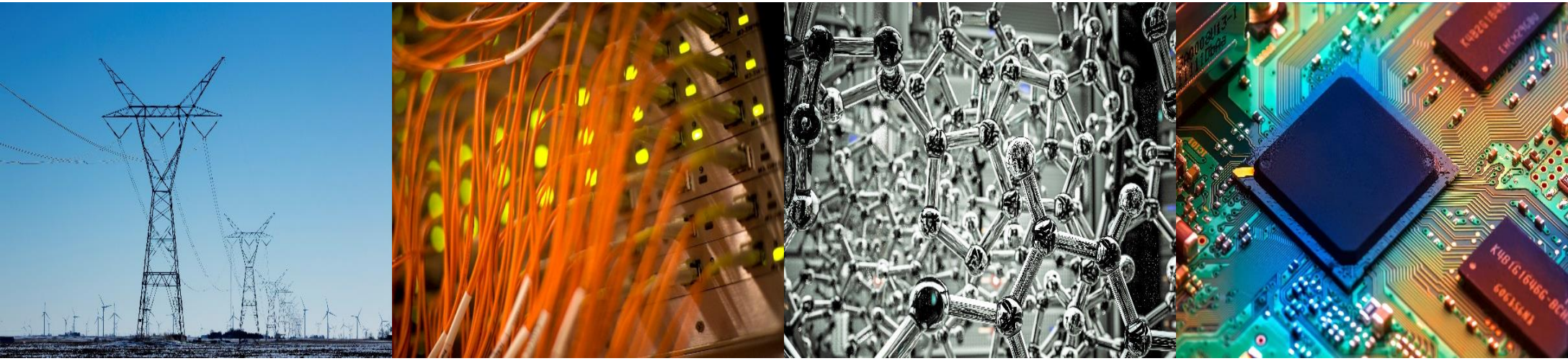
ECE 220 Computer Systems & Programming

Lecture 21 – Introduction to C++: Inheritance & Polymorphism

November 11, 2025



- **Quiz5 is next week**

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Pass by Value / Address (Pointer) / Reference in C++

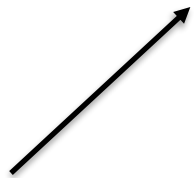
Let's look at our most familiar *swap* example.

1. Pass by value

```
void swap_val(int x, int y);
```

2. Pass by address (pointer)

```
void swap_ptr(int *x, int *y);
```



```
void swap_ptr(int *x, int *y){
    int temp = *x;
    *x = *y;
    *y = temp;
}
```

3. Pass by reference

```
void swap_ref(int &x, int &y);
```

```
void swap_ref(int &x, int &y){
    int temp = x;
    x = y;
    y = temp;
}
```

```
int main(){
   int a = 1;
   int b = 2;
   swap_val(a, b);      //pass by value
   swap_ptr(&a, &b);    //pass by address (pointer)
   swap_ref(a, b);      //pass by reference
   return 0;
}
```

More on C++ Reference

- an alias for a variable/object
- similar to pointer but safer
- no need to dereference, use it just like a variable/object
- should use "." instead of "->" to access members

Copy constructor and pass by constant reference

```
class vector{
   Protected:
   double angle_, length_;
   public:
   //copy constructor
   vector(const vector &obj){
     angle_ = obj.angle_;
     length_ = obj.length_;}
   //other methods omitted here for simplicity
};
```

Inheritance

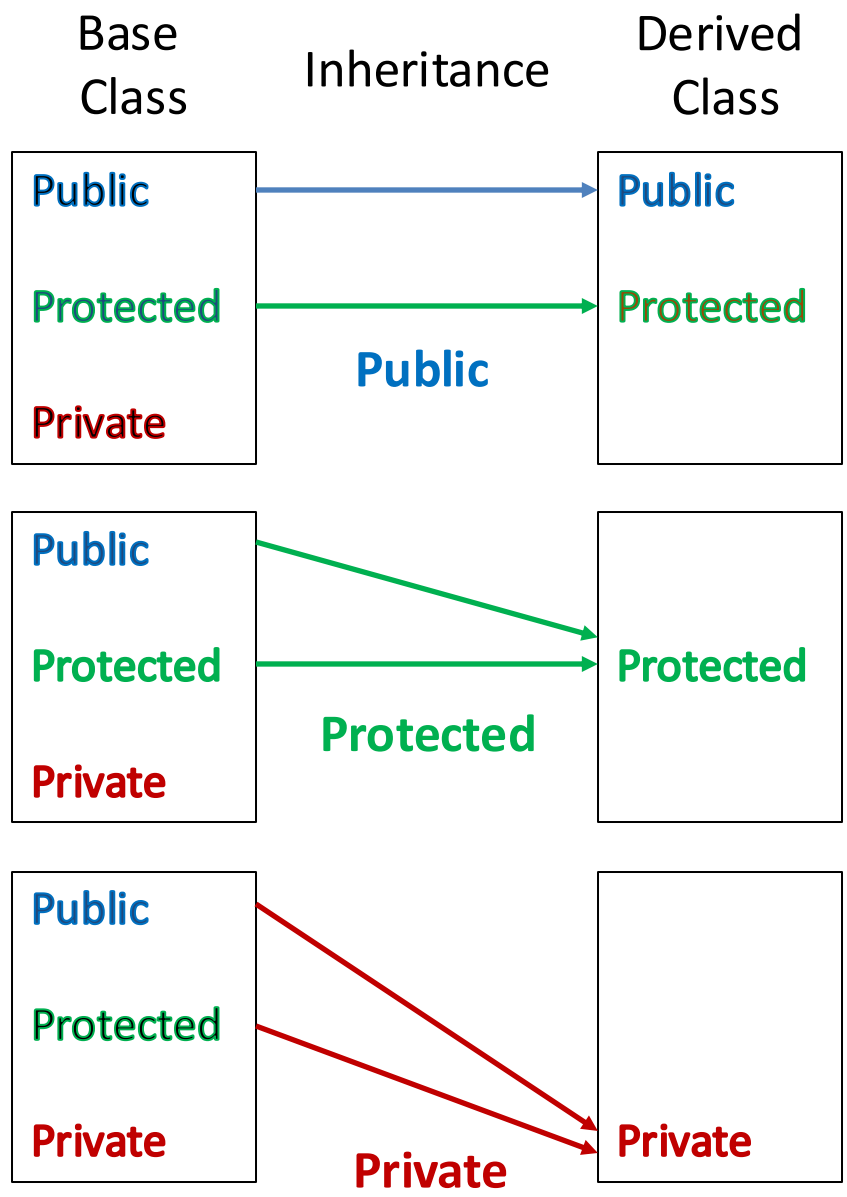
C++ allows us to define a class based on an existing class, and the new class will inherit members of the existing class.

