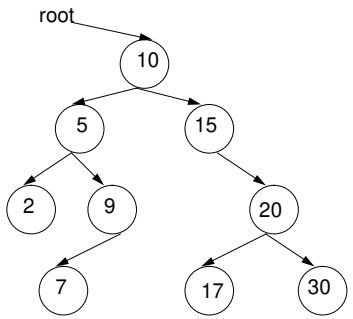
CSE 326
Lecture 8

Binary Search Trees II

Winter Quarter 1999

Examples of Finding Minimum and Maximum



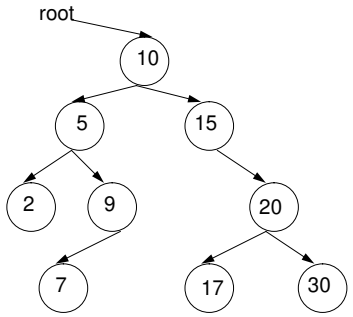
Minimum and Maximum

- Min(n) returns a pointer to the node in the subtree rooted at n with the smallest data. We assume that n points to a node.
- Min(n: node pointer): node pointer {

  if n.left = null then return(n)
  else return Min(n.left) }
- To find the minimum in the entire tree call Min(root).
- Max(n) is similar but looking right instead of left.
- Min and Max exhibit end recursion so iterative programs are easy.
- Min(n: node pointer): node pointer{

  while not(n.left = null) do n := n.left;
  return(n)}

Finding the Successor and Predecessor



Successor and Predecessor

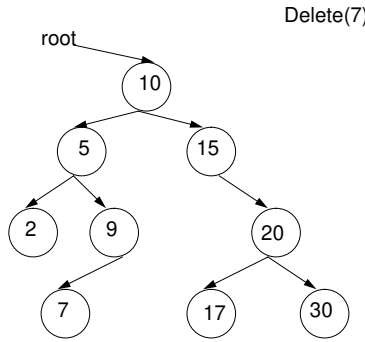
- Successor(n) finds the node whose data is next largest after n's data in the subtree rooted at n. Assume that n has a successor.
- Successor(n: node pointer): node pointer {

  return(Min(n.right)) }
- Iterative version

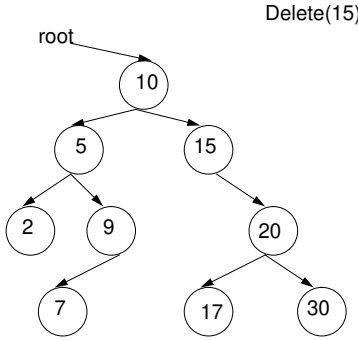
  Successor(n: node pointer): node pointer {

  n := n.right;
  while not(n.left = null) do n := n.left;
  return(n) }
- For Predecessor just reverse the roles of left and right.

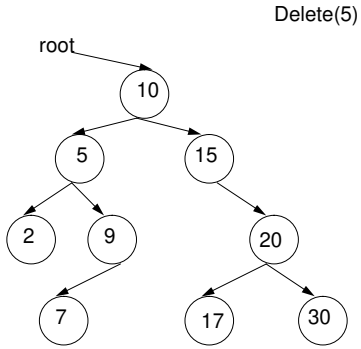
Deletion - Leaf Case



Deletion - One Child Case



Deletion - Two Child Case



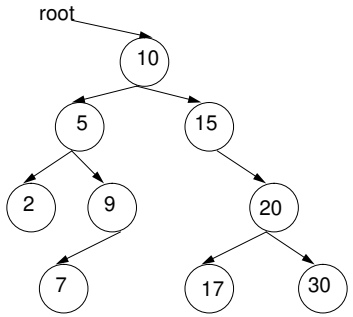
Elegant Tree Deletion

- Recursive reference parameter technique
- Delete(x: key, p: reference node pointer) {

```
local pointer q;
if not(p=null) then
  case
     p.data < x: Delete(x, p.right_child);
     p.data > x: Delete(x. p.left_child);
     p.data = x:
          case
             p.left_child = null: p := p.right_child;
             p.right_child = null: p := p.left_child;
             otherwise: {
                  q := Successor(p);
                  p.data := q.data;
                  Delete(q.data,p.right_child)}
          endcase
   endcase }
```

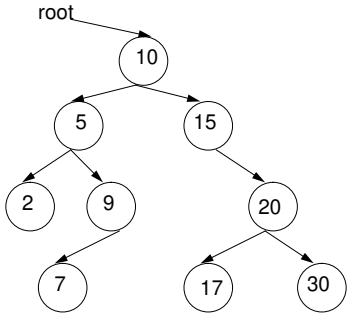

Example of Deletion

Delete(15)



Another Example of Deletion

Delete(5)



Value vs. Reference Parameters

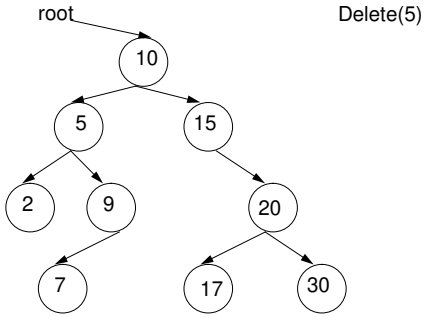
- Value parameters are generally preferred because there are no side effects.
- When to use Reference parameters

  1. The parameter is an array or some large object that needs to be acted on directly.

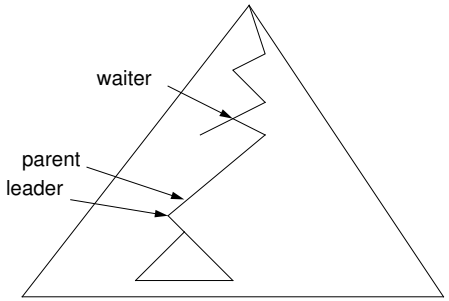
  2. The parameter is a pointer that needs to be changed as a result of the call. Because unintentional side effects care must be taken!

Iterative Delete by Example

- Three pointers are used: "leader", "parent", and "waiter". It is tricky code with much potential for problems.



General Case of Iterative Delete



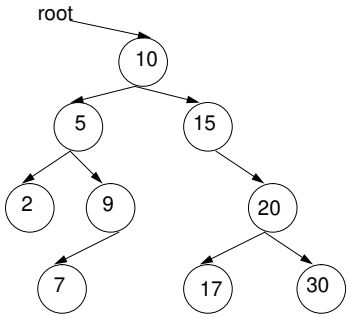
Lazy Deletion

- Instead of physically deleting nodes just mark them as deleted

+ simpler

+ physical deletions done in batch mode

+ some insertions can just unmark nodes

- many lazy deletions slows down insertions and finds

- some operations like min and max may have to be modified.