MIT World Peace University

Advanced Data Structures
Second Year B. Tech, Semester 4

Implementation of Dictionary using Binary Search Tree

Assignment No. 3

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Contents

1 Objectives

1. To study data structure : Binary Search Tree
2. To study breadth first traversal.
3. To study different operations on Binary search Tree.

2 Problem Statement

Implement dictionary using binary search tree where dictionary stores keywords and its meanings. Perform following operations:

1. Insert a keyword
2. Delete a keyword
3. Create mirror image and display level wise
4. Copy the binary Search Tree

3 Theory

3.1 Binary Search Tree

Binary Search Trees are a special type of binary trees where the value of all the nodes in the left sub-tree is less than the value of the root and the value of all the nodes in the right sub-tree is greater than the value of the root.

The left and right sub-trees are also binary search trees. This property of binary search trees makes them useful for searching, as the desired node can be found by repeatedly comparing the input to the value of the root and choosing the appropriate sub-tree, without having to search through the entire tree.

Binary search trees are also useful for sorting, as it is easy to sort the nodes in ascending order by performing an in-order traversal of the tree.

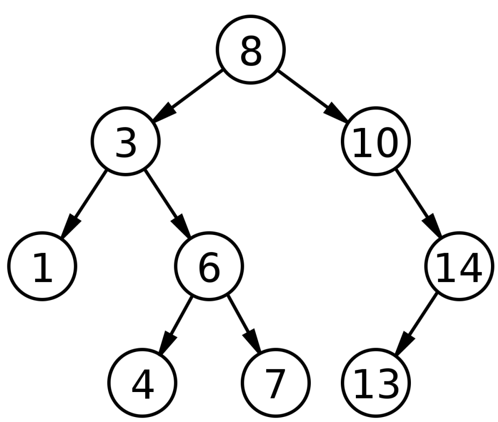

Figure 1: Example of a Binary Search Tree

3.2 Breadth First Traversal

Breadth First Traversal (or Level Order Traversal) is a tree traversal algorithm where we should start traversing the tree from root and traverse the tree level wise i.e. traverse the nodes level by level.

In level order traversal, we visit the nodes level by level from left to right.

3.3 Different operations on binary search tree

3.3.1 Copy

To copy a Binary Search Tree into another Binary Search Tree, we perform a pre-order traversal of the tree. For each node, we create a new node with the same value and then recursively copy the left and right sub-trees of the node.

To copy it Iteratively, we use a queue to store the nodes of the tree. We start by pushing the root node into the queue. We then pop a node from the queue and create a new node with the same value as the popped node. We then push the left and right child of the popped node into the queue and repeat the process until the queue is empty.

3.3.2 Insert

To insert a node in a binary search tree, we start by comparing the value of the node to be inserted with the value of the root node. If the value of the node to be inserted is less than the value of the root node, we move to the left sub-tree and repeat the process. If the value of the node to be inserted is greater than the value of the root node, we move to the right sub-tree and repeat the process.

We repeat this process until we reach a leaf node. The new node is then inserted as the left or right child of the leaf node, depending on the value of the node to be inserted.

3.3.3 Mirror Image

To create a mirror image of a binary search tree, we perform a pre-order traversal of the tree. For each node, we swap the left and right child of the node. We then recursively create the mirror image of the left and right sub-trees of the node.

To create it Iteratively, we use a stack to store the nodes of the tree. We start by pushing the root node into the stack. We then pop a node from the stack and swap the left and right child of the popped node. We then push the left and right child of the popped node into the stack and repeat the process until the stack is empty.

3.3.4 Delete

There are 3 Cases for deletion of a node in a binary search tree:

1. The node to be deleted is a leaf node. In this case, we simply remove the node from the tree.
2. The node to be deleted has only one child. In this case, we replace the node to be deleted with its child.
3. The node to be deleted has two children. In this case, we find the inorder successor of the node. The inorder successor is the smallest node in the right sub-tree of the node. We replace the value of the node to be deleted with the value of the inorder successor. We then delete the

inorder successor. The inorder successor will have at most one child node, so we can use the above two cases to delete it.

It can also be done using the inorder predecessor. The inorder predecessor is the largest node in the left sub-tree of the node. We replace the value of the node to be deleted with the value of the inorder predecessor. We then delete the inorder predecessor. The inorder predecessor will have at most one child node, so we can use the above two cases to delete it.

