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Professor Vo

CSCI 220

December 4, 2017

Project 4: Binary Search Tree

Compiler: Microsoft Visual Studio 2017
Language: C++

Files Used:

p4large.txt
Entry.h
BinaryTree.h
SearchTree.h
AVLTree.h
BeginProgram.h
Entry.cpp
BinaryTree.cpp
SearchTree.cpp
AVLTree.cpp
BeginProgram.cpp
Main.cpp

Kevin's Notes

This project is fully functional. The most troubling part for us was the restructuring of the AVL Tree. We felt like this took most of the time because most of the other code was given to us through the book and we just had to convert it to be a non-template tree. While converting the template to non-template tree, there were many problems that arose, such as how we would split up the classes, or which parameters we would have to pass. These were mainly just design issues that we faced but we ended up deciding to make the program much more modulable in case we would ever need it in the future. Personally, for me, (Kevin), I found the book's code extremely hard to follow at certain points. I had done most of my work in Java for the semester, so I needed to review the C++ syntax understand the code. On top of that, the code seemed to be very hard to follow even after I had reviewed some syntax because it required a solid foundation in the data structures we were learning in class to comprehend it. Other than that, it was not too difficult of a project. We (Anthony and I) split up the work and were both able to benefit from this project. This project helped us to become much more familiar with the debugger as well as the concept of the AVL Tree and the Binary Search Tree. On a side note, since this was a group project, Anthony and I also used this to our advantage and forced ourselves to learn how to use Git Repositories. We did this so we could easily share and update code as well as take advantage of version control. In addition, by using Git, we also got more familiar with the command line and the bash/terminal window, which is present in macOS and Linux. Learning this was one of the most important keys for this project. It allowed us to update and share our work almost instantaneously with one another as well as stay in good communication.

Anthony's Notes

Like Kevin said, this program is fully functional. The most troubling part of the program was doing the code for the restructure, setting up functions for the Search tree class to work with a specific data type, and the positions class (which was the inner class of the binary tree). I believed that it was best to pass the Entry class object that held all our data (county state code, population, and county state name) within our public functions of the Search tree and AVL tree so that our parameters wouldn't have 4 things you would need to pass in and that it was just easier to keep track of what we were passing in to fill in our tree or erase data. In addition, when creating the code for restructure and building the AVL tree I noticed that with the given Binary Tree class, that there wasn't enough data or functions for it to fully work so we had to implement our own such as having the position class have functions and data that can take store the height, setting the parents of this node, setting the right and left children of a node, and in also setting up a new root if needed if a restructure happened. Besides from the technical stuff, my experience with this team project was pretty good. We tried new things out such as using GitHub's repository so that we can always be up to date with our code if someone were to make any changes and it made communications a lot easier between the two of us.

Comparison of AVL vs BST

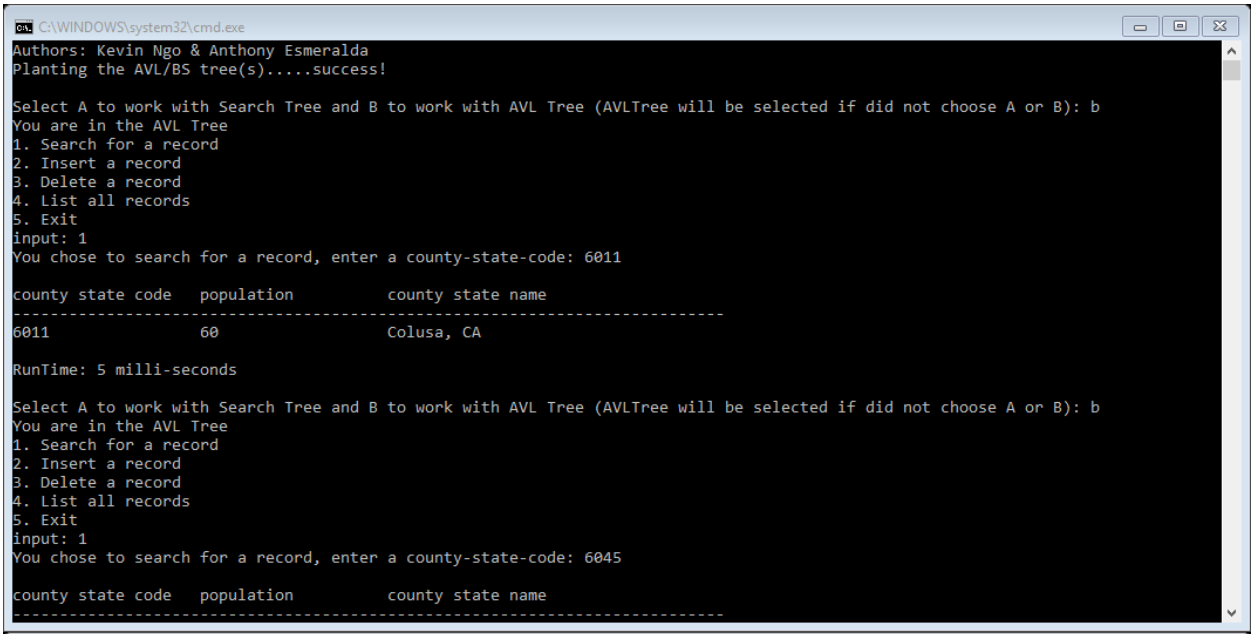
Key	Function	AVL Runtime	BST Runtime
6011	Search	5 milliseconds	8 milliseconds
6045	Search	5 milliseconds	7 milliseconds
6103	Search	6 milliseconds	7 milliseconds
6004	Insert	6 milliseconds	4 milliseconds
6060	Insert	6 milliseconds	8 milliseconds
6078	Insert	7 milliseconds	9 milliseconds
6061	Erase	6 milliseconds	6 milliseconds
6045	Erase	5 milliseconds	7 milliseconds
6049	Erase	1 milliseconds	2 milliseconds
6113	Search	4 milliseconds	8 milliseconds
8115	Insert	6 milliseconds	8 milliseconds
6089	Erase	6 milliseconds	5 milliseconds

