Name: Prema Sunil Jadhav
Sap Id: 60004220127
Batch: C2-2
Course: Advance Algorithm

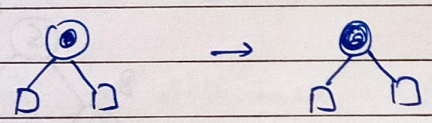
EXP - 4B

AIM: Implement Red-Black Tree Operations.
4B) Deletion.

THEORY: Deletion in Red-Black tree consists of various cases, following are those mentioned:

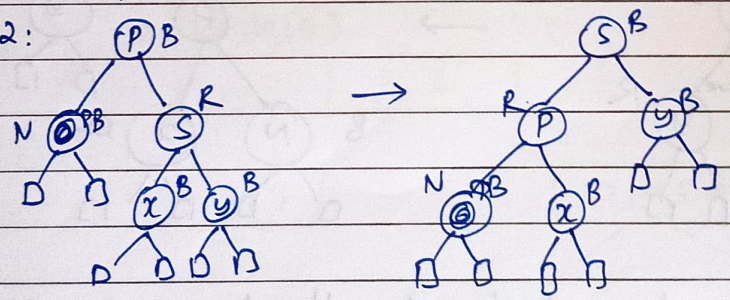
1. convert to 0 or 1 child case
2. If node to be deleted is red or child is red then do replace
3. Double black — 6 cases to handle.

Case 1:

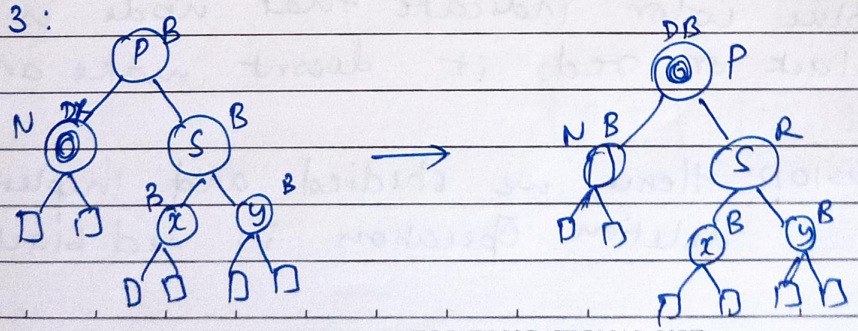


This terminator case

Case 2:

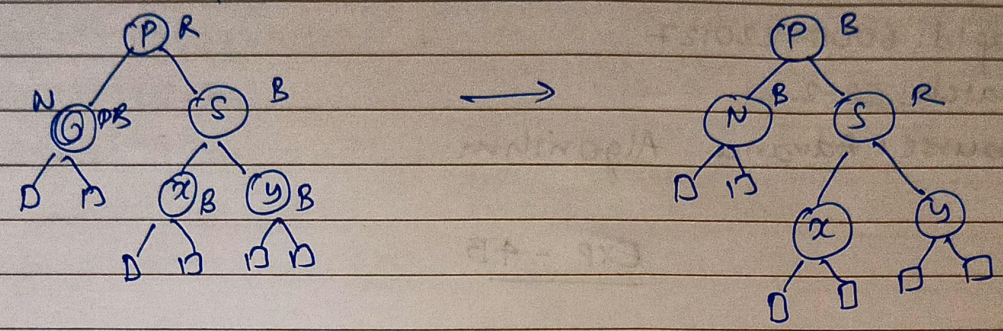


Case 3:

