Binary Search Tree (BST)

Introduction

Data structures are essential in computer science for efficient data management and retrieval. One such data structure is the Binary Search Tree (BST). A BST is a node-based binary tree where each node has up to two children, with the left child containing a value less than its parent node and the right child containing a value greater than its parent node. This property makes BSTs highly efficient for search, insert, and delete operations.

Importance of BST

BSTs are crucial due to their efficient operations:

- **Search**: Average time complexity of O(log n).
- **Insertion**: Average time complexity of O(log n).
- **Deletion**: Average time complexity of O(log n).

These operations are fundamental in various applications such as databases, file systems, and many real-time systems.

Implementation Details

```
#include <iostream>
using namespace std;

struct Node {
  int data;
  Node* left;
  Node* right;

  Node(int val) : data(val), left(nullptr), right(nullptr) {}
};

class BST {
public:
  Node* root;

  BST() : root(nullptr) {}
```

Binary Search Tree (BST)

```
  void insert(int data) {
    root = insert(root, data);
  }

  bool search(int data) {
    return search(root, data) != nullptr;
  }

  void remove(int data) {
    root = remove(root, data);
  }

  void inorder() {
    inorder(root);
    cout << endl;
  }

  void preorder() {
    preorder(root);
    cout << endl;
  }

  void postorder() {
    postorder(root);
    cout << endl;
  }

private:
  Node* insert(Node* node, int data) {
```

Binary Search Tree (BST)

```
    if (node == nullptr) {
        return new Node(data);
    }

    if (data < node->data) {
        node->left = insert(node->left, data);
    } else {
        node->right = insert(node->right, data);
    }

    return node;
}

Node* search(Node* node, int data) {
    if (node == nullptr || node->data == data) {
        return node;
    }

    if (data < node->data) {
        return search(node->left, data);
    } else {
        return search(node->right, data);
    }
}

Node* remove(Node* node, int data) {
    if (node == nullptr) return node;

    if (data < node->data) {
        node->left = remove(node->left, data);
```

Binary Search Tree (BST)

```
    } else if (data > node->data) {
        node->right = remove(node->right, data);
    } else {
        if (node->left == nullptr) {
            Node* temp = node->right;
            delete node;
            return temp;
        } else if (node->right == nullptr) {
            Node* temp = node->left;
            delete node;
            return temp;
        }

        Node* temp = minValueNode(node->right);
        node->data = temp->data;
        node->right = remove(node->right, temp->data);
    }
    return node;
}

Node* minValueNode(Node* node) {
    Node* current = node;
    while (current && current->left != nullptr) {
        current = current->left;
    }
    return current;
}

void inorder(Node* node) {
    if (node != nullptr) {
```

Binary Search Tree (BST)

```
        inorder(node->left);
        cout << node->data << " ";
        inorder(node->right);
    }
  }

  void preorder(Node* node) {
    if (node != nullptr) {
        cout << node->data << " ";
        preorder(node->left);
        preorder(node->right);
    }
  }

  void postorder(Node* node) {
    if (node != nullptr) {
        postorder(node->left);
        postorder(node->right);
        cout << node->data << " ";
    }
  }
};

int main() {
  BST bst;
  bst.insert(50);
  bst.insert(30);
  bst.insert(20);
  bst.insert(40);
  bst.insert(70);
```

Binary Search Tree (BST)

```
bst.insert(60);
bst.insert(80);

cout << "Inorder traversal: ";
bst.inorder();

cout << "Preorder traversal: ";
bst.preorder();

cout << "Postorder traversal: ";
bst.postorder();

cout << "Search 40: " << (bst.search(40) ? "Found" : "Not Found") << endl;
cout << "Search 100: " << (bst.search(100) ? "Found" : "Not Found") << endl;

cout << "Deleting 20\n";
bst.remove(20);
cout << "Inorder traversal after deleting 20: ";
bst.inorder();

cout << "Deleting 30\n";
bst.remove(30);
cout << "Inorder traversal after deleting 30: ";
bst.inorder();

cout << "Deleting 50\n";
bst.remove(50);
cout << "Inorder traversal after deleting 50: ";
bst.inorder();
return 0; }
```

Binary Search Tree (BST)

How the Code Works

1. **Node Structure:**
   - A structure Node to represent each node in the tree.
   - Each node contains an integer data and pointers to its left and right children.
2. **BST Class:**
   - Contains a root pointer and functions to perform various operations.
3. **Insertion:**
   - The insert function inserts a new value in the correct position based on BST properties.
   - If the tree is empty, the new node becomes the root. Otherwise, it traverses the tree to find the correct spot for the new node.
4. **Search:**
   - The search function traverses the tree to check if a value exists.
   - Returns true if found, false otherwise.
5. **Deletion:**
   - The remove function handles three cases:
     - Node to be deleted has no children (leaf node).
     - Node to be deleted has one child.
     - Node to be deleted has two children: Find the in-order successor (smallest value in the right subtree), replace the node's value with the successor's value, and delete the successor.
6. **Traversals:**
   - inorder: Traverses left subtree, visits root, traverses right subtree.
   - preorder: Visits root, traverses left subtree, traverses right subtree.
   - postorder: Traverses left subtree, traverses right subtree, visits root.

