Outline

- Inheritance
  - Public
  - Protected
  - Private
- Constructors under Inheritance
- Destructors under Inheritance
- Q&A
Inheritance

• Software reusability
• Create new class from existing class instead of building it entirely from the scratch
  – Existing class’s data and behaviors
  – Adding new capabilities
  – Derived class inherits from base class
Class hierarchy

- Direct base class
  - Inherited explicitly (one level up hierarchy)
- Indirect base class
  - Inherited two or more levels up hierarchy
- Single inheritance
  - Inherits from one base class
- Multiple inheritance
  - Inherits from multiple base classes
    - Base classes possibly unrelated
Three Types of Inheritance

• public
  – Every object of derived class is also an object of base class
    • Base-class objects are not objects of derived classes
      – All cars are vehicles, but not all vehicles are cars

• Can access non-private members of base class
  – To access private base-class members
    • Derived class must use inherited non-private member functions

• private (later)
  – Alternative to composition

• protected (later)
  – Rarely used
“is-a” vs “has-a”

• “is-a”
  – Inheritance
  – Derived class object can be treated as base class object
    • Car is a vehicle
      – Vehicle properties/behaviors also apply to a car

• “has-a”
  – Composition
  – Object contains one or more objects of other classes as members
    • Car has a steering wheel
Base Classes and Derived Classes

- Object of one class “is an” object of another class
  - Rectangle is quadrilateral
    - Class Rectangle inherits from class Quadrilateral
      - base class: quadrilateral
      - derived class: rectangle

- Base class typically represents larger set of objects than derived classes
  - Base class: Vehicle
    - Derived class: Car
• GraduatedStudent class is derived from Student class
• GraduatedStudent class is inherited from Student class
• Student class is super class of GraduatedStudent
• Graduated class is child class or subclass of Student class
class TwoDimensionalShape : public Shape
– Class TwoDimensionalShape inherits from class Shape

• Base class private members
– Not accessible directly, but still inherited
– Accessed through inherited public member functions

• Base class public and protected members
– Inherited with original member access

• friend functions
– Not inherited

class BaseClass {
    // ...
};
class DerivedClass : public BaseClass {
    // ...
};
Public Inheritance Cont’d

class BaseClass {
    public:
        void public_method();
    protected:
        void protected_method();
    private:
        void private_method();
};

class DerivedClass : public BaseClass {
    public:
        void public_method();
    protected:
        void protected_method();
};
Protected Access Specifier

- Intermediate level of protection between public and private
- Protected methods/data cannot be accessible by other classes except for subclasses
- Other classes consider protected members as normal “private” members
- Subclasses consider protected members as normal “public” members
Protected members are accessible to
- Base class members
- Base class friends
- Derived class members
- Derived class friends
Protected Access Specifier Cont’d

• Public members in base class is public in derived class
• Protected members in base class are protected in derived class
• Derived-class members
  – Refer to public and protected members of base class
    • Simply use member names
  – Redefined base class members can be accessed by using base-class name and binary scope resolution operator (::)
Protected Inheritance

- public and protected members in base class become protected in derived class

```cpp
class BaseClass {
public:
    void public_method();
protected:
    void protected_method();
private:
    void private_method();
};
class DerivedClass : protected BaseClass {
    protected:
        void public_method();
    protected:
        void protected_method();
};
```
class BaseClass {
    public:
        void public_method();
    protected:
        void protected_method();
    private:
        void private_method();
};

class DerivedClass : private BaseClass {
    private:
        void public_method();
    private:
        void protected_method();
};
Protected Data Members

- **Advantages**
  - Derived class can modify values directly
    - No set/get method call overhead

- **Disadvantages**
  - No validity checking
    - Derived class can assign invalid value
  - Implementation dependent
    - Derived class more likely dependent on base class implementation
    - Base class implementation may result in derived class’s modification
      - fragile software
#ifndef COMMISSION_H
#define COMMISSION_H

#include <string>
using std::string;

class CommissionEmployee 
{
public:
    CommissionEmployee( const string &, const string &, const string &, double = 0.0, double = 0.0 );

    void setFirstName( const string & );
    string getFirstName() const;

    void setLastName( const string & );
    string getLastName() const;

    void setSocialSecurityNumber( const string & );
    string getSocialSecurityNumber() const;

    void setGrossSales( double );
    double getGrossSales() const;

    void setCommissionRate( double );
    double getCommissionRate() const;

    double earnings() const;
    void print() const;

protected:
    string firstName;
    string lastName;
    string socialSecurityNumber;
    double grossSales;
    double commissionRate;
};
#endif
#ifndef BASEPLUS_H
#define BASEPLUS_H

#include <string> // C++ standard string class
using std::string;

#include "CommissionEmployee.h"

class BasePlusCommissionEmployee :
    public CommissionEmployee
{
    public:
        BasePlusCommissionEmployee( const string &, const string &, const string &, double = 0.0, double = 0.0, double = 0.0 );

        void setBaseSalary( double );
        double getBaseSalary() const;

        double earnings() const;
        void print() const;

    private:
        double baseSalary;

    };

