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 {
    ...
}
```

Access to private members

```cpp
class Grade {
    private members:
    char letter;
    float score;
    void calcGrade();

    public members:
    void setScore(float);
    float getScore();
    char getLetter();
}
```

When `Test` class inherits from `Grade` class using `public` access, it looks like this:

```cpp
class Test : public Grade {
    private members:
    int numQuestions;
    float pointsEach;
    int numMissed;

    public members:
    Test(int, int);
    void setScore(float);
    float getScore();
    float getLetter();
}
```

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: example

```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.
```

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
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;
}
```

Output:

```
species Animal
species Primate,
\# of heart chambers 4
```
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) functions
  - that have different behavior depending on the (specific derived) type of object that they are called on.

```cpp
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 "; }
};
```

```cpp
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 functions AND
  - pointers to objects OR reference parameters.
- without these, C++ determines which function to invoke at compile time (using the variable type).
- when virtual functions and pointer/references are used together, C++ determines which function to invoke at run time (using the specific type of the instance currently referenced by the variable).
Virtual functions

- **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 functions

```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 functions

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

```cpp
void f (Animal &a) {
    a.speak();
}
int main() {
    Cat c;
    Dog d;
    f(c);
    f(d);
}
```

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

Output: I am One

```
```
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

- **Pure virtual function**: a virtual member function that **must** be overridden in a derived class.

  ```cpp
  virtual void Y() = 0;
  ```

- The `= 0` indicates a pure virtual function
- Must have no function definition in the base class.

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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.

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Example: Abstract Class

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

- 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.

```cpp
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;}  // CAbstractCircle ::vDraw() is a pure virtual function
        virtual void speak() = 0;
};
class Cat : public Animal {
public:
    Cat(string n) : Animal(n) { }
    void speak() {cout << "meow \n"; }
};
class Dog : public Animal {
public:
    Dog(string n) : Animal(n) { }
    void speak() {cout << "bark \n"; }
};
class Pig : public Animal {
public:
    Pig(string n) : Animal(n) { }
    void speak() {cout << "oink \n"; }
};
```  

```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 \n"; }
};
class Dog : public Animal {
public:
    Dog(string n) : Animal(n) { }
    void speak() {cout << "bark \n"; }
};
class Pig : public Animal {
public:
    Pig(string n) : Animal(n) { }
    void speak() {cout << "oink \n"; }
};
```  

```cpp
int main()
{
    Animal* animals[ ] = {
        new Cat("Charlie"),
        new Cat("Scamp"),
        new Dog("Penny"),
        new Cat("Libby"),
        new Cat("Patches"),
        new Dog("Milo"),
        new Pig("Wilbur")
    };
    for (int i=0; i<7; i++) {
        animals[i]->speak();
    }
}
```  

Output:
meow meow bark meow meow bark oink