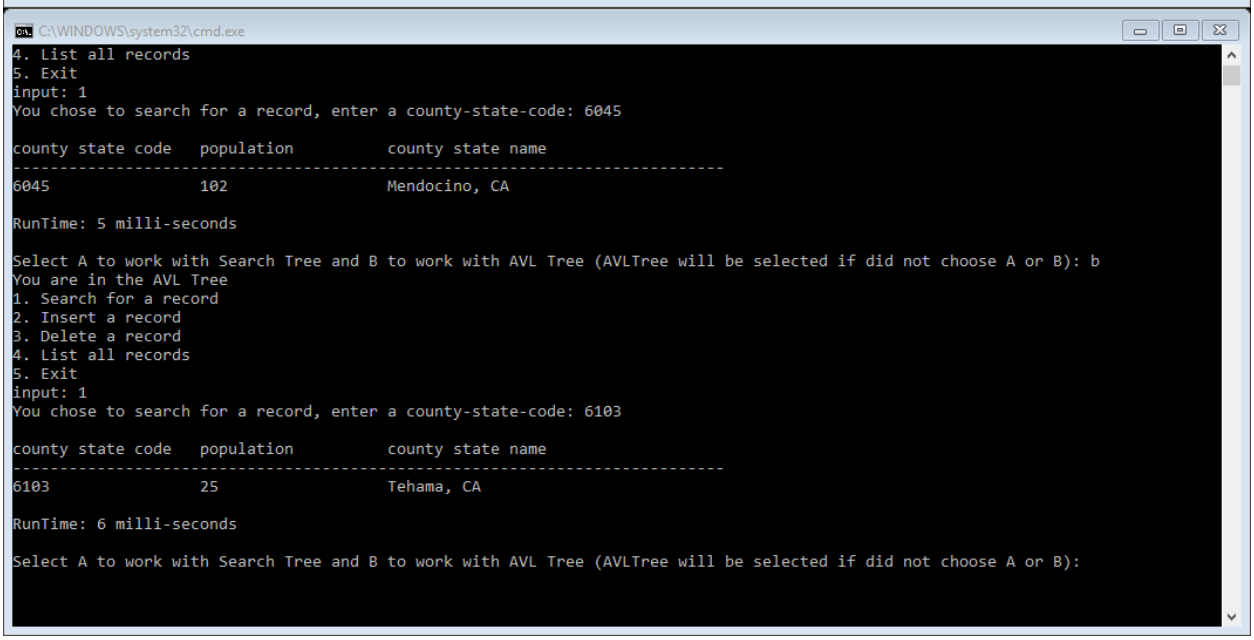
Notes on differences

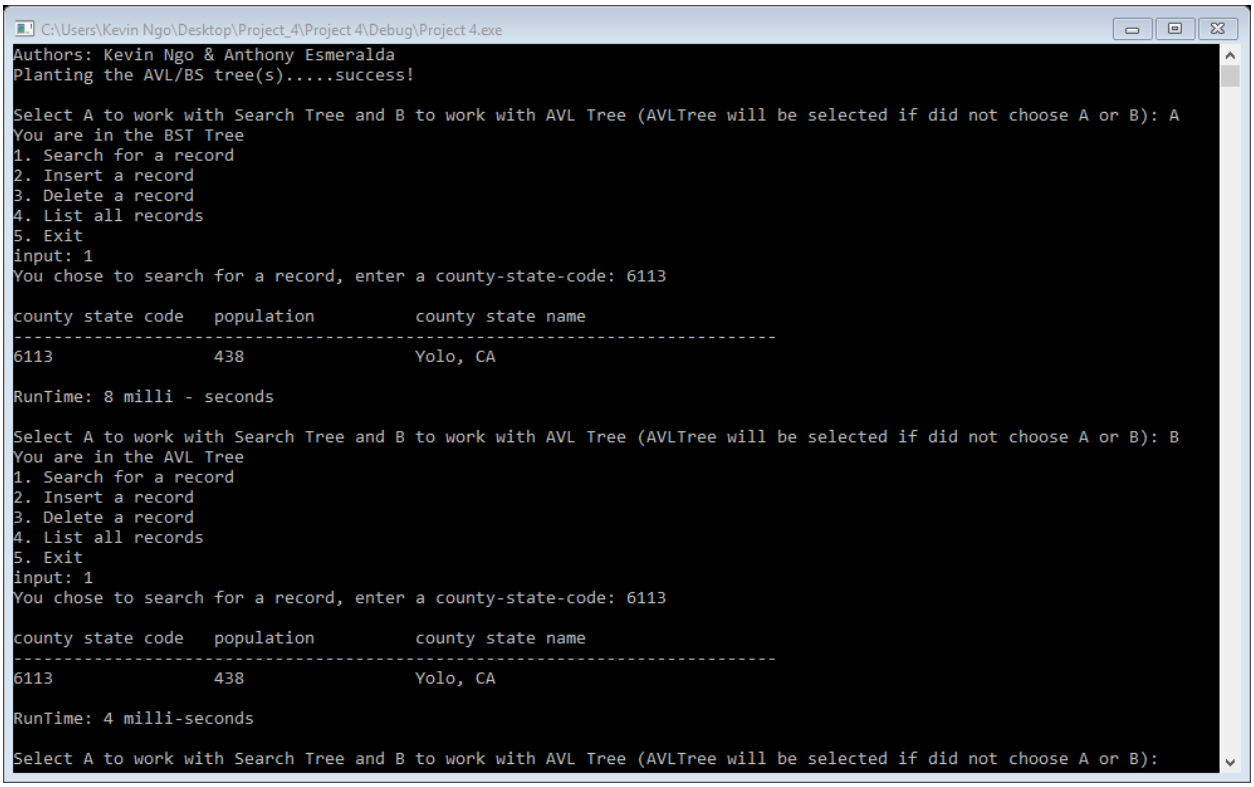
Based on the data documented, it is obvious the AVL Tree seems to be more efficient than the BST, on average. As it can be seen, on our very last case, there was an erase that was faster in the BST than it was in the AVL Tree. There are differences like this, most likely do to the restructuring required after performing such actions. Although the cases for erase and insert vary (due to restructuring), it is obvious to see that the search is much more efficient than the BST. In some cases, our AVL searches were better than the BST searches (in terms of milliseconds) by a factor or two. This proves that although the AVL takes some more time to insert and also remove (due to the restructure requirement), when searching the AVL Tree is more efficient than the BST tree and is faster at locating records.

Input/Output

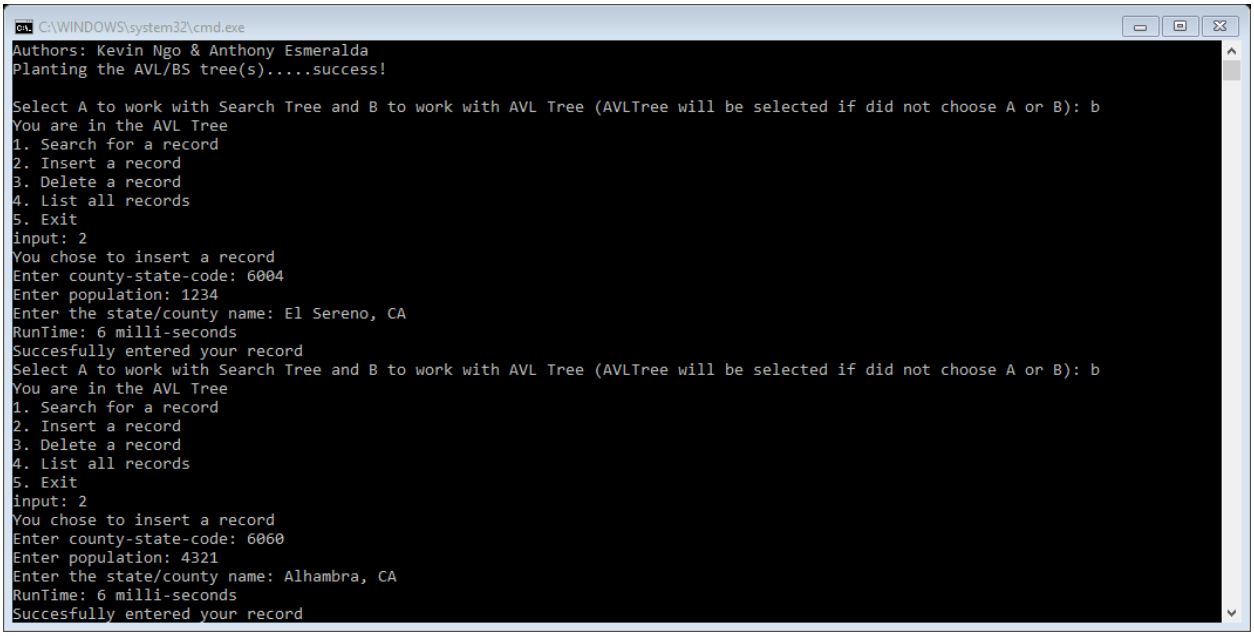
Option 1:

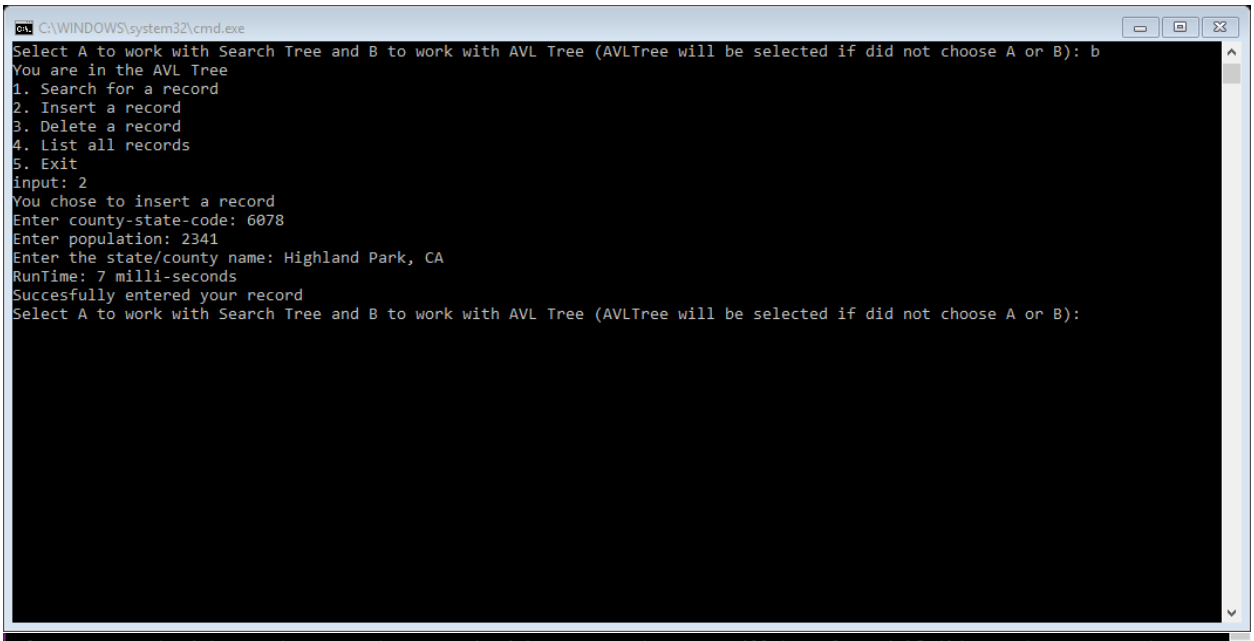





C:\Users\Kevin Ngo\Desktop\Project_4\Project 4\Debug\Project 4.exe
Authors: Kevin Ngo & Anthony Esmeralda
Planting the AVL/BS tree(s).....success!
Select A to work with Search Tree and B to work with AVL Tree (AVLTree will be selected if did not choose A or B): A
You are in the BST Tree
1. Search for a record
2. Insert a record
3. Delete a record
4. List all records
5. Exit
input: 1
You chose to search for a record, enter a county-state-code: 6113
county state code population county state name
6113 438 Yolo, CA
RunTime: 8 milli - seconds
Select A to work with Search Tree and B to work with AVL Tree (AVLTree will be selected if did not choose A or B): B
You are in the AVL Tree
1. Search for a record
2. Insert a record
3. Delete a record
4. List all records
5. Exit
input: 1
You chose to search for a record, enter a county-state-code: 6113
county state code population county state name
6113 438 Yolo, CA
RunTime: 4 milli-seconds
Select A to work with Search Tree and B to work with AVL Tree (AVLTree will be selected if did not choose A or B):

