61B Lecture #21: Tree Searching

Divide and Conquer

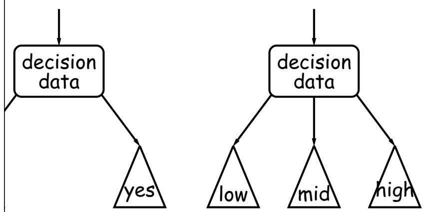
) computation is devoted to finding things in response
rms of query.

h for response can be expensive, especially when data
ge for primary memory.

o have criteria for *dividing* data to be searched into
sively

figure for $\lg N$ algorithms: at 1 μsec per comparison,
s 10^{300000} items in 1 sec.

ural framework for the representation:



Binary Search Trees

Property:

ontain *keys,* and possibly other data.

eft subtree of node have *smaller* keys.

ight subtree of node have *larger* keys.

ans any complete transitive, anti-symmetric ordering on

e of $x \prec y$ and $y \prec x$ true.

$y \prec z$ imply $x \prec z$.

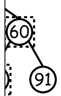
fy, won't allow duplicate keys this semester).

nary database, node label would be (*word, definition*):
key.

ness here, we'll just use the standard Java convention
mpareTo.

Finding

r 50 and 49:

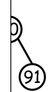



```
/** Node in T containing L, or null if none */
static BST find(BST T, Key L) {
  if (T == null)
    return T;
  if (L.compareTo(T.label()) == 0)
    return T;
  else if (L.compareTo(T.label()) < 0)
    return find(T.left(), L);
  else
    return find(T.right(), L);
}
```

s show which node labels we look at.

ed at proportional to height of tree.

Inserting

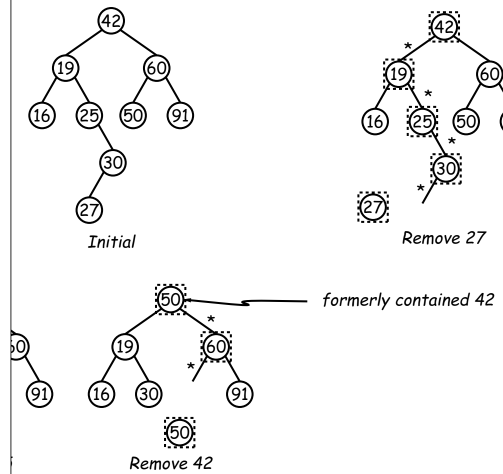



```
/** Insert L in T, replacing existing
 *  value if present, and returning
 *  new tree. */
static BST insert(BST T, Key L) {
  if (T == null)
    return new BST(L);
  if (L.compareTo(T.label()) == 0)
    T.setLabel(L);
  else if (L.compareTo(T.label()) < 0)
    T.setLeft(insert(T.left(), L));
  else
    T.setRight(insert(T.right(), L));
  return T;
}
```

es are set (to themselves, unless initially null).

roportional to height.

Deletion



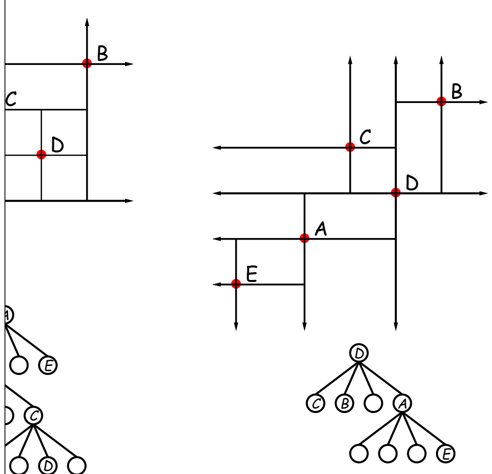
Deletion Algorithm

```
/** Remove L from T, returning new tree. */
static BST remove(BST T, Key L) {
  if (T == null)
    return null;
  if (L.compareTo(T.label()) == 0) {
     if (T.left() == null)
        return T.right();
     else if (T.right() == null)
        return T.left();
     else {
        Key smallest = minVal(T.right());  // ??
        T.setRight(remove(T.right(), smallest));
        T.setLabel(smallest);
     }
  }
  else if (L.compareTo(T.label()) < 0)
    T.setLeft(remove(T.left(), L));
  else
    T.setRight(remove(T.right(), L));
  return T;
}
```


ore Than Two Choices: Quadtrees

- *ex* information about 2D locations so that items can be position.
- lo so using standard data-structuring trick: *Divide and*
- (2D) space into four *quadrants,* and store items in the quadrant. Repeat this recursively with each quadrant s more than one item.
- nition: a quadtree is either
- t some position (x, y), called the root, plus
- trees, each containing only items that are northwest, , southwest, and southeast of (x, y).
- at if you are looking for point (x', y') and the root is not are looking for, you can narrow down which of the four the root to look in by comparing coordinates (x, y) with

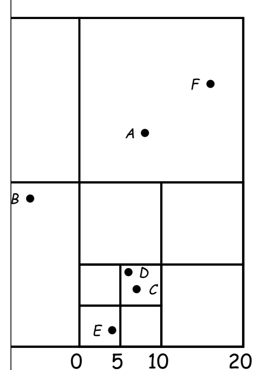
Classical Quadtree: Example

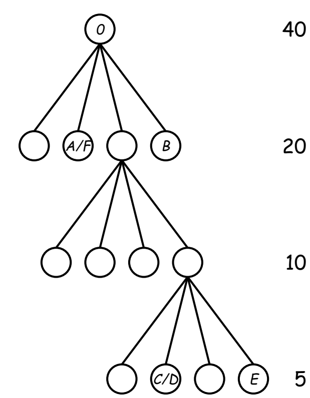


Point-region (PR) Quadtrees

- Quadtree to track moving objects, it may be useful to *lelete* items from a tree: when an object moves, the it goes in may change.
- do with the classical data structure above, so we'll de-
- onsists of a bounding rectangle, B and either
- a small number of items that lie in that rectangle, or
- trees whose bounding rectangles are the four quadrants f equal size).
- empty quadtree can have an arbitrary bounding rect- can wait for the first point to be inserted.

Example of PR Quadtree





2 points per leaf)

Navigating PR Quadtrees

- em at (x, y) in quadtree T,
- s outside the bounding rectangle of T, or T is empty, is not in T.
- e, if T contains a small set of items, then (x, y) is in T nong these items.
- e, T consists of four quadtrees. Recursively look for ach (however, step #1 above will cause all but one of nding boxes to reject the point immediately).
- edure works when looking for all items within some rect-
- s not intersect the bounding rectangle of T, or T is en there are no items in R.
- e, if T contains a set of items, return those that are in
- e, T consists of four quadtrees. Recursively look for R in each one of them.

Insertion into PR Quadtrees

or inserting a new point N, assuming maximum occupancy
showing initial state $\Longrightarrow$ final state.