C++ TEMPLATES

Problem Solving with Computers-II

Announcements

- Pa02 released!
  - Its about implementing a BST with a movie data set, collecting and analyzing running time!
  - Part of the assignment involves writing a report, explaining the trends in your data
  - Due 06/06
  - Start early!
- Midterm grades released!
  - Max: 55/50 (5 students)
  - Median: 90%
  - Mean: 88%

Finding the Maximum of Two Integers

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

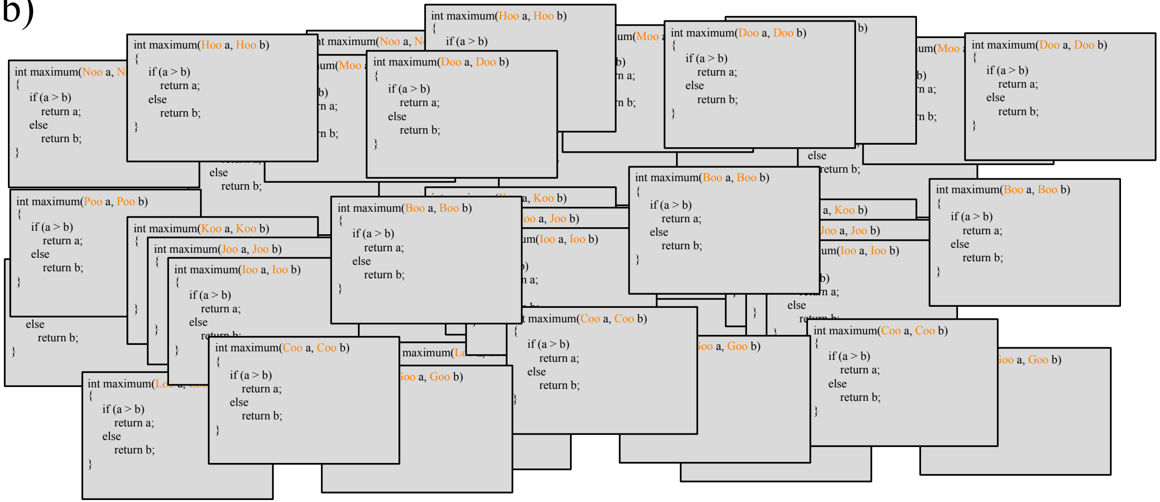
```
int maximum(int a, int b)
{
    if (a > b)
        return a;
    else
        return b;
}
```

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

One Hundred Million Functions...

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

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



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;
}
```

type

generic Blueprint of the maximum function

int a = 10, b = 20;
maximum (a, b);
string x = "apple", y = "banana";
maximum (x, y);

The compiler creates actual instances of maximum depending on the parameters passed to the function when it's called

BST, without templates:

```
class BSTNode {
public:
  BSTNode* left;
  BSTNode* right;
  BSTNode* parent;
  int const data;

  BSTNode( const int& d ) :
     data(d) {
    left = right
         = parent = nullptr;
  }

};
```

BST, with templates:

```
template<class Data>
class BSTNode {
public:
  BSTNode<Data>* left;
  BSTNode<Data>* right;
  BSTNode<Data>* parent;
  Data const data;

  BSTNode( const Data & d ) :
     data(d) {
    left = right
         = parent = nullptr;
  }

};
```

Now that BSTNode uses templates, we need to specify the template parameter when declared objects or pointers of type BSTNode

e.g. previously (without templates) to create a stack object of type BSTNode, we would write the following declaration

```
BSTNode n;
```

This is no longer a valid declaration. Instead we need to specify the template parameter as follows

```
BSTNode <int> n;
```

Similarly the declaration to create a pointer to a BSTNode is:

```
BSTNode<int>* p;
```

If we are creating an object of type BSTNode within another function or class that uses templates we may use the template parameter of that function /class

e.g.

