CSC212

Data Structure

COMPUTER SCIENCE
CITY COLLEGE OF NEW YORK

Lecture 9

Templates, Iterators and STL

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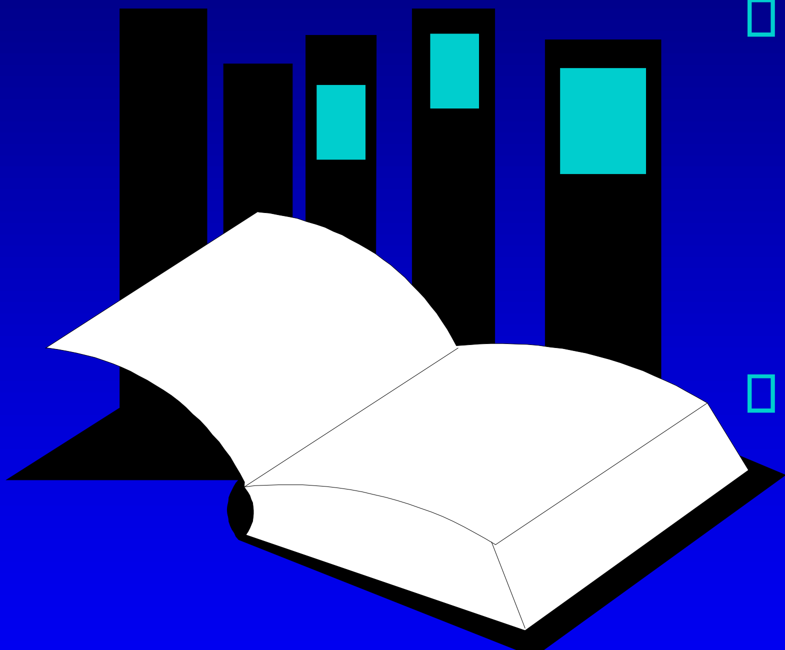
Topics

- Template Functions and Template Classes
  - for code that is meant be reused in a variety of settings in a single program
- Iterators
  - step through all items of a container in a standard manner
- Standard Template Library (STL)
  - the ANSI/ISO C++ Standard provides a variety of container classes in the STL

Template Functions



- Chapter 6 introduces templates, which are a C++ feature that easily permits the reuse of existing code for new purposes.
- This presentation shows how to implement and use the simplest kinds of templates: template functions.

CHAPTER 6

Data Structures and Other Objects

Finding the Maximum of Two Integers

- Here’s a small function that you might write to find the maximum of two integers.

```
int maximum(int a, int b)
{
    if (a > b)
        return a;
    else
        return b;
}
```

Finding the Maximum of Two Doubles

- Here's a small function that you might write to find the maximum of two double numbers.

```
double maximum(double a, double b)
{
    if (a > b)
        return a;
    else
        return b;
}
```

Finding the Maximum of Two Gongfus

- Here's a small function that you might write to find the maximum of two Gongfus.

```
Gongfu maximum(Gongfu a, Gongfu b)
{
    if (a > b)
        return a;
    else
        return b;
}
```

Gong Fu

(Kung Fu)

Martial Arts

Finding the Maximum of Two ...

- Here's a small function that you might write to find the maximum of two ...using typedef

