

CS271: DATA STRUCTURES

Instructor: Dr. Stacey Truex

Project #4

This project is meant to be completed in groups. You should work in your Unit 3 groups. Implementation solutions should be written in C++. Only one submission (the last submission uploaded to canvas) will be graded per group. Submissions should be a compressed file following the naming convention: `NAMES_cs271_project4.zip` where `NAMES` is replaced by the first initial and last name of each group member. For example, if Dr. Truex and Dr. Kahn were in a group they would submit one file titled `STruexDKahn_cs271_project4.zip`. **You will lose points if you do not follow the course naming convention.** Your .zip file should contain a *minimum* of 6 files:

1. `makefile`
2. `bst.cpp`
3. `test_bst.cpp`
4. `usecase.cpp`
5. `main.cpp`
6. `commits.pdf`: a commit history for your GitHub project

Additional files such as a `bst.h` header file or `README.md` are welcome. The above merely represent the minimum files required for project completion. Your code is expected to implement a BST class. Details for each part of the project are as follows.

Specifications

Binary Search Tree

Implement a BST template class using **two** templates - one for the data associated with each BST node and one for the key associated with each node. In your implementation, denote the data template first. Your class should, at a minimum, support the following operations:

- `empty()`: `bst.empty()` should indicate whether the binary search tree `bst` is empty. For example:

```
BST<int, string> bst;
if(bst.empty()){
    cout << "the bst is empty" << endl;
}
```

should result in the printing of the statement `"the bst is empty"`

- `insert(d, k)`: `bst.insert(d, k)` should insert a node with data `d` and key `k` into the binary search tree `bst`. For example, using `bst` from above:

```
bst.insert(271, "cs");
```

should result in a `bst` with 1 node (the root) with a key of `"cs"` and data of `271`

- `get(k)`: `bst.get(k)` should return the *data* associated with the *key* `k`. For example, using the tree `bst` from above:

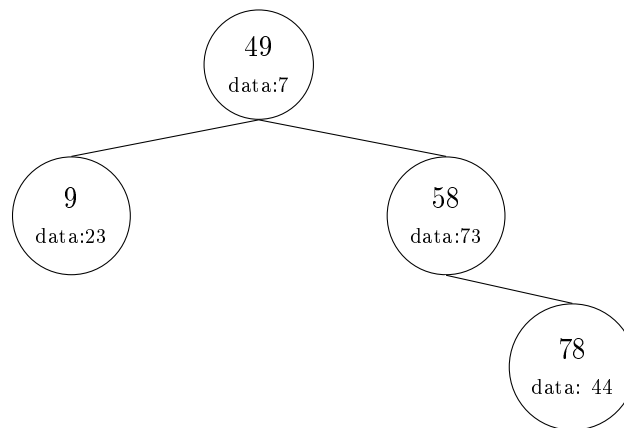
```
cout << bst.get("cs") << endl;
```

should result in the printing of the data `271`

- `remove(k)`: `bst.remove(k)` should delete the first (closest to the root) node in the tree `bst` with key `k`. For example:

```
BST<int, int> bst2;
bst2.insert(7, 49);
bst2.insert(73, 58);
bst2.insert(30, 72);
bst2.insert(44, 78);
bst2.insert(23, 9);
bst2.remove(72);
```

should result in the following BST:



- `max_data()`: `bst.max_data()` should return the *data* associated with the max *key* in the tree `bst`. For example, using `bst2` from above:

```
cout << bst2.max_data() << endl;
```

should result in the printing of the data value `44`.

- `max_key()`: `bst.max_key()` should return the *key* associated with the max *key* in the tree `bst`. For example, using `bst2` from above:

```
cout << bst2.max_key() << endl;
```

should result in the printing of the key value `78`.

- `min_data()`: `bst.min_data()` should return the *data* associated with the min *key* in the tree `bst`. For example, using `bst2` from above:

```
cout << bst2.min_data() << endl;
```

should result in the printing of the data value `23`.

- `min_key()`: `bst.min_key()` should return the *key* associated with the min *key* in the tree `bst`. For example, using `bst2` from above:

```
cout << bst2.min_key() << endl;
```

should result in the printing of the key value `9`.

- `successor(k)`: `bst.successor(k)` should return the successor *key* in the tree `bst` for the key `k` (i.e., the smallest key in `bst` that is larger than `k`) if `k` is in the tree `bst`. For example:

```
cout << bst2.successor(49) << endl;
```

should result in the printing of the key value `58` while

```
cout << bst2.successor(10) << endl;
```

should print `0` as `10` is not a key in `bst2`

- `in_order()`: `bst.in_order()` should return a **string** of the keys in `bst` in *ascending* order separated by a single space. For example, using the `bst` from above:

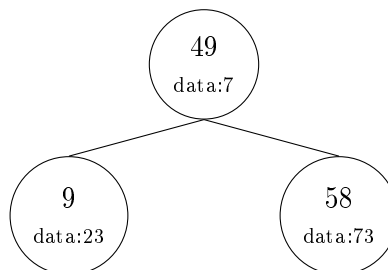
```
cout << bst2.in_order() << endl;
```

should print the string `"9 59 58 78"`

- `trim(low, high)`: `bst.trim(low, high)` should trim the binary search tree `bst` so that the keys of every node lie in the interval `[low, high]`. Trimming the tree should not change the relative structure of the elements that will remain in the tree (i.e., any node's descendant should remain a descendant). For example, using the `bst` above:

```
bst2.trim(9, 65);
```

should result in the following BST:



Unit Testing

In addition to the functionality above, you are expected to implement a `to_string()` method which returns a string with the **keys** in the BST *separated by a single space* and ordered from top (root) to bottom (leaves) and left to right. For example, using the binary search tree `bst2` generated in the above specifications:

```
cout << bst2.to_string() << endl;
```

should result in the printing of the string `"49 9 58"`. Your `to_string()` method will be required for your class to pass testing.

