

# C/C++ Programming Language

CS205 Spring

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Week 14



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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**

Class template

- C++ string class

- The valarray Class

- Examples of constructor

```
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
```

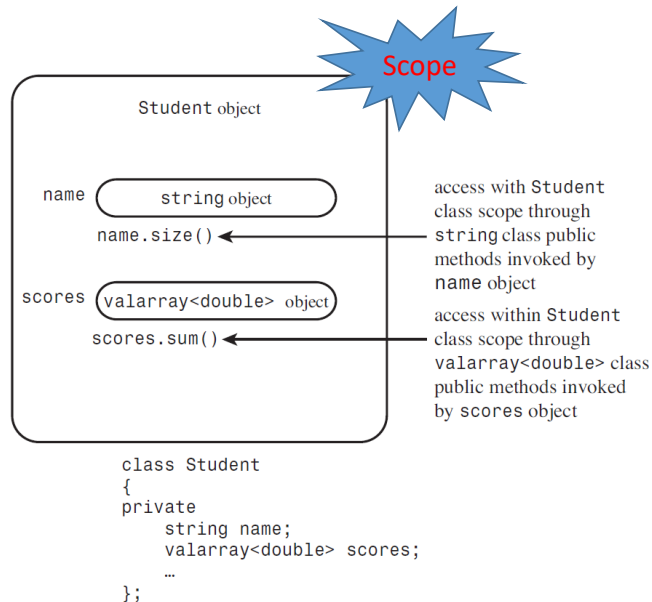
- A few of the methods

- ✓ 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







# 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
```

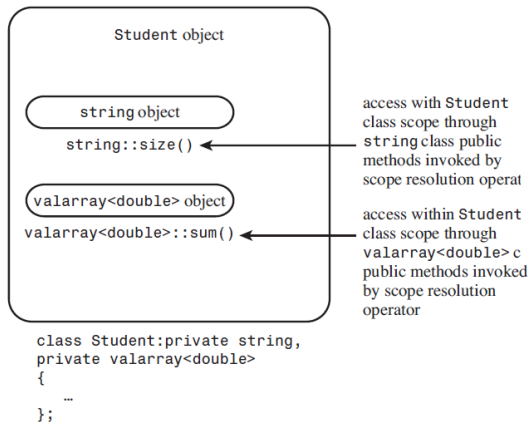
```
Student(const char * str, const double * pd, int n)
    : name(str), scores(pd, n) {}          // use object names for containment
```



# 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

```
class Student : protected std::string,  
                protected std::valarray<double>
```

- 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





# 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

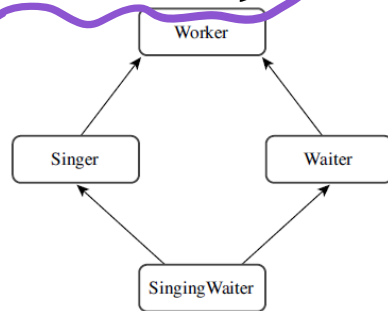


# Multiple Inheritance **Public MI**

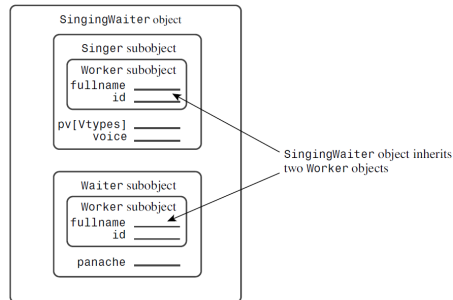
- MI describes a class that has **more than one** immediate base class
- An **example**:
  - If you have a Waiter class and a Singer class, you could derive a SingingWaiter class from the two

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

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



# 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
  - The 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**

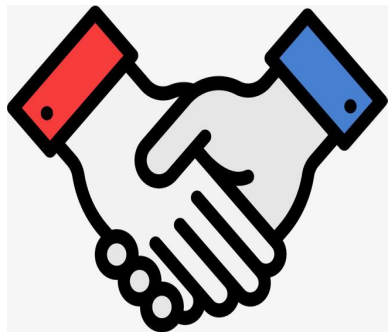
```
ArrayTP< ArrayTP<int,5>, 10> twodee;
```

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

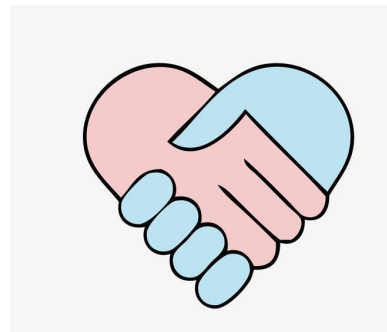
template <typename Type>
class GrowArray : public Array<Type> {...}; // inheritance

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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