AMRITA VISHWA VIDYAPEETHAM DEEMED TO BE UNIVERSITY UNDER SECTION 3 OF UGC ACT, 1956 SCHOOL OF COMPUTING

Design s Analysis of Algorithm

CSE211

Date: 8/1/2026

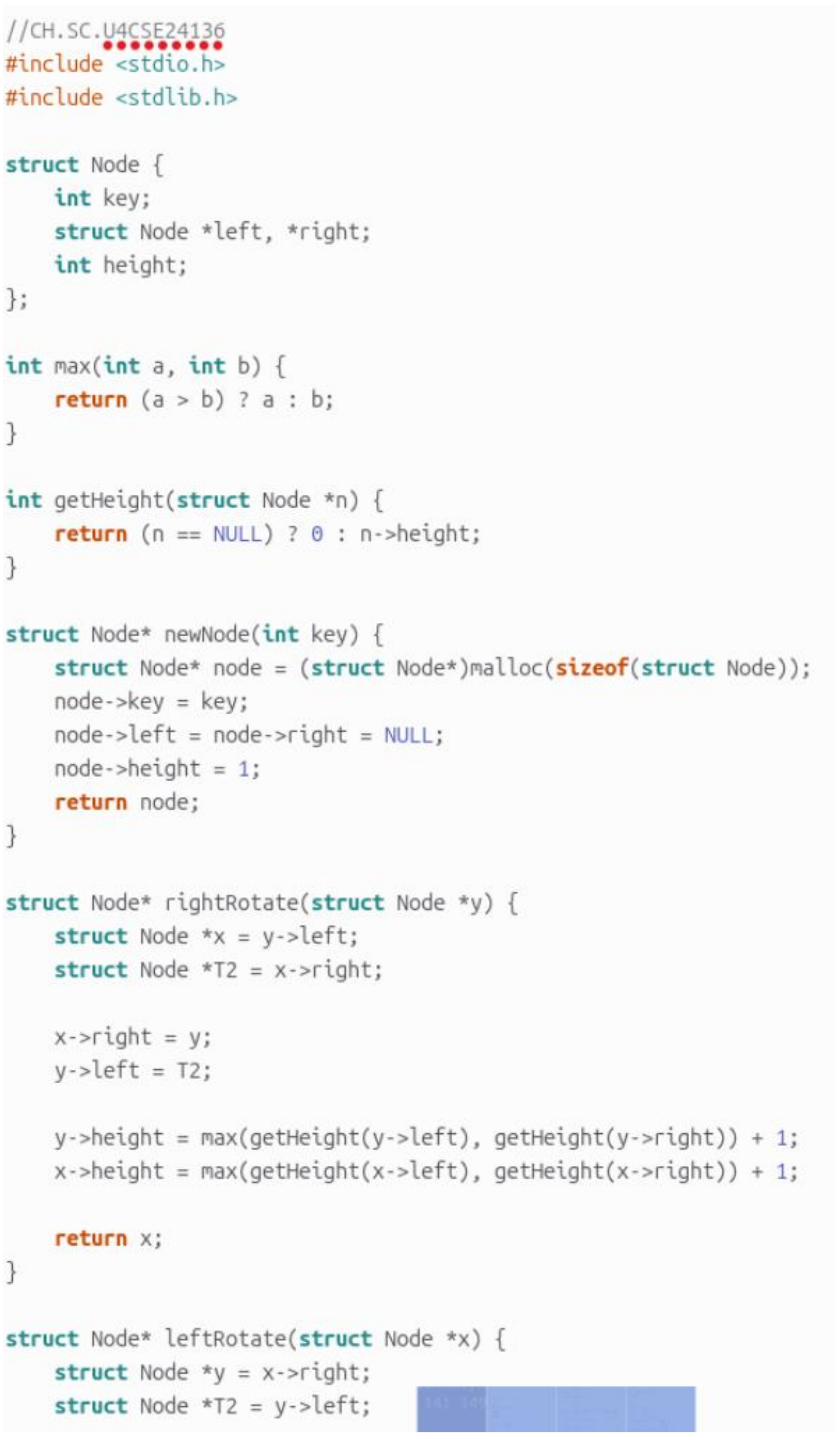
Week-4

CH.SC.U4CSE24136

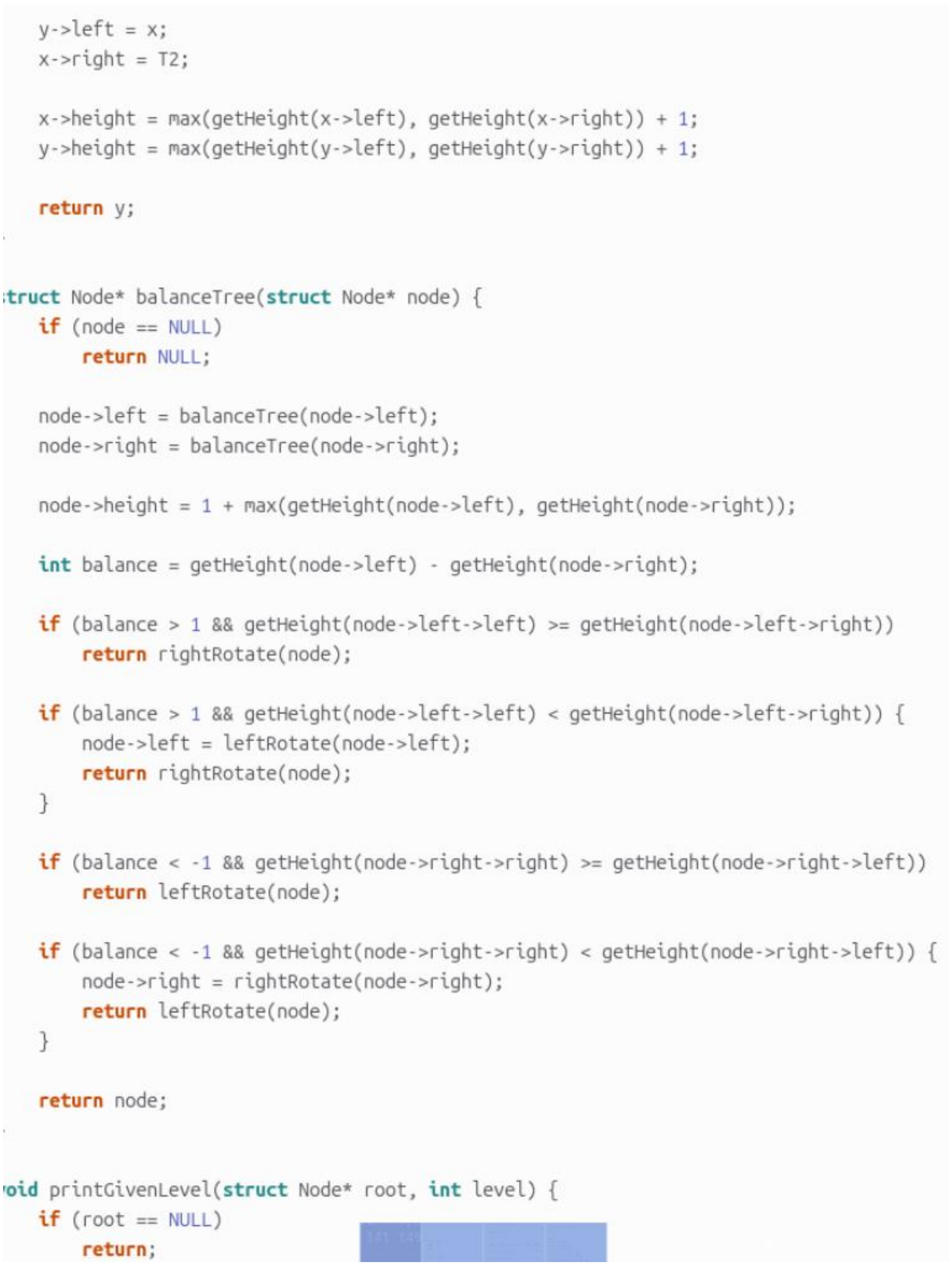
P. Geetesh

1. AVL

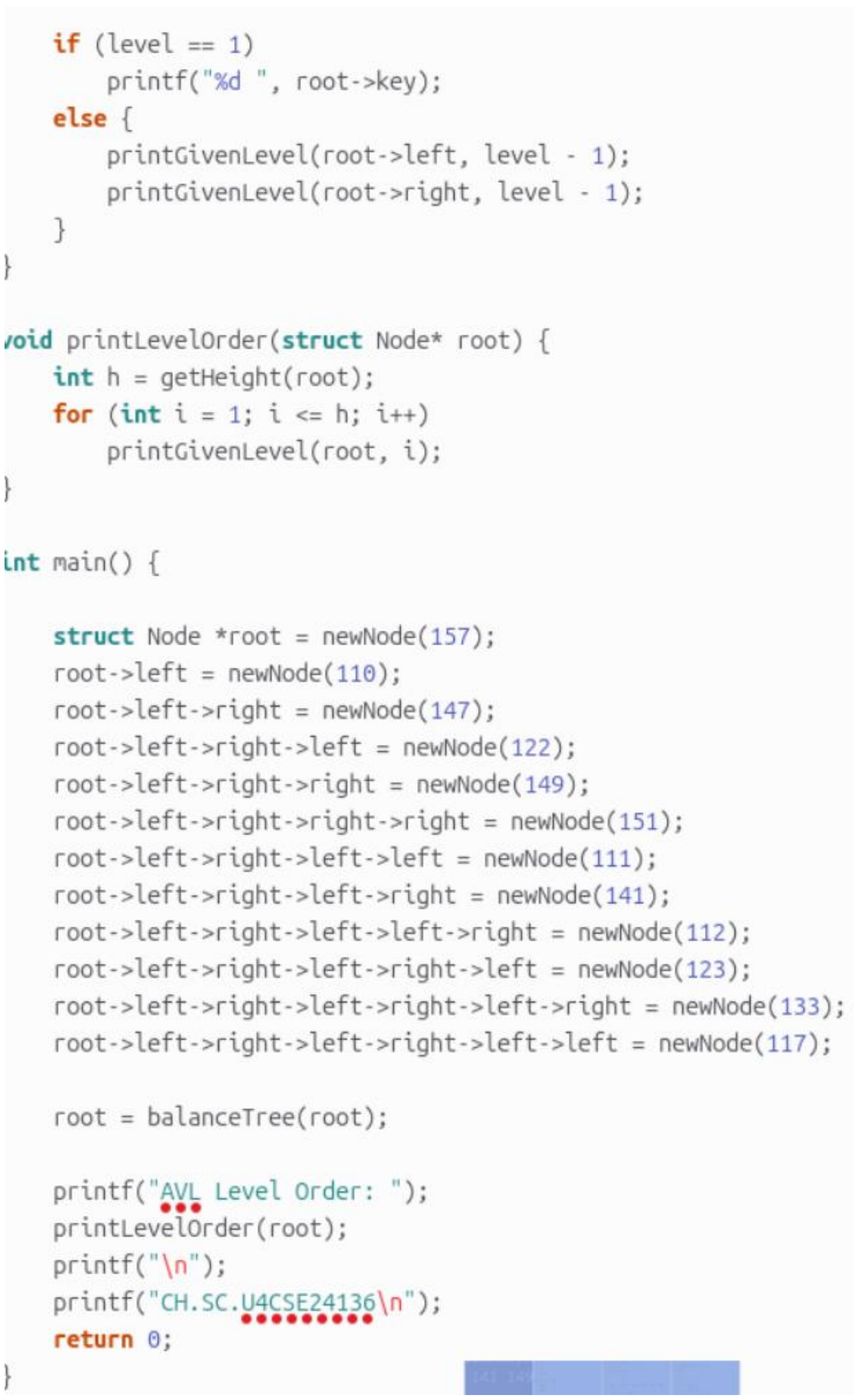
Code:



```c
//CH.SC.U4CSE24136
#include <stdio.h>
#include <stdlib.h>

struct Node {
    int key;
    struct Node *left, *right;
    int height;
};

int max(int a, int b) {
    return (a > b) ? a : b;
}

int getHeight(struct Node *n) {
    return (n == NULL) ? 0 : n->height;
}

struct Node* newNode(int key) {
    struct Node* node = (struct Node*)malloc(sizeof(struct Node));
    node->key = key;
    node->left = node->right = NULL;
    node->height = 1;
    return node;
}

struct Node* rightRotate(struct Node *y) {
    struct Node *x = y->left;
    struct Node *T2 = x->right;

    x->right = y;
    y->left = T2;

    y->height = max(getHeight(y->left), getHeight(y->right)) + 1;
    x->height = max(getHeight(x->left), getHeight(x->right)) + 1;

    return x;
}

struct Node* leftRotate(struct Node *x) {
    struct Node *y = x->right;
    struct Node *T2 = y->left;
```