- the **existing** class –
- the **new** class –

Exceptions in inheritance (things not inherited):

- constructors, destructors and copy constructors of the base class
- overloaded operators of the base class
- friend functions of the base class

➢ Are private members in the base class inherited?



```
class orthovector : public vector{
   protected:
   int d_; //direction can be 0,1,2,3, indicating r, l, u, d
   public:
   orthovector(int dir, double l){
      const double halfPI = 1.507963268;
      d_ = dir;
      angle_ = dir*halfPI;
      length_ = l;
   }
   orthovector() {d_ = 0; angle_ = 0.0; length_ = 0.0;}
   double hypotenuse(const orthovector &b){
      if((d_+b.d_)%2 == 0) return length_ + b.length_;
      return (sqrt(length_*length_ + b.length_*b.length_));
   }
};
```

Access	public	protected	private
Same Class	Y	Y	Y
Derived Class	Y	Y	N
Outside Class	Y	N	N

Polymorphism

A call to a member function will cause a **different function to be executed** depending on the type of the object that invokes the function. In the example below, function call is determined during _____ (**static linkage**).

```
int main(){
    Rectangle rec(3,5);
    Triangle tri(4,5);

    rec.area();
    tri.area();

    return 0;
}
```

Example:

```
//base class
class Shape{
   protected:
   double width_, height_;
   public:
   Shape() {width_ = 0; height_ = 0;}
   Shape(double a, double b) { width_ = a; height_ = b; }
   double area() { cout << "Base class area unknown" << endl;
                   return 0; }
};
```

```
//derived classes
class Rectangle : public Shape{
   public:
   Rectangle(double a, double b) : Shape(a,b){}
   double area() {


                                                                    }
};

class Triangle : public Shape{
   public:
   Triangle(double a, double b) : Shape(a,b){}
   double area() {


                                                                    }
};
```

- Which function will be invoked when we execute the code in main?

Declared Type vs. Actual Type

```
int main(){
        Shape *ptr;
        Rectangle rec(3,5);
        Triangle tri(4,5);

        //use ptr to point to Rectangle class object
        ptr = &rec;
        ptr->area();

        //use ptr to point to Triangle class object
        ptr = &tri;
        ptr->area();

        return 0;
}
```

- What would this program print?

Virtual Function

- member functions in the base class you expect to redefine in the derived classes are called **virtual functions**
- derived class declares instances of that member function
- function call is determined during _____ (**dynamic linkage**)

```
//base class
class Shape{
   protected:
   double width_, height_;
   public:
   Shape() {width_ = 0; height_ = 0;}
   Shape(double a, double b) { width_ = a; height_ = b; }
   virtual double area(){
                cout << "Base class area unknown" << endl;
                return 0; }
};
```

Virtual Function Table (vtbl)

- stores pointers to all virtual functions
- created for ***each class*** that uses virtual functions
- lookup during the function call

➢ Where are things being stored at?

Program Text (Code Segment)
Data (Static, Global, etc.)
Heap
Stack

Pure Virtual Functions & Abstract Class

```
class Shape{ //Shape is an abstract class
   protected:
   double width_, height_;
   public:
   Shape(double a, double b) { width_ = a; height_ = b; }
   virtual double area()=0; //pure virtual function
};

int main(){
   Shape shape1(2,4);     // this will cause a compiler error!
   Shape *p_shape1;       // this is allowed
}
```

More on Abstract Class

- a class with one or more pure virtual functions is an abstract class, no objects of that abstract class can be created
- a pure virtual function that is not defined in a derived class remains a pure virtual function, so the derived class is also an abstract class
- an abstract class is intended as an **interface** to objects accessed through **pointers** and **references**