C/C++ Programming Language

CS219 Spring

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Lecture 13

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Content

- Review
- Has-a Relationship
  - Classes with Object Members (containment)
  - Private Inheritance
- Multiple Inheritance (public)
- Class Templates

Brief Review

Review

- Class Inheritance
- Static and Dynamic Binding
- Access Control: protected
- Inheritance and DMA

Reuse of Code

- Do you remember public inheritance?
- More choices?
  - Class members
    - ✓ Referred to as containment or composition or layering
  - Private or protected inheritance
    - ✓ *has-a* relationships
- Do you remember function templates?
- Class templates for reuse of code
  - A class template lets you define a class in generic terms
  - Then use the template to create specific classes defined for specific types

Classes with Object Members

Two Classes for Defining Student Class

- What is a student?
  - Someone with an identifying name and a set of quiz scores?
  - Two members: one for the name and one for the scores
- C++ string class
- The valarray Class
  - Examples of constructor

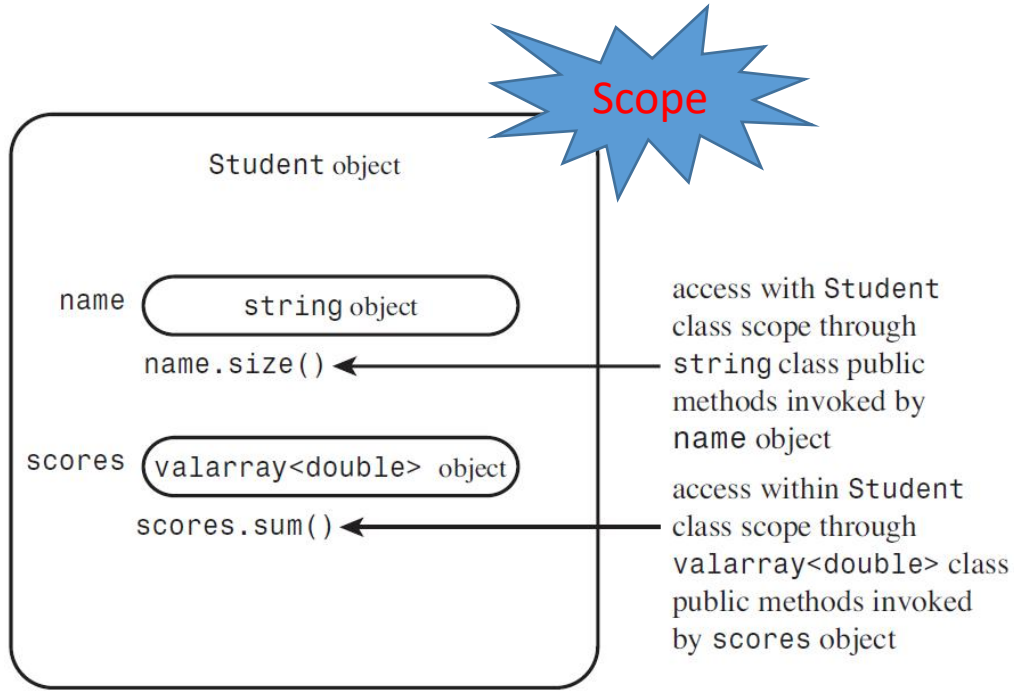
Class template

```
double gpa[5] = {3.1, 3.5, 3.8, 2.9, 3.3};
valarray<double> v1;          // an array of double, size 0
valarray<int> v2(8);          // an array of 8 int elements
valarray<int> v3(10,8);       // an array of 8 int elements,
                              // each set to 10
valarray<double> v4(gpa, 4); // an array of 4 elements
                  // initialized to the first 4 elements of gpa
```

  - A few of the methods
    - ✓ size(): return the number of elements
    - ✓ sum(): return the sum of the elements
    - ✓ max(): return the largest element
    - ✓ min(): return the smallest element
    - ✓ operator[](): provide access to individual elements

Define The Student Class

- has-a relationship
  - A student has a name,
  - A student has an array of scores
- Interfaces and implementations
  - For public inheritance (is-a), a class can inherit an implementation
  - Not inheriting the interface is part of the has-a relationship
    - ✓ Example 1: string overloads the **+ operator**, but it doesn't make sense to concatenate two Student objects
    - ✓ Example 2: can use the **operator<()** method from the string interface to sort Student objects by name




```
class Student
{
private
    string name;
    valarray<double> scores;
    …
};
```