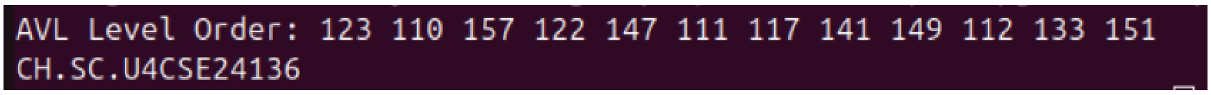


```
    y->left = x;
    x->right = T2;

    x->height = max(getHeight(x->left), getHeight(x->right)) + 1;
    y->height = max(getHeight(y->left), getHeight(y->right)) + 1;

    return y;


truct Node* balanceTree(struct Node* node) {
    if (node == NULL)
        return NULL;

    node->left = balanceTree(node->left);
    node->right = balanceTree(node->right);

    node->height = 1 + max(getHeight(node->left), getHeight(node->right));

    int balance = getHeight(node->left) - getHeight(node->right);

    if (balance > 1 && getHeight(node->left->left) >= getHeight(node->left->right))
        return rightRotate(node);

    if (balance > 1 && getHeight(node->left->left) < getHeight(node->left->right)) {
        node->left = leftRotate(node->left);
        return rightRotate(node);
    }

    if (balance < -1 && getHeight(node->right->right) >= getHeight(node->right->left))
        return leftRotate(node);

    if (balance < -1 && getHeight(node->right->right) < getHeight(node->right->left)) {
        node->right = rightRotate(node->right);
        return leftRotate(node);
    }

    return node;


oid printGivenLevel(struct Node* root, int level) {
    if (root == NULL)
        return;
```



```c
    if (level == 1)
        printf("%d ", root->key);
    else {
        printGivenLevel(root->left, level - 1);
        printGivenLevel(root->right, level - 1);
    }
}

void printLevelOrder(struct Node* root) {
    int h = getHeight(root);
    for (int i = 1; i <= h; i++)
        printGivenLevel(root, i);
}

int main() {

    struct Node *root = newNode(157);
    root->left = newNode(110);
    root->left->right = newNode(147);
    root->left->right->left = newNode(122);
    root->left->right->right = newNode(149);
    root->left->right->right->right = newNode(151);
    root->left->right->left->left = newNode(111);
    root->left->right->left->right = newNode(141);
    root->left->right->left->left->right = newNode(112);
    root->left->right->left->right->left = newNode(123);
    root->left->right->left->right->left->right = newNode(133);
    root->left->right->left->right->left->left = newNode(117);

    root = balanceTree(root);

    printf("AVL Level Order: ");
    printLevelOrder(root);
    printf("\n");
    printf("CH.SC.U4CSE24136\n");
    return 0;
}
```

Output:



```
AVL Level Order: 123 110 157 122 147 111 117 141 149 112 133 151
CH.SC.U4CSE24136
```

Space Complexity and it’s Justification:

Time Complexity

O(n)

Justification: Each node is visited once; height check and rotations take O(1) time.

