



## Module 23

Instructors: Abir  
Das and  
Sourangshu  
Bhattacharya

Objectives &  
Outlines

Inheritance in  
C++

protected  
Access

Streaming

Constructor &  
Destructor

Object Lifetime

Module Summary

# Module 23: Programming in C++

## Inheritance (Part 3): Constructors, Destructors & Object Lifetime

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Slides taken from NPTEL course on Programming in Modern C++

by **Prof. Partha Pratim Das**



# Module Recap

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Module Summary

- Discussed the effect of inheritance on Data Members and Object Layout
- Discussed the effect of inheritance on Member Functions with special reference to Overriding and Overloading



# Module Objectives

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Module Summary

- Understand **protected** access specifier
- Understand the construction and destruction process on an object hierarchy
- Revisit Object Lifetime for a hierarchy



# Module Outline

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- 1 Inheritance in C++
- 2 protected Access
  - Streaming
- 3 Constructor & Destructor
- 4 Object Lifetime
- 5 Module Summary



# Inheritance in C++: Semantics

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Module Summary

- **Derived ISA Base**
- **Data Members**
  - **Derived** class *inherits* all data members of **Base** class
  - **Derived** class may *add* data members of its own
- **Member Functions**
  - **Derived** class *inherits* all member functions of **Base** class
  - **Derived** class may *override* a member function of **Base** class by *redefining* it with the *same signature*
  - **Derived** class may *overload* a member function of **Base** class by *redefining* it with the *same name*; but *different signature*
  - **Derived** class *may add* new member functions
- **Access Specification**
  - **Derived** class *cannot access private* members of **Base** class
  - **Derived** class *can access protected* members of **Base** class
- **Construction-Destruction**
  - A *constructor* of the **Derived** class *must first* call a *constructor* of the **Base** class to construct the **Base** class instance of the **Derived** class
  - The *destructor* of the **Derived** class *must* call the *destructor* of the **Base** class to destruct the **Base** class instance of the **Derived** class



# protected Access

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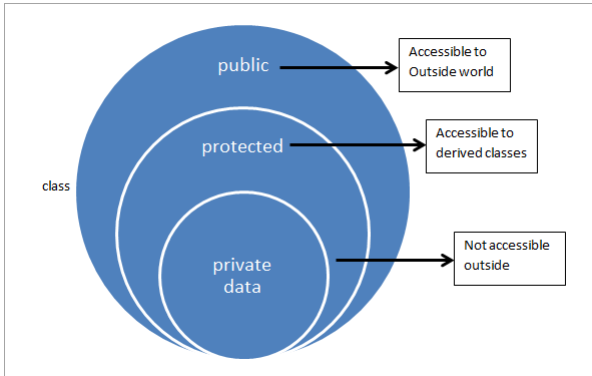
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## protected Access



# Access Members of Base: protected Access

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Module Summary

- **Derived ISA Base**
- **Access Specification**
  - **Derived** class *cannot access private* members of **Base** class
  - **Derived** class *can access public* members of **Base** class
- **protected Access Specification**
  - A new **protected** access specification is introduced for **Base** class
  - **Derived** class *can access protected* members of **Base** class
  - **No other class** or **global** function *can access protected* members of **Base** class
  - A **protected** member in **Base** class is like **public** in **Derived** class
  - A **protected** member in **Base** class is like **private** in **other classes** or **global** functions



# protected Access

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### private Access

```

class B {
private: // Inaccessible to child
        // Inaccessible to others
    int data_;
public: // ...
    void Print() { cout << "B Object: ";
                  cout << data_ << endl;
    }
};

class D: public B { int info_; public: // ...
    void Print() { cout << "D Object: ";
                  cout << data_ << ", "; // Inaccessible
                  cout << info_ << endl;
    }
};

B b(0);
D d(1, 2);

b.data_ = 5; // Inaccessible to all

b.Print();
d.Print();

```

- `D::Print()` cannot access `B::data_` as it is private

### protected Access

```

class B {
protected: // Accessible to child
            // Inaccessible to others
    int data_;
public: // ...
    void Print() { cout << "B Object: ";
                  cout << data_ << endl;
    }
};

class D: public B { int info_; public: // ...
    void Print() { cout << "D Object: ";
                  cout << data_ << ", "; // Accessible
                  cout << info_ << endl;
    }
};

B b(0);
D d(1, 2);

b.data_ = 5; // Inaccessible to others

b.Print();
d.Print();

```

- `D::Print()` can access `B::data_` as it is protected





# Why do we need protected access?

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Module Summary

- **Handling Encapsulation:** Encapsulation, the first principle of OOAD, can be enforced in a single class by **private** and **public** access specifiers
  - **private** hides the state (data) of the object and **public** allows the service (method / interface) to be exposed
  - We fine-grain this by **get/set** paradigm to achieve effective information hiding
  - Further **friend** provides a way to sneak through encapsulation for *easy yet safe coding*
- **Encapsulation-Inheritance Conflict:** The above approach to Encapsulation conflicts with Inheritance, the second principle of OOAD