4 Platform

Operating System: Arch Linux x86-64
IDEs or Text Editors Used: Visual Studio Code
Compilers : g++ and gcc on linux for C++

5 Input

1. Input at least 10 nodes.
2. Display binary search tree levelwise traversals of binary search tree with 10 nodes
3. Display mirror image and copy operations on BST

6 Output

1. The traversal of the binary tree in different ways.

7 Test Conditions

1. Input at least 10 nodes.
2. Display all traversals of binary tree with 10 nodes.(recursive and nonrecursive)

8 Pseudo Code

8.1 Create

```
void create_root()
      root = new WordNode
      display - "Enter the data: " << endl
      Take Input of root->word
      Take Input of root->definition
      root->left = NULL
      root->right = NULL
      create_recursive(root)

  void create_recursive(WordNode *Node)
      int choice = 0
      WordNode *new_node
      display - "Enter if you want to enter a left node (1/0): "
```

```
                 << "for the node -- " << Node->word << ":  " << Node->definition << " -- "
        Take Input of choice
        if (choice == 1)
            new_node = new WordNode
            display - "Enter the data: "
            Take Input of new_node->word
            Take Input of new_node->definition
            Node->left = new_node
            create_recursive(new_node)
        display - "Enter if you want to enter a right node (1/0): "
                 << "for the node -- " << Node->word << ":  " << Node->definition << " -- "
        Take Input of choice
        if (choice == 1)
            new_node = new WordNode
            display - "Enter the data: "
            Take Input of new_node->word
            Take Input of new_node->definition
            Node->right = new_node
            create_recursive(new_node)
```

8.2 Display

```
    void bfs()
    {
        WordNode *temp = root
        queue<WordNode *> q
        q.push(temp)
        while (!q.empty())
        {
            temp = q.front()
            q.pop()
            display - temp->word << " : " << temp->definition << endl
            if (temp->left != NULL)
            {
                q.push(temp->left)
            }
            if (temp->right != NULL)
            {
                q.push(temp->right)
            }
        }
    }
```

8.3 Delete

8.4 Mirror Image

```
    void mirror_recursive(WordNode *temp)
    {
        if (temp == NULL)
        {
            return
```

```
        }
        else
        {
            WordNode *temp1
            // Swapping
            temp1 = temp->left
            temp->left = temp->right
            temp->right = temp1

            // Recursively calling the function
            mirror_recursive(temp->left)
            mirror_recursive(temp->right)
        }
    }
```

8.5 Copy

```
    WordNode *create_copy_recursive(WordNode *temp)
    {
        if (temp == NULL)
        {
            return NULL
        }
        else
        {
            WordNode *new_node = new WordNode
            new_node->word = temp->word
            new_node->definition = temp->definition
            new_node->left = create_copy_recursive(temp->left)
            new_node->right = create_copy_recursive(temp->right)
            return new_node
        }
    }
```

9 Time Complexity

9.1 Create

- **Time Complexity Worst Case**:
$$\bigcirc(n^2)$$

- **Time Complexity Best Case**:
$$\bigcirc(\log(n))$$

9.2 Display

- **Time Complexity**:
$$\bigcirc(n)$$

9.3 Delete

- **Time Complexity**:
$$\bigcirc(h)$$

$$h$$

is the height of the Binary search tree.

9.4 Mirror Image

- **Time Complexity**:

$$O(n)$$

9.5 Copy

- **Time Complexity**:

$$O(n)$$

10 Code

10.1 Program

```
#include <iostream>
#include <queue>
#include <stack>
#include <string.h>
using namespace std;

class WordNode
{
    string word;
    string definition;
    WordNode *left;
    WordNode *right;
    friend class BinarySearchTree;
};

class BinarySearchTree
{
public:
    WordNode *root;
    BinarySearchTree()
    {
        root = NULL;
    }
    void create_root()
    {
        root = new WordNode;
        cout << "Enter the data: " << endl;
        cin >> root->word;
        cin >> root->definition;
        root->left = NULL;
        root->right = NULL;
        create_recursive(root);
    }
    void create_recursive(WordNode *Node)
    {
```

```
        int choice = 0;
        WordNode *new_node;
        cout << "Enter if you want to enter a left node (1/0): "
             << "for the node -- " << Node->word << ":  " << Node->definition << " -- ";
        cin >> choice;
        if (choice == 1)
        {
            new_node = new WordNode;
            cout << "Enter the data: ";
            cin >> new_node->word;
            cin >> new_node->definition;
            Node->left = new_node;
            create_recursive(new_node);
        }
        cout << "Enter if you want to enter a right node (1/0): "
             << "for the node -- " << Node->word << ":  " << Node->definition << " -- ";
        cin >> choice;
        if (choice == 1)
        {
            new_node = new WordNode;
            cout << "Enter the data: ";
            cin >> new_node->word;
            cin >> new_node->definition;
            Node->right = new_node;
            create_recursive(new_node);
        }
    }
    void create_root_and_tree_iteratively()
    {
        WordNode *temp, *current_word;
        int choice = 0;
        root = new WordNode;
        cout << "Enter the Word: ";
        cin >> root->word;
        cout << "Enter the definition of the word: ";
        cin >> root->definition;
        bool flag = false;
        cout << "Do you want to enter more Nodes? (0/1) " << endl;
        cin >> choice;
        while (choice == 1)
        {
            temp = root;
            flag = false;
            current_word = new WordNode;
            cout << "Enter the Word: ";
            cin >> current_word->word;
            cout << "Enter the definition of the word: ";
            cin >> current_word->definition;

            while (!flag)
            {
                if (strcmp(current_word->word.c_str(), temp->word.c_str()) <= 0)
                {
                    if (temp->left == NULL)
                    {
                        temp->left = current_word;
                        flag = true;
```

```
                    }
                    else
                    {
                        temp = temp->left;
                    }
                }
                else
                {
                    if (temp->right == NULL)
                    {
                        temp->right = current_word;
                        flag = true;
                    }
                    else
                    {
                        temp = temp->right;
                    }
                }
            }
            cout << "Do you want to enter another word? (1/0): ";
            cin >> choice;
        }
    }

    // breadth First Search using queue.
    void bfs()
    {
        WordNode *temp = root;
        queue<WordNode *> q;
        q.push(temp);
        while (!q.empty())
        {
            temp = q.front();
            q.pop();
            cout << temp->word << " : " << temp->definition << endl;
            if (temp->left != NULL)
            {
                q.push(temp->left);
            }
            if (temp->right != NULL)
            {
                q.push(temp->right);
            }
        }
    }

    WordNode *create_copy_recursive(WordNode *temp)
    {
        if (temp == NULL)
        {
            return NULL;
        }
        else
        {
            WordNode *new_node = new WordNode;
            new_node->word = temp->word;
            new_node->definition = temp->definition;
            new_node->left = create_copy_recursive(temp->left);
            new_node->right = create_copy_recursive(temp->right);
```

```
            return new_node;
        }
    }

    WordNode *create_copy_interatively(WordNode *temp)
    {
        // We have to create a queue to pop things
        queue<WordNode *> q;
        WordNode *copied_tree;
        WordNode *new_node = new WordNode;
        new_node->word = temp->word;
        new_node->definition = temp->definition;
        q.push(new_node);
        while (!q.empty())
        {
            copied_tree = q.front();
            q.pop();
            if (temp->left != NULL)
            {
                WordNode *new_node1 = new WordNode;
                new_node1->word = temp->left->word;
                new_node1->definition = temp->left->definition;
                copied_tree->left = new_node1;
                q.push(new_node1);
            }
            if (temp->right != NULL)
            {
                WordNode *new_node1 = new WordNode;
                new_node1->word = temp->right->word;
                new_node1->definition = temp->right->definition;
                copied_tree->right = new_node1;
                q.push(new_node1);
            }
            temp = temp->left;
        }
        return copied_tree;
    }

    void mirror_recursive(WordNode *temp)
    {
        if (temp == NULL)
        {
            return;
        }
        else
        {
            WordNode *temp1;
            // Swapping
            temp1 = temp->left;
            temp->left = temp->right;
            temp->right = temp1;

            // Recursively calling the function
            mirror_recursive(temp->left);
            mirror_recursive(temp->right);
        }
    }

    void mirror_iterative(WordNode *node)
```

```
    {
        WordNode *temp;
        queue<WordNode *> q;
        q.push(node);
        while (!q.empty())
        {
            temp = q.front();
            q.pop();
            WordNode *temp1;

            // Swapping
            temp1 = temp->left;
            temp->left = temp->right;
            temp->right = temp1;

            if (temp->left != NULL)
            {
                q.push(temp->left);
            }
            if (temp->right != NULL)
            {
                q.push(temp->right);
            }
        }
    }

    WordNode *create_mirror_tree_recursive()
    {
        WordNode *mirror_tree = create_copy_recursive(root);
        mirror_recursive(mirror_tree);
        return mirror_tree;
    }

    WordNode *create_mirror_tree_iterative()
    {
        WordNode *mirror_tree = create_copy_recursive(root);
        mirror_iterative(mirror_tree);
        return mirror_tree;
    }

    void delete_node(WordNode *temp, string word)
    {
        WordNode *parent = NULL;
        while (temp != NULL)
        {
            if (temp->word == word)
            {
                break;
            }
            else
            {
                parent = temp;
                if (strcmp(word.c_str(), temp->word.c_str()) < 0)
                {
                    temp = temp->left;
                }
                else
                {
                    temp = temp->right;
```

```
                }
            }
        }
        if (temp == NULL)
        {
            cout << "Word not found" << endl;
            return;
        }
        else
        {
            if (temp->left == NULL && temp->right == NULL)
            {
                if (parent->left == temp)
                {
                    parent->left = NULL;
                }
                else
                {
                    parent->right = NULL;
                }
                delete temp;
            }
            else if (temp->left == NULL)
            {
                if (parent->left == temp)
                {
                    parent->left = temp->right;
                }
                else
                {
                    parent->right = temp->right;
                }
                delete temp;
            }
            else if (temp->right == NULL)
            {
                if (parent->left == temp)
                {
                    parent->left = temp->left;
                }
                else
                {
                    parent->right = temp->left;
                }
                delete temp;
            }
            else
            {
                WordNode *temp1 = temp->right;
                while (temp1->left != NULL)
                {
                    temp1 = temp1->left;
                }
                temp->word = temp1->word;
                temp->definition = temp1->definition;
                delete_node(temp->right, temp1->word);
            }
        }
    }
```

```
    void inorder_iterative(WordNode *temp)
    {
        if (!temp)
        {
            return;
        }

        stack<WordNode *> s;
        WordNode *current = temp;

        while (current != NULL || s.empty() == false)
        {
            while (current != NULL)
            {
                s.push(current);
                current = current->left;
            }
            current = s.top();
            s.pop();
            cout << current->word << " : " << current->definition << endl;
            current = current->right;
        }
    }
    void preorder_iterative(WordNode *temp)
    {
        if (!temp)
        {
            return;
        }

        stack<WordNode *> s;
        s.push(temp);

        while (s.empty() == false)
        {
            WordNode *current = s.top();
            cout << current->word << " : " << current->definition << endl;
            s.pop();

            if (current->right)
            {
                s.push(current->right);
            }
            if (current->left)
            {
                s.push(current->left);
            }
        }
    }
    void postorder_iterative(WordNode *temp)
    {
        if (!temp)
        {
            return;
        }

        stack<WordNode *> s1;
        stack<WordNode *> s2;
```

```cpp

        s1.push(temp);

        while (s1.empty() == false)
        {
            WordNode *current = s1.top();
            s1.pop();
            s2.push(current);

            if (current->left)
            {
                s1.push(current->left);
            }
            if (current->right)
            {
                s1.push(current->right);
            }
        }
        while (s2.empty() == false)
        {
            WordNode *current = s2.top();
            cout << current->word << " : " << current->definition << endl;
            s2.pop();
        }
    }
};

int main()
{
    int choice = 0;
    string word;
    BinarySearchTree main_tree, mirror_tree, copy_tree;

    while (choice != 10)
    {
        cout << "\nWhat would like to do? " << endl;
        cout << "\n\nWelcome to ADS Assignment 2 - Binary Tree Traversals\n\nWhat would you like to do? " << endl;
        cout << "1. Create a Binary Search Tree"
             << endl;
        cout << "2. Traverse the Tree Inorder Iteratively"
             << endl;
        cout << "3. Traverse the Tree PreOrder Iteratively"
             << endl;
        cout << "4. Traverse the Tree PostOrder Iteratively"
             << endl;
        cout << "5. Traverse it using BFS"
             << endl;
        cout << "6. Create a Copy of the tree Recursively and Iteratively"
             << endl;
        cout << "7. Create a Mirror of the Tree Recursively"
             << endl;
        cout << "8. Create a Mirror of the Tree Iteratively"
             << endl;
        cout << "9. Delete a Node from the Tree"
             << endl;
        cout << "10. Exit" << endl
             << endl;