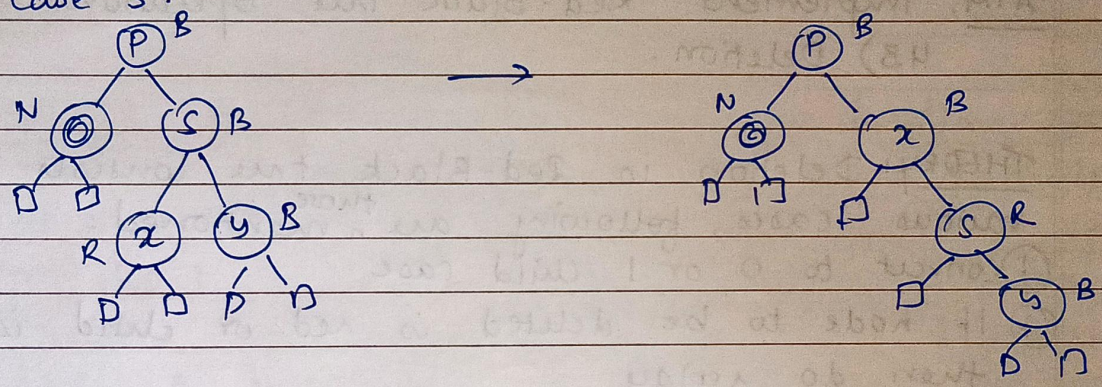


Note: case 2, 3, 4 and 5, 6 have mirror case.

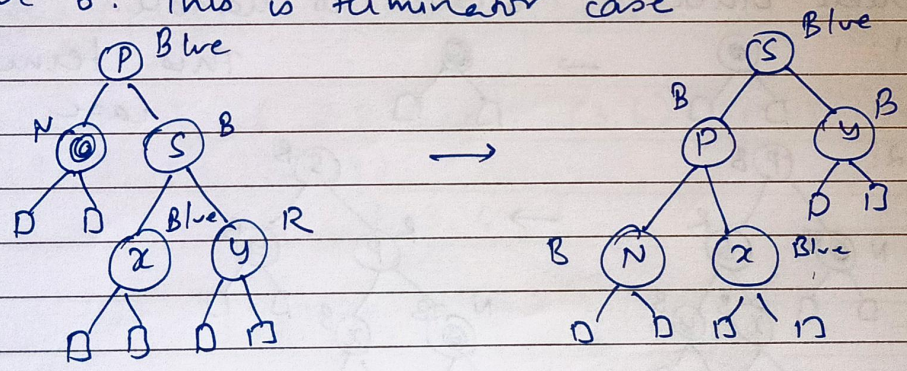
case 4: This is terminator case



Case 5:



case 6: This is terminator case



∴ Blue color indicate that node is either black or red it doesnt make any difference

CONCLUSION: Hence, we studied and implement the deletion operation in red black tree

Academic Year: 2022-2023

Name:	Prerna Sunil Jadhav
Sap Id:	60004220127
Class:	T. Y. B. Tech (Computer Engineering)
Course:	Advance Algorithm Laboratory
Course Code:	DJ19CEL602
Experiment No.:	04-B

