CMSC 132, Object-Oriented Programming II **Summer 2017**

Lecture 12

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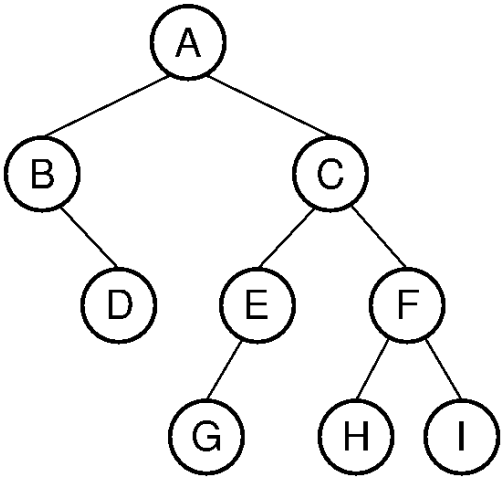
12.1 Trees

12.1.1 Binary Tree

A binary tree is a tree data structure in which each node has at most two children, which are referred to as the left child and the right child.



- Tree Traversal: tree traversal refers to the process of visiting (examining and/or updating) each node in a tree data structure, exactly once, in a systematic way.
  - preOrder:root, left child, right child: A,B,D,C,E,G,G,H,I
  - inOrder: left child, root, right child : B,D,A,G,E,C,H,F,I
  - postOrder:left child, right child, root: D,B,G,E,H,I,F,C,A
  - levelOrder:A,B,C,D,E,F,G,G,I