```

```
        cin >> choice;
        switch (choice)
        {
        case 1:
            main_tree.create_root_and_tree_iteratively();
            break;
        case 2:
            cout << "Traversing through the Binary Tree Inorder Iteratively: " <<
    endl;
            main_tree.inorder_iterative(main_tree.root);
            break;
        case 3:
            cout << "Traversing through the Binary Tree PreOrder Iteratively: " <<
     endl;
            main_tree.preorder_iterative(main_tree.root);
            break;
        case 4:
            cout << "Traversing through the Binary Tree PostOrder Iteratively: "
    << endl;
            main_tree.postorder_iterative(main_tree.root);
            break;
        case 5:
            cout << "Traversing through the Binary Tree using BFS: " << endl;
            main_tree.bfs();
            break;
        case 6:
            cout << "Creating a copy of the tree" << endl;
            copy_tree.root = copy_tree.create_copy_recursive(main_tree.root);
            cout << "Traversing via Breadth First Search: " << endl;
            copy_tree.bfs();
            break;
        case 7:
            cout << "Creating a mirror of the tree" << endl;
            mirror_tree.root = main_tree.create_mirror_tree_recursive();
            cout << "Traversing via Breadth First Search: " << endl;
            mirror_tree.bfs();
            break;
        case 8:
            cout << "Creating a mirror of the tree Iteratively" << endl;
            mirror_tree.root = main_tree.create_mirror_tree_iterative();
            cout << "Traversing via Breadth First Search: " << endl;
            mirror_tree.bfs();
            break;
        case 9:
            cout << "Enter the word you want to delete: " << endl;
            cin >> word;
            main_tree.delete_node(main_tree.root, word);
            cout << "Traversing through the Binary Tree Inorder Iteratively: " <<
    endl;
            main_tree.inorder_iterative(main_tree.root);
            break;
        case 10:
            cout << "Exiting the program" << endl;
            break;
        default:
            cout << "Invalid Choice" << endl;
            break;
        }
    }
```

```
}
```

