Computer Science
City College of New York

CSC212
Data Structure
- Section FG

Lecture 11
Templates, Iterators and STL

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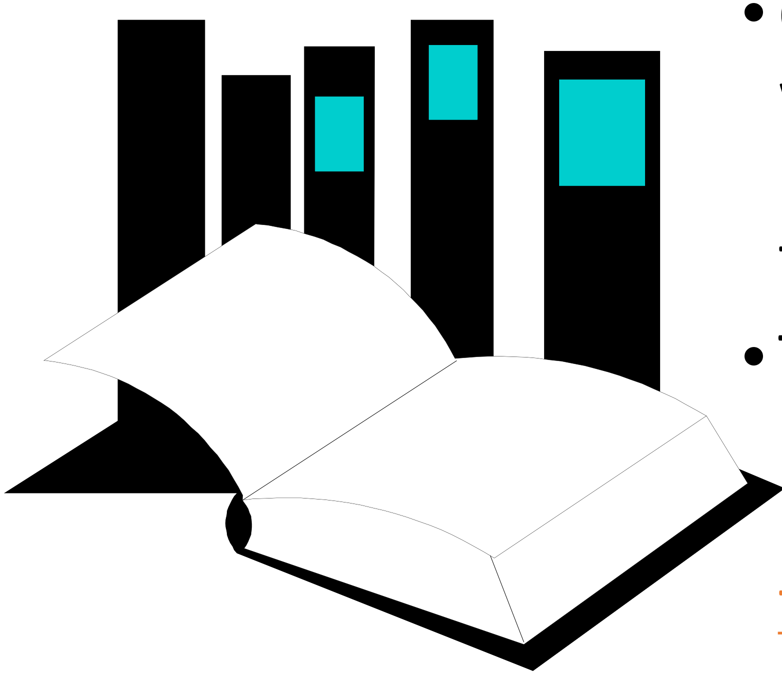
Topics

- 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

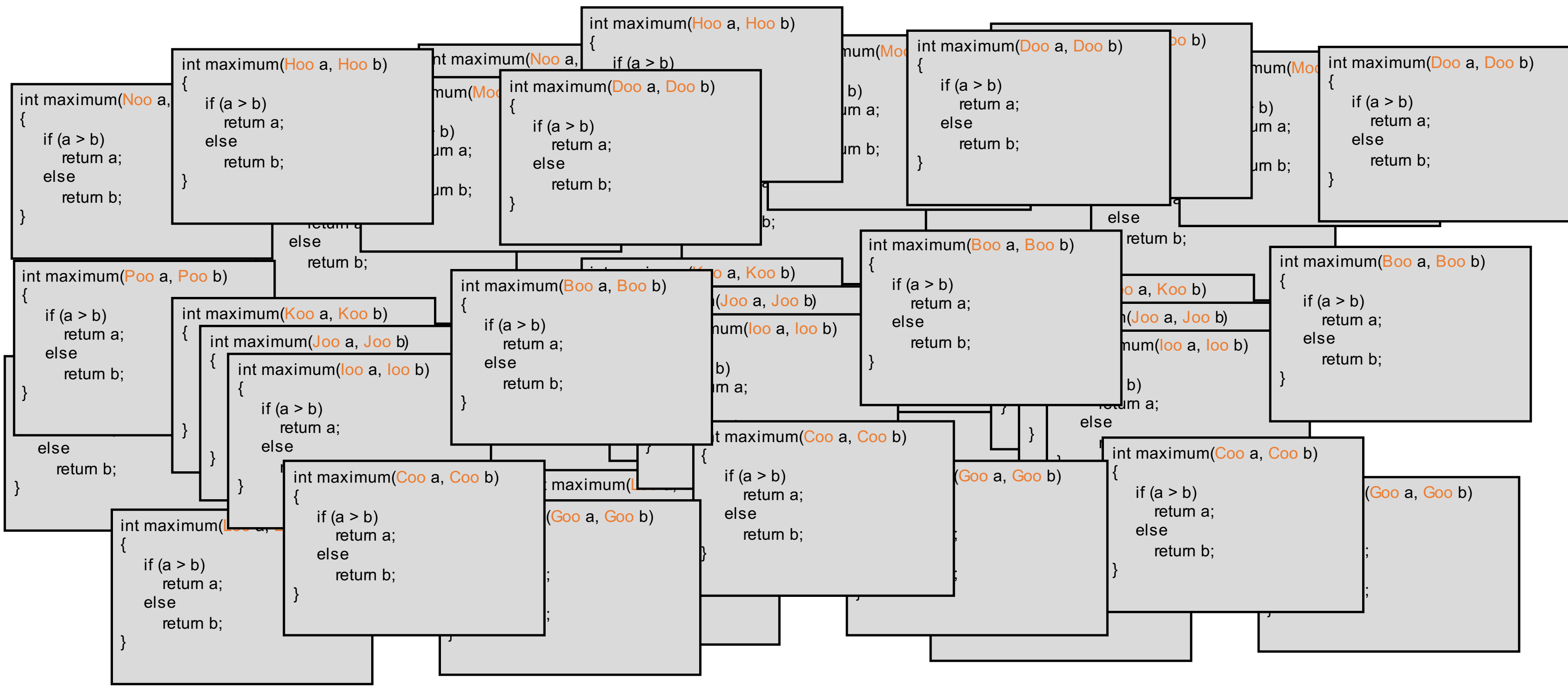
```
typedef ..int.... data_type

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.

Course Bonus and Assignment 3 Deadline

- There will be a bonus point for this course based on the improvement of the performance in the exams with the following rule:
  - Bonus = (max(0, (E3-E2))+max(0,(E2-E1)))/5 for performance increase between consecutive exams. Every 5-point increase gains 1 bonus point; no penalty if performance is decreased; but you have to take all the three exams.
- Due to the request of many students, the assignment 4 deadline will be 11:59pm Oct. 22 (Saturday). This is a hard deadline, however, and no submission afterward will be accepted.

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 .cxx) – 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 ?

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

Exercise

program n2demo.cxx with the lines in the previous slide, make sure you have the correct include and using directives. Then print out the data in node *ages, name and *seat.

Try to run the program with

point.h, point.cxx (online with lecture 2)

node2.h, node2.template (online today)

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

Turn in n2demo.cxx and the output(if any) in paper version on Wednesday, for the purpose of checking the usage of template class.

```
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));
```

Attendance check (1 point)

Send me an email (fhu@gradcenter.cuny.edu) listing your current expectations/comments/suggestions of this course, as one attendance (1 point of the 100 points).

- Next Class…

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
  - 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

bag template class

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