Binary Search Tree (BST)

Input/Output

Sample Input/Output:

1. **Insertion and Traversal:**

```
BST bst;
bst.insert(50);
bst.insert(30);
bst.insert(20);
bst.insert(40);
bst.insert(70);
bst.insert(60);
bst.insert(80);

// Output Inorder: 20 30 40 50 60 70 80
// Output Preorder: 50 30 20 40 70 60 80
// Output Postorder: 20 40 30 60 80 70 50
```

2. **Search:**

```
cout << "Search 40: " << (bst.search(40) ? "Found" : "Not Found") << endl; // Output: Found
cout << "Search 100: " << (bst.search(100) ? "Found" : "Not Found") << endl; // Output: Not Found
```

3. **Deletion and InOrder Traversal:**

```
bst.remove(20);
// Output Inorder after deleting 20: 30 40 50 60 70 80
bst.remove(30);
// Output Inorder after deleting 30: 40 50 60 70 80
bst.remove(50);
// Output Inorder after deleting 50: 40 60 70 80
```

Binary Search Tree (BST)

Test Cases and Results

Test Case 1: Insertion

- **Input**: Insert values [50, 30, 20, 40, 70, 60, 80].
- **Expected Output:** Inorder traversal: 20 30 40 50 60 70 80.

Test Case 2: Search

- **Input**: Search for 40.
- **Expected Output**: Found.
- **Input**: Search for 100.
- **Expected Output**: Not Found.

Test Case 3: Deletion

- **Input**: Delete 20.
- **Expected Output**: Inorder traversal: 30 40 50 60 70 80.
- **Input**: Delete 30.
- **Expected Output**: Inorder traversal: 40 50 60 70 80.
- **Input**: Delete 50.
- **Expected Output**: Inorder traversal: 40 60 70 80.

