Polymorphism in languages and its implications (Smalltalk, Modula-3, Java, and C++)

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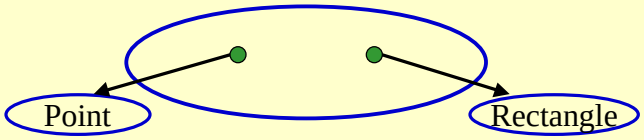
Outline

- Not much to say about ad-hoc polymorphism in languages
- Case studies from inclusion polymorphism
  - "Smalltalk"
  - Modula-3
  - Java
  - C++
- Case study from parametric polymorphism
  - SML

Smalltalk

- Example:
  myThings ← Bag new
  myThings add (Point new)
  myThings add (Rectangle new)



- Point and Rectangle may be unrelated classes (i.e., common supertype is Object)

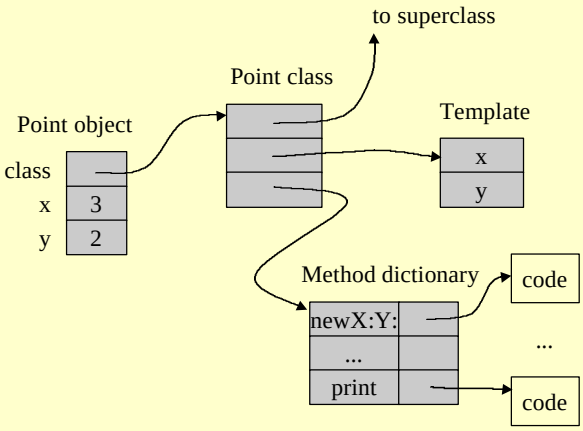
Example (cont.)

- myThings do: [:oneThing | oneThing print]
  Above code works on any collection of any classes
- "Implicitly" the items in the collection must have a "print" method

Discussion

- Does Smalltalk's polymorphism fits in with Cardelli and Wegner's classification?

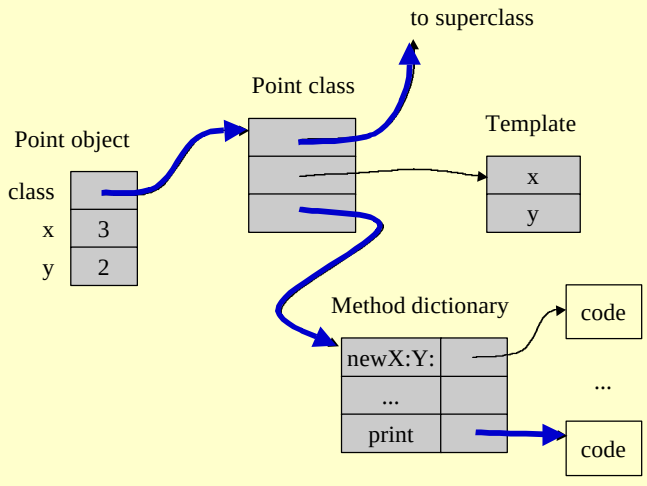
Run-time representation (from Mitchell's book)



How to implement method dispatch?

- Steps:
  - Get class object
  - Get method dictionary
  - Search method dictionary
    - If found, invoke code
    - If not found, continue search in superclass
    - If reached “Object” then “method not understood”

Finishing up the example



How to improve the performance of method dispatch?

- Search is very expensive. What to do?

Modula-3

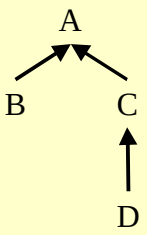
- Polymorphism is a direct consequence of subtyping
- Example:

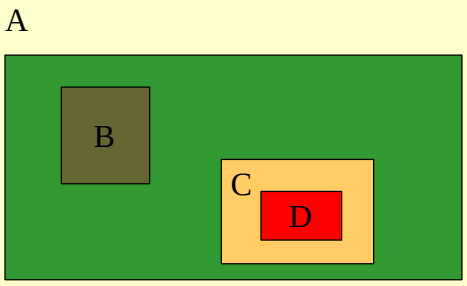
```
TYPE printableBag =
  OBJECT
    values: ARRAY OF printableThing;
    METHODS add(v: printableThing) …
VAR myThings: printableBag;
 myThings.Add(new point); myThings.Add(new Rect)
```

Example (Cont.)

- FOR i = 0 TO LAST(myThings.values) DO
  myThing.values[i].print()
- How is this different from Smalltalk?
- What kind of polymorphism is this in Cardelli and Wegner's terminology?