For each **BST** method included in your **BST** class, write a unit test method in a separate unit test file that *thoroughly* tests that method. Think, in addition to common cases: what are my boundary cases? edge cases? disallowed input? Each method should have *its own* test method.

An example test file `test_bst_example.cpp` has been provided and demonstrates (1) a general outline of what is expected in a test file and (2) a guide on how your projects will be tested after submission. The tests included in `test_bst_example.cpp` are not exhaustive. The unit testing in your `test_bst.cpp` file should be much more complete. Additionally, for grading purposes, your code will be put through significantly more thorough testing than what is represented by `test_bst_example.cpp`. Passing the tests in this example file should be viewed as a lower bound.

Documentation

The expectation of all coding assignments is that they are well-documented. This means that logic is documented with line comments and method pre- and post- conditions are properly documented immediately after the method's parameter list.

Pre-conditions and post-conditions are used to specify precisely what a method does. However, a pre-condition/post-condition specification does not indicate how that method accomplishes its task (if such commenting is necessary it should be done through line level comments). Instead, pre-conditions indicate what must be true before the method is called while the post-condition indicates what will be true when the method is finished.

Use Case

Finally, use your **BST** to solve the following problem:

You are given a csv file in which each line represents a hex, bin pair where each bin is a 4-bit binary and each hex is the corresponding 1 digit hexadecimal. Use the csv to build a **BST** using your **BST** class where each node in the tree is characterized by: (1) a key of the 4-bit binary and (2) data denoting the corresponding hexadecimal conversion. Your program should then accomplish the following:

- Ask the user for a binary value for conversion.
- Convert the binary value to the corresponding hexadecimal.
- Display the result.

Two examples might be as follows:

```
Enter binary representation for conversion:
111010100101
Hexidecimal representation of 111010100101 is EA5

Enter binary representation for conversion:
110101
Hexidecimal representation of 110101 is 35
```

The csv file for building your **BST** has been provided. Note that the binary representation provided by the user may not be in multiples of 4. In that case, pad the front of the input with additional zeros.

Your solution should be implemented in `usecase.cpp` using the following two functions:

```
BST<D, K>*create_bst(string fname)
string convert(BST<D, K>*bst, string bin)
```

where `fname` is the name of the csv file containing the binary, hexadecimal pairs. Your generated binary search tree should then be used with the `convert` function where `bst` is the tree from the `create_bst` function and `bin` is the entered binary representation you wish to convert. Your function should return the `string` corresponding to the hexadecimal conversion of this `bin` *based on the data from the csv*. Note that your use case code will only be tested when the templates are both set to `string`.

In your `main.cpp` file, your `main` function should include at least one example test case demonstrating the accuracy of your solution which allows for user input from the terminal.

Makefile

With each project you should be submitting a corresponding makefile. Once unpacking your `.zip` file, the single command `make` should create a `test` executable **and** a `usecase` executable. The command `./test` should then run all the unit tests in your `test_bst.cpp` file evaluating your `BST` class. The command `./usecase` should run the example test case in your `main.cpp` file demonstrating the accuracy of your conversion solution.

Efficiency

Each project in this course will additionally be evaluated for efficiency. Each method detailed in the `BST` class methods section of this document will be called 1 time using a very large example. The total time to execute all methods will be clocked.

Rubric

Note that any coding projects that do not compile with the provided `test_bst_example.cpp` file will be given a 0. All projects that are able to be successfully compiled will be graded using the following rubric.

C++ Implementation	does not compile: 0/40		
	40 Total Points		
	Code	Completeness met submission requirements	10 pts
		Correctness passes unit testing	17 pts
		Validation implementation deductions ex: incomplete destructor	—
	Usecase	Correctness passes unit testing	5 pts
	Efficiency	Time Test	2 pts
		encountered error - could not complete time test	0/2
		takes over 2x fastest submission	1/2
		within 2x fastest submission	2/2
		fastest submission	3/2
	Documentation	Documentation	3 pts
		extremely sparse documentation	0/3
		missing comments or pre- and post-conditions	1/3
		documentation lacks detail in areas	2/3
		detailed comments & pre- and post-conditions	3/3
	Testing	Unit tests	3 pts
		does not expand on example test file	0/3
		not all functions tested <i>or</i>	—
		testing not implemented as unit testing <i>or</i>	1/3
		no variation in templates	—
		caught some of the bugs in classmates' code	2/3
		caught most bugs in classmates' code	3/3