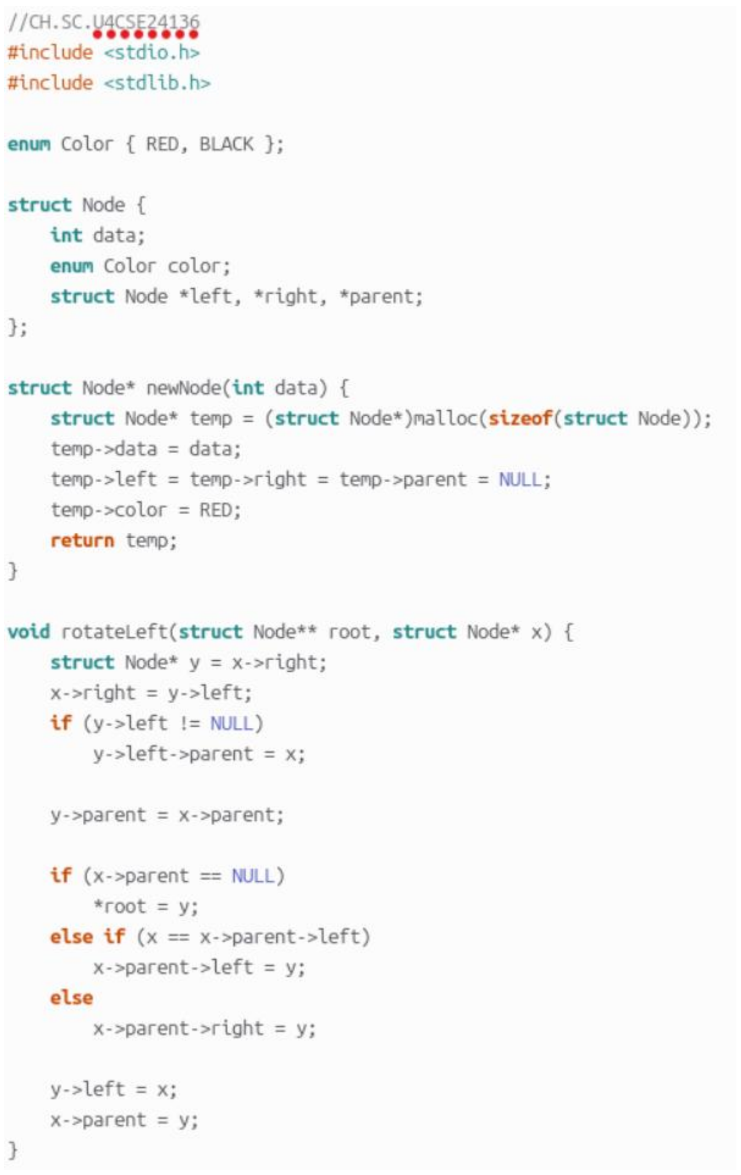
Space Complexity

O(h) → O(log n) (balanced), O(n) (skewed)

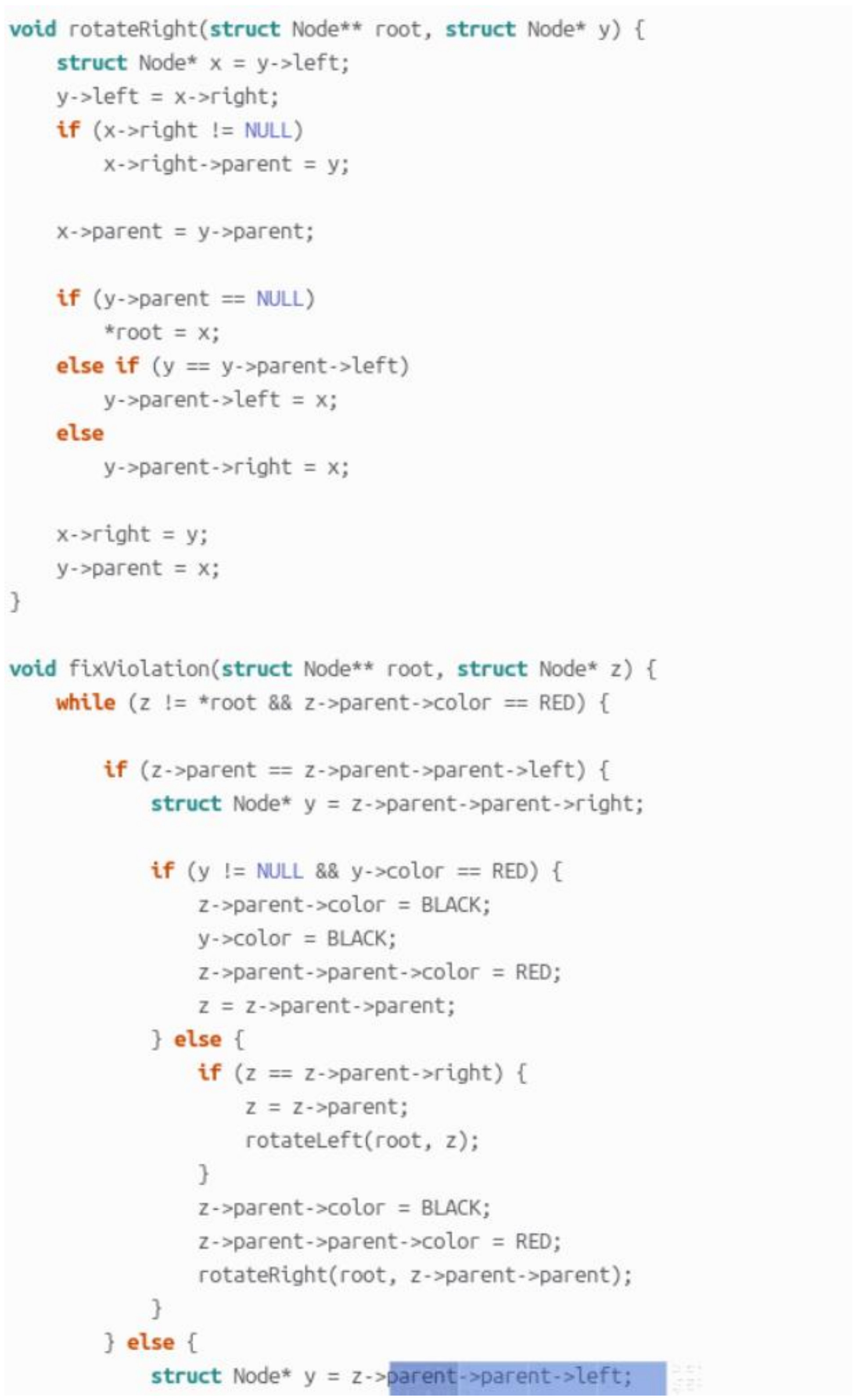
Justification: Space used only by recursion stack, proportional to tree height.