Visualizing object types in Modula-3





Subtyping restricted to simple inclusion for objects

Discussion

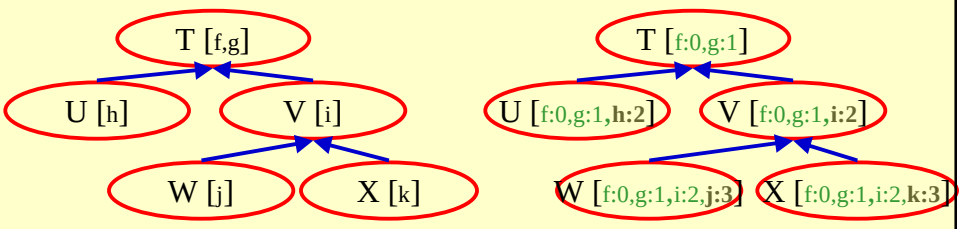
- How to represent in Modula-3?
  - value moveX = fun(p: Point, dx: Int)(returns Point)
    p.x = p.x + dx; p
  - value moveX =all[P<: Point] fun(p: P, dx: Int)
    (returns P)
    p.x = p.x + dx; p

How to implement method dispatch?

- Can do it like Smalltalk but can we exploit
  - Static typing?
    - Possible types of object is constrained statically
  - Single inheritance?
    - Exactly one immediate supertype

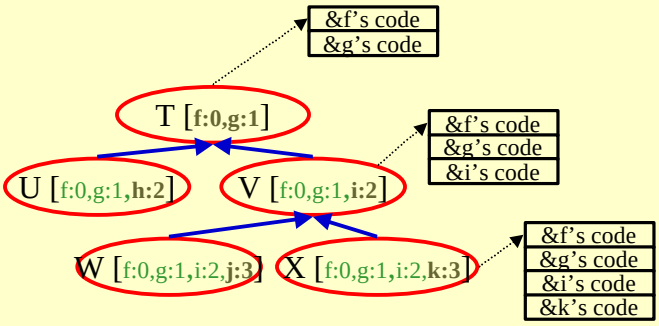
V-Tables

- Idea:
  - Prepend the methods of a supertype to a subtype
  - A method T::m appears in the same position in all T's subclasses



V-tables (cont.)

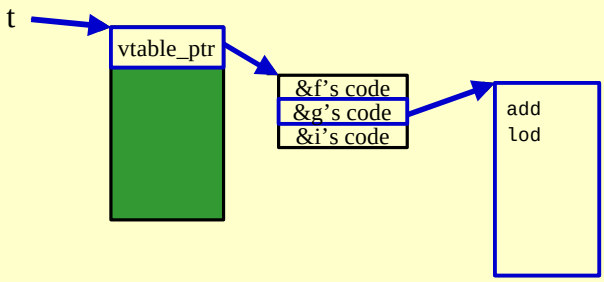
Construct a v-table for each class



v-tables are typically part of the type descriptor

V-tables(cont.)

t->g() becomes
vp = t->vtable_ptr
gaddr =*(vp+g's offset)
(*gaddr)()

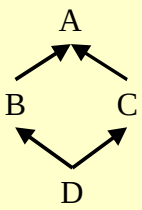


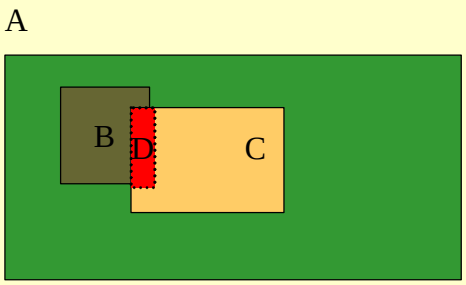
How to improve the performance of method dispatch?

C++

- Similar to Modula-3 except for
  - virtual/non-virtual distinction
- Multiple inheritance

Visualizing object types in C++

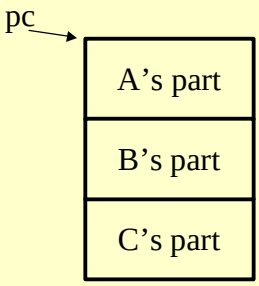




Multiple inheritance allows classes that partially overlap

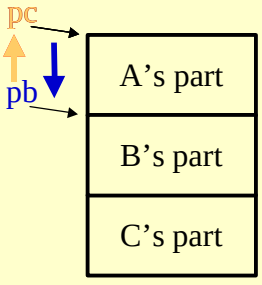
Challenges with multiple inheritance

- Conflicts:
  - e.g., what if two inherited methods have the same name?
- Implementation
  - class C : A, B {…}
    C *pc; B* pb;
    pc = new C;
    pb = (B*)pc;



Implementation issues

- Need to adjust pointers when casting, invoking methods, comparing, ...