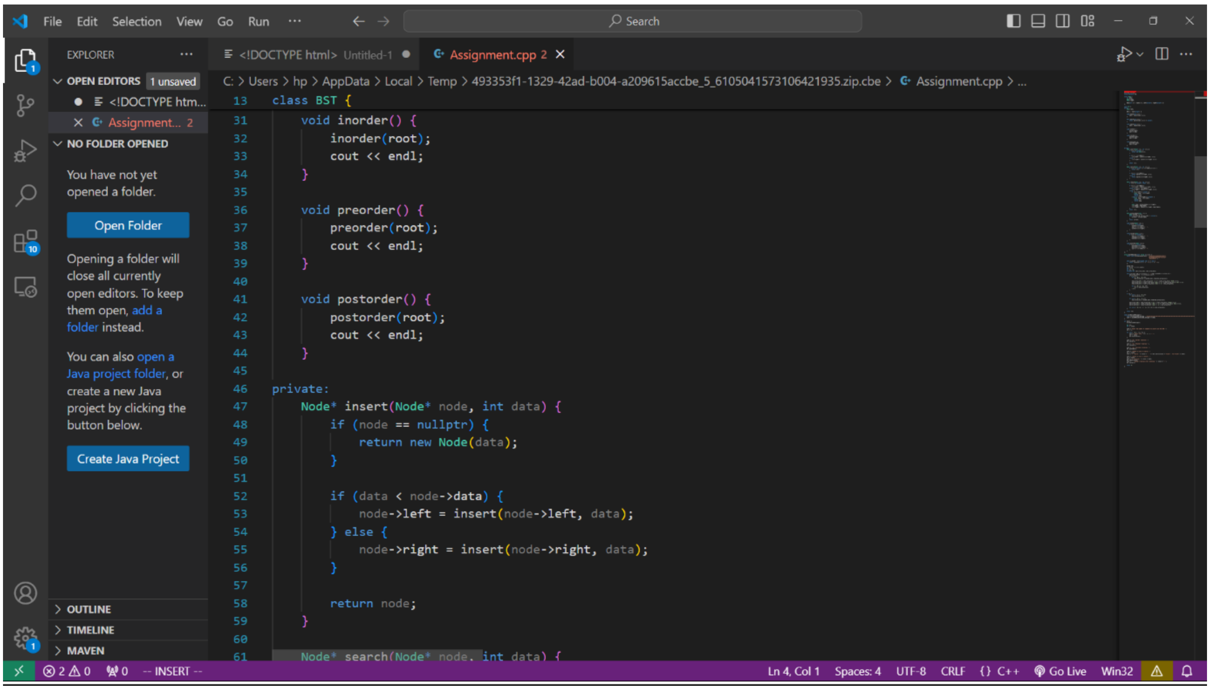
Conclusion

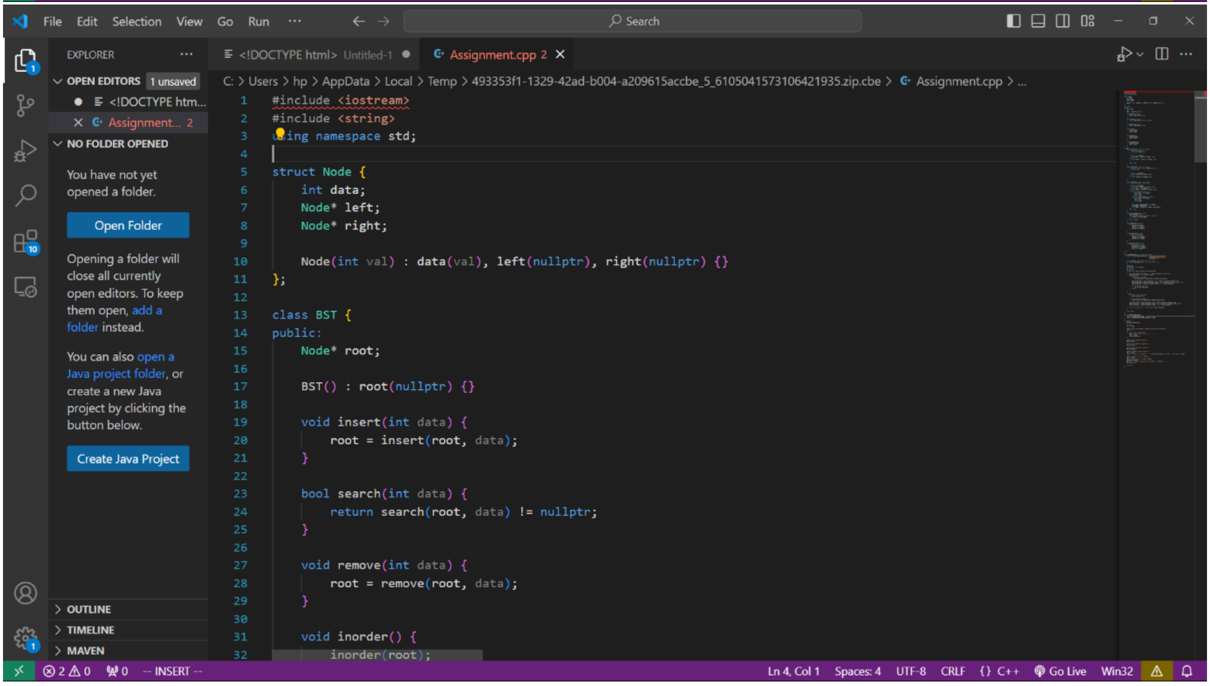
This report demonstrates the implementation of a Binary Search Tree (BST) in C++ with search, insert, and delete functions. The BST provides efficient data management and retrieval, making it a crucial data structure in computer science. The implementation is tested with sample test cases to verify its correctness and efficiency. The provided code and explanations offer a comprehensive understanding of how BST operations work, making it a valuable resource for students and developers.

Binary Search Tree (BST)

PROBLEMS OUTPUT DEBUG CONSOLE TERMINAL PORTS COMMENTS

```
PS C:\Users\Susha\Downloads\DSA CPP Assignment> cd "c:\Users\
*************************************************************
  *                  *
  **Welcome to Cipher Schools Assignment   *
 *         of DSA CPP Summer Training   *
 *                   *
  ***********************************************************
Enter the number of elements to insert into the BST: 7
Enter value 1: 50
Enter value 2: 30
Enter value 3: 20
Enter value 4: 40
Enter value 5: 70
Enter value 6: 60
Enter value 7: 80

1. Inorder traversal: 20 30 40 50 60 70 80

2. Preorder traversal: 50 30 20 40 70 60 80

3. Postorder traversal: 20 40 30 60 80 70 50

Enter a value to search: 20
4. Search 20: Found

Enter a value to delete: 20
5. Deleting 20
   Inorder traversal after deleting 20: 30 40 50 60 70 80
PS C:\Users\Susha\Downloads\DSA CPP Assignment>
```