2. Red Black Method

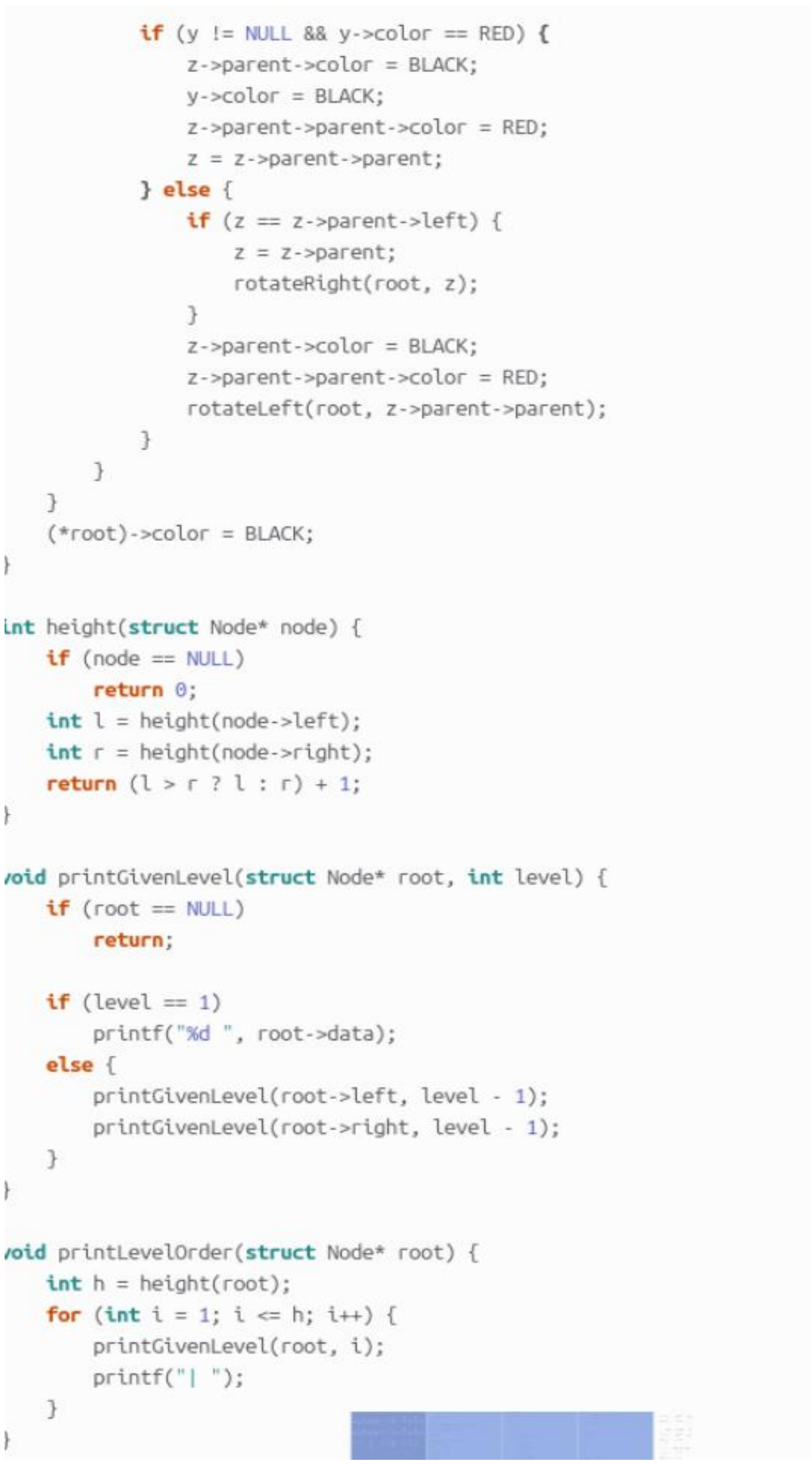
Code:



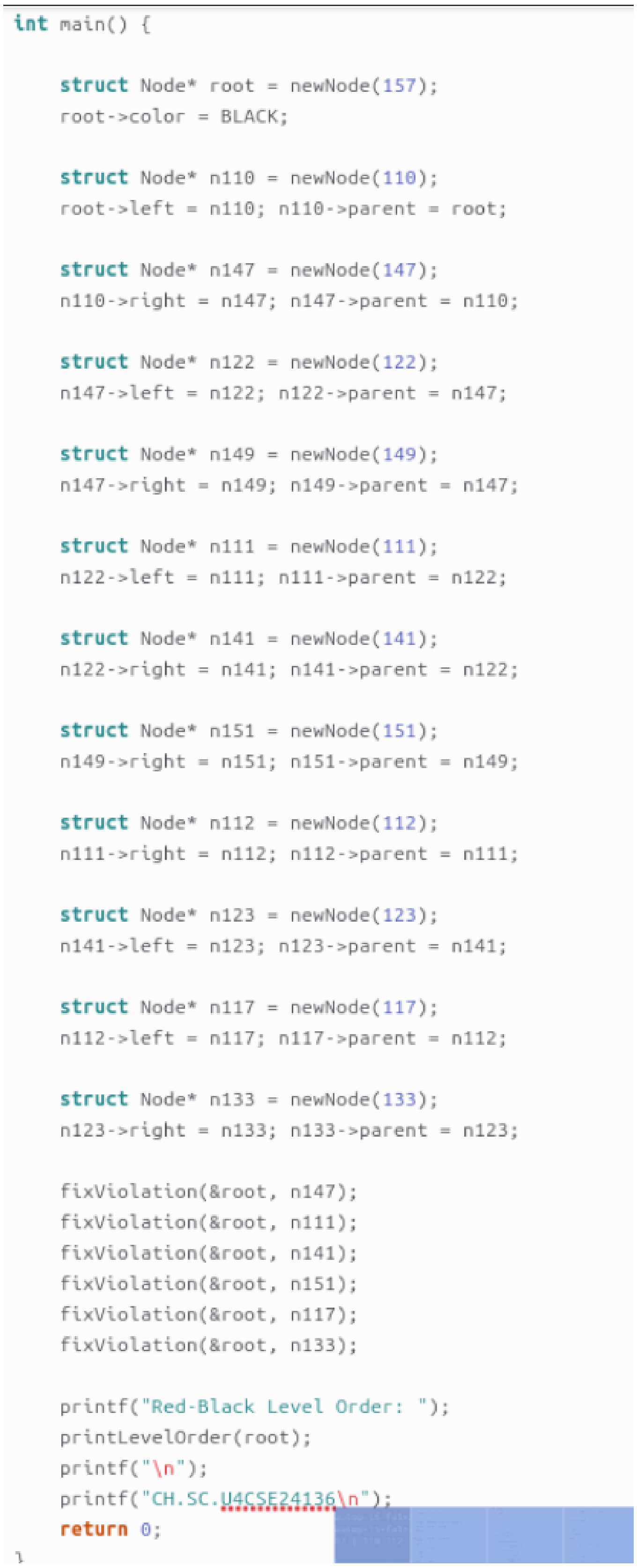
```c
//CH.SC.U4CSE24136
#include <stdio.h>
#include <stdlib.h>

enum Color { RED, BLACK };

struct Node {
    int data;
    enum Color color;
    struct Node *left, *right, *parent;
};

struct Node* newNode(int data) {
    struct Node* temp = (struct Node*)malloc(sizeof(struct Node));
    temp->data = data;
    temp->left = temp->right = temp->parent = NULL;
    temp->color = RED;
    return temp;
}

void rotateLeft(struct Node** root, struct Node* x) {
    struct Node* y = x->right;
    x->right = y->left;
    if (y->left != NULL)
        y->left->parent = x;

    y->parent = x->parent;

    if (x->parent == NULL)
        *root = y;
    else if (x == x->parent->left)
        x->parent->left = y;
    else
        x->parent->right = y;

    y->left = x;
    x->parent = y;
}
```



```
void rotateRight(struct Node** root, struct Node* y) {
    struct Node* x = y->left;
    y->left = x->right;
    if (x->right != NULL)
        x->right->parent = y;

    x->parent = y->parent;

    if (y->parent == NULL)
        *root = x;
    else if (y == y->parent->left)
        y->parent->left = x;
    else
        y->parent->right = x;

    x->right = y;
    y->parent = x;
}

void fixViolation(struct Node** root, struct Node* z) {
    while (z != *root && z->parent->color == RED) {

        if (z->parent == z->parent->parent->left) {
            struct Node* y = z->parent->parent->right;

            if (y != NULL && y->color == RED) {
                z->parent->color = BLACK;
                y->color = BLACK;
                z->parent->parent->color = RED;
                z = z->parent->parent;
            } else {
                if (z == z->parent->right) {
                    z = z->parent;
                    rotateLeft(root, z);
                }
                z->parent->color = BLACK;
                z->parent->parent->color = RED;
                rotateRight(root, z->parent->parent);
            }
        } else {
            struct Node* y = z->parent->parent->left;
```

