Templates I

CMSC 202

Warmup

- Define a class that represents an index out of bounds exception
  - Your class should have:
    - Data member that is the index requested
    - Data member that is the function name that throws the exception
    - Data member that is the vector/array that the index was out of bounds on

Recall…

- Polymorphism
  - "Many shapes"
- Types seen so far?
  - Ad-hoc
    - Functional overloading
  - Dynamic (true)
    - Virtual member functions, dynamic binding
- What's left?
  - Parameterized
    - Parameter-based (type based), static binding
      - Function & class-based templates

Problem?

- Common algorithms/actions for all/many types
  - Swap
  - findMax/Min/Worst/Better
  - Sort
  - search

Imagine…

```
float    max ( const float a, const float b );
int      max ( const int a, const int b );
Rational max ( const Rational& a, const Rational& b);
myType   max ( const myType& a, const myType& b);
```

Code for each looks the same…

```
if ( a < b )
   return b;
else
   return a;
```

We want to reuse this code for ALL types!

Templates

Fundamental idea

- Write one implementation
- Use for any type
- Compiler generates appropriate code

Important!

Wherever you would usually use the type of the templating object, you use T instead!

T can be any identifier you want

Syntax

```
template <class T>
retType funcName ( …, T varName, … )
{
   // some code…
}
```

Template Example

Function Template

```
template <class T>
T max ( const T& a, const T& b)
{
    if ( a < b )
        return b;
    else
        return a;
}
```

Notice how 'T' is mapped to 'int' everywhere in the function…

Compiler generates code based on the argument type

```
cout << max(4, 7) << endl;
```

Generates the following:

```
int max ( const int& a, const int& b)
{
    if ( a < b )
        return b;
    else
        return a;
}
```

A Closer Look…

Function Template

```
template <class T>
T max ( const T& a, const T& b)
{
    if ( a < b )
        return b;
    else
        return a;
}
```

- Notice
  - Types that you want to use with this function must support the operator<
  - Compiler will give you an error if this operator is not supported

New variables of type T?

- Let's think about Swap()
  - There is a templated swap() already defined for your use…
- What might it look like?

```
template <class T>
void Swap ( T& a, T& b)
{
    T temp;
    temp = a;
    a = b;
    b = temp;
}
```

Assuming the code:

```
double x = 7.0;
double y = 5.4;
Swap(x, y);
```

Compiler generates:

```
void Swap (double & a, double & b)
{
        double temp;
        temp = a;
        a = b;
        b = temp;
}
```

What's wrong here?

```
template <class T>
T max ( const T& a, const T& b)
{
   if ( a < b )
      return b;
   else
      return a;
}
```

- Assume the code:

```
char* s1 = "hello";
char* s2 = "goodbye";
cout << max( s1, s2 );
```

Compiler generates:

```
char* max ( const char*& a,
            const char*& b)
{
      if ( a < b )
            return b;
      else
            return a;
}
```

Is this what we want?

How can we fix this?

- Create an explicit version of max to handle char*'s
  - Compiler will match this version and not use the template…

```
char* max(char *a, char *b)
{
   if (strcmp(a,b) < 0)
      return b;
   else
      return a;
}
```

Compiling Templates

- First trick…
  - Since compiler generates code based on function call…
  - If you don't actually CALL a templated function, it MIGHT not get compiled!
    - Or it might only get a general syntax check without strong type-checking…
- As you create templated functions…
  - Create a "dummy" main to call the function
  - Similarly with templated classes…

Practice

- Implement a templated function that
  - Searches a vector of some type
  - Finds the minimum element
    - You may assume the operator< is defined
  - Returns that element

Challenge

- Create a templated function
  - Sorts a vector of a templated type
    - Use any style of sort you like
      - Quicksort
      - Linear
      - Insertion
      - Merge
      - Bubble
  - Assume that operator> and operator< are overloaded
    - (so that you can use either…)
  - Try and do it in the fewest lines of code!