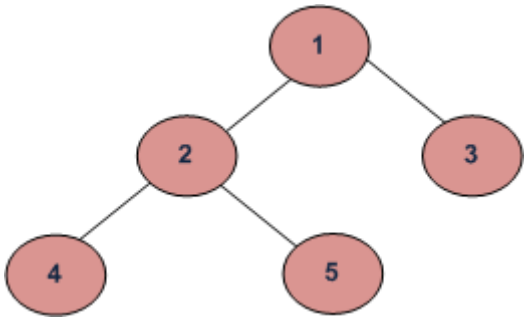
Tree Traversals (Inorder, Preorder and Postorder)

1.4

Unlike linear data structures (Array, Linked List, Queues, Stacks, etc) which have only one logical way to traverse them, trees can be traversed in different ways. Following are the generally used ways for traversing trees.



Example Tree

Depth First Traversals:
(a) Inorder (Left, Root, Right) : 4 2 5 1 3
(b) Preorder (Root, Left, Right) : 1 2 4 5 3
(c) Postorder (Left, Right, Root) : 4 5 2 3 1

Breadth First or Level Order Traversal : 1 2 3 4 5
Please see this post for Breadth First Traversal.

Inorder Traversal:

```
Algorithm Inorder(tree)
   1. Traverse the left subtree, i.e., call Inorder(left-subtree)
   2. Visit the root.
   3. Traverse the right subtree, i.e., call Inorder(right-subtree)
```

Uses of Inorder

In case of binary search trees (BST), Inorder traversal gives nodes in non-decreasing order. To get

nodes of BST in non-increasing order, a variation of Inorder traversal where Inorder itraversal s reversed, can be used.
Example: Inorder traversal for the above given figure is 4 2 5 1 3.

Practice Inorder Traversal

Preorder Traversal:

```
Algorithm Preorder(tree)
   1. Visit the root.
   2. Traverse the left subtree, i.e., call Preorder(left-subtree)
   3. Traverse the right subtree, i.e., call Preorder(right-subtree)
```

Uses of Preorder
Preorder traversal is used to create a copy of the tree. Preorder traversal is also used to get prefix expression on of an expression tree. Please see http://en.wikipedia.org/wiki/Polish_notation to know why prefix expressions are useful.
Example: Preorder traversal for the above given figure is 1 2 4 5 3.

Practice Preorder Traversal

Postorder Traversal:

```
Algorithm Postorder(tree)
   1. Traverse the left subtree, i.e., call Postorder(left-subtree)
   2. Traverse the right subtree, i.e., call Postorder(right-subtree)
   3. Visit the root.
```

Uses of Postorder
Postorder traversal is used to delete the tree. Please see the question for deletion of tree for details. Postorder traversal is also useful to get the postfix expression of an expression tree. Please see http://en.wikipedia.org/wiki/Reverse_Polish_notation to for the usage of postfix expression.

Practice Postorder Traversal

Example: Postorder traversal for the above given figure is 4 5 2 3 1.

C

```
// C program for different tree traversals
#include <stdio.h>
#include <stdlib.h>

/* A binary tree node has data, pointer to left child
```

```
   and a pointer to right child */
struct node
{
     int data;
     struct node* left;
     struct node* right;
};

/* Helper function that allocates a new node with the
   given data and NULL left and right pointers. */
struct node* newNode(int data)
{
     struct node* node = (struct node*)
                                  malloc(sizeof(struct node));
     node->data = data;
     node->left = NULL;
     node->right = NULL;

     return(node);
}

/* Given a binary tree, print its nodes according to the
  "bottom-up" postorder traversal. */
void printPostorder(struct node* node)
{
     if (node == NULL)
        return;

     // first recur on left subtree
     printPostorder(node->left);

     // then recur on right subtree
     printPostorder(node->right);

     // now deal with the node
     printf("%d ", node->data);
}

/* Given a binary tree, print its nodes in inorder*/
void printInorder(struct node* node)
{
     if (node == NULL)
          return;

     /* first recur on left child */
     printInorder(node->left);

     /* then print the data of node */
     printf("%d ", node->data);

     /* now recur on right child */
     printInorder(node->right);
}

/* Given a binary tree, print its nodes in preorder*/
void printPreorder(struct node* node)
{
     if (node == NULL)
          return;

     /* first print data of node */
     printf("%d ", node->data);

     /* then recur on left sutree */
     printPreorder(node->left);

     /* now recur on right subtree */
     printPreorder(node->right);
}
```

```c
/* Driver program to test above functions*/
int main()
{
     struct node *root  = newNode(1);
     root->left             = newNode(2);
     root->right           = newNode(3);
     root->left->left     = newNode(4);
     root->left->right   = newNode(5);

     printf("\nPreorder traversal of binary tree is \n");
     printPreorder(root);

     printf("\nInorder traversal of binary tree is \n");
     printInorder(root);

     printf("\nPostorder traversal of binary tree is \n");
     printPostorder(root);

     getchar();
     return 0;
}
```

Run on IDE

Python

```python
# Python program to for tree traversals

# A class that represents an individual node in a
# Binary Tree
class Node:
    def __init__(self,key):
        self.left = None
        self.right = None
        self.val = key


# A function to do inorder tree traversal
def printInorder(root):

    if root:

        # First recur on left child
        printInorder(root.left)

        # then print the data of node
        print(root.val),

        # now recur on right child
        printInorder(root.right)



# A function to do postorder tree traversal
def printPostorder(root):

    if root:

        # First recur on left child
        printPostorder(root.left)

        # the recur on right child
        printPostorder(root.right)

        # now print the data of node
```

```
        print(root.val),


# A function to do postorder tree traversal
def printPreorder(root):

    if root:

        # First print the data of node
        print(root.val),

        # Then recur on left child
        printPreorder(root.left)

        # Finally recur on right child
        printPreorder(root.right)


# Driver code
root = Node(1)
root.left      = Node(2)
root.right     = Node(3)
root.left.left  = Node(4)
root.left.right  = Node(5)
print "Preorder traversal of binary tree is"
printPreorder(root)

print "\nInorder traversal of binary tree is"
printInorder(root)

print "\nPostorder traversal of binary tree is"
printPostorder(root)
```