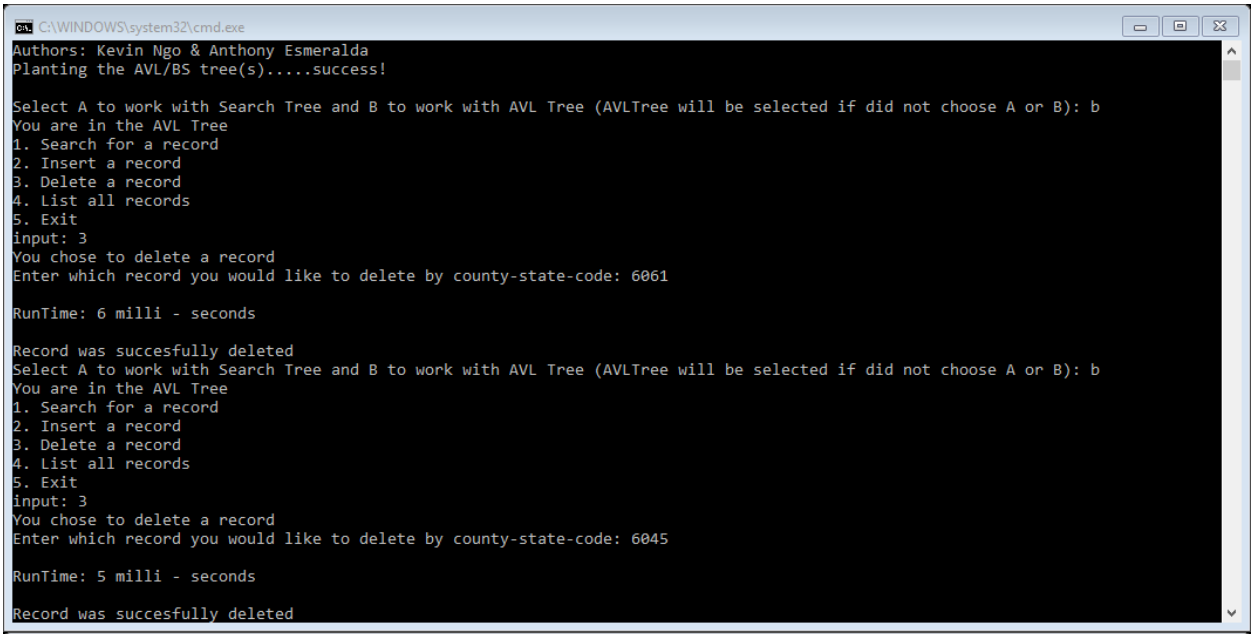
Option 2:

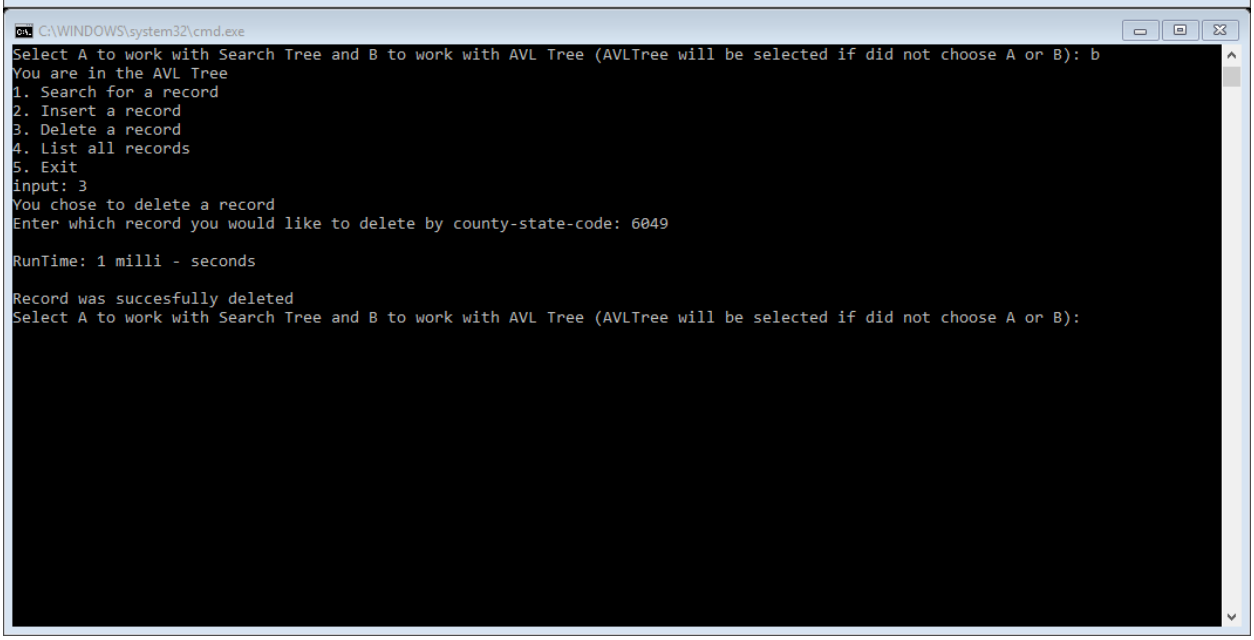

C:\WINDOWS\system32\cmd.exe
Authors: Kevin Ngo & Anthony Esmeralda
Planting the AVL/BS tree(s).....success!
Select A to work with Search Tree and B to work with AVL Tree (AVLTree will be selected if did not choose A or B): b
You are in the AVL Tree
1. Search for a record
2. Insert a record
3. Delete a record
4. List all records
5. Exit
input: 2
You chose to insert a record
Enter county-state-code: 6004
Enter population: 1234
Enter the state/county name: El Sereno, CA
RunTime: 6 milli-seconds
Succesfully entered your record
Select A to work with Search Tree and B to work with AVL Tree (AVLTree will be selected if did not choose A or B): b
You are in the AVL Tree
1. Search for a record
2. Insert a record
3. Delete a record
4. List all records
5. Exit
input: 2
You chose to insert a record
Enter county-state-code: 6060
Enter population: 4321
Enter the state/county name: Alhambra, CA
RunTime: 6 milli-seconds
Succesfully entered your record

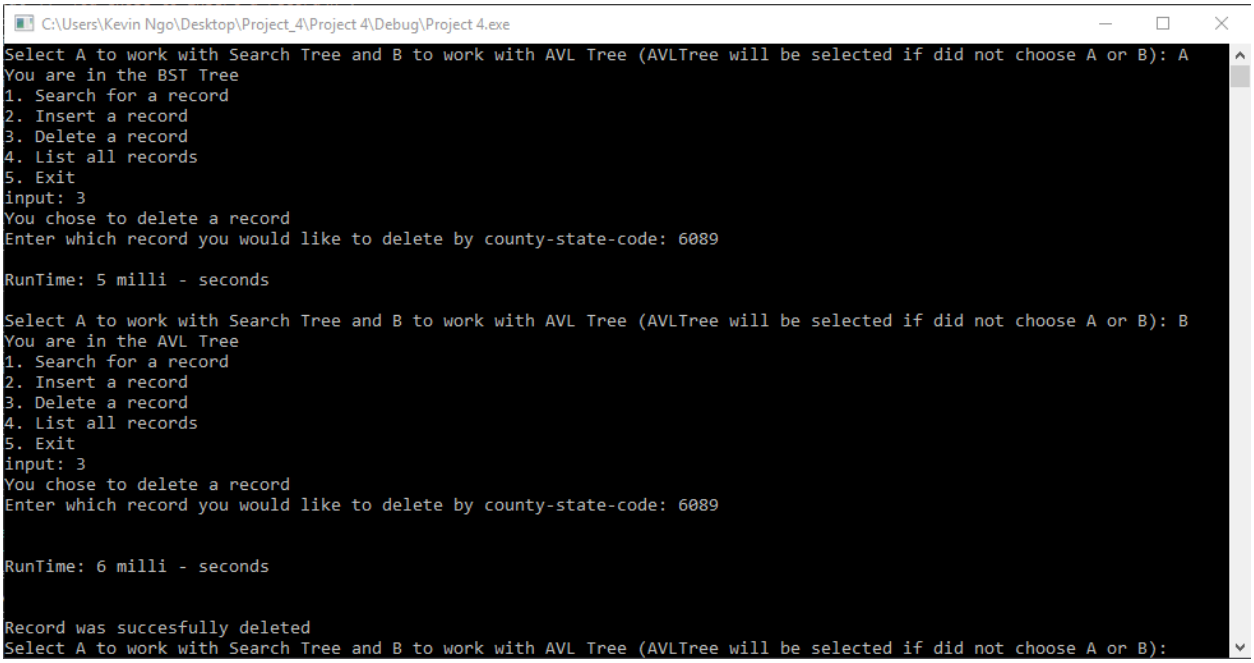



```
Select A to work with Search Tree and B to work with AVL Tree (AVLTree will be selected if did not choose A or B): A
You are in the BST Tree
1. Search for a record
2. Insert a record
3. Delete a record
4. List all records
5. Exit
input: 2
You chose to insert a record
Enter county-state-code: 8115
Enter population: 82931
Enter the state/county name: Ontario, CA

RunTime: 8 milli - seconds

Succesfully entered your record
Select A to work with Search Tree and B to work with AVL Tree (AVLTree will be selected if did not choose A or B): B
You are in the AVL Tree
1. Search for a record
2. Insert a record
3. Delete a record
4. List all records
5. Exit
input: 2
You chose to insert a record
Enter county-state-code: 8115
Enter population: 82931
Enter the state/county name: Ontario, CA
RunTime: 6 milli-seconds
Succesfully entered your record
Select A to work with Search Tree and B to work with AVL Tree (AVLTree will be selected if did not choose A or B): _
```

