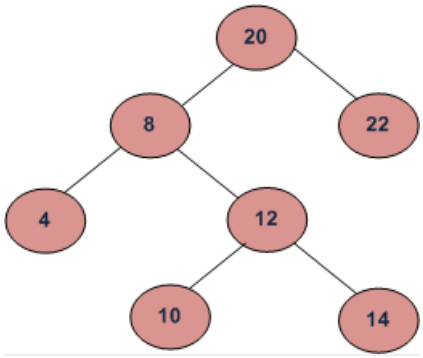
K'th smallest element in BST using O(1) Extra Space

Given a Binary Search Tree (BST) and a positive integer k, find the k'th smallest element in the Binary Search Tree.

For example, in the following BST, if k = 3, then output should be 10, and if k = 5, then output should be 14.



We have discussed two methods in this post and one method in this post. All of the previous methods require extra space. How to find the k'th largest element without extra space?

We strongly recommend to minimize your browser and try this yourself first. Implementation

The idea is to use Morris Traversal. In this traversal, we first create links to Inorder successor and print the data using these links, and finally revert the changes to restore original tree. See this for more details.

Below is C++ implementation of the idea.

```
// C++ program to find k'th largest element in BST
#include<iostream>
#include<climits>
using namespace std;

// A BST node
struct Node
{
    int key;
    Node *left, *right;
};

// A function to find
int KSmallestUsingMorris(Node *root, int k)
{
    // Count to iterate over elements till we
    // get the kth smallest number
    int count = 0;

    int ksmall = INT_MIN; // store the Kth smallest
    Node *curr = root; // to store the current node

    while (curr != NULL)
    {
        // Like Morris traversal if current does
        // not have left child rather than printing
        // as we did in inorder, we will just
        // increment the count as the number will
        // be in an increasing order
        if (curr->left == NULL)
        {
            count++;

            // if count is equal to K then we found the
            // kth smallest, so store it in ksmall
            if (count==k)
                ksmall = curr->key;
```

```
            // go to current's right child
            curr = curr->right;
        }
        else
        {
            // we create links to Inorder Successor and
            // count using these links
            Node *pre = curr->left;
            while (pre->right != NULL && pre->right != curr)
                pre = pre->right;

            // building links
            if (pre->right==NULL)
            {
                //link made to Inorder Successor
                pre->right = curr;
                curr = curr->left;
            }

            // While breaking the links in so made temporary
            // threaded tree we will check for the K smallest
            // condition
            else
            {
                // Revert the changes made in if part (break link
                // from the Inorder Successor)
                pre->right = NULL;

                count++;

                // If count is equal to K then we found
                // the kth smallest and so store it in ksmall
                if (count==k)
                    ksmall = curr->key;

                curr = curr->right;
            }
        }
    }
    return ksmall; //return the found value
}

// A utility function to create a new BST node
Node *newNode(int item)
{
    Node *temp = new Node;
    temp->key = item;
    temp->left = temp->right = NULL;
    return temp;
}

/* A utility function to insert a new node with given key in BST */
Node* insert(Node* node, int key)
{
    /* If the tree is empty, return a new node */
    if (node == NULL) return newNode(key);

    /* Otherwise, recur down the tree */
    if (key < node->key)
        node->left  = insert(node->left, key);
    else if (key > node->key)
        node->right = insert(node->right, key);

    /* return the (unchanged) node pointer */
    return node;
}

// Driver Program to test above functions
int main()
{
    /* Let us create following BST
```

```
              50
           /     \
          30      70
         /  \    /  \
       20   40  60   80 */
    Node *root = NULL;
    root = insert(root, 50);
    insert(root, 30);
    insert(root, 20);
    insert(root, 40);
    insert(root, 70);
    insert(root, 60);
    insert(root, 80);

    for (int k=1; k<=7; k++)
       cout << KSmallestUsingMorris(root, k) << " ";

    return 0;
}
```

Output:

```
20 30 40 50 60 70 80
```