CS 251 Spring 2020
Principles of Programming Languages
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Dynamic Dispatch

semantic essence
of "object-oriented" programming languages
(OOP)

https://cs.wellesley.edu/~cs251/s20/

How are names resolved?

Key piece of semantics in any language.

- ML, Racket:
  - Just one kind of *variables.*
  - Lexical scope – unambiguous binding
  - Record *field names* are not variables: no "lookup"
- Java, ...:
  - Local variables: lexical scope (more limited)
  - Instance variables, methods
    - Look up in terms of special `this` "variable"
    - it's more complicated...

Method lookup in OO languages

Two key questions for Java:

- General case:
  What `m` is run by ___`.m()` ?
- Specific case:
  What `m` is run by `this.m()` ?

dynamic dispatch

```
class Point {
  double x, y;
  Point(double x, double y) {
    this.x = x; this.y = y;
  }
  double getX() { return this.x; }
  double getY() { return y; }
  double distFromOrigin() {
    return Math.sqrt(this.getX() * this.getX()
                     + getY() * getY());
  }
}

class PolarPoint extends Point { // poor design, useful example
  double r, theta;
  PolarPoint(double r, double theta) {
    super(0.0, 0.0);    this.r = r;    this.theta = theta;
  }
  double getX() { return this.r * Math.cos(this.theta); }
  double getY() { return r * Math.sin(theta); }
}
```

implicit `this.`

overriding

```
Point p = …;          // ???
p.getX();             // ???
p.distFromOrigin();   // ???
```

Aside: what about overloading?

- **Overloading** = multiple different methods/functions with different argument or return types that happen to share the same name. semantically uninteresting
- **Overriding** = method in subclass that "replaces" method in superclass in dynamic dispatch. semantically interesting!
- **Overloading != Overriding**

For purposes of 251: ignore overloading!

Method lookup: example

```
Point p = …;          // ???
p.getX();             // ???
p.distFromOrigin();   // ???
```

Key questions:

– Which **distToOrigin** is called?

– Which **getX**, **getY** methods does it call?

Dynamic dispatch

(a.k.a. late binding, virtual methods)

The unique OO semantics feature.

Method call: `e.m()`

Evaluation rule:

1. Under the current environment, evaluate `e` to value `v`.
2. Let `C` refer to the class of the receiver object `v`.
3. Until class `C` contains a method definition `m() { body }` let `C` refer to the superclass of the current `C` and repeat step 3.
4. Under the environment of class C, extended with the binding `this` ↦ `v`, evaluate the `body` found in step 3.

Note: `this` refers to ***current* receiver *object***, not containing class.

– **`this.m()`** uses **dynamic dispatch** just like other calls.

– **NOT** lexical scope, not dynamic scope

Dynamic dispatch is not ...

obj0.m(obj1,...,objn)

≠

m(**obj0**,obj1,...,objn)

Is **this** just an implicit parameter that captures a first argument written in a different spot?

NO!

"What **m** means" is determined by run-time class of **obj0**!

Must inspect **obj0** before starting to execute **m**.

this is different than any other parameters.

Key artifacts of dynamic dispatch

- Why **overriding** works…
  `distFromOrigin` in `PolarPoint`
- Subclass definition of **`m`** "shadows" superclass definition of **`m`** when dispatching on object of subclass (or descendant) in all contexts,
  even if dispatching from method in superclass.
- More complicated than the rules for closures
  - Must treat `this` specially
  - May seem simpler only if you learned it first
  - Complicated != inferior or superior

Closed vs. open

ML: closures are, well, *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)
```

May shadow `even`, but calls to `odd` are unaffected.

```
(* does not change odd: too bad, would help *)
fun even x = (x mod 2) = 0
```

```
(* does not change odd: good, would break *)
fun even x = false
```


Closed vs. open

Most OOP languages: subclasses can change the behavior of superclass methods they do not override.

```
class A {
  boolean even(int x) {
    if (x == 0) return true;
    else return odd(x-1);
  }
  boolean odd(int x) {
    if (x == 0) return false;
    else return even(x-1);
  }
}
class B extends A {  // improves odd in B objects
  boolean even(int x) { return x % 2 == 0; }
}
class C extends A {  // breaks odd in C objects
  boolean even(int x) { return false; }
}
```


OOP trade-off: implicit extensibility

Any method that calls overridable methods may have its behavior changed by a subclass ***even if it is not overridden.***

- On purpose, by mistake?
- Behavior depends on calls to overridable methods

- *Harder* to reason about "the code you're looking at."
  - Sources of unknown behavior are pervasive:
    all overridable methods transitively called by this method.
  - Avoid by disallowing overriding: "private" or "final"
- *Easier* for subclasses to extend existing behavior without copying code.
  - Assuming superclass method is not modified later

FP trade-off: explicit extensibility

A function that calls other functions may have its behavior affected ***only where it calls functions passed as arguments.***

- ***Easier*** to reason about "the code you're looking at."
  - Sources of unknown behavior are explicit: calls to argument functions.
- ***Harder*** for other code to extend existing behavior without copying code.
  - Only by functions as arguments.

Aside: *overloading* is static.

overloading:
> 1 methods in class have same name

Pick the "best" overloaded method using the ***static*** types of the arguments

- Complicated rules for "best"
- Some confusion when expecting wrong *over*-thing
- Not all that semantically interesting

overriding:
if and only if same number/types of arguments

Aside: static dispatch

(a.k.a early binding, non-virtual methods)

Requires static types...

Lookup method based on static type of receiver.

Using static dispatch, a call `e.m2()`, where `e` has declared class `C`:

Always resolves to "closest" method `m2` defined in `C` or `C`'s ancestor classes.

Completely ignores run-time class of object result of `e`.

... similar to lexical scope for method lookup with inheritance.

Same method call **always** resolves to same method definition.
Determined statically by type system *before* running program.

used for super in Java, non-virtual methods in C++

static dispatch

```
class Point {
  double x, y;
  Point(double x, double y) {
    this.x = x; this.y = y;
  }
  double getX() { return this.x; }
  double getY() { return y; }
  double distFromOrigin() {
    return Math.sqrt(this.getX() * this.getX()
                   + getY() * getY());
  }
}

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overriding

```
Point p = …;          // ???
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