Listing 1: Binary Tree

```
1  /**
2   *            2
3   *         /     \
4   *     7             50
5   *   /   \             \
6   *  20     6             9
7   *      /   \           /
```

```
 *    5   11         4
 *
 */

package binarytree;

import java.util.LinkedList;
import java.util.Queue;
import java.util.Stack;
public class BinaryTree {

    private Node root;             // root of binary tree
    Stack<Node> pathStack;
    BinaryTree(){
        pathStack = new Stack();
        create();
    }
    private class Node {
        private Integer key;           // sorted by key
        private Node left, right;  // left and right subtrees

        public Node(Integer key) {
            this.key = key;
            left = null;
            right = null;

        }
    }

    private void create(){
        root = new Node(2);
        root.left = new Node(7);

        root.left.left = new Node(20);
        root.left.right = new Node(6);
        root.left.right.left = new Node(5);
        root.left.right.right = new Node(11);

        root.right = new Node(50);
        root.right.right = new Node(9);
        root.right.right.left = new Node(4);

    }
    /*
     * preOrder traverse the binary tree
     */
    public void preOrder(){
        preOrderTraverseIterate(root);
    }
    /*
     * Preorder traverse the binary tree starting from a node
     */
    public void preOrder(Node r){
        if(r == null){return;}
        System.out.print(r.key+",");
        preOrder(r.left);
        preOrder(r.right);
    }

    /*
     * inOrder traverse the binary tree
     */
    public void inOrder(){
        inOrderTraverseIterate(root);
    }
    /*
     * inOrder traverse the binary tree starting from a node
     */
```

```
76      public void inOrder(Node r){
77          if(r == null){return;}
78          inOrder(r.left);
79          System.out.print(r.key+",");
80          inOrder(r.right);
81      }
82
83      /*
84       * postOrder traverse the binary tree
85       */
86      public void postOrder(){
87          postOrder(root);
88      }
89      /*
90       * postOrder traverse the binary tree starting from a node
91       */
92      public void postOrder(Node r){
93          if(r == null){return;}
94          postOrder(r.left);
95          postOrder(r.right);
96          System.out.print(r.key+",");
97      }
98
99
100     private void preOrderTraverseIterate(Node r){
101         Stack<Node> S = new Stack();
102         Node current = root;
103         while(current != null || !S.empty()){
104             while(current != null){
105                 System.out.print(current.key +"->");
106                 S.push(current.right);
107                 current = current.left;
108             }
109             if(!S.empty()){
110                 current = S.pop();
111             }
112         }
113     }
114     private void inOrderTraverseIterate(Node r){
115     Stack<Node> S = new Stack();
116     Node current = root;
117     while(current != null  || !S.empty()){
118         if(current != null){
119            S.push(current);
120            current = current.left;
121         }else{
122             current = S.pop();
123             System.out.print(current.key+ "->");
124             current = current.right;
125         }
126     }
127 }
128
129     // is the symbol table empty?
130     public boolean isEmpty() {
131         return root == null;
132     }
133
134     // return number of nodes in the tree
135     public int size() {
136         return size(root);
137     }
138     // return the number of nodes in a subtree rooted at r
139     private int size(Node r){
140         if(r == null) return 0;
141         return 1 + size(r.left )+ size(r.right);
142     }
143
```

```
144
145     // height of this binary tree (one-node tree has height 0)
146     public int height() {
147         return height(root);
148     }
149     // height of a tree rooted at r
150     private int height(Node r) {
151         if (r == null) return -1;
152         return 1 + Math.max(height(r.left), height(r.right));
153     }
154
155     //return the number of leaves
156     public int countLeaves(){
157         return countLeaves(root);
158     }
159
160     //return the number of leaves of a rooted at r
161     public int countLeaves(Node r){
162         if(r == null) return 0;
163         if(r.left == null && r.right == null) return 1;
164         return countLeaves(r.left) + countLeaves(r.right) ;
165     }
166
167    //return diameter of the tree
168    public int diameter(){
169        return diameter(root);
170    }
171    //return diameter of the tree rooted at r
172    public int diameter(Node r){
173        if (r == null) return 0;
174        int lheight = height(r.left)+1;
175        int rheight = height(r.right)+1;
176        int ldiameter = diameter(r.left);
177        int rdiameter = diameter(r.right);
178        return Math.max(lheight + rheight + 1, Math.max(ldiameter,rdiameter));
179     }
180
181     public void levelOrder(){
182         if(root == null){ return; }
183         Queue<Node> q = new LinkedList();
184         q.offer(root);
185         while(!q.isEmpty()){
186             Node t = q.poll();
187             System.out.print(t.key+",");
188             if(t.left != null) q.offer(t.left);
189             if(t.right != null) q.offer(t.right);
190         }
191     }
192
193
194     public void path(Integer k){
195         path(root,k);
196     }
197     public void path(Node r, Integer k){
198         if(r == null) return;
199         pathStack.push(r);
200         if(r.key.equals(k)) {
201             System.out.println("\nPath␣to␣" + k +":" );
202             for(Node tt: pathStack){
203                 System.out.print(tt.key+"-->");
204             }
205             System.out.println("\n");
206             return;
207         }
208         path(r.left,k);
209         path(r.right,k);
210         pathStack.pop();
211     }
```

```
212
213     public void path_recursive(Integer x){
214                 path_recursive(root,x);
215         }
216         private boolean path_recursive(Node r, Integer x){
217                 if(r==null) return false;
218                 if(path_recursive(r.left,x) || path_recursive(r.right,x)
219                         ||r.data.equals(x)){
220                          System.out.print(r.data+"->");
221                          return true;
222                 }else{
223                          return false;
224                 }
225         }
226
227
228
229     /**
230      * @param args the command line arguments
231      */
232     public static void main(String[] args) {
233         BinaryTree b = new BinaryTree();
234         System.out.println("preOrder␣traversal:");
235         b.preOrder();
236         System.out.println("\ninOrder␣traversal:");
237         b.inOrder();
238         System.out.println("\npostOrder␣traversal:");
239         b.postOrder();
240         System.out.println("\n");
241         System.out.println("Size:" + b.size());
242         System.out.println("Height:" + b.height());
243         System.out.println("Number␣of␣leaves:" + b.countLeaves());
244         System.out.println("Diameter:" + b.diameter());
245         System.out.println("Level␣Order:");
246         b.levelOrder();
247         b.path(12);
248     }
249 }
```