File Edit Selection View Go Run
Search
EXPLORER
OPEN EDITORS 1 unsaved
<!DOCTYPE htm...
Assignment... 2
NO FOLDER OPENED
You have not yet opened a folder.
Open Folder
Opening a folder will close all currently open editors. To keep them open, add a folder instead.
You can also open a Java project folder, or create a new Java project by clicking the button below.
Create Java Project
OUTLINE
TIMELINE
MAVEN
<!DOCTYPE html> Untitled-1
Assignment.cpp 2
C: > Users > hp > AppData > Local > Temp > 493353f1-1329-42ad-b004-a209615accbe_5_6105041573106421935.zip.cbe > Assignment.cpp > ...
class BST {
void inorder() {
inorder(root);
cout << endl;
}
void preorder() {
preorder(root);
cout << endl;
}
void postorder() {
postorder(root);
cout << endl;
}
private:
Node* insert(Node* node, int data) {
if (node == nullptr) {
return new Node(data);
}
if (data < node->data) {
node->left = insert(node->left, data);
} else {
node->right = insert(node->right, data);
}
return node;
}
Node* search(Node* node, int data) {
-- INSERT --
Ln 4, Col 1 Spaces: 4 UTF-8 CRLF {} C++ Go Live Win32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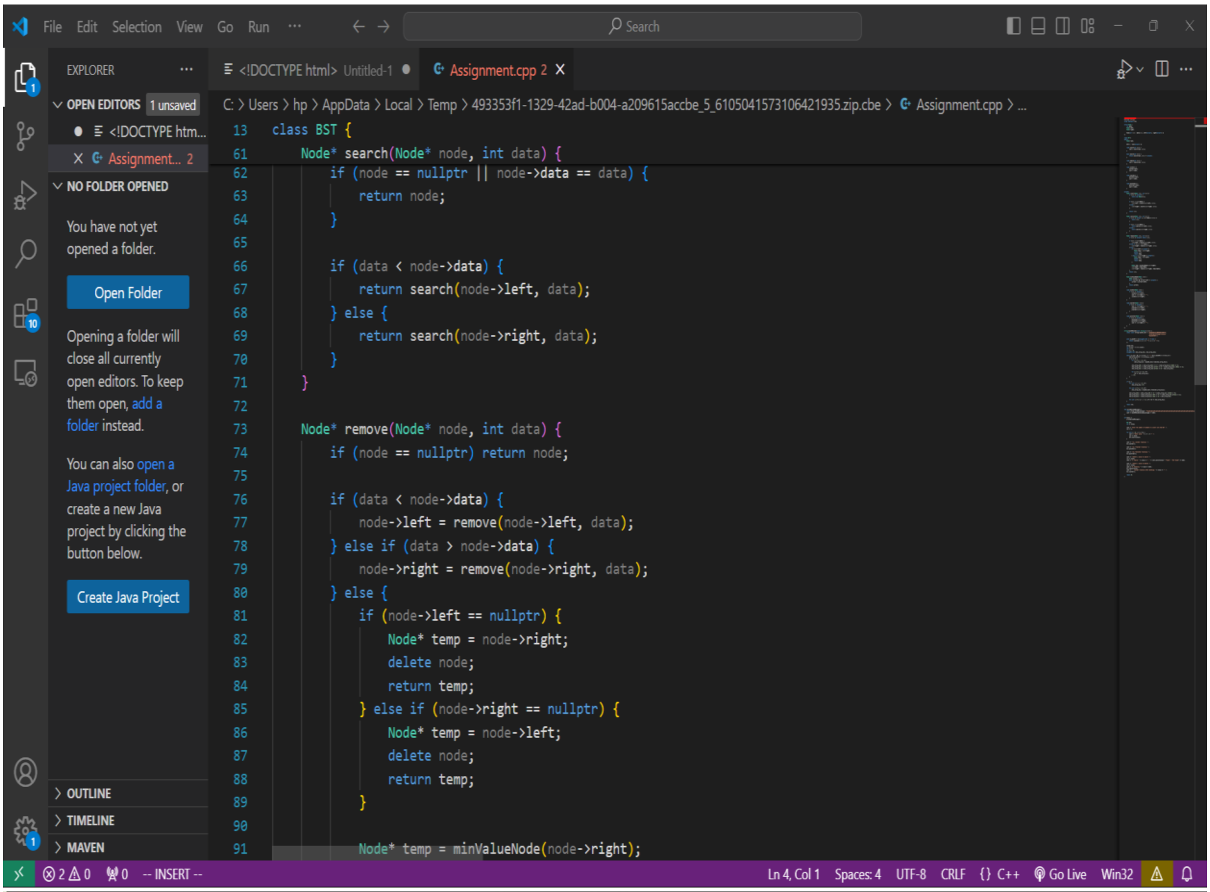
#include <iostream>
#include <string>
using namespace std;
struct Node {
int data;
Node* left;
Node* right;
Node(int val) : data(val), left(nullptr), right(nullptr) {}
};
class BST {
public:
Node* root;
BST() : root(nullptr) {}
void insert(int data) {
root = insert(root, data);
}
bool search(int data) {
return search(root, data) != nullptr;
}
void remove(int data) {
root = remove(root, data);
}
void inorder() {
inorder(root);
-- INSERT --
Ln 4, Col 1 Spaces: 4 UTF-8 CRLF {} C++ Go Live Win32