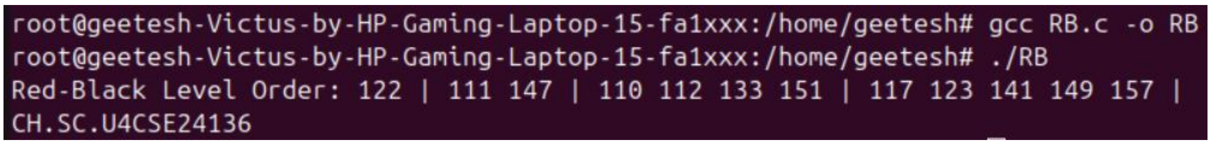


```
            if (y != NULL && y->color == RED) {
                z->parent->color = BLACK;
                y->color = BLACK;
                z->parent->parent->color = RED;
                z = z->parent->parent;
            } else {
                if (z == z->parent->left) {
                    z = z->parent;
                    rotateRight(root, z);
                }
                z->parent->color = BLACK;
                z->parent->parent->color = RED;
                rotateLeft(root, z->parent->parent);
            }
        }
    }
    (*root)->color = BLACK;
}

int height(struct Node* node) {
    if (node == NULL)
        return 0;
    int l = height(node->left);
    int r = height(node->right);
    return (l > r ? l : r) + 1;
}

void printGivenLevel(struct Node* root, int level) {
    if (root == NULL)
        return;

    if (level == 1)
        printf("%d ", root->data);
    else {
        printGivenLevel(root->left, level - 1);
        printGivenLevel(root->right, level - 1);
    }
}

void printLevelOrder(struct Node* root) {
    int h = height(root);
    for (int i = 1; i <= h; i++) {
        printGivenLevel(root, i);
        printf("| ");
    }
}
```



```c
int main() {

    struct Node* root = newNode(157);
    root->color = BLACK;

    struct Node* n110 = newNode(110);
    root->left = n110; n110->parent = root;

    struct Node* n147 = newNode(147);
    n110->right = n147; n147->parent = n110;

    struct Node* n122 = newNode(122);
    n147->left = n122; n122->parent = n147;

    struct Node* n149 = newNode(149);
    n147->right = n149; n149->parent = n147;

    struct Node* n111 = newNode(111);
    n122->left = n111; n111->parent = n122;

    struct Node* n141 = newNode(141);
    n122->right = n141; n141->parent = n122;

    struct Node* n151 = newNode(151);
    n149->right = n151; n151->parent = n149;

    struct Node* n112 = newNode(112);
    n111->right = n112; n112->parent = n111;

    struct Node* n123 = newNode(123);
    n141->left = n123; n123->parent = n141;

    struct Node* n117 = newNode(117);
    n112->left = n117; n117->parent = n112;

    struct Node* n133 = newNode(133);
    n123->right = n133; n133->parent = n123;

    fixViolation(&root, n147);
    fixViolation(&root, n111);
    fixViolation(&root, n141);
    fixViolation(&root, n151);
    fixViolation(&root, n117);
    fixViolation(&root, n133);

    printf("Red-Black Level Order: ");
    printLevelOrder(root);
    printf("\n");
    printf("CH.SC.U4CSE24136\n");
    return 0;
}
```

Output:



```
root@geetesh-Victus-by-HP-Gaming-Laptop-15-fa1xxx:/home/geetesh# gcc RB.c -o RB
root@geetesh-Victus-by-HP-Gaming-Laptop-15-fa1xxx:/home/geetesh# ./RB
Red-Black Level Order: 122 | 111 147 | 110 112 133 151 | 117 123 141 149 157 |
CH.SC.U4CSE24136
```

Space Complexity and Its Justification:

Time Complexity

O(log n)

Justification:

Red-Black Tree height is always O(log n).

Insertion fix (fixViolation) does at most constant rotations and recolorings while moving up the tree.

Space Complexity

O(h) → O(log n)

Justification:

Uses recursion only for traversal/height, and recursion depth equals tree height.

No extra data structures are used.