CSE 333 Section 6

Templates, STL and Smart Pointers

Administrivia

Midterm Not-An-Exam	Due Friday 11:59pm
Exercise 8	Due Monday 11am

Templates

- C++ syntax to generate code that works with *generic types*
- Generates a new implementation in assembly for every type it is used with:
  - *e.g.*, calls to `foo<int>()` and `foo<double>()` generate two implementations
  - *e.g.*, calls to `foo<int>()` and another `foo<int>()` require only one implementation
  - *e.g.*, if `foo` is never used, zero implementations are generated

Template Function

```
template<typename T>
T add3(T arg) {
    T result = arg + 3;
    return result;
}
```

Results?

```
add3<int>(3);           // uses add3<int>, returns 6
add3(5.5);
add3<char*>("a str");
add3<string>("a str");
```

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add3<int>(3);           // uses add3<int>, returns 6
add3(5.5);              // uses add3<double>, returns 8.5
add3<char*>("a str");
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add3<char*>("a str");   // uses add3<char*>, return ->"tr"
add3<string>("a str");
```

Template Function

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Results?

```
add3<int>(3);           // uses add3<int>, returns 6
add3(5.5);              // uses add3<double>, returns 8.5
add3<char*>("a str");   // uses add3<char*>, return ->"tr"
add3<string>("a str"); // Compiler error! No `+` for string
                        //                 and num
```

Template Class

- A member variable of a template class can be declared using one of the class' template types
  - Very useful for implementing data structures that support *generic types*:

```
template<typename K, typename V>
struct HTKeyValue {
  K HTKey;
  V* HTValue;
};
```

```
typedef uint64_t HTKey_t;
typedef void*    HTValue_t;
typedef struct {
  HTKey_t   key;
  HTValue_t value;
} HTKeyValue_t;
```

Exercise 1

Exercise 1 Solution

```
_______________                 // template type definition
struct Node {
  _______________               // two-argument constructor

  ~Node() { delete value; }     // destructor cleans up the payload

  _______________               // public field value
  _______________               // public field next
};
```

Exercise 1 Solution

```
template <typename T>          // template type definition
struct Node {
  ______________              // two-argument constructor

  ~Node() { delete value; }   // destructor cleans up the payload

  ______________              // public field value
  ______________              // public field next
};
```

Exercise 1 Solution

```
template <typename T>          // template type definition
struct Node {
  ______________              // two-argument constructor

  ~Node() { delete value; }   // destructor cleans up the payload

  T* value                    // public field value
  Node<T>* next               // public field next
};
```

Exercise 1 Solution

```
template <typename T>          // template type definition
struct Node {
  Node(T* val, Node<T>* node): value(val), next(node) {}
                              // two-argument constructor

  ~Node() { delete value; }   // destructor cleans up the payload

  T* value                    // public field value
  Node<T>* next               // public field next
};
```

C++ standard lib is built around templates

- *Containers* store data using various underlying data structures
  - The specifics of the data structures define properties and operations for the container
- *Iterators* allow you to traverse container data
  - Iterators form the common interface to containers
  - Different flavors based on underlying data structure
- *Algorithms* perform common, useful operations on containers
  - Use the common interface of iterators, but different algorithms require different ‘complexities’ of iterators

Common C++ STL Containers (and Java equiv)

- *Sequence* containers can be accessed sequentially
  - **`vector<Item>`** uses a dynamically-sized contiguous array (like `ArrayList`)
  - **`list<Item>`** uses a doubly-linked list (like `LinkedList`)
- *Associative* containers use search trees and are sorted by keys
  - **`set<Key>`** only stores keys (like `TreeSet`)
  - **`map<Key,Value>`** stores key-value `pair<>`'s (like `TreeMap`)
- *Unordered associative* containers are hashed
  - **`unordered_map<Key,Value>`** (like `HashMap`)

Common C++ STL Methods

	vector	list	set	map	unordered_map
`.size()` // get number of elements					
`.push_back()` // add element to back `.pop_back()` // remove back element					
`.push_front()` // add element to front `.pop_front()` // remove front element					
`.operator[]()` // random access element					
`.insert()` // insert key					
`.find()` // find key					

Common C++ STL Methods

	vector	list	set	map	unordered_map
`.size()` // get number of elements	✔	✔	✔	✔	✔
`.push_back()` // add element to back `.pop_back()` // remove back element	✔	✔			
`.push_front()` // add element to front `.pop_front()` // remove front element		✔			
`.operator[]()` // random access element	✔			✔	✔
`.insert()` // insert key			✔	✔	✔
`.find()` // find key			✔	✔	✔

Common STL Containers

Many more containers and methods!

See full documentation here:
http://www.cplusplus.com/reference/stl

Exercise 2

Exercise 2 Solution

