Dynamic dispatch

Dynamic dispatch
– Also known as late binding or virtual methods
– Call self.m2() in method m1 defined in class C can resolve to a method m2 defined in a subclass of C
– Most unique characteristic of OOP

Need to define the semantics of method lookup as carefully as we defined variable lookup for our PLs

Review: variable lookup

Rules for “looking things up” is a key part of PL semantics

• ML: Look up variables in the appropriate environment
  – Lexical scope for closures
  – Field names (for records) are different: not variables
• Racket: Like ML plus let, letrec
• Ruby:
  – Local variables and blocks mostly like ML and Racket
  – But also have instance variables, class variables, methods (all more like record fields)
    • Look up in terms of self, which is special

Using self

• self maps to some “current” object
• Look up instance variable @x using object bound to self
• Look up class variables @@x using object bound to self.class
• Look up methods...

Ruby method lookup

The semantics for method calls also known as message sends e0.m(e1,...,en)

1. Evaluate e0, e1, ..., en to objects obj0, obj1, ..., objn
   – As usual, may involve looking up self, variables, fields, etc.
2. Let C be the class of obj0 (every object has a class)
3. If m is defined in C, pick that method, else recur with the superclass of C unless C is already Object
   – If no m is found, call method_missing instead
   • Definition of method_missing in Object raises an error
4. Evaluate body of method picked:
   – With formal arguments bound to obj1, ..., objn
   – With self bound to obj0 -- this implements dynamic dispatch!

Note: Step (3) complicated by mixins: will revise definition later

Punch-line again

e0.m(e1,...,en)

To implement dynamic dispatch, evaluate the method body with self mapping to the receiver (result of e0)

• That way, any self calls in body of m use the receiver’s class,
  – Not necessarily the class that defined m
• This much is the same in Ruby, Java, C#, Smalltalk, etc.
Comments on dynamic dispatch

• This is why distFromOrigin2 worked in PolarPoint

• More complicated than the rules for closures
  – Have to treat self specially
  – May seem simpler only if you learned it first
  – Complicated does not necessarily mean inferior or superior

Static overloading

In Java/CP/C++, method-lookup rules are similar, but more complicated because > 1 methods in a class can have same name
  – Java/CP/C++: Overriding only when number/types of arguments the same
  – Ruby: same-method-name always overriding

Pick the “best one” using the static (!) types of the arguments
  – Complicated rules for “best”
  – Type-checking error if there is no “best”

Relies fundamentally on type-checking rules
  – Ruby has none

A simple example, part 1

In ML (and other languages), closures are closed

fun even x = if x=0 then true else odd (x-1)
and odd x = if x=0 then false else even (x-1)

So we can shadow odd, but any call to the closure bound to odd above will “do what we expect”
  – Does not matter if we shadow even or not

(*) does not change odd – too bad; this would improve it *)
fun even x = (x mod 2)=0

(*) does not change odd – good thing; this would break it *)
fun even x = false

A simple example, part 2

In Ruby (and other OOP languages), subclasses can change the behavior of methods they do not override

class A
  def even x
    if x==0 then true else odd (x-1) end
  end
  def odd x
    if x==0 then false else even (x-1) end
  end
end

class B < A # improves odd in B objects
  def even x ; x % 2 == 0 end
end

class C < A # breaks odd in C objects
  def even x ; false end
end

The OOP trade-off

Any method that makes calls to overridable methods can have its behavior changed in subclasses even if it is not overridden
  – Maybe on purpose, maybe by mistake
  – Observable behavior includes calls-to-overridable methods

• So harder to reason about “the code you’re looking at”
  – Can avoid by disallowing overriding
    • “private” or “final” methods

• So easier for subclasses to affect behavior without copying code
  – Provided method in superclass is not modified later

Manual dynamic dispatch

Now: Write Racket code with little more than pairs and functions that acts like objects with dynamic dispatch

Why do this?
  – (Racket actually has classes and objects available)

• Demonstrates how one language’s semantics is an idiom in another language
• Understand dynamic dispatch better by coding it up
  – Roughly how an interpreter/compiler might

Analogy: Earlier optional material encoding higher-order functions using objects and explicit environments
Our approach

Many ways to do it; our code does this:

- An "object" has a list of field pairs and a list of method pairs
  
  \[
  \text{(struct obj (fields methods))}
  \]

- Field-list element example:
  
  \[
  (\text{mcons 'x 17})
  \]

- Method-list element example:
  
  \[
  (\text{cons 'get-x (lambda (self args) ...)})
  \]

Notes:

- Lists sufficient but not efficient
- Not class-based: object has a list of methods, not a class that has a list of methods [could do it that way instead]
- Key trick is lambdas taking an extra \text{self} argument
  
  - All "regular" arguments put in a list \text{args} for simplicity

Key helper functions

Now define plain Racket functions to get field, set field, call method

\[
\begin{align*}
\text{(define (assoc-m v xs) \\
  \ldots) ; assoc for list of mutable pairs} \\
\text{(define (get obj fld) \\
  \text{(let ((pr (assoc-m fld (obj-fields obj)))) \\
  \text{(if pr (mcdr pr) (error \ldots))))})} \\
\text{(define (set obj fld v) \\
  \text{(let ((pr (assoc-m fld (obj-fields obj)))) \\
  \text{(if pr (set-mcdr! pr v) (error \ldots))))})} \\
\text{(define (send obj msg . args) \\
  \text{(let ((pr (assoc msg (obj-methods obj)))) \\
  \text{(if pr ((cdr pr) obj args) (error \ldots))))})}
\end{align*}
\]

Constructing points

- Plain-old Racket function can take initial field values and build a point object
  
  - Use functions \text{get}, \text{set}, and \text{send} on result and in "methods"
  
  - Call to self: \text{(send self 'm \ldots)}
  
  - Method arguments in \text{args} list

\[
\begin{align*}
\text{(define (make-point _x _y) \\
  \text{(obj) \\
  \text{(list (mcons 'x _x) \\
  \text{(mcons 'y _y))} \\
  \text{(list (cons 'get-x (lambda (self args) (get self 'x))) \\
  \text{(cons 'get-y (lambda (self args) (get self 'y)))} \\
  \text{(cons 'set-x (lambda (self args) (\ldots))} \\
  \text{(cons 'set-y (lambda (self args) (\ldots))} \\
  \text{(cons 'distToOrigin (lambda (self args) (\ldots))))})}
\end{align*}
\]

"Subclassing"

- Can use make-point to write make-color-point or make-polar-point functions (see code)

- Build a new object using fields and methods from "super" constructor
  
  - Add new or overriding methods to the \text{beginning} of the list
  
  - Send will find the first matching method
  
  Since \text{send} passes the entire receiver for \text{self}, dynamic dispatch works as desired
Why not ML?

• We were wise not to try this in ML!

• ML’s type system does not have subtyping for declaring a polar-point type that “is also a” point type
  – Workarounds possible (e.g., one type for all objects)
  – Still no good type for those self arguments to functions
    • Need quite sophisticated type systems to support dynamic dispatch if it is not built into the language

• In fairness, languages with subtyping but not generics make it analogously awkward to write generic code