*What should be the access specification for data members of a Base class?*

  - If they are **public**, the encapsulation is lost for the base class objects
  - If they are **private**, even the derived class methods cannot access them
  - So the derived class object contains the base class data members but cannot access them

*Notably, the state of the derived class object depends on the state of its base class part*
  - The **get/set** paradigm does not work as it is clumsy and creates an encapsulation hole like **public** if used for all data members
- **Solution:** The **protected** access specifier provides a neat solution by making **protected** base class members available to the derived class while being hidden from the rest of the world
- **Caveat:** **protected** specifier still does not solve all situations and we need to use **friend** to provide a way to sneak through encapsulation as the next example illustrates



# Streaming

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## Streaming in B

```

class B { protected: int data_;
public:
    friend ostream& operator<<(ostream& os,
        const B& b) { os << "B Object: ";
        os << b.data_ << endl;
        return os;
    }
};

class D: public B { int info_;
public:
    //friend ostream& operator<<(ostream& os,
    //    const D& d) { os << "D Object: ";
    //    os << d.data_ << ' ' << d.info_ << endl;
    //    return os;
    //}
};

B b(0);    cout << b; // Printed a B object
D d(1, 2); cout << d; // Printed a B object

```

B Object: 0

B Object: 1

- d printed as a B object; info\_ missing

## Streaming in B & D

```

class B { protected: int data_;
public:
    friend ostream& operator<<(ostream& os,
        const B& b) { os << "B Object: ";
        os << b.data_ << endl;
        return os;
    }
};

class D: public B { int info_;
public:
    friend ostream& operator<<(ostream& os,
        const D& d) { os << "D Object: ";
        os << d.data_ << ' ' << d.info_ << endl;
        return os;
    }
};

B b(0);    cout << b; // Printed a B object
D d(1, 2); cout << d; // Printed a D object

```

B Object: 0

D Object: 1 2

- d printed as a D object as expected



# Constructor and Destructor

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Module Summary

- **Derived ISA Base**
- **Constructor-Destructor**
  - **Derived** class *does not inherit* the **Constructors** and **Destructor** of **Base** class but *must have access to them*
  - **Derived** class *must provide* its own **Constructors** and **Destructor**
  - **Derived** class *cannot override* or *overload* a **Constructor** or the **Destructor** of **Base** class
- **Construction-Destruction**
  - A *constructor* of the **Derived** class *must first* call a *constructor* of the **Base** class to construct the **Base** class instance of the **Derived** class
  - The *destructor* of the **Derived** class *must* call the *destructor* of the **Base** class to destruct the **Base** class instance of the **Derived** class



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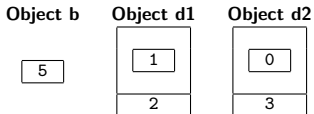
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```
class B { protected: int data_; public:
    B(int d = 0) : data_(d) { cout << "B::B(int): " << data_ << endl; }
    ~B() { cout << "B::~~B(): " << data_ << endl; }
    // ...
};

class D: public B { int info_; public:
    D(int d, int i) : B(d), info_(i) // ctor-1: Explicit construction of Base
    { cout << "D::D(int, int): " << data_ << ", " << info_ << endl; }
    D(int i) : info_(i) // ctor-2: Default construction of Base
    { cout << "D::D(int): " << data_ << ", " << info_ << endl; }
    ~D() { cout << "D::~~D(): " << data_ << ", " << info_ << endl; }
    // ...
};

B b(5);
D d1(1, 2); // ctor-1: Explicit construction of Base
D d2(3); // ctor-2: Default construction of Base
```

## Object Layout





# Object Lifetime

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```

class B { protected: int data_; public:
    B(int d = 0) : data_(d) { cout << "B::B(int): " << data_ << endl; }
    ~B() { cout << "B::~~B(): " << data_ << endl; }
    // ...
};
class D: public B { int info_; public:
    D(int d, int i) : B(d), info_(i) // ctor-1: Explicit construction of Base
    { cout << "D::D(int, int): " << data_ << ", " << info_ << endl; }
    D(int i) : info_(i) // ctor-2: Default construction of Base
    { cout << "D::D(int): " << data_ << ", " << info_ << endl; }
    ~D() { cout << "D::~~D(): " << data_ << ", " << info_ << endl; }
    // ...
};
B b;
D d1(1, 2); // ctor-1: Explicit construction of Base
D d2(3); // ctor-2: Default construction of Base

```

### Construction O/P

```

B::B(int): 0 // Object b
B::B(int): 1 // Object d1
D::D(int, int): 1, 2 // Object d1
B::B(int): 0 // Object d2
D::D(int): 0, 3 // Object d2

```

### Destruction O/P

```

D::~~D(): 0, 3 // Object d2
B::~~B(): 0 // Object d2
D::~~D(): 1, 2 // Object d1
B::~~B(): 1 // Object d1
B::~~B(): 0 // Object b

```

- First construct base class object, then derived class object
- First destruct derived class object, then base class object



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Module Summary

- Understood the need and use of `protected` Access specifier
- Discussed the Construction and Destruction process of class hierarchy and related Object Lifetime