Inheritance & Polymorphism

Week 7
Gaddis: Chapter 15

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Inheritance

• A way to create a new class from an existing class
• The new class is a specialized version of the existing class
• Base class (or parent) – the existing class
• Derived class (or child) – inherits from the base class

The derived class contains all the members from the base class (in addition to the ones in the derived class).

```cpp
class Student {
    . . .
};

class UnderGrad : public Student {
    . . .
};
```

Constructors and Destructors in Base and Derived Classes

• Derived classes can have their own constructors and destructors

When an object of a derived class is created,
1. the base class’s (default) constructor is executed first,
2. followed by the derived class’s constructor

When an object of a derived class is destroyed,
1. the derived class destructor is called first,
2. then the base class destructor
Constructors and Destructors:

```cpp
class BaseClass {
public:
    BaseClass() { cout << "This is the BaseClass constructor.\n"; }
~BaseClass() { cout << "This is the BaseClass destructor.\n"; }
};

class DerivedClass : public BaseClass {
public:
    DerivedClass() { cout << "This is the DerivedClass constructor.\n"; }
~DerivedClass() { cout << "This is the DerivedClass destructor.\n"; }
};

int main() {
    cout << "We will now define a DerivedClass object.\n";
    DerivedClass object;
    cout << "The program is now going to end.\n";
}
```

Output:
```
We will now define a DerivedClass object. This is the BaseClass constructor.
This is the DerivedClass constructor. The program is now going to end.
This is the DerivedClass destructor. This is the BaseClass destructor.
```

Redefining Base Class Functions

- **Redefining function**: a function in a derived class that has the same name and parameter list as a function in the base class.
- Not the same as overloading – with overloading, parameter lists must be different.
- Objects of base class use base class version of function; objects of derived class use derived class version of function.
- To call the base class version from the derived class version, you must prefix the name of the function with the base class name and the scope resolution operator:

  ```cpp
  Rectangle::display()
  ```

Passing Arguments to a non-default Base Class Constructor

- Allows programmer to choose which base class constructor is called from the derived class constructor.
- Specify arguments to base constructor in the derived constructor function header:

  ```cpp
  //assuming Square is derived from Rectangle:
  Rectangle::Rectangle(double w, double len)
  { width = w; length = len; }
  Square::Square(int side) : Rectangle(side, side)
  {  // code for Square constr goes here, if any }
  ```

  **You must** specify a call to a base class constructor if base class has no default constructor.

Redefining Base Class Functions:

```cpp
class Animal {
private:
    string species;
public:
    Animal() { species = "Animal"; }
    Animal(string spe) { species = spe; }
    void display() { cout << "species " << species; }
};

class Primate: public Animal {
private:
    int heartCham;
public:
    Primate() : Animal("Primate") { }
    Primate(int in) : Animal("Primate") { heartCham = in; }
    void display() {
        Animal::display(); //calls base class display()
        cout << ", \# of heart chambers " << heartCham; 
    }
};

int main() {
    Animal  jasper;   //  Animal()
    Primate fred(4);  //  Primate(int)
    jasper.display(); cout << endl;
    fred.display();   cout << endl;
}
```
Include Guards

- These preprocessor directives prevent the header file from accidentally being included more than once.
- If you have a base class with 2 derived classes, and the derived classes are both included in a driver...

```cpp
#ifndef RECTANGLE_H
#define RECTANGLE_H

class Rectangle
{
    private:
        double width;
        double length;
    public:
        void setWidth(double);
        void setLength(double);
        double getWidth() const;
        double getLength() const;
        double getArea() const;
};
#endif
```

Polymorphism

- The Greek word poly means many, and the Greek word morphism means form.
- So, polymorphism means 'many forms'.
- In object-oriented programming (OOP), polymorphism refers to
  - identically named (and redefined) methods
  - that have different behavior depending on the (specific derived) type of object that they are called on.

Example of polymorphism?

```cpp
class Animal {
    private:
        ...
    public:
        void speak() { cout << "none "; }
};
class Cat : public Animal {
    private:
        ...
    public:
        void speak() { cout << "meow "; }
};
class Dog : public Animal {
    private:
        ...
    public:
        void speak() { cout << "bark "; }
};

void f (Animal a) {
    a.speak();
}

int main() {
    Cat c;
    Dog d;
    f(c);
    f(d);
}
```

- IF the output is “meow bark”, yes, polymorphism.
  - The behavior of a in f would depend on its specific (derived) type.
- IF the output is “none none”, no it’s not.

Polymorphism in C++

- Polymorphism in C++ is supported through:
  - virtual methods AND
  - pointers to objects OR reference parameters.
- without these, C++ determines which method to invoke at compile time (using the variable type).
- when virtual methods and pointer/references are used together, C++ determines which method to invoke at run time (using the specific type of the instance currently referenced by the variable).
Virtual methods

- Virtual member function: function in a base class that expects to be redefined in derived class
- Function defined with key word virtual:

```cpp
virtual void Y() {...}
```

- Supports dynamic binding: functions bound at run time to function that they call
- Without virtual member functions, C++ uses static (compile time) binding