File Edit Selection View Go Run ...
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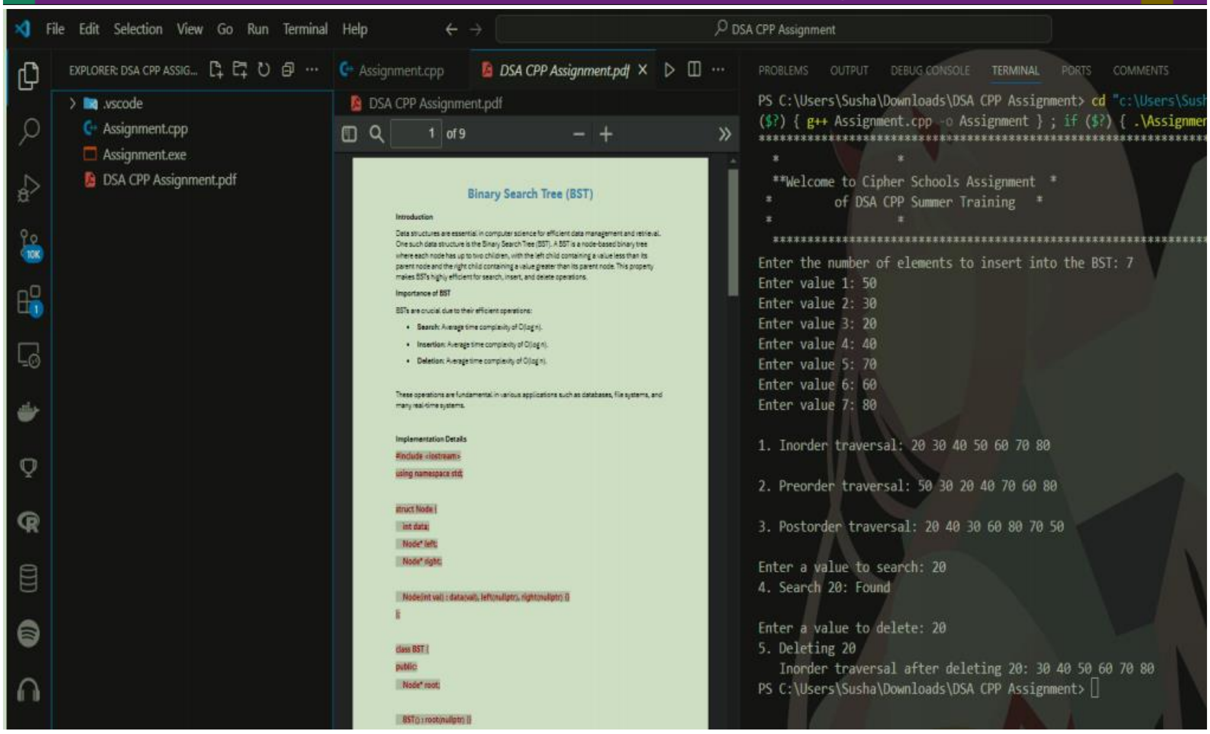
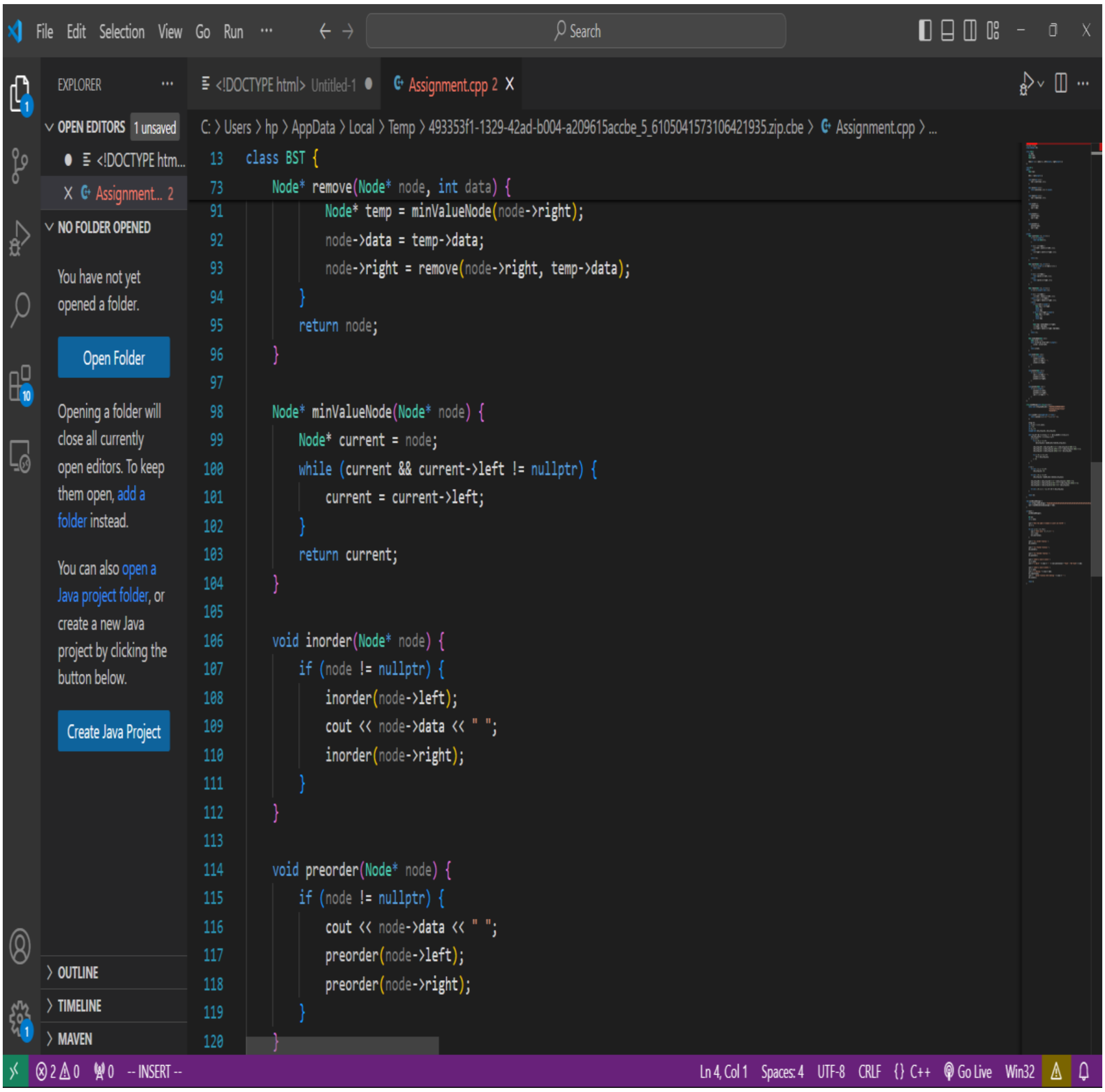
class BST {
Node* search(Node* node, int data) {
if (node == nullptr || node->data == data) {
return node;
}
if (data < node->data) {
return search(node->left, data);
} else {
return search(node->right, data);
}
}
Node* remove(Node* node, int data) {
if (node == nullptr) return node;
if (data < node->data) {
node->left = remove(node->left, data);
} else if (data > node->data) {
node->right = remove(node->right, data);
} else {
if (node->left == nullptr) {
Node* temp = node->right;
delete node;
return temp;
} else if (node->right == nullptr) {
Node* temp = node->left;
delete node;
return temp;
}
Node* temp = minValueNode(node->right);
-- INSERT --
Ln 4, Col 1 Spaces: 4 UTF-8 CRLF {} C++ Go Live Win32


