The University of North Carolina at Chapel Hill

COMP 144 Programming Language Concepts

Spring 2002

Lecture 24: Dynamic Binding

Felix Hernandez-Campos

March 20

Fundamental Concepts in OOP

- **Encapsulation**
  - Data Abstraction
  - Information hiding
  - The notion of class and object
- **Inheritance**
  - Code reusability
  - Is-a vs. has-a relationships
- **Polymorphism**
  - Dynamic method binding

Fundamental Concepts in OOP

- **Encapsulation**
  - Data Abstraction
  - Information hiding
  - The notion of class and object
- **Inheritance**
  - Code reusability
  - Is-a vs. has-a relationships
- **Polymorphism**
  - Dynamic method binding

Inheritance

- Encapsulation improves code reusability
  - Abstract Data Types
  - Modules
  - Classes
- However, it is generally the case that the code a programmer wants to reuse is close but not exactly what the programmer needs
- **Inheritance** provides a mechanism to extend or refine units of encapsulation
  - By adding or *overriding* methods
  - By adding attributes

Inheritance
Notation

Java.awt.Dialog

Base Class (or Parent Class or Superclass)

⇧ **Is-a relationship**

Java.awt.FileDialog

Derived Class (or Child Class or Subclass)

Inheritance
Subtype

Java.awt.Dialog

Base Class

⇧ **Is-a relationship**

Java.awt.FileDialog

Derived Class

- The derived class has all the members (*i.e.* attributes and methods) of the base class
  - Any object of the derived class can be used in any context that expect an object of the base class
  - fp = new FileDialog() is **both** an object of class Dialog and an object of class File Dialog

Method Binding

```
class person { ...
class student : public person { ...
class professor : public person { ...

student s;
professor p;

person *x = &s;
person *y = &p;

void person::print_mailing_label () { ...
...
s.print_mailing_label ();   // student::print_mailing_label (s)
p.print_mailing_label ();   // professor::print_mailing_label (p)

x->print_mailing_label ();  // ??
y->print_mailing_label ();  // ??
```

Classes Student and Professor derive from class Person

Method print_mailing_list is *polymorphic*

Results depend on the binding: static or dynamic

Print_mailing_label redefined for student and professor classes

Method Binding
Static and Dynamic

- In **static method binding**, method selection depends on the type of the variable x and y
  - Method print_mailing_label() of class person is executed in both cases
  - Resolved at compile time
- In **dynamic method binding**, method selection depends on the class of the objects s and p
  - Method print_mailing_label() of class student is executed in the first case, while the corresponding methods for class professor is executed in the second case
  - Resolved at run time

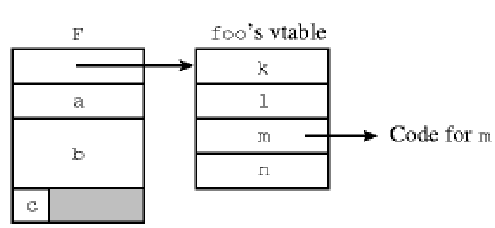
Polymorphism and Dynamic Binding

- The is-a relationship supports the development of *generic operations* that can be applied to objects of a class and all its subclasses
  - This feature is known as *polymorphism*
  - E.g. `paint()` method is polymorphic (accepts multiple types)
- The binding of messages to method definitions is instance-dependent, and it is known as dynamic binding
  - It has to be resolved at run-time
  - Dynamic binding requires the `virtual` keyword in C++
  - Static binding requires the `final` keyword in Java

Dynamic Binding Implementation

- A common implementation is based on a *virtual method table* (vtable)
  - Each object keeps a pointer to the vtable that corresponds to its class

```
class foo {
    int a;
    double b;
    char c;
public:
    virtual void k ( ...
    virtual int l ( ...
    virtual void m ();
    virtual double n( ...
    ...
} F;
```



Dynamic Binding Implementation

- Given an object of class foo, and pointer f to this object, the code that is used to invoked the appropriate method would be