Example virtual methods

```cpp
class Animal {
public:
    virtual void speak();
    int age();
};
class Cat : public Animal {
public:
    virtual void speak(); //redefining a virtual
    int age();            //redefining a normal function
};
int main()
{
    Cat morris;
    Animal *pA = &morris; //using a pointer to get dynamic binding
    pA -> age();   // Animal::age() is invoked (base) (not virtual)
    pA -> speak(); // Cat::speak()  is invoked (derived)
...
}
```

Virtual methods

- In compile-time binding, the data type of the pointer resolves which method is invoked.
- In run-time binding, the type of the object pointed to resolves which method is invoked.

```cpp
void f (Animal &a) {
    a.speak();
}
int main() {
    Cat c;
    Dog d;
    COne c1;
    CTwo c2;
    CThree c3;
    f(c); f(d); f(c1); f(c2); f(c3);
}
```

- Assuming speak is virtual, since a is passed by reference, the output is:

```
meow bark
```

Heterogeneous Array version 1:

```cpp
class COne {
public:
    void vWhoAmI() { cout << "I am One" << endl; }
};
class CTwo : public COne {
public:
    void vWhoAmI() { cout << "I am Two" << endl; }
};
class CThree : public CTwo {
public:
    void vWhoAmI() { cout << "I am Three" << endl; }
};

int main() {
    COne *spCOne[3] = { new COne, new CTwo, new CThree);
    for (int i = 0; i < 3; i++)
        spCOne[i] -> vWhoAmI();
}
```

Output:

```
imOne
imOne
```
Heterogeneous Array version 2:

```cpp
class COne {
    public:
        virtual void vWhoAmI() { cout << "I am One" << endl; }
};
class CTwo : public COne {
    public:
        void vWhoAmI() { cout << "I am Two" << endl; }
};
class CThree : public CTwo {
    public:
        void vWhoAmI() { cout << "I am Three" << endl; }
};

int main() {
    COne *apCOne[3] = { new COne, new CTwo, new CThree };
    for (int i = 0; i < 3; i++)
        apCOne[i] -> vWhoAmI();
}
```

Output: I am One
        I am Two
        I am Three

Abstract classes and Pure virtual functions

- **Abstract base class**: a class that can have no objects (instances).
- Serves as a basis for derived classes that will have objects
- A class becomes an abstract base class when one or more of its member functions is a pure virtual function.

Example: Abstract Class

```cpp
class CShape {
    public:
        CShape ( ) { }
        virtual void vDraw ( ) const = 0; // pure virtual method
};
```

• **An abstract class may not** be used as an argument type, as a function return type, or as the type of an explicit conversion.

• Pointers and references to an abstract class may be declared.

```
CShape CShape1;  // Error: object of abstract class
CShape* pCShape; // Ok
CShape CShapeFun(); // Error: return type
void vg(CShape);   // Error: argument type
```
Example: Abstract Class

• Pure virtual functions are inherited as pure virtual functions.

```cpp
class CAbstractCircle : public CShape {
private:
    int m_iRadius;
public:
    void vRotate(int) {}
    // CAbstractCircle::vDraw() is a pure virtual function
};
```

• Or else:

```cpp
class CCircle : public CShape {
private:
    int m_iRadius;
public:
    void vRotate(int) {}
    void vDraw();  // define here or in impl file
};
```

Heterogeneous collection: abstract base class

```cpp
class Animal {
private:
    string name;
public:
    Animal(string n) {name = n;}
    virtual void speak() = 0;
};
class Cat : public Animal {
public:
    Cat(string n) : Animal(n) {};
    void speak() {cout << "meow ";}
};
class Dog : public Animal {
public:
    Dog(string n) : Animal(n) {};
    void speak() {cout << "bark ";}
};
class Pig : public Animal {
public:
    Pig(string n) : Animal(n) {};
    void speak() {cout << "oink ";}
};
```

```cpp
typedef Animal* AnimalPtr;
```

```cpp
AnimalPtr animals[ ] = {
    new Cat("Charlie"),
    new Cat("Scamp"),
    new Dog("Penny"),
    new Cat("Libby"),
    new Cat("Patches"),
    new Dog("Milo"),
    new Pig("Wilbur")
};
```

```cpp
for (int i=0; i< 7; i++) {
    animals[i]->speak();
}
```

Output:

```
meow meow bark meow meow bark oink
```

Sample Problem

Ship, CruiseShip, and CargoShip Classes: Design a Ship class that has the following members:

• A member variable for the name of the ship (a string)
• A member variable for the year the ship was built (a string)
• A constructor and appropriate accessors and mutators
• A virtual print function that displays the ship’s name and the year it was built.

Design a CruiseShip class that is derived from the Ship class. The CruiseShip class should have the following members:

• A member variable for the maximum number of passengers (an int)
• A constructor and appropriate accessors and mutators
• A print function that overrides the print function in the base class. The CruiseShip class’s print function should display only the ship’s name and the maximum number of passengers.

Design a CargoShip class that is derived from the Ship class. The CargoShip class should have the following members:

• A member variable for the cargo capacity in tonnage (an int).
• A constructor and appropriate accessors and mutators.
• A print function that overrides the print function in the base class. The CargoShip class’s print function should display only the ship’s name and the ship’s cargo capacity.

Demonstrate the classes in a program that has an array of Ship pointers. The array elements should be initialized with the addresses of dynamically allocated Ship, CruiseShip, and CargoShip objects. The program should then step through the array, calling each object’s print function.