AIM: **Implement Red-black Tree Operations.**
04-B) DELETION

CODE:

```
import sys
# Node creation
class Node():
    def __init__(self, item):
        self.item = item
        self.parent = None
        self.left = None
        self.right = None
        self.color = 1

class RedBlackTree():
    def __init__(self):
        self.TNULL = Node(0)
        self.TNULL.color = 0
        self.TNULL.left = None
        self.TNULL.right = None
        self.root = self.TNULL

    # Preorder
    def pre_order_helper(self, node):
        if node != TNULL:
            sys.stdout.write(node.item + " ")
            self.pre_order_helper(node.left)
            self.pre_order_helper(node.right)

    # Inorder
    def in_order_helper(self, node):
        if node != TNULL:
            self.in_order_helper(node.left)
            sys.stdout.write(node.item + " ")
            self.in_order_helper(node.right)

    # Postorder
```

```
    def post_order_helper(self, node):
        if node != TNULL:
            self.post_order_helper(node.left)
            self.post_order_helper(node.right)
            sys.stdout.write(node.item + " ")

    # Search the tree
    def search_tree_helper(self, node, key):
        if node == TNULL or key == node.item:
            return node
        if key < node.item:
            return self.search_tree_helper(node.left, key)
        return self.search_tree_helper(node.right, key)

    # Balancing the tree after deletion
    def delete_fix(self, x):
        while x != self.root and x.color == 0:
            if x == x.parent.left:
                s = x.parent.right
                if s.color == 1:
                    s.color = 0
                    x.parent.color = 1
                    self.left_rotate(x.parent)
                    s = x.parent.right
                if s.left.color == 0 and s.right.color == 0:
                    s.color = 1
                    x = x.parent
                else:
                    if s.right.color == 0:
                        s.left.color = 0
                        s.color = 1
                        self.right_rotate(s)
                        s = x.parent.right

                    s.color = x.parent.color
                    x.parent.color = 0
                    s.right.color = 0
                    self.left_rotate(x.parent)
                    x = self.root
            else:
                s = x.parent.left
                if s.color == 1:
                    s.color = 0
                    x.parent.color = 1
```

```
                    self.right_rotate(x.parent)
                    s = x.parent.left
                if s.right.color == 0 and s.right.color == 0:
                    s.color = 1
                    x = x.parent
                else:
                    if s.left.color == 0:
                        s.right.color = 0
                        s.color = 1
                        self.left_rotate(s)
                        s = x.parent.left
                    s.color = x.parent.color
                    x.parent.color = 0
                    s.left.color = 0
                    self.right_rotate(x.parent)
                    x = self.root
        x.color = 0

    def __rb_transplant(self, u, v):
        if u.parent == None:
            self.root = v
        elif u == u.parent.left:
            u.parent.left = v
        else:
            u.parent.right = v
        v.parent = u.parent

    # Node deletion
    def delete_node_helper(self, node, key):
        z = self.TNULL
        while node != self.TNULL:
            if node.item == key:
                z = node
            if node.item <= key:
                node = node.right
            else:
                node = node.left
        if z == self.TNULL:
            print("Cannot find key in the tree")
            return
        y = z
        y_original_color = y.color
        if z.left == self.TNULL:
            x = z.right
```

```
            self.__rb_transplant(z, z.right)
        elif (z.right == self.TNULL):
            x = z.left
            self.__rb_transplant(z, z.left)
        else:
            y = self.minimum(z.right)
            y_original_color = y.color
            x = y.right
            if y.parent == z:
                x.parent = y
            else:
                self.__rb_transplant(y, y.right)
                y.right = z.right
                y.right.parent = y
            self.__rb_transplant(z, y)
            y.left = z.left
            y.left.parent = y
            y.color = z.color
        if y_original_color == 0:
            self.delete_fix(x)

    # Balance the tree after insertion
    def fix_insert(self, k):
        while k.parent.color == 1:
            if k.parent == k.parent.parent.right:
                u = k.parent.parent.left
                if u.color == 1:
                    u.color = 0
                    k.parent.color = 0
                    k.parent.parent.color = 1
                    k = k.parent.parent
                else:
                    if k == k.parent.left:
                        k = k.parent
