333 Section 6 - C++ Templates, STL and Smart Pointers

Welcome back to section! We're glad that you're here :)

C++ Templates

Exercise:

1) Templates & Things

Fill in the blanks below for the definition of a simple templated struct `Node` for a singly-linked list. The struct has two public fields: a `value`, which is a pointer of template type `T` pointing to a heap allocated payload, and a `next`, which is a pointer to another struct `Node`. The struct also has a two-argument constructor that takes a `T` pointer for `value` and another `Node<T>` pointer for `next`.

```
template <typename T>
struct Node {
  Node(T* val, Node<T>* node): value(val), next(node) {}

  ~Node() { delete value; }

  T* value;
  Node<T>* next;
};
```

Remember that struct in C++ by default has its members being public, so no need to specify the access modifiers explicitly here.

C++'s Standard Library

Exercises:

2) Standard Template Library

Complete the function `ChangeWords` below. This function has as inputs a vector of strings, and a map of <string, string> key-value pairs. The function should return a new vector<string> value (not a pointer) that is a copy of the original vector except that every string in the original vector that is found as a key in the map should be replaced by the corresponding value from that key-value pair.

Example: if vector `words` is `{"the", "secret", "number", "is", "xlii"}` and map `subs` is `{{"secret", "magic"}, {"xlii", "42"}}`, then `ChangeWords(words, subs)` should return a new vector `{"the", "magic", "number", "is", "42"}`.

Hint: Remember that if `m` is a map, then referencing `m[k]` will insert a new key-value pair into the map if `k` is not already a key in the map. You need to be sure your code doesn't alter the map by adding any new key-value pairs. (Technical nit: `subs` is not a const parameter because you might want to use its `operator[]` in your solution, and `[]` is not a const function. It's fine to use `[]` as long as you don't actually change the contents of the map `subs`.)

Write your code below. Assume that all necessary headers have already been written for you.

```
using namespace std;
vector<string> ChangeWords(const vector<string> &words,
                           map<string,string> &subs) {

  vector<string> result;
  for (auto &word : words) {
    if (subs.find(word) != subs.end()) {
      result.push_back(subs[word]);
    } else {
      result.push_back(word);
    }
  }
  return result;

}
```

3) STL Debugging

Here is a little program that has a small class Thing and main function (assume that necessary #includes and using namespace std; are included).

```
class Thing {
 public:
  Thing(int n): n_(n) { }
  int getThing() const { return n_; }
  void setThing(int n) { n_ = n; }
 private:
  int n_;
};

int main() {
  Thing t(17);
  vector<Thing> v;
  v.push_back(t);
}
```

This code compiled and worked as expected, but then we added the following two lines of code (plus the appropriate `#include <set>`):

```
  set<Thing> s;
  s.insert(t);
```

The second line (`s.insert(t)`) failed to compile and produced dozens of spectacular compiler error messages, all of which looked more-or-less like this (edited to save space):

```
In file included from string:48:0, from bits/locale_classes.h:40, from
bits/ios_base.h:41,from ios:42,from ostream:38, from /iostream:39,from
thing.cc:3: bits/stl_function.h: In instantiation of 'bool
std::less<_Tp>::operator()(const _Tp&, const _Tp&) const [with _Tp =
Thing]': <<many similar lines omitted>> thing.cc:37:13: required from here
bits/stl_function.h:
387:20: error: no match for 'operator<' (operand types are 'const Thing'
and 'const Thing') { return __x < __y; }
```

What on earth is wrong? Somehow class Thing doesn't work with set<Thing> even though insert is the correct function to use here. (a) What is the most likely reason, and (b) what would be needed to fix the problem? (Be brief but precise – you don't need to write code in your answer, but you can if that helps make your explanation clear.)

STL has to compare them using operator<. Add an appropriate operator< as either a member function in Thing, or as a free-standing function that compares two Thing& parameters.

C++ Smart Pointers

C++'s smart pointers can be used to automatically manage memory if used properly.