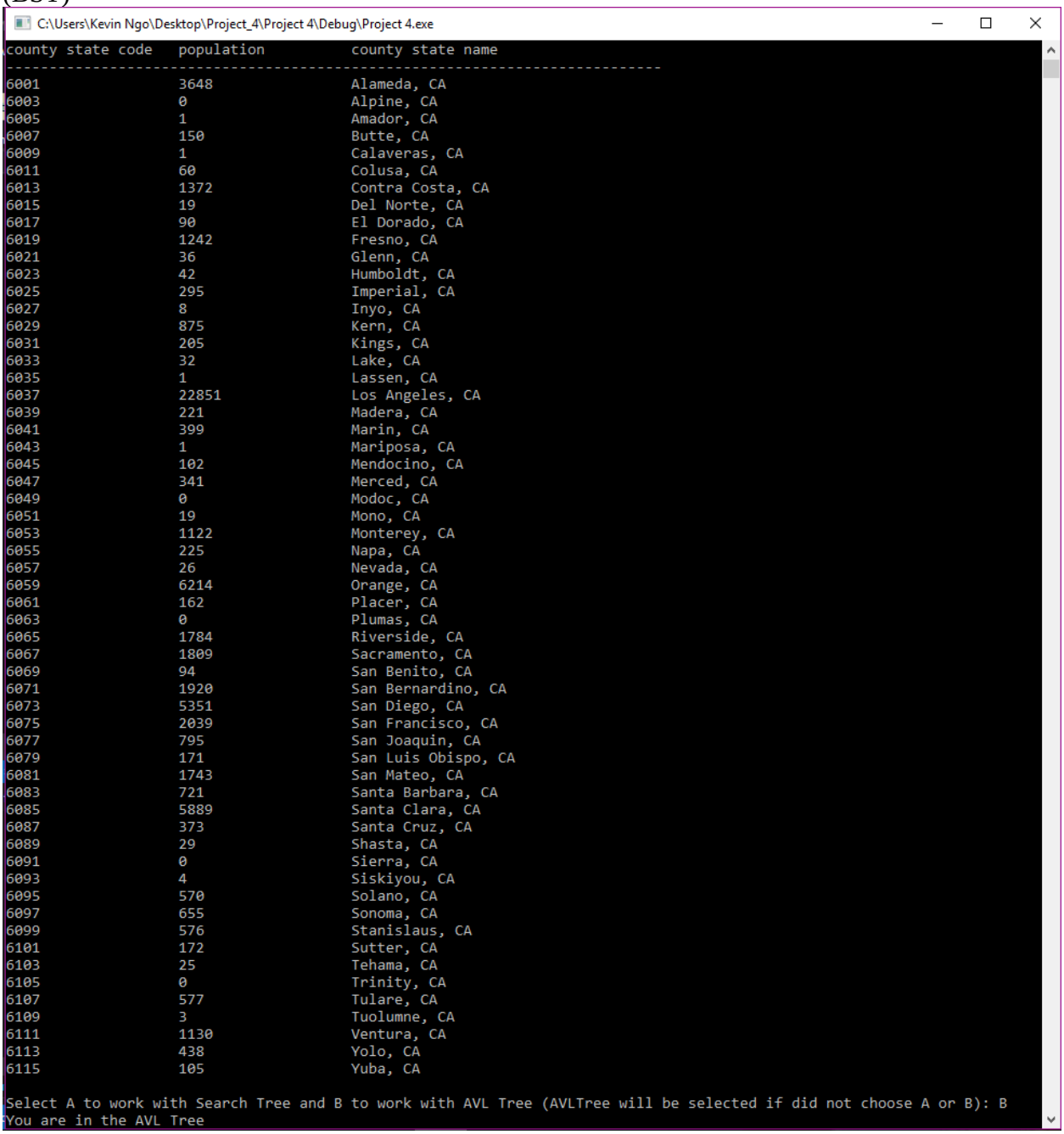
Option 3:


C:\WINDOWS\system32\cmd.exe
Authors: Kevin Ngo & Anthony Esmeralda
Planting the AVL/BS tree(s).....success!
Select A to work with Search Tree and B to work with AVL Tree (AVLTree will be selected if did not choose A or B): b
You are in the AVL Tree
1. Search for a record
2. Insert a record
3. Delete a record
4. List all records
5. Exit
input: 3
You chose to delete a record
Enter which record you would like to delete by county-state-code: 6061
RunTime: 6 milli - seconds
Record was succesfully deleted
Select A to work with Search Tree and B to work with AVL Tree (AVLTree will be selected if did not choose A or B): b
You are in the AVL Tree
1. Search for a record
2. Insert a record
3. Delete a record
4. List all records
5. Exit
input: 3
You chose to delete a record
Enter which record you would like to delete by county-state-code: 6045
RunTime: 5 milli - seconds
Record was succesfully deleted

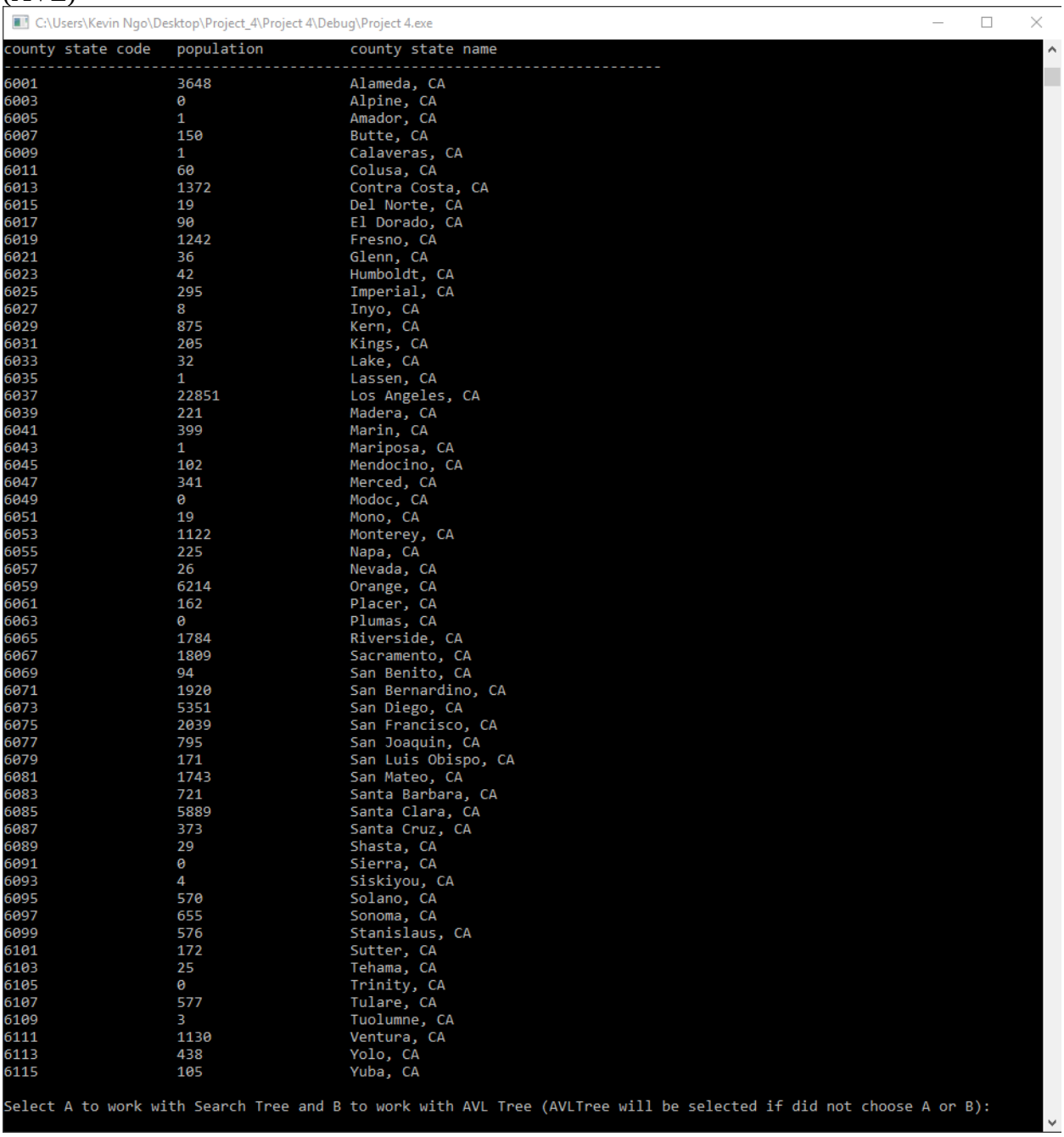

C:\WINDOWS\system32\cmd.exe
Select A to work with Search Tree and B to work with AVL Tree (AVLTree will be selected if did not choose A or B): b
You are in the AVL Tree
1. Search for a record
2. Insert a record
3. Delete a record
4. List all records
5. Exit
input: 3
You chose to delete a record
Enter which record you would like to delete by county-state-code: 6049
RunTime: 1 milli - seconds
Record was succesfully deleted
Select A to work with Search Tree and B to work with AVL Tree (AVLTree will be selected if did not choose A or B):


C:\Users\Kevin Ngo\Desktop\Project_4\Project 4\Debug\Project 4.exe
Select A to work with Search Tree and B to work with AVL Tree (AVLTree will be selected if did not choose A or B): A
You are in the BST Tree
1. Search for a record
2. Insert a record
3. Delete a record
4. List all records
5. Exit
input: 3
You chose to delete a record
Enter which record you would like to delete by county-state-code: 6089
RunTime: 5 milli - seconds
Select A to work with Search Tree and B to work with AVL Tree (AVLTree will be selected if did not choose A or B): B
You are in the AVL Tree
1. Search for a record
2. Insert a record
3. Delete a record
4. List all records
5. Exit
input: 3
You chose to delete a record
Enter which record you would like to delete by county-state-code: 6089
RunTime: 6 milli - seconds
Record was succesfully deleted
Select A to work with Search Tree and B to work with AVL Tree (AVLTree will be selected if did not choose A or B):