Using the New Student Class

- Run use_stuc.cpp, studentc.cpp, studentc.h
- Some points
  - typedef enables the remaining code to use the more convenient notation
  - explicit constructors
    - ✓ With one argument, constructors serve as an implicit conversion function
    - ✓ Using explicit turns off implicit conversions
  - Initializing contained objects
    - ✓ For inherited objects, constructors use the class name in the member initializer list to invoke a specific base-class constructor
    - ✓ For member objects, constructors use the member name
  - Using an interface for a contained object
    - ✓ The interface for a contained object isn't public, but it can be used within the class
    - ✓ A friend function (access private) uses the string version of the << operator

Private Inheritance

Implementing a New has-a Relationship

- Private inheritance
  - public and protected members of the base class become **private** members of the derived class
    - ✓ Methods of base class don't become the public interface of the derived object
    - ✓ They can be used inside the member functions of the derived class
    - ✓ The derived class does not inherit the base-class interface
  - What is the difference to the public inheritance?
    - ✓ Public inheritance: inherit the base-class interface
  - What is the relationship with the containment?
    - ✓ Acquire the implementation: the same
    - ✓ Don't acquire the interface: the same

```
class Student : private std::string, private std::valarray<double>
{
public:
    ...
};
```

Initializing

- What is the difference to the containment?
  - Containment provides **explicitly named** objects as members
  - Private inheritance provides **nameless** subobjects as inherited members
- Initializing base-class components
  - Use the class name instead of a member name (containment) to identify a constructor
  - The same to public inheritance

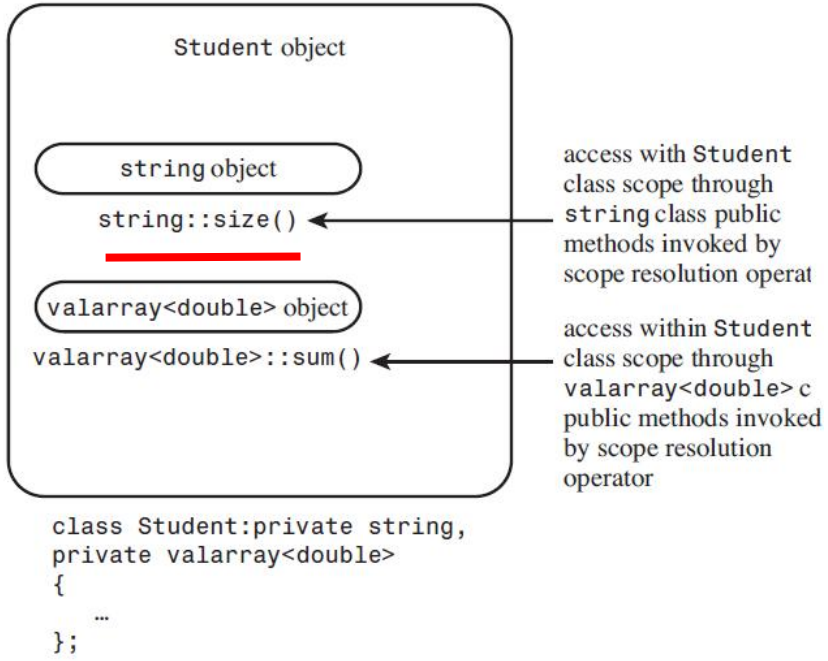
```
Student(const char * str, const double * pd, int n)
    : std::string(str), ArrayDb(pd, n) {}  // use class names for inheritance

Student(const char * str, const double * pd, int n)
    : name(str), scores(pd, n) {}      // use object names for containment
```

Accessing Base-Class Methods

- Private inheritance limits the use of base-class methods to within derived-class methods
- Inheritance lets you use the class name and the scope-resolution operator to invoke base-class methods

typedef std::valarray<double> ArrayDb;

```
double Student::Average() const
{
    if (ArrayDb::size() > 0)
        return ArrayDb::sum()/ArrayDb::size();
    else
        return 0;
}
```



More Accessing

- What if you need the base-class **object** itself?
- Accessing base-class objects

```
const string & Student::Name() const
{
    return (const string &) *this;
}
```

  - Use the **type cast** to create a reference (avoid to create a new object)
  - Return a reference to the inherited string object residing in the invoking Student object
- Accessing base-class **friends**
  - Use an explicit type cast – two reasons
  - Have a name for object
- Run studenti.cpp, studenti.h, use_stui.cpp

If implicit type cast used:

1. Leading to a recursive call
2. The class uses MI, and thus the compiler **can't tell which base class to convert**

```
ostream & operator<<(ostream & os, const Student & stu)
{
    os << "Scores for " << (const String &) stu << ":\n";
...

}
```

Which function is invoked?