10.2 Input and Output

```
What would like to do?


Welcome to ADS Assignment 2 - Binary Tree Traversals

What would you like to do?
1. Create a Binary Search Tree
2. Traverse the Tree Inorder Iteratively
3. Traverse the Tree PreOrder Iteratively
4. Traverse the Tree PostOrder Iteratively
5. Traverse it using BFS
6. Create a Copy of the tree Recursively
7. Create a Mirror of the Tree Recursively
8. Exit

1
Enter the Word: apple
Enter the definition of the word: fruit
Do you want to enter more Nodes? (0/1)

1
Enter the Word: banana
Enter the definition of the word: fruit
Do you want to enter another word? (1/0): 1
Enter the Word: keyboard
Enter the definition of the word: input
Do you want to enter another word? (1/0): 1
Enter the Word: pears
Enter the definition of the word: fruit
Do you want to enter another word? (1/0): 1
Enter the Word: bottle
Enter the definition of the word: water
Do you want to enter another word? (1/0): 1
Enter the Word: charger
Enter the definition of the word: charging
Do you want to enter another word? (1/0): 1
Enter the Word: monitor
Enter the definition of the word: see
Do you want to enter another word? (1/0): 1
Enter the Word: paper
Enter the definition of the word: 1
Do you want to enter another word? (1/0): 1
Enter the Word: pen
Enter the definition of the word: writing
Do you want to enter another word? (1/0): 1
Enter the Word: phone
Enter the definition of the word: scrolling
Do you want to enter another word? (1/0): 0

What would like to do?


Welcome to ADS Assignment 2 - Binary Tree Traversals

What would you like to do?
```

```
1. Create a Binary Search Tree
2. Traverse the Tree Inorder Iteratively
3. Traverse the Tree PreOrder Iteratively
4. Traverse the Tree PostOrder Iteratively
5. Traverse it using BFS
6. Create a Copy of the tree Recursively
7. Create a Mirror of the Tree Recursively
8. Exit

2
Traversing through the Binary Tree Inorder Iteratively:
apple : fruit
banana : fruit
bottle : water
charger : charging
keyboard : input
monitor : see
paper : 1
pears : fruit
pen : writing
phone : scrolling

What would like to do?


Welcome to ADS Assignment 2 - Binary Tree Traversals

What would you like to do?
1. Create a Binary Search Tree
2. Traverse the Tree Inorder Iteratively
3. Traverse the Tree PreOrder Iteratively
4. Traverse the Tree PostOrder Iteratively
5. Traverse it using BFS
6. Create a Copy of the tree Recursively
7. Create a Mirror of the Tree Recursively
8. Exit

5
Traversing through the Binary Tree using BFS:
apple : fruit
banana : fruit
keyboard : input
bottle : water
pears : fruit
charger : charging
monitor : see
pen : writing
paper : 1
phone : scrolling

What would like to do?


Welcome to ADS Assignment 2 - Binary Tree Traversals

What would you like to do?
1. Create a Binary Search Tree
2. Traverse the Tree Inorder Iteratively
3. Traverse the Tree PreOrder Iteratively
```

```
4. Traverse the Tree PostOrder Iteratively
5. Traverse it using BFS
6. Create a Copy of the tree Recursively
7. Create a Mirror of the Tree Recursively
8. Exit

6
Creating a copy of the tree
Traversing through the Binary Tree Inorder Iteratively:
apple : fruit
banana : fruit
bottle : water
charger : charging
keyboard : input
monitor : see
paper : 1
pears : fruit
pen : writing
phone : scrolling
Traversing via Breadth First Search:
apple : fruit
banana : fruit
keyboard : input
bottle : water
pears : fruit
charger : charging
monitor : see
pen : writing
paper : 1
phone : scrolling

What would like to do?


Welcome to ADS Assignment 2 - Binary Tree Traversals

What would you like to do?
1. Create a Binary Search Tree
2. Traverse the Tree Inorder Iteratively
3. Traverse the Tree PreOrder Iteratively
4. Traverse the Tree PostOrder Iteratively
5. Traverse it using BFS
6. Create a Copy of the tree Recursively
7. Create a Mirror of the Tree Recursively
8. Exit

7
Creating a mirror of the tree
Traversing through the Binary Tree Inorder Iteratively:
phone : scrolling
pen : writing
pears : fruit
paper : 1
monitor : see
keyboard : input
charger : charging
bottle : water
banana : fruit
apple : fruit
```

```
Traversing via Breadth First Search:
apple : fruit
banana : fruit
keyboard : input
pears : fruit
bottle : water
pen : writing
monitor : see
charger : charging
phone : scrolling
paper : 1

What would like to do?


Welcome to ADS Assignment 2 - Binary Tree Traversals

What would you like to do?
1. Create a Binary Search Tree
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5. Traverse it using BFS
6. Create a Copy of the tree Recursively
7. Create a Mirror of the Tree Recursively
8. Exit

8
Exiting the program
```