- ***std::unique_ptr*** – `.get()`, `.release()`, `.reset()`
- ***std::shared_ptr*** – `.get()`, `.use_count()`, `.unique()`
- ***std::weak_ptr*** – `.lock()`, `.use_count()`, `.expired()`

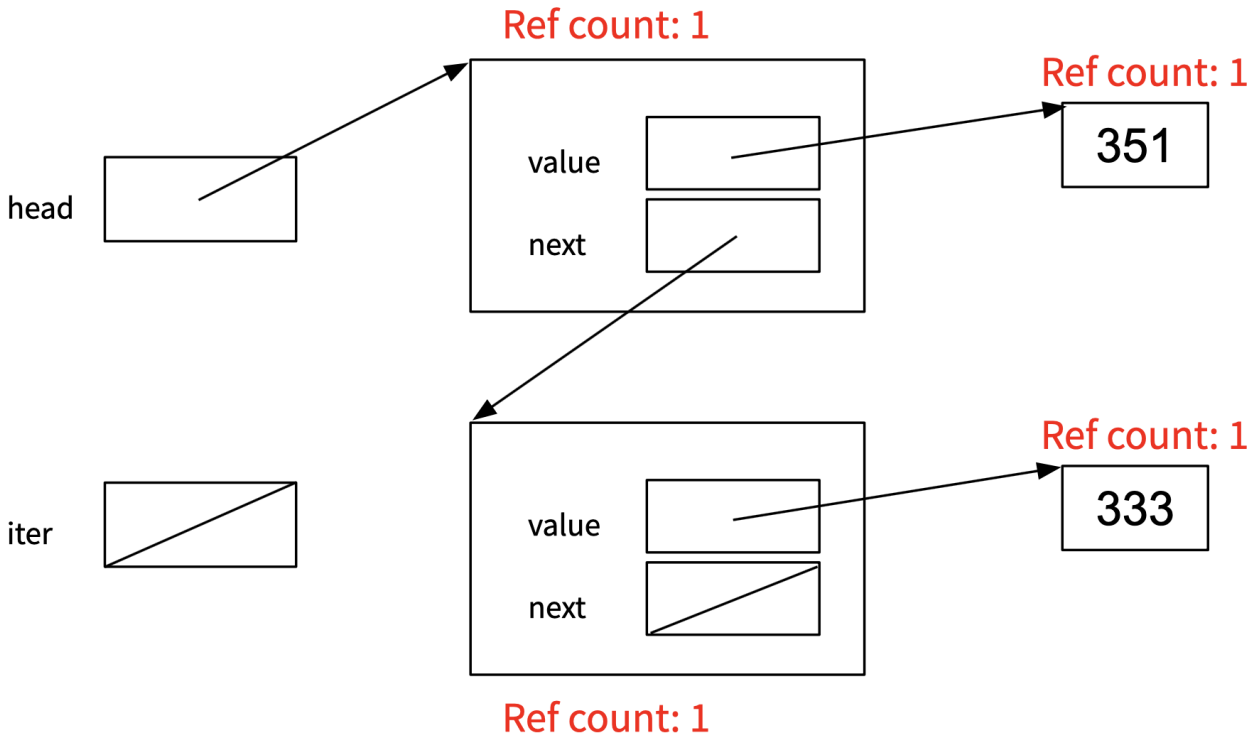
4) "Smart" LinkedList

Consider the `Node` struct that you completed in Exercise 1 below. Convert the `Node` struct to be "smart" by using `shared_ptr`s.

```
#include <memory>
using std::shared_ptr;

template <typename T>
struct Node {
  Node(T* val, Node<T>* node): value(shared_ptr<T>(val)),
                               next(shared_ptr<Node<T>>(node)) {}

  ~Node() { delete value; }

  shared_ptr<T> value;
  shared_ptr<Node<T>> next;
};
```

After the conversion, we should be able to get rid of the destructor and the following program that uses this `Node` struct should have no memory leak. (Note that we never called `delete` ourselves!)

```
#include <iostream>

using std::cout;
using std::endl;

int main() {
  shared_ptr<Node<int>> head =
                       shared_ptr<Node<int>>(new Node<int>(new int(351),
                 nullptr));
  head->next = shared_ptr<Node<int>>(new Node<int>(new int(333), nullptr));
  shared_ptr<Node<int>> iter = head;
  while (iter != nullptr) {
    cout << *(iter->value) << endl;
    iter = iter->next;
  }
}
```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Ref count: 1
351
head
value
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333
value
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