#endif
The Best Software Engineering Practice

• Declare data members as private
  – Enables programmers to change the base-class implementation without having to change derived-class implementations
  – Use the protected access specifier when a base class should provide a service (i.e., a member function) only to its derived classes (and friends), not to other clients

• Provide public get and set functions

• Use get method to obtain values of data members
The Best Software Engineering Practice Cont’d

- Set/get method slightly slower than direct access
  - But today’s optimizing compiler inlines set/get methods
  - Or you can explicitly specify “inline” keyword

```cpp
class BaseClass
{
 public:
   inline int
   getx() const{ return x; }
   inline void setx( int v )
   {
     if( v > 100 ) error();
     else x = v;
   }
 private:
   int x;
};
```
Selection of public/protected/private Methods

- According to the service range
  - for all other classes: public
  - for itself and subclasses: protected
  - only for itself: private
Constructors under Inheritance

• Constructor in base class
  – Does not construct derived class specific parts

• Constructor in derived class
  – Initialize its own data members
  – Invokes the constructor of the base class
    • Implicitly or explicitly
Constructors under Inheritance Cont’d

• Base of inheritance hierarchy
  – Last constructor called in chain
  – First constructor body to finish executing
  – CommissionEmployee/BasePlusCommissionEmployee hierarchy
    • CommissionEmployee constructor called last
    • CommissionEmployee constructor body finishes execution first

• Initializing data members
  – Each base-class constructor initializes its data members that are inherited by derived class
class BaseClass
{
    public:
        BaseClass() { x = 1; }
        BaseClass( int a ) { x = a; }
    private:
        int x;
};

class DerivedClass : public BaseClass
{
    public:
        DerivedClass() { y = 2; }
        DerivedClass( int x ) :
            BaseClass( x ) { y = 2; }
    private:
        int y;
};
Constructors under Inheritance
Cont’d

class BaseClass
{
    public:
        // BaseClass() { x = 1; }
        BaseClass( int a ) { x = a; }

    private:
        int x;
};

class DerivedClass : public BaseClass
{
    public:
        DerivedClass() { y = 2; }
        // error

    private:
        int y;
};

class BaseClass
{
    public:
        BaseClass() {
            cout << "base";
            cout << endl;
        }

};

class DerivedClass : public BaseClass
{
    public:
        DerivedClass() {
            cout << "derived";
            cout << endl;
        }

};

============================
base
derived
Destructors under Inheritance

• Destroying derived-class object
  – Chain of destructor calls
    • Reverse order of constructor chain
    • Destructor of derived-class called first
    • Destructor of next base class up hierarchy next
      – Continue up hierarchy until final base reached
      – After final base-class destructor, object removed from memory
class BaseClass
{
    public:
    BaseClass() { x = new int[100]; }
    ~BaseClass() { delete[] x; }
    private:
    int* x;
};

class DerivedClass : public BaseClass
{
    public:
    DerivedClass() { y = new int[10]; }
    ~DerivedClass() { delete[] y; }
    private:
    int* y;
};

class BaseClass {
    public:
    BaseClass() {
        cout << "base con";
        cout << endl;
    }
    ~BaseClass() {
        cout << "base des";
        cout << endl; }
};
class DerivedClass : public BaseClass {
    public:
    DerivedClass() {
        cout << "derived con";
        cout << endl;
    }
    ~DerivedClass() {
        cout << "derived des";
        cout << endl; }
};
# Base-class Member Accessibility in a Derived Class

<table>
<thead>
<tr>
<th>Base-class member-access specifier</th>
<th>Type of inheritance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>public inheritance</td>
</tr>
<tr>
<td></td>
<td>protected inheritance</td>
</tr>
<tr>
<td></td>
<td>private inheritance</td>
</tr>
<tr>
<td>public</td>
<td>public in derived class.</td>
</tr>
<tr>
<td></td>
<td>Can be accessed directly by member functions, friend functions and nonmember functions.</td>
</tr>
<tr>
<td>protected</td>
<td>protected in derived class.</td>
</tr>
<tr>
<td></td>
<td>Can be accessed directly by member functions and friend functions.</td>
</tr>
<tr>
<td>private</td>
<td>private in derived class.</td>
</tr>
<tr>
<td></td>
<td>Can be accessed directly by member functions and friend functions.</td>
</tr>
<tr>
<td></td>
<td>Hidden in derived class.</td>
</tr>
<tr>
<td></td>
<td>Can be accessed by member functions and friend functions through public or protected member functions of the base class.</td>
</tr>
<tr>
<td></td>
<td>Hidden in derived class.</td>
</tr>
<tr>
<td></td>
<td>Can be accessed by member functions through public or protected member functions of the base class.</td>
</tr>
<tr>
<td></td>
<td>Hidden in derived class.</td>
</tr>
<tr>
<td></td>
<td>Can be accessed by member functions and friend functions through public or protected member functions of the base class.</td>
</tr>
</tbody>
</table>
Customizing and Reusing Existing Software

- Derived class can
  - re-implement the behaviors of the base class
    - Known as “method overriding”
  - add new behaviors or data
    - We can use not only new behaviors but also the existing behaviors
- Factor out common attributes and behaviors and place these in a base class
- Use inheritance to form derived classes, endowing them with capabilities beyond those inherited from the base class
- The creation of a derived class does not affect its base class’s source code