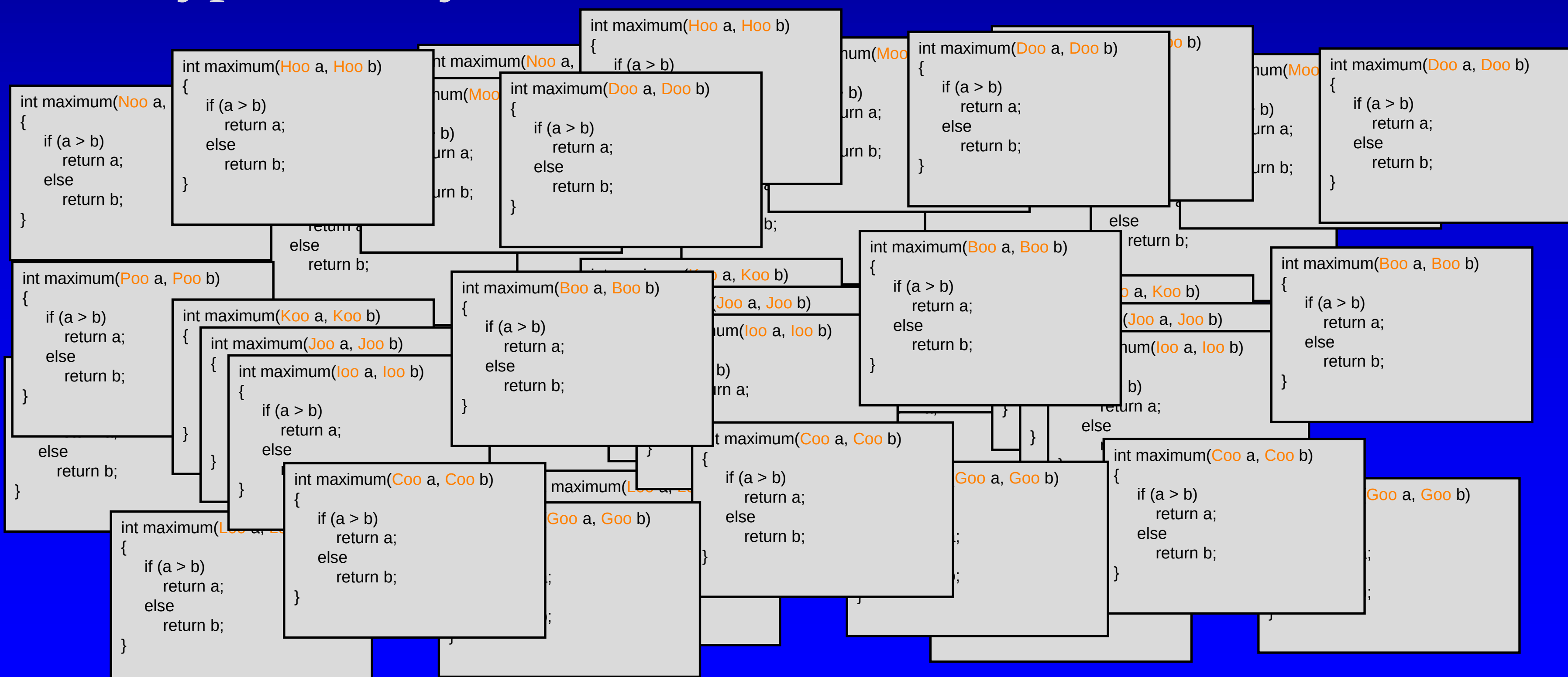
```
typedef ..int.... data_type

data_type maximum(data_type a, data_type b)
{
    if (a > b)
        return a;
    else
        return b;
}
```

But you need to re-compile your program every time you change the data_type, and you still only have one kind of data type

One Hundred Million Functions...

- Suppose your program uses 100,000,000 different data types, and you need a maximum function for each...



A Template Function for Maximum

- This template function can be used with many data types.

```
template <class Item>
Item maximum(Item a, Item b)
{
    if (a > b)
        return a;
    else
        return b;
}
```

Item:

Underlying data type, template parameter

With two features...

A Template Function for Maximum

- When you write a template function, you choose a data type for the function to depend upon...

```
template <class Item>
Item maximum(Item a, Item b)
{
    if (a > b)
        return a;
    else
        return b;
}
```

A Template Function for Maximum

- A template prefix is also needed immediately before the function's implementation:

```
template <class Item>
Item maximum(Item a, Item b)
{
    if (a > b)
        return a;
    else
        return b;
}
```

Using a Template Function

- Once a template function is defined, it may be used with any adequate data type in your program...

```
template <class Item>
Item maximum(Item a, Item b)
{
    if (a > b)
        return a;
    else
        return b;
}
```

```
cout << maximum(1,2);
cout << maximum(1.3, 0.9);
...
```

What's behind the scene?

Finding the Maximum Item in an Array

- Here's another function that can be made more general by changing it to a template function:

```
int array_max(int data[  ], size_t n)
{
    size_t i;
    int answer;

    assert(n > 0);
    answer = data[0];
    for (i = 1; i < n; i++)
        if (data[i] > answer) answer = data[i];
    return answer;
}
```

Finding the Maximum Item in an Array

- Here's the template function:

```
template <class Item>
Item array_max(Item data[  ], size_t n)
{
    size_t i;
    Item answer;

    assert(n > 0);
    answer = data[0];
    for (i = 1; i < n; i++)
        if (data[i] > answer) answer = data[i];
    return answer;
}
```

Template Functions: a summary

- A template function depends on an underlying data type – the template parameter.
- More complex template functions and template classes are discussed in Chapter 6.