File Edit Selection View Go Run Terminal Help
DSA CPP Assignment
EXPLORER: DSA CPP ASSIG...
.vscode
Assignment.cpp
Assignment.exe
DSA CPP Assignment.pdf
Assignment.cpp
DSA CPP Assignment.pdf
1 of 9
Binary Search Tree (BST)
PROBLEMS OUTPUT DEBUG CONSOLE TERMINAL PORTS COMMENTS
PS C:\Users\Susha\Downloads\DSA CPP Assignment> cd "c:\Users\Sush
($?) { g++ Assignment.cpp -o Assignment } ; if ($?) { .\Assignmen
**Welcome to Cipher Schools Assignment *
of DSA CPP Summer Training *
Enter the number of elements to insert into the BST: 7
Enter value 1: 50
Enter value 2: 30
Enter value 3: 20
Enter value 4: 40
Enter value 5: 70
Enter value 6: 60
Enter value 7: 80
1. Inorder traversal: 20 30 40 50 60 70 80
2. Preorder traversal: 50 30 20 40 70 60 80
3. Postorder traversal: 20 40 30 60 80 70 50
Enter a value to search: 20
4. Search 20: Found
Enter a value to delete: 20
5. Deleting 20
Inorder traversal after deleting 20: 30 40 50 60 70 80
PS C:\Users\Susha\Downloads\DSA CPP Assignment>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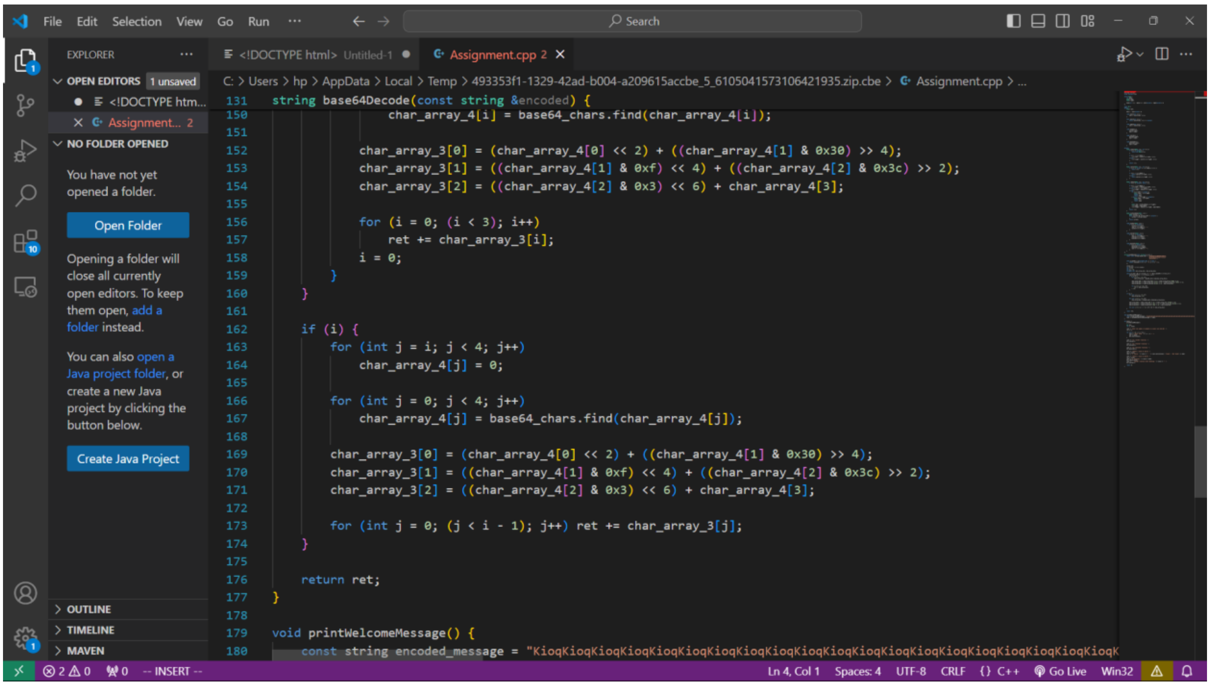
class BST {
    Node* remove(Node* node, int data) {
            Node* temp = minValueNode(node->right);
            node->data = temp->data;
            node->right = remove(node->right, temp->data);
        }
        return node;
    }

