Inheritance (with C++)

Starting to cover Savitch Chap. 15

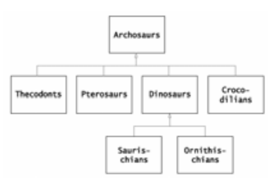
More OS topics in later weeks

(memory concepts, libraries)

Inheritance Basics

- A new class is inherited from an existing class
- Existing class is termed the base class
  - It is the "general" class (a.k.a. superclass, or parent)
- New class is termed the derived class
  - It is the "specific" class (a.k.a. subclass, or child)
  - Automatically has (i.e., "inherits") all of the base class's member functions and variables
  - Can define *additional* member functions and variables
    - And override inherited virtual functions (but that's a later topic)

Inheritance begets hierarchies



- "Is a" relationships
- Imagine:

`class Basketball`

is derived from

`class Ball`

- Then:

any `Basketball` *is a* `Ball`

- Reverse not always true: a `Ball` can be a `Football`, or a `Baseball`, or …

Base class example: Employee

```
class Employee {
public:
    Employee( );
    Employee(string theName, string theSsn);
    string getName( ) const;
    string getSsn( ) const;
    double getNetPay( ) const;
    void setName(string newName);
    void setSsn(string newSsn);
    void setNetPay(double newNetPay);
    void printCheck( ) const;
private:
    string name;
    string ssn;
    double netPay;
};
```

Derived class: HourlyEmployee

```
class HourlyEmployee : public Employee {
// Instantly inherits all member functions and variables of class Employee
public:
    HourlyEmployee( );
    HourlyEmployee(string theName, string theSsn,
            double theWageRate, double theHours);
    void setRate(double newWageRate);
    double getRate( ) const;
    void setHours(double hoursWorked);
    double getHours( ) const;
    void printCheck( ); // plan to redefine printCheck function
private:
    double wageRate;
    double hours;
};
```

Writing derived classes

- 3 possibilities for member functions:
  - Inherit – i.e., do nothing
  - Redefine – have new method act differently
  - Define new – add abilities not in base class at all
- 2 possibilities for member variables:
  - Inherit – though if private, may not directly access/set
  - Define new – more data in addition to base class data
- Notice: cannot redefine member variables – attempts to do so will create "shadow variables"
  - i.e., just creates a new variable with the same name, effectively hiding the inherited one – usually a mistake

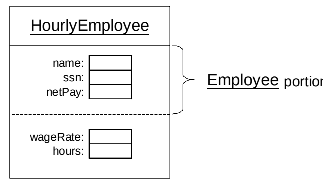
Derived class constructors

- A base class constructor is *always* invoked first
  - i.e., first task of derived class constructor's initialization list
  - If not done explicitly, base class default constructor will be called implicitly
    - Will result in compile error if base class has no default ctor
- Need explicit call to use an alternative base class ctor
  - Syntax: `BaseClassName(arg1, arg2, …)`
- Derived Employee example:

```
HourlyEmployee::HourlyEmployee(string name,
    string number, double rate, double hours)
    : Employee(name, number), wageRate(rate),
      hours(hours)
{ }
```

A subclass object's composition

- Remember: a derived class definition just defines part of the resulting object
  - The rest of the object is the base class portion



Redefining ≠ overloading

- Redefining only applies to a derived class
  - Same parameter list (i.e., same "signature")
  - Essentially "re-writes" the same function
- Overloading can happen in base or derived
  - Different parameter list – different signature
  - Defining a new function with the same name
- Recall definition of a signature:
  - Name(parameter list)
  - Does not include return type, and '&' ignored

Accessing redefined base function

- A redefined base class definition is not "lost"

```
Employee jane;
HourlyEmployee sally;
jane.printCheck(); // Employee function
sally.printCheck(); // HourlyEmployee function
sally.Employee::printCheck();
    // uses scope resolution to call Employee function!
```

- Often done while implmenting derived class – let base function do some of the work

Some functions are not inherited

- All "normal" functions in the base class are inherited in the derived class
- The exceptions ("abnormal" functions?):
  - Constructors and destructor
  - Copy constructor and assignment operator
- Compiler generates default versions if you don't redefine them in the derived class
  - But remember that can be problematic if pointing to dynamic memory, so often should redefine

Subclass operator= and copy ctor

- Although not inherited, a derived class typically must use the base class's versions
- e.g., an `operator=` in `class D : public B`

```
D& D::operator=(const D &right) {
    // first call assignment operator of base class to take
    // care of all the inherited member variables
    B::operator=(right);
    ... // then set new variables of derived class
}
```

- Copy ctor must use base class version too

```
D::D(const D &other) : B(other), ...{ }
```

Destructors in derived classes

- Easy to write if base class dtor is correct
  - No need to call base class dtor – because it is called automatically at the end of the derived class's dtor
- So derived class destructors need only worry about derived class variables
  - Usual purpose: release resources allocated during the object's life
  - Let base class dtor handle inherited resources

Examples: PFArrayD and …Bak

~mikec/cs32/demos/SavitchAbsolute_ch14/PFArrayD.h

- Base class `PFArrayD`:
  - Stores a *pointer* to a double array on free store
    - Array has a fixed capacity after construction
  - Has mgr., other functions, plus [] and = ops
- Derived class `PFArrayDBak`: …PFArrayDBak
  - Has pointer to its *own array* – can be used to backup and restore data in base class's array
  - Redefines ctors, dtor and operator=