Option 4:
(BST)


C:\Users\Kevin Ngo\Desktop\Project_4\Project 4\Debug\Project 4.exe
county state code population county state name
6001 3648 Alameda, CA
6003 0 Alpine, CA
6005 1 Amador, CA
6007 150 Butte, CA
6009 1 Calaveras, CA
6011 60 Colusa, CA
6013 1372 Contra Costa, CA
6015 19 Del Norte, CA
6017 90 El Dorado, CA
6019 1242 Fresno, CA
6021 36 Glenn, CA
6023 42 Humboldt, CA
6025 295 Imperial, CA
6027 8 Inyo, CA
6029 875 Kern, CA
6031 205 Kings, CA
6033 32 Lake, CA
6035 1 Lassen, CA
6037 22851 Los Angeles, CA
6039 221 Madera, CA
6041 399 Marin, CA
6043 1 Mariposa, CA
6045 102 Mendocino, CA
6047 341 Merced, CA
6049 0 Modoc, CA
6051 19 Mono, CA
6053 1122 Monterey, CA
6055 225 Napa, CA
6057 26 Nevada, CA
6059 6214 Orange, CA
6061 162 Placer, CA
6063 0 Plumas, CA
6065 1784 Riverside, CA
6067 1809 Sacramento, CA
6069 94 San Benito, CA
6071 1920 San Bernardino, CA
6073 5351 San Diego, CA
6075 2039 San Francisco, CA
6077 795 San Joaquin, CA
6079 171 San Luis Obispo, CA
6081 1743 San Mateo, CA
6083 721 Santa Barbara, CA
6085 5889 Santa Clara, CA
6087 373 Santa Cruz, CA
6089 29 Shasta, CA
6091 0 Sierra, CA
6093 4 Siskiyou, CA
6095 570 Solano, CA
6097 655 Sonoma, CA
6099 576 Stanislaus, CA
6101 172 Sutter, CA
6103 25 Tehama, CA
6105 0 Trinity, CA
6107 577 Tulare, CA
6109 3 Tuolumne, CA
6111 1130 Ventura, CA
6113 438 Yolo, CA
6115 105 Yuba, CA
Select A to work with Search Tree and B to work with AVL Tree (AVLTree will be selected if did not choose A or B): B
You are in the AVL Tree

(AVL)


C:\Users\Kevin Ngo\Desktop\Project_4\Project 4\Debug\Project 4.exe
county state code population county state name
6001 3648 Alameda, CA
6003 0 Alpine, CA
6005 1 Amador, CA
6007 150 Butte, CA
6009 1 Calaveras, CA
6011 60 Colusa, CA
6013 1372 Contra Costa, CA
6015 19 Del Norte, CA
6017 90 El Dorado, CA
6019 1242 Fresno, CA
6021 36 Glenn, CA
6023 42 Humboldt, CA
6025 295 Imperial, CA
6027 8 Inyo, CA
6029 875 Kern, CA
6031 205 Kings, CA
6033 32 Lake, CA
6035 1 Lassen, CA
6037 22851 Los Angeles, CA
6039 221 Madera, CA
6041 399 Marin, CA
6043 1 Mariposa, CA
6045 102 Mendocino, CA
6047 341 Merced, CA
6049 0 Modoc, CA
6051 19 Mono, CA
6053 1122 Monterey, CA
6055 225 Napa, CA
6057 26 Nevada, CA
6059 6214 Orange, CA
6061 162 Placer, CA
6063 0 Plumas, CA
6065 1784 Riverside, CA
6067 1809 Sacramento, CA
6069 94 San Benito, CA
6071 1920 San Bernardino, CA
6073 5351 San Diego, CA
6075 2039 San Francisco, CA
6077 795 San Joaquin, CA
6079 171 San Luis Obispo, CA
6081 1743 San Mateo, CA
6083 721 Santa Barbara, CA
6085 5889 Santa Clara, CA
6087 373 Santa Cruz, CA
6089 29 Shasta, CA
6091 0 Sierra, CA
6093 4 Siskiyou, CA
6095 570 Solano, CA
6097 655 Sonoma, CA
6099 576 Stanislaus, CA
6101 172 Sutter, CA
6103 25 Tehama, CA
6105 0 Trinity, CA
6107 577 Tulare, CA
6109 3 Tuolumne, CA
6111 1130 Ventura, CA
6113 438 Yolo, CA
6115 105 Yuba, CA
Select A to work with Search Tree and B to work with AVL Tree (AVLTree will be selected if did not choose A or B):

Source Code

Headers:

AVLTree.h

```
/*  Program: Project 4 - BST
 Author: Anthony Esmeralda, Kevin Ngo
 Class: CSCI 220
 Date:  Novemember 14, 2017
 Description: Binary Search Tree that uses an AVL tree search through records
 of county/state, population, and county/state name

 I certify that the code below is my own work.

 Exception(s): N/A
 */
#ifndef _AVL_TREE_H_
#define _AVL_TREE_H_
#include "SearchTree.h"
#include <cmath>
#include <algorithm>
// AVL Tree Class Definition
class AVLTree : public SearchTree
{
protected:
	typedef int county_state_code;	// a key
	typedef BinaryTree::Position TPos;		// a tree position

public:						// public functions
	AVLTree();				// constructor
	Iterator insert(Entry& entry); //Insert the entry based on the key
(county_state_code)
	void erase(const county_state_code& key); // remove country_state_code's entry
	void erase(const Iterator& it);		// remove entry at it

protected:					// utility functions
	int height(const TPos& pos) const;		// node height utility
	void setHeight(TPos pos);			// set height utility
	bool isBalanced(const TPos& pos) const;		// is the position balanced?
	TPos tallGrandchild(const TPos& pos) const;		// get tallest grandchild
	void rebalance(const TPos& pos);		// rebalance utility
};

#endif // !_AVL_TREE_H_
```

BinaryTree.h

```
/*  Program: Project 4 - BST
 Author: Anthony Esmeralda, Kevin Ngo
 Class: CSCI 220
 Date:  Novemember 14, 2017
 Description: Binary Search Tree that uses an AVL tree search through records
 of county/state, population, and county/state name

 I certify that the code below is my own work.
```

```
 Exception(s): N/A
 */
#ifndef _BINARY_TREE_H_
#define _BINARY_TREE_H_
#include <iostream>
#include <list>
#include <iterator>
#include "Entry.h"

using namespace std;

class BinaryTree {
protected:
	struct Node {
		Entry element;
		int height;
		Node *parent;
		Node *left;
		Node *right;
		Node()
		{
			parent = nullptr;
			left = nullptr;
			right = nullptr;
			height = 0;
		}
	};
	// POSITION CLASS (NESTED CLASS)
public:
	class Position {
	private:
		Node *curNode;
	public:
		Position()
		{
			curNode = nullptr;
		}
		Position(Node *passedNode)
		{
			curNode = passedNode;
		}
		void addElement(Entry data)
		{
			curNode->element = data;
		}
		Entry& operator*()
		{
			return curNode->element;
		}
		Position left() const
		{
			return Position(curNode->left);
		}
		Position right() const
		{
			return Position(curNode->right);
		}
		Position parent() const
```

```
		{
			return Position(curNode->parent);
		}
		void setParent(const Position &p)
		{
			curNode->parent = p.curNode;
		}
		void setRightChild(const Position &p)
		{
			curNode->right = p.curNode;
		}
		void setLeftChild(const Position &p)
		{
			curNode->left = p.curNode;
		}
		bool isRoot()
		{
			return curNode->parent == NULL;
		}
		bool isExternal() const
		{
			return ((curNode->left == NULL) && (curNode->right == NULL));
		}
		bool operator==(const Position &p)
		{
			return curNode == p.curNode;
		}
		bool operator!=(const Position &p)
		{
			return curNode != p.curNode;
		}
		int getHeight() const
		{
			return curNode->height;
		}
		void setHeight(int h)
		{
			if (h >= 0)
				curNode->height = h;
		}
		friend class BinaryTree;
	};
	typedef list<Position> PositionList;		// CREATE A LIST NAMED
POSITIONLIST TO HOLD OUR POSITIONS.

////////////////////////////////////////////////////////
//	The Binary Tree's Public and Protected Functions   //
//		the list of prototypes for all the		//
//			functions that is required		//
//			  while using the binary		//
//					tree				//
////////////////////////////////////////////////////////
public:
	BinaryTree();
	int size() const;
	Position root() const;
	PositionList positions() const;
	void addRoot();
```

```
        void setRoot(const Position & p);
        void expandExternal(const Position& p);
        Position removeAboveExternal(const Position &p);
protected:
        void inorder(Node *curNode, PositionList& pl) const;
private:
        Node *_root;
        int counter;
};
#endif // !_BINARY_TREE_H_
```