```
template <class T>
void foo (T t) {
    BSTNode <T> b;

}
```

In this case the template parameter T is determined when we call the function foo

```
int x=5;
foo(x);
```

BST, with templates:

```
template<class Data>
class BSTNode {
public:
  BSTNode<Data>* left;
  BSTNode<Data>* right;
  BSTNode<Data>* parent;
  Data const data;

  BSTNode( const Data & d ) :
     data(d) {
    left = right = parent = nullptr ;
  }

};
```

How would you create **a BSTNode object** on the runtime stack?

A. BSTNode n(10);
B. BSTNode<int> n;
C. BSTNode<int> n(10);
D. BSTNode<int> n = new BSTNode<int>(10);
E. More than one of these will work

{ } syntax OK too

BST, with templates:

```
template<class Data>
class BSTNode {
public:
  BSTNode<Data>* left;
  BSTNode<Data>* right;
  BSTNode<Data>* parent;
  Data const data;

  BSTNode( const Data & d ) :
      data(d) {
    left = right = parent = nullptr ;
  }

};
```

How would you create a **pointer** to BSTNode with integer data?

A. BSTNode* nodePtr;
B. BSTNode<int> nodePtr;
C. BSTNode<int>* nodePtr;

BST, with templates:

```
template<class Data>
class BSTNode {
public:
  BSTNode<Data>* left;
  BSTNode<Data>* right;
  BSTNode<Data>* parent;
  Data const data;

  BSTNode( const Data & d ) :
     data(d) {
    left = right = parent = nullptr ;
  }

};
```

Complete the line of code to create a new BSTNode object with int data on the heap and assign nodePtr to point to it.

```
BSTNode<int>* nodePtr ;
```

nodePtr = new BSTNode<int>(10);

Working with a BST

```
template<typename Data>
class BST {

private:
  BSTNode<Data>* root;  //Pointer to the root of this BS

public:
  /** Default constructor. Initialize an empty BST. */
  BST() : root(nullptr){  }

  void insertAsLeftChild(BSTNode<Data>* parent, const Data& item){
     // Your code here



  }
```

Working with a BST: Insert

```
//Assume this is inside the definition of the class
void insertAsLeftChild(BSTNode<Data>* parent, const Data& item)
  {
     // Your code here
  }
```

Which line of code correctly inserts the data item into the BST as the left child of the parent parameter.

```
A.parent.left = item;
B.parent->left = item;
C.parent->left = BSTNode(item);
D.parent->left = new BSTNode<Data>(item);
E.parent->left = new Data(item);
```

Working with a BST: Insert

```
void insertAsLeftChild(BSTNode<Data>* parent, const Data& item) {
    parent->left = new BSTNode<Data>(item);
    parent->left->parent = parent;
}
```

Is this function complete? (i.e. does it do everything it needs to correctly insert the node?)

A. Yes. The function correctly inserts the data
B. No. There is something missing.

Need to update the parent pointer as shown

What is difference between templates and typedefs?

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

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

Demo maximum.cpp

Template classes: Non-member functions

```
BST operator+(const BST& b1, const BST&b2);
```

```
template <class T>
BST<T> operator+(const BST<T>& b1, const BST<T>&b2);
```

Template classes: Member function definition

For the compiler a name used in a template declaration or definition and that is dependent on a template-parameter is assumed not to name a type *unless* its preceded by a typename

```
template<class T>
class BST{
    //Other code
    Node* getNodeFor(T value, Node* n) const;
};
```

The correct way of defining this function outside the class definition is

```
template <class T>
typename BST<T>::Node * getNodeFor (T value, Node* n) const
{}
```

Template classes: Including the implementation

```
//In bst.h
class BST{
//code
};

#include "bst.cpp"
```

The include statement comes at the bottom because the class definition should precede the definition of the functions defined in bst.cpp

How to Convert a Container Class to a Template

1. The template prefix precedes each function prototype or implementation.
2. Outside the class definition, place the word `<Item>` with the class name, such as `bag<Item>`.
3. Use the name `Item` instead of `value_type`.
4. Outside of member functions and the class definition itself, add the keyword *typename* before any use of one of the class's type names. For example:

   typename `bag<Item>::size_type`
5. The implementation file name now ends with `.template` (instead of `.cxx`), and it is included in the header by an include directive.
6. Eliminate any using directives in the implementation file. Therefore, we must then write `std::` in front of any Standard Library function such as `std::copy`.
7. Some compilers require any default argument to be in both the prototype and the function implementation.

Review and demo an example