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Template Classes

- How to turn our node class into node template class
  - template <class Item> precedes the node class definition
  - value_type -> Item
  - Outside the template class definition
    - template prefix precedes each function prototype and implementation
    - node -> node <Item>
- Exercise: Turn node into node template class
  - handout node1 ....then node2

Template Classes

node template class

- How to turn our node class into node template class (continued)
  - The implementation file name with .template extension (instead of .cpp) – cannot be compiled!
  - it should be included in the header by
    - #include “node2.template”
  - eliminate any using directives in the implementation file, so you must write
    - std::size_t, std::copy, etc.
  - More changes ... please read Chapter 6

Template Classes

- How to use it ?

```
node<int>* ages = NULL;
list_head_insert(ages,18);
node<string> name;
name.set_data("Jorge");
node<point> *seat;
seat = new node<point>;
(*seat).set_data(point(2,4));
```

All you need to know about Templates

- Template Function
  - a template prefix before the function implementation
  - template <class Item1, class Item2, ...>
- Function Prototype
  - a template prefix before the function prototypes
- Template Class
  - a template prefix right before the class definition
- Instantiation
  - template functions/classes are instantiated when used

Better Understanding of classes and functions

Homework

```
node<int>* ages = NULL;
list_head_insert(ages,18);
node<string> name;
name.set_data("Jorge");
node<point> *seat;
seat = new node<point>;
(*seat).set_data(point(2,4));
```

Write a small program n2demo.cpp
previous slide, make sure you have
using directives. Then print out the
and *seat.

Try to run the program with

point.h, point.cpp (online with lecture 3)

node2.h, node2.template (online today)

Note: you only need to compile point.cpp with your n2demo.cpp

Turn in n2demo.cpp and the output in paper version on Wednesday

Iterators

- We are going to see how to build an iterator for the linked list
- so that each of the containers can build its own iterator(s) easily
- A node_iterator is an object of the node_iterator class, and can step through the nodes of the linked list

Reviews:Linked Lists Traverse

- How to access the next node by using link pointer of the current node
- the special for loop still works with template

```
template <class Item>
std::size_t list_length(const node<Item>* head_ptr)
{
   const node<Item> *cursor;
   std::size_t count = 0;
   for (cursor = head_ptr; cursor != NULL; cursor = cursor->link())
          count++;
   return count;
}
```

Linked Lists Traverse using Iterators

- It would be nicer if we could use an iterator to step through a linked list following the
  [...) left-inclusive pattern

```
template <class Item>
std:: size_t list_length(const node<Item>* head_ptr)
{
   const_node_iterator<Item> start(head_ptr), finish, position;
   std:: size_t count = 0;
    for (position = start; position != finish; ++position)
              count++;
    return count;
}
```

node_iterator key points:

node template class

handout!

- derived from std::iterator (may NOT exist!)
  - node_iterator<Item> position;
- a private variable - a pointer to current node
  - node <Item>* current;
- * operator – get the current data
  - using the notation *position
- Two versions of the ++ operator
  - prefix version: ++position; postfix ver: position++
- Comparison operators == and !=
- Two versions of the node_iterator
  - node_iterator and const_node_iterator

Linked List Version the bag Template Class with an Iterator

- Most of the implementation of this new bag is a straightforward translation of the bag in Chapter 5 that used an ordinary linked list
- Two new features bag template class
  - Template class with a underlying type Item
  - iterator and const_iterator – defined from node_iterator and const_node_iterator, but use the C++ standard [...) left inclusive pattern

The C++ standard [...) pattern

- You can use an iterator to do many things!

```
bag<int> b;
bag<int>::iterator position; // this iterator class is defined in the bag class
std::size_t count =0;

b.insert(18);
...
for (position = b.begin(); position!= b.end(); ++position) // step through nodes
{
		count++;
		cout << *position << endl; // print the data in the node
}
```

Standard Template Library (STL)

- The ANSI/ISO C++ Standard provides a variety of container classes in the STL
  - set, multiset, stack, queue, string, vector
- Featured templates and iterators
- For example, the multiset template class is similar to our bag template class
- More classes summarized in Appendix H

Summary

- Five bag implementations
- *A template function* depends on a underlying data type (e.g Item) which is *instantiated* when *used*.
- A single program may has several different instantiations of a template function
- A template class depends on a underlying data type
- A iterator allows a programmer to easily step through the items of a container class
- The C++ STL container classes are all provided with iterators