SearchTree.h

```
/*  Program: Project 4 - BST
 Author: Anthony Esmeralda, Kevin Ngo
 Class: CSCI 220
 Date:  Novemember 14, 2017
 Description: Binary Search Tree that uses an AVL tree search through records
 of county/state, population, and county/state name

 I certify that the code below is my own work.

 Exception(s): N/A
 */
#ifndef _SEARCH_TREE_H_
#define _SEARCH_TREE_H_
#include "BinaryTree.h"

class SearchTree {
private:
        BinaryTree T;
        int tSize;

//////////////////////////////////////
//      Functions that we will be able    //
//             to use outside of                //
//                 SearchTree                        //
//                     Class                              //
//////////////////////////////////////

public:
        class Iterator;
        SearchTree();
        int size() const;
        bool empty() const;
        void erase(int key);
        void erase(const Iterator &p);
        int findDepth(int key);
        Iterator find(int key);
        Iterator insert(Entry data);
        Iterator begin();
        Iterator end();

protected:
        BinaryTree::Position root() const;
        BinaryTree::Position finder(int key,BinaryTree::Position &data);
```

```
        int depth(BinaryTree::Position &data);
        BinaryTree::Position inserter(Entry data);
        BinaryTree::Position eraser(BinaryTree::Position data);
        BinaryTree::Position restructure(BinaryTree::Position x);
        void newRoot(BinaryTree::Position x);
////////////////////////////////////
//              Iterator SubClass       //
////////////////////////////////////

public:
        class Iterator {
        private:
                BinaryTree::Position data;
        public:
                Iterator(const BinaryTree::Position input)
                {
                        data = input;
                }
                const Entry operator*()
                {
                        return *data;
                }
                bool operator==(const Iterator&p)
                {
                        return data == p.data;
                }
                bool operator!=(const Iterator&p)
                {
                        return data != p.data;
                }
                Iterator& operator++()                                          // use
inorder.
                {
                        BinaryTree::Position w = data.right();
                        if (!w.isExternal())
                        {
                                do
                                {
                                        data = w;
                                        w = w.left();
                                } while (!w.isExternal());
                        }
                        else
                        {
                                w = data.parent();
                                while (data == w.right())
                                {
                                        data = w;
                                        w = w.parent();
                                }
                                data = w;
                        }
                        return *this;
                }
                friend class SearchTree;
        };
};
#endif // !_SEARCH_TREE_H
```

Entry.h

```
/*  Program: Project 4 - BST
 Author: Anthony Esmeralda, Kevin Ngo
 Class: CSCI 220
 Date:  Novemember 14, 2017
 Description: Binary Search Tree that uses an AVL tree search through records
 of county/state, population, and county/state name

 I certify that the code below is my own work.

 Exception(s): N/A
 */
#ifndef _ENTRY_H_
#define _ENTRY_H_
#include <iostream>
#include <string>
#include <iomanip>
using namespace std;

class Entry {
public:
	int county_state_code;
	string county_state_name;
	int population;
public:
	Entry();
	Entry(int code, int pop, string name);
	int getCode();
	int getPop();
	string getName();
	void setName(string name);
	void setCode(int code);
	void setPop(int pop);
	void printData();
};
#endif // !_ENTRY_H_
```

BeginProgram.h

```
#ifndef _BEGIN_PROGRAM_H
#define _BEGIN_PROGRAM_H
#include "AVLTree.h"
#include <fstream>
#include <iostream>

using namespace std;

class BeginProgram {
private:
	AVLTree oak;
	SearchTree mahogany;
	ofstream myFile;
public:
	BeginProgram();
	void start();
protected:
```

```
        void fillTree(SearchTree st, AVLTree at, string fileName);
        void stringToEntry(string s, Entry & e);
        int menu();
        void performAction(AVLTree& tree, int _case);
        void performAction(SearchTree& tree, int _case);
};
#endif // !_BEGIN_PROGRAM_H
```

Implementations:

AVLTree.cpp

```
/*  Program: Project 4 - BST
 Author: Anthony Esmeralda, Kevin Ngo
 Class: CSCI 220
 Date:  Novemember 14, 2017
 Description: Binary Search Tree that uses an AVL tree search through records
 of county/state, population, and county/state name

 I certify that the code below is my own work.

 Exception(s): N/A
 */
#include "AVLTree.h"
/*****************************************/
//     Starting by defining the utilities    //
/*****************************************/

int AVLTree::height(const TPos& pos) const
{
        if (pos.isExternal()) // If the node is equal to null, then return 0 because you
are at the end.
                return 0;
    else
        return pos.getHeight(); // Else will return the node's current height
}

// Will simply set h equal to the highest height of the left or right node
void AVLTree::setHeight(TPos pos)
{
    int heightL = height(pos.left()); // Get the left node's height
    int heightR = height(pos.right()); // Get the right node's height
    pos.setHeight(1 + max(heightL,heightR)); // set the position as the max of the two
}

// Returns true if the position's height is balanced
bool AVLTree::isBalanced(const TPos& pos) const
{
        TPos left = pos.left();
        TPos right = pos.right();
    int bal = height(left) - height(right); // Checks if the balance is over 1
        return ((bal >= -1) && (bal <= 1)); // If it is over 1 or less than 1

}

// Returns the tallest grandchild
AVLTree::TPos AVLTree::tallGrandchild(const TPos& pos) const
```

```
{
    TPos posL = pos.left();
    TPos posR = pos.right();
    if (height(posL) >= height(posR)) // If the height of the left position is greater
than the height of the right's
    {
        if (height(posL.left()) >= height(posL.right())) // Check the height of the left
position's children, if the left position's left child is greater than its right return
the left that position
            return posL.left();
        else
            return posL.right(); // Since the right child's height is greater, return the
right
    }
    else // The height of the right position is greater than the height of the left's
    {
        if (height(posR.right()) >= height(posR.left())) // If the right position's
height of the right child is greater than the left child return the right
            return posR.right();
        else // Return the left one since its greater
            return posR.left();
    }
}

// Rebalances the tree
void AVLTree::rebalance(const TPos& pos) // Will rebalance whatever position passed
{
    TPos temp = pos; // Assigns a temporary position to the passed position
       TPos whatRoot = root();
    while (temp != root()) // While temp is not the root
    {
              whatRoot = root();
        temp = temp.parent(); // Assign temp to be its parent
        setHeight(temp); // set the height of the parent
        if (!isBalanced(temp)) // If the node is unbalanced will balance it
        {
            TPos otherTemp = tallGrandchild(temp); // Sets another position as the
tallest grandchild
            temp = restructure(otherTemp); // Restructures that grandchild then assigns
the rebalanced section to temp
            setHeight(temp.left()); // Corrects the height
            setHeight(temp.right());
            setHeight(temp); // Sets temp's height
        }
    }
}

/************
 Starting by defining the public
 ************/

// Will call the constructor of SearchTree since, there is no new data type (compared to
the BST), but rather just functions in the AVLTree class
AVLTree::AVLTree() : SearchTree() {};

// Will insert an entry, then return an iterator at that position
AVLTree::Iterator AVLTree::insert(Entry& entry)
{
```

```
    TPos temp = inserter(entry); // Inserts the entry then returns that position
    setHeight(temp); // Sets the height at that position so it can be used before
rebalancing
    rebalance(temp);
    return Iterator(temp);
}

// Erases a position in the AVLTree (parameter is a key which should be a
county_state_code
void AVLTree::erase(const county_state_code& key)// Erase a key
{
    TPos temp = finder(key, root());
       if (!temp.isExternal()) // If the item is a external
       {
              TPos otherTemp = eraser(temp); // Erases the temp and returns the position
of the position for rebalance
              rebalance(otherTemp);
              cout << "Record was succesfully deleted" << endl;
       }
       else cout << "Record doesnt exists" << endl;

}
```

BinaryTree.cpp

```
/*  Program: Project 4 - BST
 Author: Anthony Esmeralda, Kevin Ngo
 Class: CSCI 220
 Date:  Novemember 14, 2017
 Description: Binary Search Tree that uses an AVL tree search through records
 of county/state, population, and county/state name

 I certify that the code below is my own work.

 Exception(s): N/A
 */
#include "BinaryTree.h"
BinaryTree::BinaryTree()
{
       _root = nullptr;
       counter = 0;
}

int BinaryTree::size() const
{
       return counter;
}

BinaryTree::Position BinaryTree::root() const
{
       return Position(_root);
}

BinaryTree::PositionList BinaryTree::positions() const
{
       PositionList pl;
       inorder(_root, pl);
```

```
	return PositionList(pl);
}

void BinaryTree::addRoot()
{
	_root = new Node;
	counter++;
}
void BinaryTree::setRoot(const Position & p)
{
	Node *temp = p.curNode;
	_root = temp;
}
BinaryTree::Position BinaryTree::removeAboveExternal(const Position & p)
{
	Node *temp = p.curNode;
	Node *par = temp->parent;
	Node *sibling;
	if (temp == par->left)
	{
		sibling = par->right;
	}
	else sibling = par->left;
	if (par == _root)
	{
		_root = sibling;
		sibling->parent = NULL;
	}
	else
	{
		Node *grandparent = par->parent;
		if (par == grandparent->left)
		{
			grandparent->left = sibling;
		}
		else grandparent->right = sibling;
		sibling->parent = grandparent;
	}
	delete temp;
	delete par;
	counter -= 2;
	return Position(sibling);
}

void BinaryTree::expandExternal(const Position &p)
{
	Node *curNode = p.curNode;
	curNode->left = new Node;
	curNode->right = new Node;
	curNode->left->parent = curNode;
	curNode->right->parent = curNode;
}

void BinaryTree::inorder(Node *curNode, PositionList &pl) const
{
	if (curNode->left != nullptr)
	{
		inorder(curNode->left, pl);
```

```
	}
	pl.push_back(Position(curNode));
	if (curNode->right != nullptr)
	{
		inorder(curNode->right, pl);
	}
}
```

