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).

```
class Student {
    . . .
}
```

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

Base class
Derived class

Access to private members

```
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 class access, it looks like this:

```
class Test : public Grade {
    private members:
    int numQuestions;
    float pointsEach;
    int numMissed;
    public members:
    Test(int, int);
    void setScore(float);
    float getScore();
    char getLetter();
}
```

An instance of `Test` contains letter and score, but they are not directly accessible from inside (or outside) the `Test` member functions.

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.

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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

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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()
```

---

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;
  }
};
```

```cpp
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.

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 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**: 
  ```
  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**

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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
  ```

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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:**

```text
I am One
I am One
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 }; // Output: I am One I am Two I am Three
    for (int i = 0; i < 3; i++)
        apCOne[i] -> vWhoAmI();
}
```

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.

```cpp
class CShape {
    public:
        CShape() { }
        virtual void vDraw() const = 0; // pure virtual function
};
CShape CShape1; // Error: object of abstract class
CShape* pCShape; // Ok
CShape CShapeFun(); // Error: return type
void vg(CShape); // Error: argument type
```

Example: Abstract Class
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 ";}
    };

class 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