Binary Search Tree

Problems Tutorial

For a binary tree to be a binary search tree, the data of all the nodes in the left sub-tree of the root node should be $\leq$ the data of the root. The data of all the nodes in the right subtree of the root node should be $>$ the data of the root.

Example

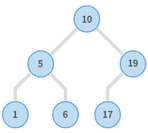


Fig. 1

In Fig. 1, consider the root node with data = 10.

- Data in the left subtree is: $[5, 1, 6]$
- All data elements are < 10
- Data in the right subtree is: $[19, 17]$
- All data elements are > 10

Also, considering the root node with $data = 5$, its children also satisfy the specified ordering. Similarly, the root node with $data = 19$ also satisfies this ordering. When recursive, all subtrees satisfy the left and right subtree ordering.

The tree is known as a Binary Search Tree or BST.

Traversing the tree

There are mainly *three* types of tree traversals.

Pre-order traversal

In this traversal technique the traversal order is root-left-right i.e.

- Process data of root node
- First, traverse left subtree completely
- Then, traverse right subtree

```
void perorder(struct node*root)
{
    if(root)
    {
        printf("%d ",root->data);    //Printf root->data
        preorder(root->left);    //Go to left subtree
        preorder(root->right);     //Go to right subtree
    }
}
```

Post-order traversal

In this traversal technique the traversal order is left-right-root.

- Process data of left subtree
- First, traverse right subtree
- Then, traverse root node

```
void postorder(struct node*root)
{
    if(root)
    {
        postorder(root->left);    //Go to left sub tree
        postorder(root->right);     //Go to right sub tree
        printf("%d ",root->data);    //Printf root->data
    }
}
```

In-order traversal

In in-order traversal, do the following:

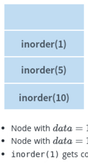
- First process left subtree (before processing root node)
- Then, process current root node
- Process right subtree

```
void inorder(struct node*root)
{
    if(root)
    {
        inorder(root->left);    //Go to left subtree
        printf("%d ",root->data);    //Printf root->data
        inorder(root->right);     //Go to right subtree
    }
}
```

Consider the in-order traversal of a sample BST

- The 'inorder( )' procedure is called with root equal to node with $data = 10$
- Since the node has a left subtree, 'inorder( )' is called with root equal to node with $data = 5$
- Again, the node has a left subtree, so 'inorder( )' is called with $root = 1$

The function call stack is as follows:



- Node with $data = 1$ does not have a left subtree. Hence, this node is processed.
- Node with $data = 1$ does not have a right subtree. Hence, nothing is done.
- `inorder(1)` gets completed and this function call is popped from the call stack.

The stack is as follows:

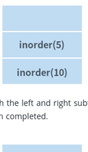
- Left subtree of node with $data = 5$ is completely processed. Hence, this node gets processed.
- Right subtree of this node with $data = 5$ is non-empty. Hence, the right subtree gets processed now. 'inorder(6)' is then called.

Note

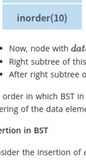
'inorder(6)' is only equivalent to saying inorder(pointer to node with $data = 6$). The notation has been used for brevity.

The function call stack is as follows:

Again, the node with $data = 6$ has no left subtree, Therefore, it can be processed and it also has no right subtree. 'inorder(6)' is then completed.



Both the left and right subtrees of node with $data = 5$ have been completely processed. Hence, `inorder(5)` is then completed.



- Now, node with $data = 10$ is processed
- Right subtree of this node gets processed in a similar way as described until step 10
- After right subtree of this node is completely processed, entire traversal of the BST is complete

The order in which BST in Fig. 1 is visited is: 1, 5, 6, 10, 17, 19. The in-order traversal of a BST gives a sorted ordering of the data elements that are present in the BST. This is an important property of a BST.

Insertion in BST

Consider the insertion of $data = 20$ in the BST.

Algorithm

Compare data of the root node and element to be inserted.

1. If the data of the root node is greater, and if a left subtree exists, then repeat step 1 with root = root of left subtree. Else, insert element as left child of current root.
2. If the data of the root node is greater, and if a right subtree exists, then repeat step 2 with root = root of right subtree. Else, insert element as right child of current root.

Implementation

```
struct node* insert(struct node* root, int data)
{
    if (root == NULL)    //If the tree is empty, return a new,single node
        return newNode(data);
    else
    {
        //Otherwise, recur down the tree
        if (data <= root->data)
            root->left  = insert(root->left, data);
        else
            root->right = insert(root->right, data);
        //return the (unchanged) root pointer
        return root;
    }
}
```

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