SearchTree.cpp

```
/*  Program: Project 4 - BST
 Author: Anthony Esmeralda, Kevin Ngo
 Class: CSCI 220
 Date:  Novemember 14, 2017
 Description: Binary Search Tree that uses an AVL tree search through records
 of county/state, population, and county/state name

 I certify that the code below is my own work.

 Exception(s): N/A
 */
#include "SearchTree.h"
SearchTree::SearchTree()
{
	T.addRoot();
	tSize = 0;
	T.expandExternal(T.root());
}

int SearchTree::size() const
{
	return tSize;
}

bool SearchTree::empty() const
{
	return tSize == 0;
}

void SearchTree::erase(int key)
{
	BinaryTree::Position v = finder(key, root());
	if (v.isExternal())
	{
		cout << "data was not found on " << key;
	}
	else eraser(v);
}

void SearchTree::erase(const Iterator & p)
{
	eraser(p.data);
}

int SearchTree::findDepth(int key)
{
	BinaryTree::Position value = finder(key, root());
```

```
	int n = depth(value);
	return n;
}

SearchTree::Iterator SearchTree::find(int key)
{

	BinaryTree::Position value = finder(key, root());		// use the finder
function to find our position
	if (!value.isExternal())							// if
our value function is internal
	{
		return SearchTree::Iterator(value);				//
return the iterator
	}
	else return SearchTree::Iterator(root().parent());		//
else return NULL.
}

SearchTree::Iterator SearchTree::insert(Entry data)
{
	BinaryTree::Position value = inserter(data);		// use our inserter
function to input our data
	return SearchTree::Iterator(value);					//
return our iterator.
}

SearchTree::Iterator SearchTree::begin()
{
	BinaryTree::Position v = root();
	while (!v.isExternal())
	{
		v = v.left();
	}
	return Iterator(v.parent());
}

SearchTree::Iterator SearchTree::end()
{
	return Iterator(T.root());
}

BinaryTree::Position SearchTree::root() const
{
	return T.root().left();
	// since T.root() is our superroot, we go to the left to get our root.
}

BinaryTree::Position SearchTree::finder(int key,BinaryTree::Position  &data)
{
	Entry dataEntry = *data;							// grab the data's
position entry data.
	if (data.isExternal())								// check if
the data's position is external
	{
		return data;									// then it
was not found and return data position
	}
```

```
	if (key < dataEntry.county_state_code)			// if the key is less than
the data position key
	{
		return finder(key, data.left());		// recursively go to the
left until the position key == key
	}
	else if (dataEntry.county_state_code < key)		// if the key is greater
than the position key
	{
		return finder(key, data.right());		// then recursively  go to
the right until the position key == key
	}
	else return data;
}

int SearchTree::depth(BinaryTree::Position & data)
{
	int n = 1;
	while (data != root())
	{
		data = data.parent();
		n++;
	}
	return n;
}

BinaryTree::Position SearchTree::inserter(Entry data)
{
	int key = data.county_state_code;					// obtain the
key from our Entry variable data
	BinaryTree::Position value = finder(key, root());
	while (!value.isExternal())						//
while value is internal
	{
		value = finder(key, value.right());				//
find a position to place our Entry variable data
	}
	Entry temp = *value;

	T.expandExternal(value);					//
expand that position
	value.addElement(data);
	// and add the data into that position
	tSize++;
	// increase our size
	return value;
}

BinaryTree::Position SearchTree::eraser(BinaryTree::Position data)
{
	BinaryTree::Position w;
	// create a position holder (we named it w)
	if (data.left().isExternal())					//
check if our data position left is external
	{
		w = data.left();
	// if it is, then w = data.left
	}
```

```
	else if (data.right().isExternal())                                                    //
check if our data position right is external if left is not ex
	{
		w = data.right();
	// if it is, then w = data.right
	}
	else                                                    // if none of the above
	{
		w = data.right();
	// set w to data.right
		do
		{
			w = w.left();
	// keep looping left until we are at an external root (smallest right)
		} while (!w.isExternal());
		BinaryTree::Position u = w.parent();                          // set u to
be w's parent
		data.addElement(*u);                                                   // set
the position u's data to be added into data's position's data to save
	}
	tSize--;
	return T.removeAboveExternal(w);
}

BinaryTree::Position SearchTree::restructure(BinaryTree::Position x)
{
                                  // data is our x variable
	BinaryTree::Position y = x.parent();
	// parent is our y variable
	BinaryTree::Position z = y.parent();
	// grandparent is our z variable
	BinaryTree::Position a, b, c, t0, t1, t2, t3, newNode;
	if (y == z.right() && x == y.right())
	// if our tree is a single rotation case on the right side
	{
		a = z;
                        // set our a,b,c accordingly
		b = y;
		c = x;
		t0 = a.left();
                        // t0 is always a's left
		t1 = b.left();
                        // t1 is always b's left
		t2 = c.left();
                        // t2 is always c's left
		t3 = c.right();
                        // t3 is always c's right
		newNode = b;
                // set b to be our new subtree root
		newNode.setParent(z.parent());
		// set our newNode parents to be z's parent
		if (z != z.parent().left())
		// if z does not equal the parent of z's left
		{
			z.parent().setRightChild(newNode);
	// then newNode is the z's parent right child (since we are on the right side)
		}
```

```
            else z.parent().setLeftChild(newNode);
      // else then we are the left child since z was a root and the superoot's child is
on the left side
            t1.setParent(a);
                  // set t1 parents to be a
            a.setRightChild(t1);
            // and a's right child to be t1
            a.setParent(newNode);
                  // a's parent is our new Node
            c.setParent(newNode);
                  // c's parents is our new Node
            newNode.setLeftChild(a);
            // set new Nodes left child to be a
            newNode.setRightChild(c);

      }
      if (y == z.left() && x == y.left())
            // if our a tree is a single rotation case on left side
      {
            a = z;
                        // set our a,b,c accordingly
            b = y;
            c = x;
            t0 = a.right();
                        // t0 is always a's right
            t1 = b.right();
                        // t1 is always b's right
            t2 = c.right();
                        // t2 is always c's right
            t3 = c.left();
                        // t3 is always c's left
            newNode = b;
                  // b will be the new subtree root
            newNode.setParent(z.parent());
            // newNodes parent is z's parent
            if (z.parent().left() == z)
            {
                  z.parent().setLeftChild(newNode);
      // this one doesnt need a special case like in the right side case since we're
always making z's parent child left.
            }
            else z.parent().setRightChild(newNode);
            t1.setParent(a);
                  // t1's parent is a
            a.setLeftChild(t1);
                  // a left child is t1
            a.setParent(newNode);
                  // a's parent is newNode
            c.setParent(newNode);
                  // c's parent is newNode
            newNode.setRightChild(a);
            // newNode's right child is a
            newNode.setLeftChild(c);

                              // again, we do not need to set a left child since
newNode's left child is already c.
      }
      if (y == z.right() && x == y.left())
```

```
	{
		a = z;
				// set our a,b,c accordingly
		b = x;
		c = y;
		t0 = a.left();
				// t0 is always a's left
		t1 = b.left();
				// t1 is always b's right
		t2 = b.right();
				// t2 is always b's left
		t3 = c.right();
				// t3 is always c's right
		newNode = b;
			// b will be the new subtree root
		newNode.setParent(z.parent());
		// newNodes parent is z's parents
		if (z != z.parent().left())
				// check if z is a root since we're doing a right left
rotation
		{
			z.parent().setRightChild(newNode);
	// if its not, newNode will be the right child of z's parent
		}
		else z.parent().setLeftChild(newNode);
	// else it will be the new root
		t1.setParent(a);
			// t1's parent is a
		a.setRightChild(t1);
		// a's right child is t1
		t2.setParent(c);
			// t2's parent is c
		c.setLeftChild(t2);
			// c's left child is t2
		a.setParent(newNode);
			// a's parent is newNode
		c.setParent(newNode);
			// c's parent is newNode.
		newNode.setLeftChild(a);
		// newNodes left child is a
		newNode.setRightChild(c);
		// newNodes right child is b
	}

	if (y == z.left() && x == y.right())
	{
		c = z;
				// set our a,b,c accordingly
		b = x;
		a = y;
		t0 = a.left();
				// t0 is always a's left
		t1 = b.left();
				// t1 is always b's left
		t2 = b.right();
				// t2 is always b's right
		t3 = c.right();
				// t3 is always c's right
```

```
                newNode = b;
                        // b will be the new subtree root
                newNode.setParent(z.parent());
                // newNodes parent is z's parents
                if (z.parent().left() == z)
                {
                        z.parent().setLeftChild(newNode);
                // z's parent left child is our newNode
                }
                else z.parent().setRightChild(newNode);
                t1.setParent(a);
                        // t1's parent is a
                a.setRightChild(t1);
                // a's right child is t1
                t2.setParent(c);
                        // t2's parent is c;
                c.setLeftChild(t2);
                        // c's left child is t2
                a.setParent(newNode);
                        // a's parent is newNode
                c.setParent(newNode);
                        // c's parent is newNode
                newNode.setLeftChild(a);
                // newNodes left child is a
                newNode.setRightChild(c);
                // newNodes right child is c
        }
        if (z == root())
                        // if z was the root, we need to make sure to change the root
        {
                newRoot(newNode);

        }
        return newNode;
}

void SearchTree::newRoot(BinaryTree::Position x)
{
        T.setRoot(x);
}
```

Entry.cpp

```
/*  Program: Project 4 - BST
 Author: Anthony Esmeralda, Kevin Ngo
 Class: CSCI 220
 Date:  Novemember 14, 2017
 Description: Binary Search Tree that uses an AVL tree search through records
 of county/state, population, and county/state name

 I certify that the code below is my own work.

 Exception(s): N/A
 */
#include "Entry.h"
Entry::Entry()
{
```

```
	county_state_name = "";
	county_state_code = 0;
	population = 0;
}
Entry::Entry(int code, int pop, string name)
{
	county_state_name = name;
	county_state_code = code;
	population = pop;
}
int Entry::getCode()
{
	return county_state_code;
}
int Entry::getPop()
{
	return population;
}
string Entry::getName()
{
	return county_state_name;
}
void Entry::setName(string name)
{
	county_state_name = name;
}
void Entry::setCode(int code)
{
	county_state_code = code;
}
void Entry::setPop(int pop)
{
	population = pop;
}

void Entry::printData()
{
	setfill(" ");
	cout << left << setw(20) << county_state_code << setw(20) << population <<
setw(15) << left << county_state_name << right;
}
```