11 Conclusion

Thus, implemented Dictionary using Binary search tree.

12 FAQ

1. **Explain application of BST**

   The Applications of Binary Search Tree are:

   (a) Binary Search Tree is used to implement dictionaries.
   (b) Binary Search Tree is used to implement priority queues.
   (c) Binary Search Tree is used to implement disjoint sets.
   (d) Binary Search Tree is used to implement sorting algorithms.
   (e) Binary Search Tree is used to implement expression trees.
   (f) Binary Search Tree is used to implement Huffman coding.
   (g) Binary Search Tree is used to implement B-trees.
   (h) Binary Search Tree is used to implement red-black trees.

2. **Explain with example deletion of a node having two child.**

   If a node has two children, then we need to find the inorder successor of the node. The inorder successor is the smallest in the right subtree or the largest in the left subtree. After finding the inorder successor, we copy the contents of the inorder successor to the node and delete the inorder successor. Note that the inorder predecessor can also be used.

   An Example would be:

```
    Let us consider the following BST as an example.
              50
             / \
            30 70
           / \ / \
         20 40 60 80
 / \   / \
10 25 45 65
```

   Deleting 30 will be done in following steps. 1. Find inorder successor of 30. 2. Copy contents of the inorder successor to 30. 3. Delete the inorder successor. 4. Since inorder successor is 40 which has no left child, we simply make right child of 30 as the new right child of 20.

```
50
/ \
40 70
/   / \
20   60 80

  / \   / \
      10 25 45 65
```

3. **Define skewed binary tree.**

   A binary tree is said to be skewed if all of its nodes have only one child. A skewed binary tree can be either left or right skewed. A left skewed binary tree is a binary tree in which all the nodes have only left child. A right skewed binary tree is a binary tree in which all the nodes have only right child.