```
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;
}
```

Smart Pointers

- `std::unique_ptr`
  - Unique owner of the managed raw pointer – disabled cctor and op=
  - Used when you want to declare unique ownership of a pointer
- `std::shared_ptr`
  - Similar to `unique_ptr` but can be copied (via cctor or op=),
    uses reference counting to decide when to call delete on managed raw pointer
  - Most commonly used type of smart pointer in practice
- `std::weak_ptr`
  - Similar to `weak_ptr` but does not contribute to reference count
  - Almost always used with `shared_ptr`

Smart Pointer Usage

- Main/typical usage:
  - Call ctor with `new` keyword or existing smart pointer (*e.g.*, `unique_ptr<int[]> uptr(new int[3])`)
  - Treat like a normal pointer (*i.e.*, use `*`, `->`, `[]`)
- Other methods that may be useful in *some* cases:
  - **`unique_ptr`** – `.get()`, `.release()`, `.reset()`
  - **`shared_ptr`** – `.get()`, `.use_count()`, `.unique()`
  - **`weak_ptr`** – `.lock()`, `.use_count()`, `.expired()`

Smart Pointers Operations

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

Takeaway:

- These operations exist and can be useful in *some* cases. But most of the time in practice, you would use smart pointers just as if they were normal pointers!

Exercise 4

Exercise 4 Solution

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

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

  ~Node() { delete value; }

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

Exercise 4 Solution

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

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

  ~Node() { delete value; }

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

Exercise 4 Solution

```
#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;
};
```

Exercise 4 Solution

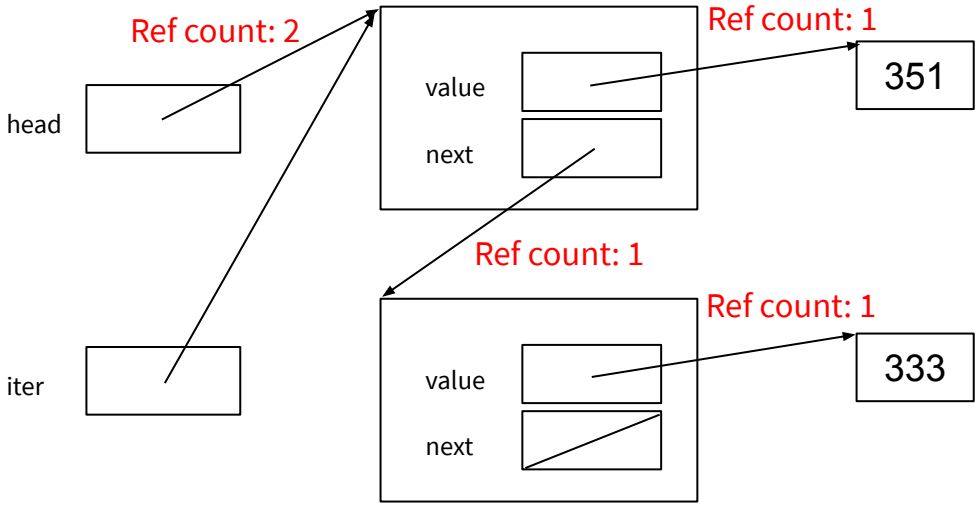
```
#include <memory>
using std::shared_ptr;

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;
};
```

Exercise 4 Solution




```
#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;
  }
}
```