BeginProgram.cpp

```
#include "BeginProgram.h"

BeginProgram::BeginProgram()
{
	fillTree(mahogany, oak, "p4Large.txt");
}

void BeginProgram::start()
{
	Entry ent;
	cout << "success!\n\n";
	int option;
	char optionTwo;
```

```
	do
	{
		cout << "Select A to work with Search Tree and B to work with AVL Tree
(AVLTree will be selected if did not choose A or B): ";
		cin >> optionTwo;
		if (toupper(optionTwo) == 'A')
		{
			cout << "You are in the BST Tree\n";
			option = menu();
			if ((option != 5) && (option != 0)) // If option is 0, will just
rerun the loop, only 5 will terminate this
			{
				performAction(mahogany, option);
			}
		}
		else
		{
			cout << "You are in the AVL Tree\n";
			option = menu();
			if ((option != 5) && (option != 0)) // If option is 0, will just
rerun the loop, only 5 will terminate this
			{
				performAction(oak, option);
			}
		}
	} while (option != 5);
}
void BeginProgram::fillTree(SearchTree st, AVLTree at, string fileName)
{
	Entry E;
	string record;
	fstream infile;
	infile.open(fileName);
	if (infile.is_open())
	{
		while (!infile.eof())
		{
			getline(infile, record);
			stringToEntry(record, E);
			st.insert(E);
			at.insert(E);
		}
	}
	else
		cout << "Incorrect file name passed or does not exist.\n";
	infile.close();
}
void BeginProgram::stringToEntry(string s, Entry &e)
{
	int sSize = s.length(), lowerBound = 0, upperBound, dummyV;
	bool commaOne = false, commaTwo = false;
	string subString;
	for (int i = 0; i < sSize; i++)
	{
		if ((s[i] == ',') && (commaOne != true))
		{
			commaOne = true;
			upperBound = i;
```

```
                        subString = s.substr(lowerBound, upperBound - lowerBound);
                        lowerBound = ++upperBound;
                        dummyV = atoi(subString.c_str());
                        e.county_state_code = dummyV;
                }
                else if ((s[i] == ',') && (commaTwo != true) && (commaOne == true))
                {
                        commaTwo = true;
                        upperBound = i;
                        subString = s.substr(lowerBound, upperBound - lowerBound);
                        lowerBound = upperBound + 2;
                        dummyV = atoi(subString.c_str());
                        e.population = dummyV;
                }
                if ((s[i] == '\"') && (commaOne && commaTwo))
                {
                        upperBound = i;
                        subString = s.substr(lowerBound, upperBound - lowerBound);
                        e.county_state_name = subString;
                }
        }
}

int BeginProgram::menu()
{
        string input;
        char inputAsChar;
        cout << "1. Search for a record\n2. Insert a record\n3. Delete a record\n4. List
all records\n5. Exit\n";
        cout << "input: ";
        cin >> input;
        inputAsChar = input[0];
        switch (inputAsChar)
        {
        case '1':
                return 1;
                break;
        case '2':
                return 2;
                break;
        case '3':
                return 3;
                break;
        case '4':
                return 4;
        case '5':
                return 5;
        default:
                return 0;
        }
}
void BeginProgram::performAction(AVLTree& tree, int _case)
{
        int countySC, population;
        string name;
        if (_case == 1)
        {
                cout << "You chose to search for a record, enter a county-state-code: ";
```

```
		cin >> countySC;
		SearchTree::Iterator found = tree.find(countySC);
		Entry element = *found;
		cout << endl;
		if (element.county_state_code != 0)
		{
			cout << left << setw(20) << "county state code" << setw(20) <<
"population" << setw(20) << left << "county state name";
			cout << endl;
			cout << "-------------------------------------------------------------
-----------------\n";
			element.printData();
			cout << endl << endl;

			int runTime = tree.findDepth(countySC);
			cout << "RunTime: " << runTime << " milli-seconds" << endl;
		}
		else cout << "No data found" << endl;
		cout << endl;
	}
	if (_case == 2)
	{
		cout << "You chose to insert a record\n";
		cout << "Enter county-state-code: ";
		cin >> countySC;
		cout << "Enter population: ";
		cin >> population;
		cout << "Enter the state/county name: ";
		cin.ignore();
		getline(cin, name);
		Entry element(countySC, population, name);
		tree.insert(element);
		int runTime = tree.findDepth(countySC);
		cout << "RunTime: " << runTime << " milli-seconds" << endl;
		cout << "Succesfully entered your record\n";
	}
	if (_case == 3)
	{
		cout << "You chose to delete a record\n";
		cout << "Enter which record you would like to delete by county-state-code:
";
		cin >> countySC;
		int runTime = tree.findDepth(countySC);
		cout << endl;
		cout << "RunTime: " << runTime << " milli - seconds" << endl << endl;
		tree.erase(countySC);
	}
	if (_case == 4)
	{
		SearchTree::Iterator it(tree.begin());
		Entry output;
		setfill(" ");
		myFile.open("AVLoutput.txt");
		cout << left << setw(20) << "county state code" << setw(20) << "population"
<< setw(20) << left << "county state name" << endl;
		cout << "-------------------------------------------------------------------
----------\n";
```

```
		myFile << left << setw(20) << "county state code" << setw(20) <<
"population" << setw(20) << left << "county state name" << endl;
		myFile << "-----------------------------------------------------------------
------------\n";
		for (it; it != tree.end(); ++it)
		{
			output = *it;
			countySC = output.getCode();
			population = output.getPop();
			name = output.getName();
			cout << left << setw(20) << countySC << setw(20) << population <<
setw(15) << left << name << right << endl;
			myFile << left << setw(20) << countySC << setw(20) << population <<
setw(15) << left << name << right << endl;
		}
		myFile.close();
		cout << endl;
	}
}
void BeginProgram::performAction(SearchTree& tree, int _case)
{
	int countySC, population;
	string name;
	if (_case == 1)
	{
		cout << "You chose to search for a record, enter a county-state-code: ";
		cin >> countySC;
		SearchTree::Iterator found = tree.find(countySC);
		Entry element = *found;
		cout << endl;
		if (element.county_state_code != 0)
		{
			cout << left << setw(20) << "county state code" << setw(20) <<
"population" << setw(20) << left << "county state name";
			cout << endl;
			cout << "-----------------------------------------------------------
-----------------\n";
			element.printData();
			cout << endl << endl;

			int runTime = tree.findDepth(countySC);
			cout << "RunTime: " << runTime << " milli - seconds" << endl;
		}
		else cout << "No data found" << endl;
		cout << endl;
	}
	if (_case == 2)
	{
		cout << "You chose to insert a record\n";
		cout << "Enter county-state-code: ";
		cin >> countySC;
		cout << "Enter population: ";
		cin >> population;
		cout << "Enter the state/county name: ";
		cin.ignore();
		getline(cin, name);
		Entry element(countySC, population, name);
		tree.insert(element);
```

```
                int runTime = tree.findDepth(countySC);
                cout << "RunTime: " << runTime << " milli - seconds" << endl;
                cout << "Succesfully entered your record\n";
        }
        if (_case == 3)
        {
                cout << "You chose to delete a record\n";
                cout << "Enter which record you would like to delete by county-state-code:
";
                cin >> countySC;
                int runTime = tree.findDepth(countySC);
                cout << endl;
                cout << "RunTime: " << runTime << " milli - seconds" << endl << endl;
                tree.erase(countySC);
        }
        if (_case == 4)
        {
                SearchTree::Iterator it(tree.begin());
                Entry output;
                setfill(" ");
                cout << endl;
                myFile.open("BSToutput.txt");
                cout << left << setw(20) << "county state code" << setw(20) << "population"
<< setw(20) << left << "county state name" << endl;
                cout << "-----------------------------------------------------------------
----------\n";
                myFile << left << setw(20) << "county state code" << setw(20) <<
"population" << setw(20) << left << "county state name" << endl;
                myFile << "-----------------------------------------------------------------
-----------\n";
                for (it; it != tree.end(); ++it)
                {
                        output = *it;
                        countySC = output.getCode();
                        population = output.getPop();
                        name = output.getName();
                        cout << left << setw(20) << countySC << setw(20) << population <<
setw(15) << left << name << right << endl;
                        myFile << left << setw(20) << countySC << setw(20) << population <<
setw(15) << left << name << right << endl;
                }
                myFile.close();
                cout << endl;
        }
}
```

Driver(s):

Main.cpp

```
/*  Program: Project 4 - BST
 Author: Anthony Esmeralda, Kevin Ngo
 Class: CSCI 220
 Date:  Novemember 14, 2017
 Description: Binary Search Tree that uses an AVL tree search through records
 of county/state, population, and county/state name
```

```
 I certify that the code below is my own work.

 Exception(s): N/A
 */
#include <iostream>
#include <fstream>
#include <string>
#include "BeginProgram.h"
using namespace std;

int main()
{
    cout << "Authors: Kevin Ngo & Anthony Esmeralda\n";
    cout << "Planting the AVL/BS tree(s).....";
       BeginProgram begin;
       begin.start();
    return 0;
}
```