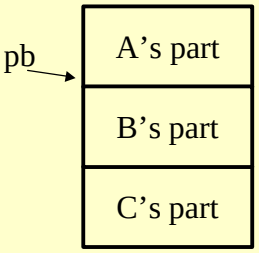
pb = (B*)pc;

pc = (C*)pb;

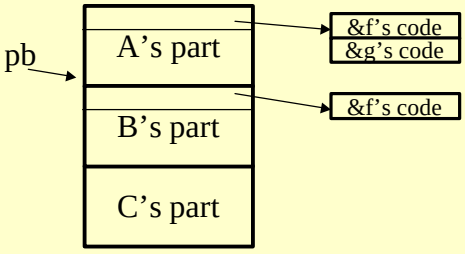
if (pc == pb) {…}

An example involving virtual functions

- class A { virtual void f(); }
  class B { virtual void f(); virtual void g(); }
  class C : A, B {void f() {...this... }}
  B *pb = new C;
  pb->f();
- Challenge?

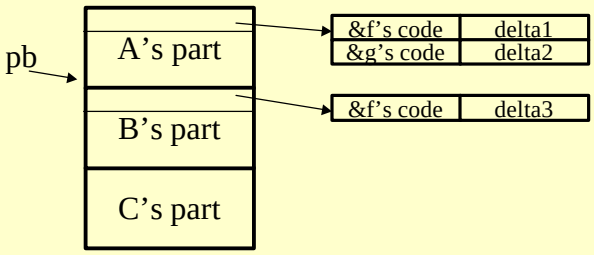


Example continued



Now we can invoke a virtual function after casting a C object to B.
But the body of f() expects "this" to be a C object not a B object!

Example continued




```
pb->f() =>
vt = pb->vtbl[index(f)]
(*vt->fct)((B*)((char *)pb + vt->delta))
```

How to speed up method dispatch?

Discussion

- How to represent in C++?
  - value moveX = fun(p: Point, dx: Int)(returns Point)
    p.x = p.x + dx; p
  - value moveX =all[P<: Point] fun(p: P, dx: Int)
    (returns P)
    p.x = p.x + dx; p

C++ and bounded quantification

- Multiple inheritance does not result in bounded universal quantifcation.
- But it provides a richer type system for expressing subtyping

Java

- Similar to Modula-3 except for invokeinterface
- Example:

```
interface hasAPrint { void print(); }
interface hasASize { void size(); }
class text implements hasAPrint {
        void print() {…} … };
class list implements hasASize {
        void size(…) {…}…}
class figure implements hasASize, hasAPrint {
        void size(…) {…}; void print(…) {…} …}
hasAPrint anobj;  anobj.print();
```

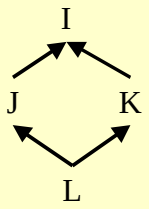
What's the problem here?

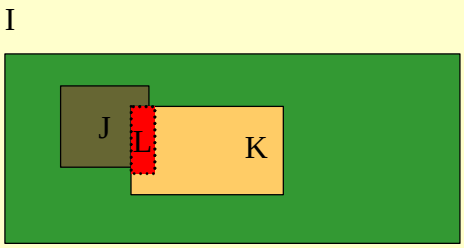
Implementing invokeinterface

- Problem: print method may have different offsets in each class implementing hasAPrint
- Solution:
  - Can implement invokeinterface using Smalltalk-like run-time method search
  - (better idea) Have v-tables for interfaces that are hashed using (class, interface name) pair

Visualizing object types in Java

Multiple inheritance of interfaces

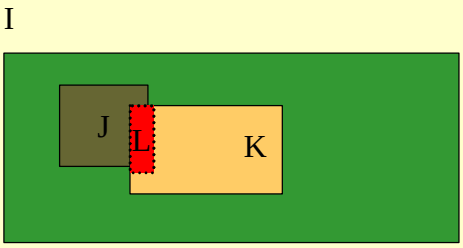


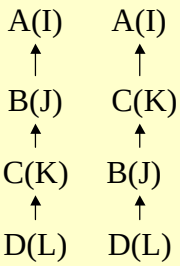


But single inheritance of implementations(classes)

How to handle the mismatch?

Single inheritance of classes





And many other possibilities...

... but awkward

Discussion

- Does Java's multiple inheritance of interfaces require the "deltas" needed in C++?

The big picture

Dictionary lookup	V-table lookup	V-table + Slower hash lookup	V-table lookup + adjustments
Untyped + Single inheritance	Single inheritance	Single inheritance + interfaces	Multiple inheritance
Inclusion polymorphism			

Discussion

- Languages implement inclusion polymorphism very differently
  - Different performance
  - Different expressiveness
- Why did different languages make different decisions?

Next lecture

- Parametric polymorphism case study: SML
- Reading: SML document, Bob Harper (link from class web page)