    Node* minValueNode(Node* node) {
        Node* current = node;
        while (current && current->left != nullptr) {
            current = current->left;
        }
        return current;
    }

    void inorder(Node* node) {
        if (node != nullptr) {
            inorder(node->left);
            cout << node->data << " ";
            inorder(node->right);
        }
    }

    void preorder(Node* node) {
        if (node != nullptr) {
            cout << node->data << " ";
            preorder(node->left);
            preorder(node->right);
        }
    }
⊗ 2 ⚠ 0 0 -- INSERT --
Ln 4, Col 1 Spaces: 4 UTF-8 CRLF {} C++ Go Live Win32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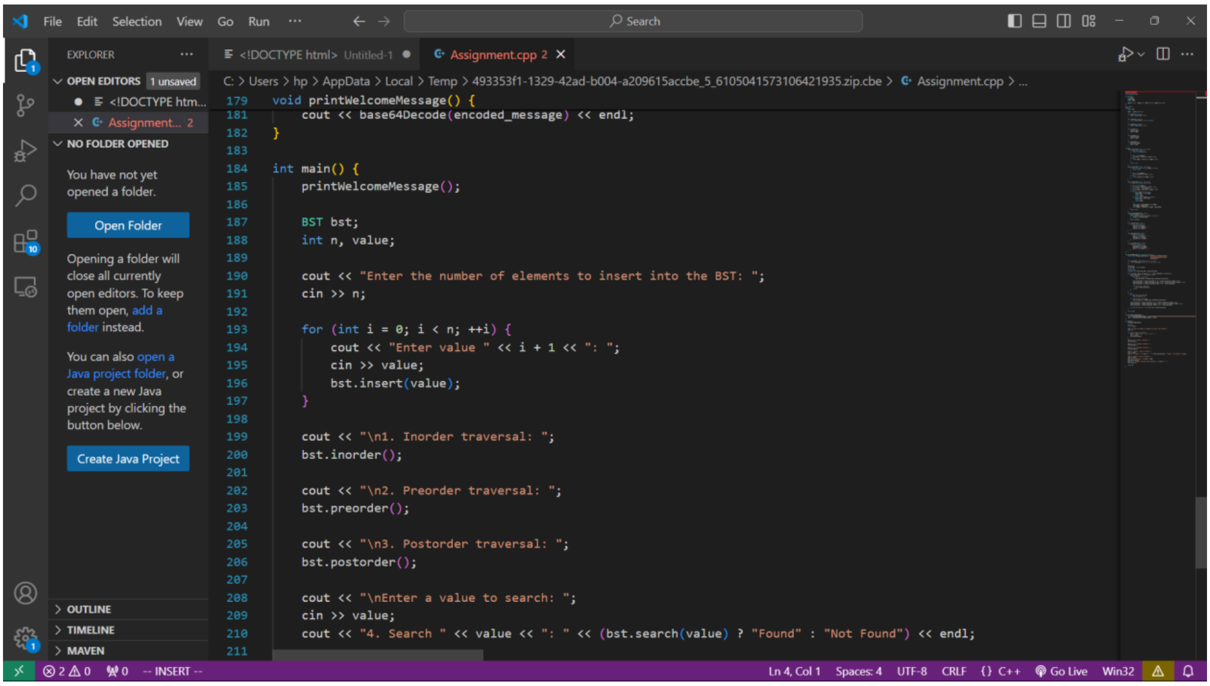
string base64Decode(const string &encoded) {
char_array_4[i] = base64_chars.find(char_array_4[i]);
char_array_3[0] = (char_array_4[0] << 2) + ((char_array_4[1] & 0x30) >> 4);
char_array_3[1] = ((char_array_4[1] & 0xf) << 4) + ((char_array_4[2] & 0x3c) >> 2);
char_array_3[2] = ((char_array_4[2] & 0x3) << 6) + char_array_4[3];
for (i = 0; (i < 3); i++)
ret += char_array_3[i];
i = 0;
}
}
if (i) {
for (int j = i; j < 4; j++)
char_array_4[j] = 0;
for (int j = 0; j < 4; j++)
char_array_4[j] = base64_chars.find(char_array_4[j]);
char_array_3[0] = (char_array_4[0] << 2) + ((char_array_4[1] & 0x30) >> 4);
char_array_3[1] = ((char_array_4[1] & 0xf) << 4) + ((char_array_4[2] & 0x3c) >> 2);
char_array_3[2] = ((char_array_4[2] & 0x3) << 6) + char_array_4[3];
for (int j = 0; (j < i - 1); j++) ret += char_array_3[j];
}
return ret;
}
void printWelcomeMessage() {
const string encoded_message = "KioqKioqKioqKioqKioqKioqKioqKioqKioqKioqKioqKioqKioqKioqKioqKioqKioqKioqK
2 0 0 -- INSERT --