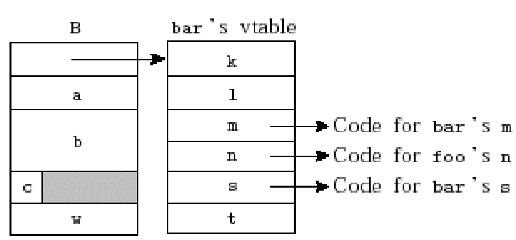
```
to call f->m():

    r1 := f                      this (self)
    r2 := *r1                    -- vtable address
    r2 := *(r2 + (3–1) × 4)      -- assuming 4 = sizeof(address)
    call *r2                     (polymorphic) method invocation
```


Dynamic Binding Implementation
Simple Inheritance

- Derived classes extend the vtable of their base class
  - Entries of overridden methods contain the address of the new methods

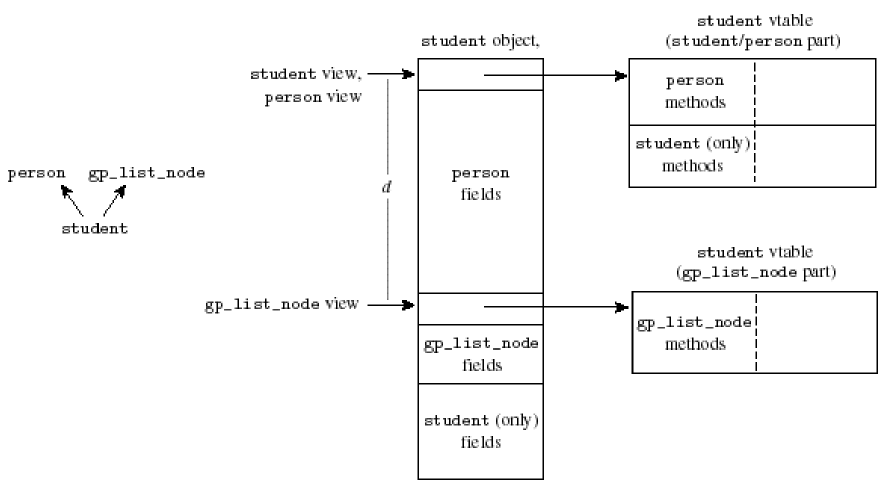
```
class bar : public foo {
    int w;
public:
    void m (); //override
    virtual double s ( ...
    virtual char *t ( ...
    ...
} B;
```



Dynamic Binding Implementation
Multiple Inheritance

- A class may derive from more that one base class
  - This is known as multiple inheritance
- Multiple inheritance is also implemented using vtables
  - Two cases
    - » Non-repeated multiple inheritance
    - » Repeated multiple inheritance

Dynamic Method Binding
Non-Repeated Multiple Inheritance



Dynamic Method Binding
Non-Repeated Multiple Inheritance

- The view of this must be corrected, so it points to the correct part of the objects
  - An offset *d* is use to locate the appropriate vtable pointer
    - » *d* is known at compile time

to call `my_student.debug_print`:

this (self)

```
r1 := my_student                  -- student view of object
r1 := r1 + d                      -- gp_list_node view of object
r2 := *r1                         -- address of appropriate vtable
r3 := *(r2 + (3−1) × 8)           -- method address
r2 := *(r2 + (3−1) × 8 + 4)       -- this correction
r1 := r1 + r2                     -- this
call *r3
```


Dynamic Method Binding
Repeated Multiple Inheritance

- Multiple inheritance introduces a semantic problem: method name collisions
  - Ambiguous method names
  - Some languages support inherited method renaming (*e.g.* Eiffel)
  - Other languages, like C++, require a reimplementation that solves the ambiguity
  - Java *solves* the problem by not supporting multiple inheritance
    - » A class may inherit multiple interfaces, but, in the absence of implementations, the collision is irrelevant

Reading Assignment

- Scott
  - Read Sect. 10.4
  - Read Sect. 10.5 intro and 10.5.1