                        self.right_rotate(k)
                    k.parent.color = 0
                    k.parent.parent.color = 1
                    self.left_rotate(k.parent.parent)
            else:
                u = k.parent.parent.right


                if u.color == 1:
                    u.color = 0
```

```
                    k.parent.color = 0
                    k.parent.parent.color = 1
                    k = k.parent.parent
                else:
                    if k == k.parent.right:
                        k = k.parent
                        self.left_rotate(k)
                    k.parent.color = 0
                    k.parent.parent.color = 1
                    self.right_rotate(k.parent.parent)
            if k == self.root:
                break
        self.root.color = 0

    # Printing the tree
    def __print_helper(self, node, indent, last):
        if node != self.TNULL:
            sys.stdout.write(indent)
            if last:
                sys.stdout.write("R----")
                indent += "     "
            else:
                sys.stdout.write("L----")
                indent += "|    "


            s_color = "RED" if node.color == 1 else "BLACK"
            print(str(node.item) + "(" + s_color + ")")
            self.__print_helper(node.left, indent, False)
            self.__print_helper(node.right, indent, True)

    def preorder(self):
        self.pre_order_helper(self.root)

    def inorder(self):
        self.in_order_helper(self.root)

    def postorder(self):
        self.post_order_helper(self.root)

    def searchTree(self, k):
        return self.search_tree_helper(self.root, k)

    def minimum(self, node):
```

```
        while node.left != self.TNULL:
            node = node.left
        return node

    def maximum(self, node):
        while node.right != self.TNULL:
            node = node.right
        return node

    def successor(self, x):
        if x.right != self.TNULL:
            return self.minimum(x.right)
        y = x.parent
        while y != self.TNULL and x == y.right:
            x = y
            y = y.parent
        return y

    def predecessor(self,  x):
        if (x.left != self.TNULL):
            return self.maximum(x.left)
        y = x.parent
        while y != self.TNULL and x == y.left:
            x = y
            y = y.parent
        return y

    def left_rotate(self, x):
        y = x.right
        x.right = y.left
        if y.left != self.TNULL:
            y.left.parent = x
        y.parent = x.parent
        if x.parent == None:
            self.root = y
        elif x == x.parent.left:
            x.parent.left = y
        else:
            x.parent.right = y
        y.left = x
        x.parent = y

    def right_rotate(self, x):
        y = x.left
```

```
        x.left = y.right
        if y.right != self.TNULL:
            y.right.parent = x
        y.parent = x.parent
        if x.parent == None:
            self.root = y
        elif x == x.parent.right:
            x.parent.right = y
        else:
            x.parent.left = y
        y.right = x
        x.parent = y

    def insert(self, key):
        node = Node(key)
        node.parent = None
        node.item = key
        node.left = self.TNULL
        node.right = self.TNULL
        node.color = 1
        y = None
        x = self.root
        while x != self.TNULL:
            y = x
            if node.item < x.item:
                x = x.left
            else:
                x = x.right
        node.parent = y
        if y == None:
            self.root = node
        elif node.item < y.item:
            y.left = node
        else:
            y.right = node
        if node.parent == None:
            node.color = 0
            return
        if node.parent.parent == None:
            return
        self.fix_insert(node)

    def get_root(self):
        return self.root
```

```python
    def delete_node(self, item):
        self.delete_node_helper(self.root, item)

    def print_tree(self):
        self.__print_helper(self.root, "", True)

if __name__ == "__main__":
    bst = RedBlackTree()
    bst.insert(55)
    bst.insert(40)
    bst.insert(65)
    bst.insert(60)
    bst.insert(75)
    bst.insert(57)
    bst.print_tree()

    print("\nAfter deleting element 40")
    bst.delete_node(40)
    bst.print_tree()

    print("\nAfter deleting element 57")
    bst.delete_node(57)
    bst.print_tree()
```

OUTPUT:

```
PS C:\Users\Jadhav\Documents\BTech\Docs\6th Sem\AA\Code> & C:/msys64/mingw64/bin/python.exe "c:/Users/Jadhav/Documents
/BTech/Docs/6th Sem/AA/Code/Red-Black_Deletion.py"
R----55(BLACK)
     L----40(BLACK)
     R----65(RED)
          L----60(BLACK)
          |    L----57(RED)
          R----75(BLACK)

After deleting element 40
R----65(BLACK)
     L----57(RED)
     |    L----55(BLACK)
     |    R----60(BLACK)
     R----75(BLACK)

After deleting element 57
R----65(BLACK)
     L----60(BLACK)
     |    L----55(RED)
     R----75(BLACK)
PS C:\Users\Jadhav\Documents\BTech\Docs\6th Sem\AA\Code>
```