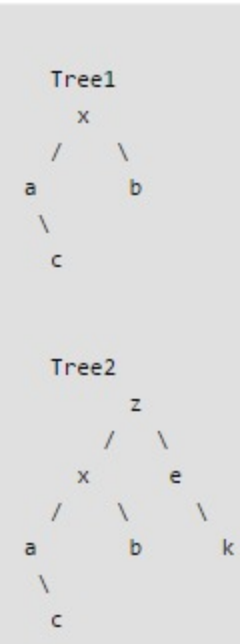
Check if a binary tree is subtree of another binary tree | Set 2

Given two binary trees, check if the first tree is subtree of the second one. A subtree of a tree T is a tree S consisting of a node in T and all of its descendants in T.

The subtree corresponding to the root node is the entire tree; the subtree corresponding to any other node is called a proper subtree.

For example, in the following case, Tree1 is a subtree of Tree2.



We have discussed a $O(n^2)$ solution for this problem. In this post a O(n) solution is discussed. The idea is based on the fact that inorder and preorder/postorder uniquely identify a binary tree. Tree S is a subtree of T if both inorder and preorder traversals of S arew substrings of inorder and preorder traversals of T respectively.

Following are detailed steps.

1) Find inorder and preorder traversals of T, store them in two auxiliary arrays inT[] and preT[].

2) Find inorder and preorder traversals of S, store them in two auxiliary arrays inS[] and preS[].

3) If inS[] is a subarray of inT[] and preS[] is a subarray preT[], then S is a subtree of T. Else not.

We can also use postorder traversal in place of preorder in the above algorithm.

Let us consider the above example

```
Inorder and Preorder traversals of the big tree are.
inT[]   =  {a, c, x, b, z, e, k}
preT[]  =  {z, x, a, c, b, e, k}

Inorder and Preorder traversals of small tree are
inS[]  = {a, c, x, b}
preS[] = {x, a, c, b}

We can easily figure out that inS[] is a subarray of
inT[] and preS[] is a subarray of preT[].
```

EDIT

```
The above algorithm doesn't work for cases where a tree is present
in another tree, but not as a subtree. Consider the following example.

        Tree1
          x
         /   \
      a       b
     /
    c


        Tree2
          x
         /   \
      a       b
     /         \
    c           d

Inorder and Preorder traversals of the big tree or Tree2 are.

Inorder and Preorder traversals of small tree or Tree1 are

The Tree2 is not a subtree of Tree1, but inS[] and preS[] are
subarrays of inT[] and preT[] respectively.
```

The above algorithm can be extended to handle such cases by adding a special character whenever we encounter NULL in inorder and preorder traversals. Thanks to Shivam Goel for suggesting this extension.

Following is the implementation of above algorithm.

C Java

```
#include <iostream>
#include <cstring>
using namespace std;
#define MAX 100

// Structure of a tree node
struct Node
{
    char key;
    struct Node *left, *right;
};

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

// A utility function to store inorder traversal of tree rooted
// with root in an array arr[]. Note that i is passed as reference
void storeInorder(Node *root, char arr[], int &i)
{
    if (root == NULL)
    {
        arr[i++] = '$';
        return;
    }
    storeInorder(root->left, arr, i);
    arr[i++] = root->key;
    storeInorder(root->right, arr, i);
}

// A utility function to store preorder traversal of tree rooted
// with root in an array arr[]. Note that i is passed as reference
void storePreOrder(Node *root, char arr[], int &i)
{
    if (root == NULL)
    {
        arr[i++] = '$';
        return;
    }
    arr[i++] = root->key;
    storePreOrder(root->left, arr, i);
    storePreOrder(root->right, arr, i);
}

/* This function returns true if S is a subtree of T, otherwise false */
bool isSubtree(Node *T, Node *S)
{
    /* base cases */
    if (S == NULL)  return true;
    if (T == NULL)  return false;

    // Store Inorder traversals of T and S in inT[0..m-1]
    // and inS[0..n-1] respectively
    int m = 0, n = 0;
    char inT[MAX], inS[MAX];
    storeInorder(T, inT, m);
    storeInorder(S, inS, n);
    inT[m] = '\0', inS[n] = '\0';

    // If inS[] is not a substring of preS[], return false
    if (strstr(inT, inS) == NULL)
        return false;

    // Store Preorder traversals of T and S in inT[0..m-1]
    // and inS[0..n-1] respectively
    m = 0, n = 0;
    char preT[MAX], preS[MAX];
    storePreOrder(T, preT, m);
    storePreOrder(S, preS, n);
    preT[m] = '\0', preS[n] = '\0';

    // If inS[] is not a substring of preS[], return false
    // Else return true
    return (strstr(preT, preS) != NULL);
}

// Driver program to test above function
int main()
{
    Node *T = newNode('a');
    T->left = newNode('b');
    T->right = newNode('d');
    T->left->left = newNode('c');
    T->right->right = newNode('e');

    Node *S = newNode('a');
    S->left = newNode('b');
    S->left->left = newNode('c');
    S->right = newNode('d');

    if (isSubtree(T, S))
        cout << "Yes: S is a subtree of T";
    else
        cout << "No: S is NOT a subtree of T";

    return 0;
}
```

Run on IDE

Output:

```
No: S is NOT a subtree of T
```

Time Complexity: Inorder and Preorder traversals of Binary Tree take O(n) time. The function strstr() can also be implemented in O(n) time using KMP string matching algorithm.

Auxiliary Space: O(n)