Run on IDE

Java

```
// Java program for different tree traversals

/* Class containing left and right child of current
   node and key value*/
class Node
{
    int key;
    Node left, right;

    public Node(int item)
    {
        key = item;
        left = right = null;
    }
}

class BinaryTree
{
    // Root of Binary Tree
    Node root;

    BinaryTree()
    {
        root = null;
    }

    /* Given a binary tree, print its nodes according to the
      "bottom-up" postorder traversal. */
    void printPostorder(Node node)
```

```
    {
        if (node == null)
            return;

        // first recur on left subtree
        printPostorder(node.left);

        // then recur on right subtree
        printPostorder(node.right);

        // now deal with the node
        System.out.print(node.key + " ");
    }

    /* Given a binary tree, print its nodes in inorder*/
    void printInorder(Node node)
    {
        if (node == null)
            return;

        /* first recur on left child */
        printInorder(node.left);

        /* then print the data of node */
        System.out.print(node.key + " ");

        /* now recur on right child */
        printInorder(node.right);
    }

    /* Given a binary tree, print its nodes in preorder*/
    void printPreorder(Node node)
    {
        if (node == null)
            return;

        /* first print data of node */
        System.out.print(node.key + " ");

        /* then recur on left sutree */
        printPreorder(node.left);

        /* now recur on right subtree */
        printPreorder(node.right);
    }

    // Wrappers over above recursive functions
    void printPostorder()  {     printPostorder(root);  }
    void printInorder()    {     printInorder(root);   }
    void printPreorder()   {     printPreorder(root);  }

    // Driver method
    public static void main(String[] args)
    {
        BinaryTree tree = new BinaryTree();
        tree.root = new Node(1);
        tree.root.left = new Node(2);
        tree.root.right = new Node(3);
        tree.root.left.left = new Node(4);
        tree.root.left.right = new Node(5);

        System.out.println("Preorder traversal of binary tree is ");
        tree.printPreorder();

        System.out.println("\nInorder traversal of binary tree is ");
        tree.printInorder();

        System.out.println("\nPostorder traversal of binary tree is ");
        tree.printPostorder();
```

```
    }
}
```

Run on IDE

Output:

```
Preorder traversal of binary tree is
1 2 4 5 3
Inorder traversal of binary tree is
4 2 5 1 3
Postorder traversal of binary tree is
4 5 2 3 1
```

One more example:

InOrder(root) visits nodes in the following order:
4, 10, 12, 15, 18, 22, 24, 25, 31, 35, 44, 50, 66, 70, 90

A Pre-order traversal visits nodes in the following order:
25, 15, 10, 4, 12, 22, 18, 24, 50, 35, 31, 44, 70, 66, 90

A Post-order traversal visits nodes in the following order:
4, 12, 10, 18, 24, 22, 15, 31, 44, 35, 66, 90, 70, 50, 25

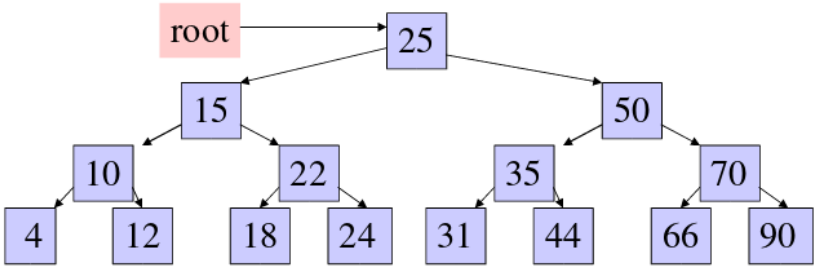


Image Source : https://www.cs.swarthmore.edu/~newhall/unixhelp/Java_bst.pdf

Time Complexity: O(n)

Let us see different corner cases.

Complexity function T(n) — for all problem where tree traversal is involved — can be defined as:

T(n) = T(k) + T(n – k – 1) + c

Where k is the number of nodes on one side of root and n-k-1 on the other side.

Let's do analysis of boundary conditions

Case 1: Skewed tree (One of the subtrees is empty and other subtree is non-empty)

k is 0 in this case.

T(n) = T(0) + T(n-1) + c

T(n) = 2T(0) + T(n-2) + 2c

T(n) = 3T(0) + T(n-3) + 3c

T(n) = 4T(0) + T(n-4) + 4c

……

……

T(n) = (n-1)T(0) + T(1) + (n-1)c

T(n) = nT(0) + (n)c

Value of T(0) will be some constant say d. (traversing a empty tree will take some constants time)

T(n) = n(c+d)

T(n) = Θ(n) (Theta of n)

Case 2: Both left and right subtrees have equal number of nodes.

T(n) = 2T(|_n/2_|) + c

This recursive function is in the standard form (T(n) = aT(n/b) + (-)(n)) for master method http://en.wikipedia.org/wiki/Master_theorem. If we solve it by master method we get (-)(n)

Auxiliary Space : If we don't consider size of stack for function calls then O(1) otherwise O(n).

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