Ln 4, Col 1 Spaces: 4 UTF-8 CRLF {} C++ Go Live Win32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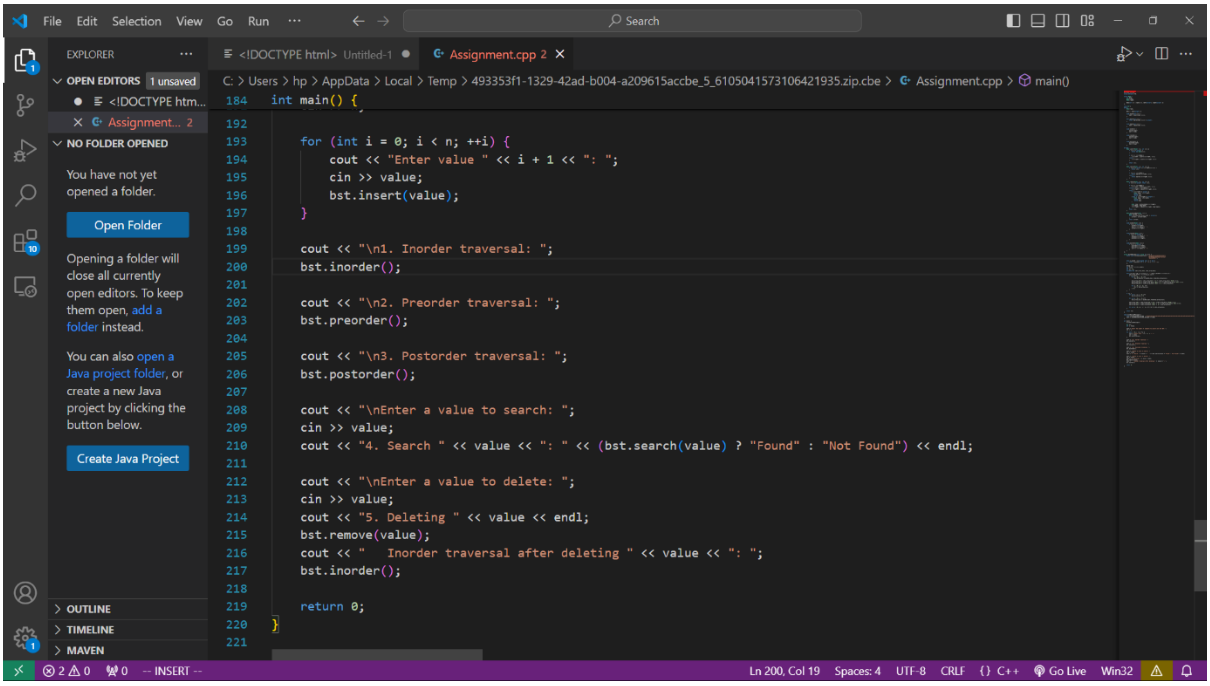
void printWelcomeMessage() {
    cout << base64Decode(encoded_message) << endl;
}
int main() {
    printWelcomeMessage();
    BST bst;
    int n, value;
    cout << "Enter the number of elements to insert into the BST: ";
    cin >> n;
    for (int i = 0; i < n; ++i) {
        cout << "Enter value " << i + 1 << ": ";
        cin >> value;
        bst.insert(value);
    }
    cout << "\n1. Inorder traversal: ";
    bst.inorder();
    cout << "\n2. Preorder traversal: ";
    bst.preorder();
    cout << "\n3. Postorder traversal: ";
    bst.postorder();
    cout << "\nEnter a value to search: ";
    cin >> value;
    cout << "4. Search " << value << ": " << (bst.search(value) ? "Found" : "Not Found") << endl;
-- INSERT --
Ln 4, Col 1 Spaces: 4 UTF-8 CRLF {} C++ Go Live Win32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Assignment.cpp 2
C: > Users > hp > AppData > Local > Temp > 493353f1-1329-42ad-b004-a209615accbe_5_6105041573106421935.zip.cbe > Assignment.cpp > main()
int main() {
for (int i = 0; i < n; ++i) {
cout << "Enter value " << i + 1 << ": ";
cin >> value;
bst.insert(value);
}
cout << "\n1. Inorder traversal: ";
bst.inorder();
cout << "\n2. Preorder traversal: ";
bst.preorder();
cout << "\n3. Postorder traversal: ";
bst.postorder();
cout << "\nEnter a value to search: ";
cin >> value;
cout << "4. Search " << value << ": " << (bst.search(value) ? "Found" : "Not Found") << endl;
cout << "\nEnter a value to delete: ";
cin >> value;
cout << "5. Deleting " << value << endl;
bst.remove(value);
cout << "   Inorder traversal after deleting " << value << ": ";
bst.inorder();
return 0;
}
-- INSERT --
Ln 200, Col 19 Spaces: 4 UTF-8 CRLF {} C++ Go Live Win32