Containment or Private Inheritance?

- Containment
  - Easier to follow
  - Explicitly named objects representing the contained classes
  - More than one subobject
- Inheritance
  - Appear more abstract
  - Have problems:
    - ✓ Separate base classes: have methods with the same name
    - ✓ Separate base classes: share a common ancestor
    - ✓ Limit to a single object
- Use private inheritance (benefits)
  - If new class needs to access protected members in the original class
  - If new class needs to redefine virtual functions
  - Redefined functions would be usable just within the class, not publicly

Protected Inheritance

- Protected inheritance: A variation on private inheritance
  - Public and protected members become **protected** members of the derived class
  - The interface is available to the derived class but not to the outside world (Inherit the interface?)
- Difference between private and protected inheritance
  - When derive another class from the derived class
    - ✓ With private inheritance, this third-generation class doesn't get the internal use of the base-class interface
      - Public base-class methods become private in the derived class, and private members and methods can't be directly accessed by the next level of derivation
    - ✓ With protected inheritance, public base-class methods become protected in the second generation and so are available internally to the next level of derivation

```
class Student : protected std::string,
                protected std::valarray<double>
{...};
```

Varieties of Inheritance

- Implicit upcasting means that a base-class pointer or reference can be used to refer to a derived class object without using an explicit type cast

Property	Public Inheritance	Protected Inheritance	Private Inheritance
Public members become	Public members of the derived class	Protected members of the derived class	Private members of the derived class
Protected members become	Protected members of the derived class	Protected members of the derived class	Private members of the derived class
Private members become	Accessible only through the base-class interface	Accessible only through the base-class interface	Accessible only through the base-class interface
Implicit upcasting	Yes	Yes (but only the derived class) within	No

Redefining Access with Using

- One option
  - Define a derived-class method that uses the base-class method

```
double Student::sum() const    // public Student method
{
    return std::valarray<double>::sum(); // use privately-inherited method
}
```

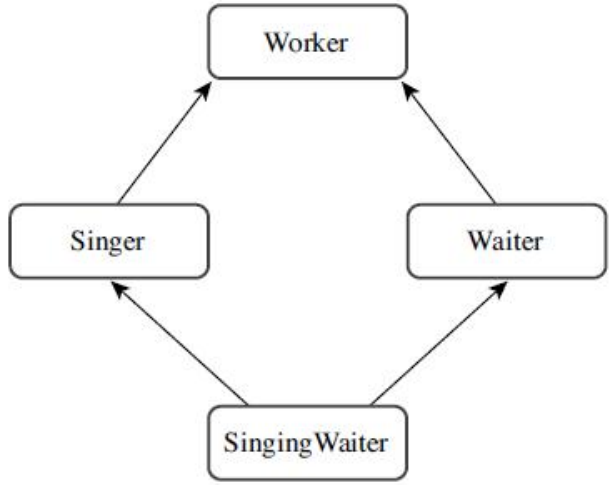
- Another: wrapping one function call in another
  - Use a using declaration
    - ✓ Announce that a particular base-class member can be used by the derived class even though the derivation is private
    - ✓ No parentheses, no function signatures, no return types

```
class Student : private std::string, private std::valarray<double>
{
...
public:
    using std::valarray<double>::min;
    using std::valarray<double>::max;
    using std::valarray<double>::operator[];
};
```

Multiple Inheritance

Multiple Inheritance (Public MI)

