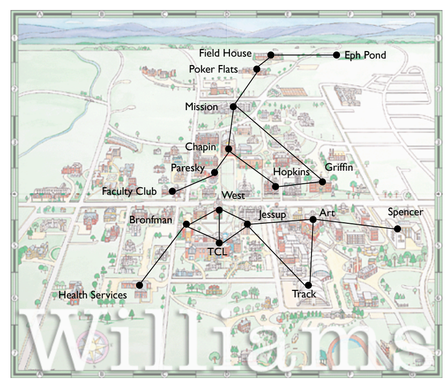
- Questions:
  - What is the shortest path from SF to NY?
  - What is the shortest *cycle* from SF to SF that goes through Atlanta and Chicago?

Connectedness

- Nodes U and V are *connected* if there is an edge between U and V
- A *connected component* is a set S where there is a path between every pair of vertices in S
  - A *fully connected component* is a set S where there is an edge between every pair of vertices in S



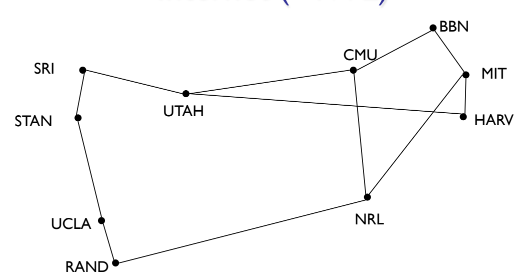
What's *reachable* from TCL?



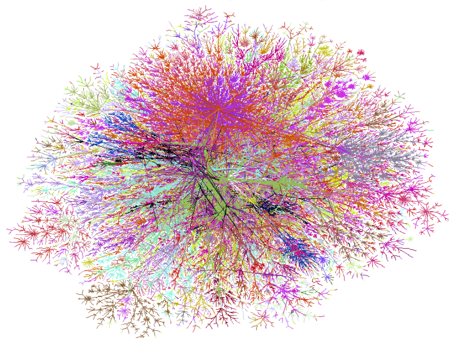
Graph Applications

- Connectedness in the real world
  - Flights, campus, networks, etc.
  - Useful for finding shortest number of steps/hops

Internet (~1972)



Internet (~1998)



Graph Applications

- Connectedness in the real world
  - Flights, campus, networks, etc.
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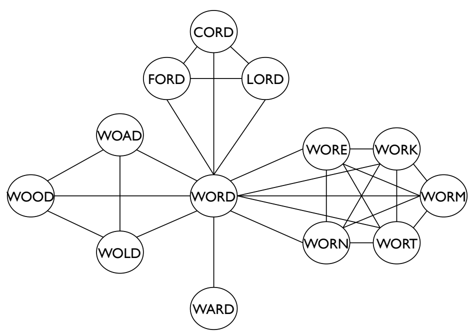
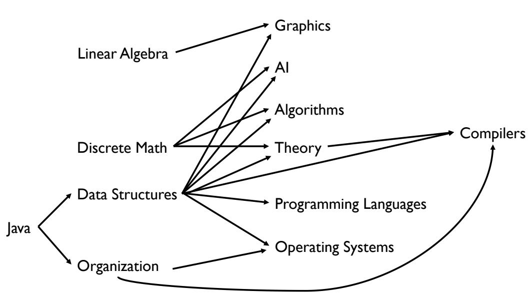
- Word "changlings"
  - Change in degree, paths, size, etc.



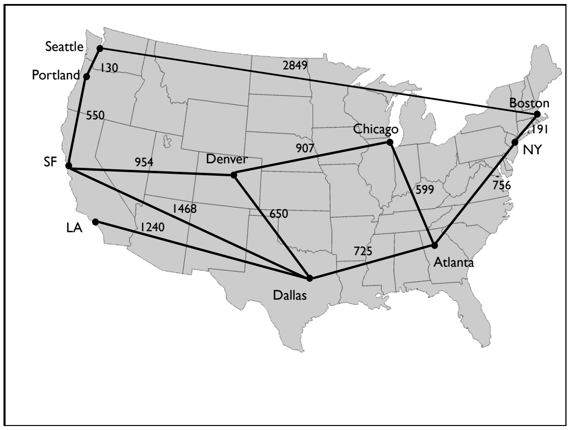
Graph Applications

- Connectedness in the real world
  - Flights, campus, networks, etc.
  - Useful for finding shortest number of steps
- Word "changlings"
  - Change in degree, paths, size, etc.
- Schedules
  - In edges/out edges indicate prerequisite relationships (why no cycles?)



Labeled Edges

- Not all edges are the same "weight"
  - Edges can carry extra info
- Weight = the *cost* of traversing that edge
  - Cost may be a function of time, distance, price to pay, etc.
- May lead to different solutions to previously answered questions
  - What is shortest path between SF and NY given edge weights?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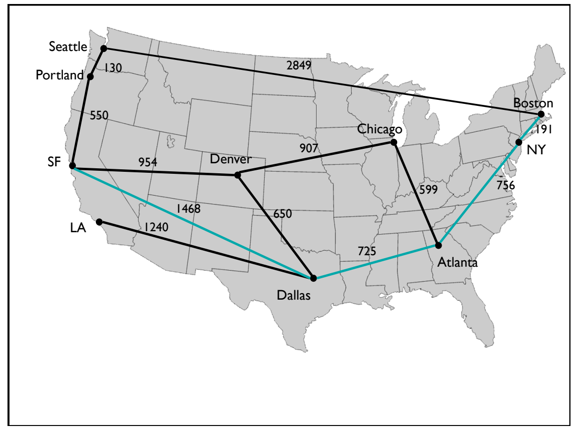
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