Writing derivable classes

- Always provide a constructor that can be called with no arguments
- Control subclass' access to member variables and functions as appropriate – three choices:
  - `public` members are accessible to all other classes
  - `private` members are not directly accessible to any other class – should be used for most variables, and also appropriate for "helper" functions
  - A third choice is `protected` member access
    - *Only subclasses* (those derived from this one) can access
    - Some consider it bad OOP practice – violates info hiding

`protected` / `private` inheritance

- Note: rarely used; frankly a little weird
  - Destroys "is a" relation of derived class object
- Protected inheritance – all public members in the base class become protected members in the derived class

```
class SalariedEmployee : protected Employee {…}
```

- Private inheritance – all members in the base class become private in the derived class

```
class SalariedEmployee : private Employee {…}
```

Many more inheritance issues

- For instance: Sometimes it is better to use "has a" instead of "is a" relationship
  - Means one class *has an* object of another class
  - Generally a more *flexible* design
- Can also do multiple inheritance in C++

```
class ClockRadio :
    public Radio, public AlarmClock;
```

  - Tricky though (more later, after `virtual` keyword)
- "Slicing" and "upcasts" – more to come

Virtual functions – concepts

- Virtual: exists in essence though not in fact
- Idea is that a virtual function can be "used" before it is defined
  - And it might be defined many, many ways!
- Relates to OOP concept of polymorphism
  - Associate many meanings to one function
- Implemented by dynamic binding
  - A.k.a. late binding – happens at run-time

Polymorphism example: figures

- Imagine classes for several kinds of figures
  - Rectangles, circles, and ovals (to start)
  - All derive from one base class: `Figure`
- All "`Figure`" objects inherit: `void draw()`
  - Of course, each one implements it differently!

```
Rectangle r;
Circle c;
r.draw(); // Calls Rectangle class's draw()
c.draw(); // Calls Circle class's draw
```

- Nothing new here yet …

Figures example cont. – center()

- Consider that base class `Figure` has functions that apply to "all" figures
- e.g., `center()`: moves figure to screen center
  - Erases existing drawing, then re-draws the figure
  - So `Figure::center()` uses `draw()` to re-draw
- But which draw() function will be used?
  - We're implementing base class center() function, so we have to use the base class draw() function. Right?
- Actually, it turns out the answer depends on how `draw()` is handled in the base class

Poor solution: base works hard

- Figure class tries to implement draw to work for all (known) figures
  - First devise a way to identify a figure's "type"
  - Then `Figure::draw()` uses conditional logic:

```
if ( /* the Figure is a Rectangle */ )
    Rectangle::draw();
else if ( /* the Figure is a Circle */ )
    Circle::draw();
...
```

- But what if a new kind of figure comes along?
  - e.g., how to handle a derived `class Triangle`?

Better solution: virtual function

- Base class declares that the function is virtual:
  `virtual void draw() const;`
- Remember it means `draw()` exists in essence
- Such a declaration tells compiler "I don't know how this function is implemented, so wait until it is used in a program, and then get its implementation from the object *instance*."
- The instance will exist in fact (eventually)
  - Therefore, so will the implementation at that time!
- Function "binding" happens late – dynamically

Another virtual function example

- Record-keeping system for auto parts store
  - Track sales, compute daily gross, other stats
  - All based on data from individual bills of sale
- Problem: lots of different types of bills
- Idea – start with a very general `Sale` class that has a *virtual* `bill()` function:
  `virtual double bill() const;`
- Rest of idea – many different types of sales will be added later, and each type will have its own version of the `bill()` function

Sale functions: savings and op <

```
double Sale::savings(const Sale &other) const
  {
     return (bill() – other.bill());
  }
bool operator < (const Sale &first,
                 const Sale &second)
  {
     return (first.bill() < second.bill());
  }
```

- Notice both functions use member function `bill()`!

A class derived from Sale

```
class DiscountSale : public Sale {
public:
  DiscountSale();
  DiscountSale(double price,
               double discount);
  double getDiscount() const;
  void setDiscount(double newDiscount);
  double bill() const; // implicitly virtual
private:
  double discount;     // inherits price
};
```

DiscountSale's bill() function

- First note – it is automatically virtual
  - Inherited trait, applies to *any* descendants
  - Also note – rude not to declare it explicitly
- Of course, definition never says virtual:

```
double DiscountSale::bill() const {
   double fraction = discount/100;
   return (1 – fraction)*getPrice();
}
```

  - Must use access method as price is private

The power of virtual is actual!

- e.g., base class `Sale` written long before derived class `DiscountSale`
- Sale had members `savings` and '<' before there was any idea of class `DiscountSale`
- Yet consider what the following code does

```
DiscountSale d1, d2;
d1.savings(d2); // calls Sale's savings function
```

- In turn, class `Sale`'s `savings` function uses class `DiscountSale`'s `bill` function.

Wow!

Clarifying some terminology

- Recall that overloading ≠ redefining
- Now a new term – overriding means *redefining* a *virtual* function
- Polymorphism is an OOP concept
  - Overriding gives many meanings to one name
- Dynamic binding is what makes it all work
- "Thus," as Savitch puts it, "polymorphism, late binding, and virtual functions are really all the same topic."

Why not all virtual functions?

- Philosophy issue: pure OOP vs. efficiency
  - All functions are virtual by default in another popular programming language (Java) – there must take steps to make functions non-virtual
  - C++ default is non-virtual – programmer must explicitly declare (except when inherited trait)
- Virtual functions have more "overhead"
  - More storage – for class virtual function table
  - Slower – a look-up step; less optimization