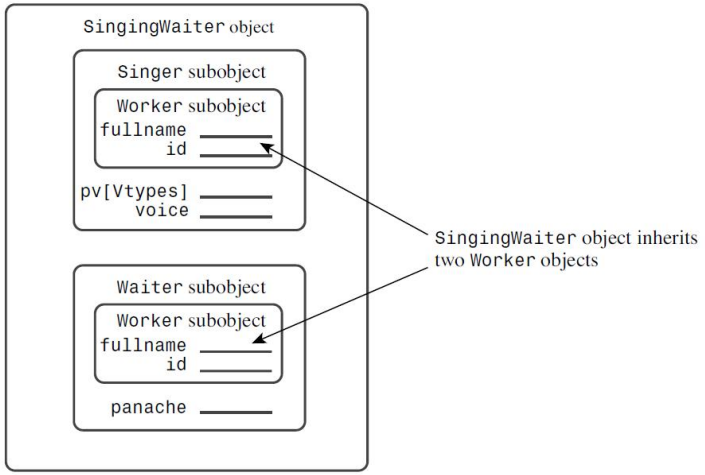
- MI describes a class that has more than one immediate base class
- An example:
  - If you have a Waiter class and a Singer class, you could derive a SingingWaiter class from the two




```
class SingingWaiter : public Waiter, public Singer {...};

class SingingWaiter : public Waiter, Singer {...}; // Singer is a private base
```

```
class Singer : public Worker { ...};
class Waiter : public Worker { ...};
class SingingWaiter : public Singer, public Waiter { ...};
```

- New problems
  - Inheriting different methods with the same name from two different base classes
  - Inheriting multiple instances of a class via two or more related immediate base classes



Class Templates

Defining a Class Template

- Reuse code
  - Inheritance (public, private or protected)
  - Containment
  - Function template
- C++'s class templates provide a better way to generate class declarations
  - Preface a template
  - Change the class **qualifier**

```
template <class Type>
template <typename Type>  // newer choice
Stack<Type>::
```

- Run stacktp.h, stacktem.cpp

```
typedef unsigned long Item;


class Stack
{
private:
    enum {MAX = 10};     // constant specific to class
    Item items[MAX];     // holds stack items
    int top;             // index for top stack item
public:
    Stack();
    bool isempty() const;
    bool isfull() const;
    // push() returns false if stack already is full, true otherwise
    bool push(const Item & item);   // add item to stack
    // pop() returns false if stack already is empty, true otherwise
    bool pop(Item & item);          // pop top into item
};
```

An Array Template Example and Non-Type Arguments

- Use a template **argument** to provide the size for a array

```
template <class T, int n>
```

  - class (typename) identifies T as a type parameter, or type argument
  - int identifies n as being an int type
  - This second parameter specifies a type instead of acting as a generic name for a type, is called a non-type, or expression, argument
  - Expression arguments have some restrictions
    - ✓ An expression can be an integer, an enumeration, a reference, or a pointer
    - ✓ double is ruled out, but double & and double * are allowed
    - ✓ Also the template code can't alter the value of the argument or take its address

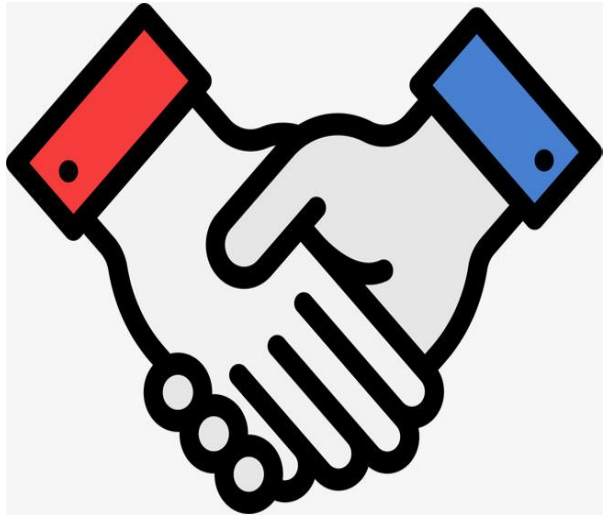
- Run arraytp.h, twod.cpp

More About the Array Template

- Drawbacks: compared to constructor approach
  - Generate multiple separate class declaration (different sizes)
  - Constructor approach is more versatile
    - ✓ The array size is stored as a class member rather than being hard-coded into the definition
- Template versatility
  - Serve as base classes
  - Can be component classes
  - Can be type arguments
    - ✓ Using a template recursively

```
ArrayTP< ArrayTP<int,5>, 10> twodee;
```

```
template <typename T>   // or <class T>
class Array
{
private:
    T entry;
    ...
};

template <typename Type>
class GrowArray : public Array<Type> {...};  // inheritance

template <typename Tp>
class Stack
{
       Array<Tp> ar;       // use an Array<> as a component
      ...
};
...
Array < Stack<int> > asi;  // an array of stacks of int
```



Thanks

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