PAUL G. ALLEN SCHOOL
OF COMPUTER SCIENCE & ENGINEERING

CSE341: Programming Languages

Lecture 23
Multiple Inheritance, Mixins, Interfaces, Abstract Methods

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What next?

Have used classes for OOP's essence: inheritance, overriding, dynamic dispatch

Now, what if we want to have more than *just 1 superclass*

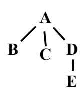
- *Multiple inheritance*: allow > 1 superclasses
  - Useful but has some problems (see C++)
- Ruby-style *mixins*: 1 superclass; > 1 method providers
  - Often a fine substitute for multiple inheritance and has fewer problems (see also Scala *traits*)
- Java/C#-style *interfaces*: allow > 1 types
  - Mostly irrelevant in a dynamically typed language, but fewer problems

Multiple Inheritance

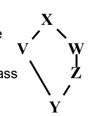
- If inheritance and overriding are so useful, why limit ourselves to one superclass?
  - Because the semantics is often awkward (this topic)
  - Because it makes static type-checking harder (not discussed)
  - Because it makes efficient implementation harder (not discussed)
- Is it useful? Sure!
  - Example: Make a `ColorPt3D` by inheriting from `Pt3D` and `ColorPt` (or maybe just from `Color`)
  - Example: Make a `StudentAthlete` by inheriting from `Student` and `Athlete`
  - With single inheritance, end up copying code or using non-OOP-style helper methods

Trees, dags, and diamonds

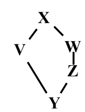
- Note: The phrases *subclass*, *superclass* can be ambiguous
  - There are *immediate* subclasses, superclasses
  - And there are *transitive* subclasses, superclasses
- Single inheritance: the *class hierarchy* is a tree
  - Nodes are classes
  - Parent is immediate superclass
  - Any number of children allowed



- Multiple inheritance: the class hierarchy no longer a tree
  - Cycles still disallowed (a directed-acyclic graph)
  - If multiple paths show that *X* is a (transitive) superclass of *Y*, then we have *diamonds*



What could go wrong?



- If *V* and *Z* both define a method `m`, what does *Y* inherit? What does `super` mean?
  - *Directed resends* useful (e.g., `Z::super`)
- What if *X* defines a method `m` that *Z* but not *V* overrides?
  - Can handle like previous case, but sometimes undesirable (e.g., `ColorPt3D` wants `Pt3D`'s overrides to "win")
- If *X* defines fields, should *Y* have one copy of them (`f`) or two (`V::f` and `Z::f`)?
  - Turns out each behavior can be desirable (next slides)
  - So C++ has (at least) two forms of inheritance

3DColorPoints

If Ruby had multiple inheritance, we would want `ColorPt3D` to inherit methods that share one `@x` and one `@y`

```
class Pt
  attr_accessor :x, :y
  …
end
class ColorPt < Pt
 attr_accessor :color
 …
end
class Pt3D < Pt
 attr_accessor :z
 … # override some methods
end
class ColorPt3D < Pt3D, ColorPt # not Ruby!
end
```

ArtistCowboys

This code has **Person** define a pocket for subclasses to use, but an **ArtistCowboy** wants *two* pockets, one for each **draw** method

```
class Person
  attr_accessor :pocket
  …
end
class Artist < Person # pocket for brush objects
 def draw # access pocket
 …
end
class Cowboy < Person # pocket for gun objects
 def draw # access pocket
 …
end
class ArtistCowboy < Artist, Cowboy # not Ruby!
end
```


Mixins

- A *mixin* is (just) a collection of methods
  - Less than a class: no instances of it
- Languages with mixins (e.g., Ruby modules) typically let a class have one superclass but *include* any number of mixins
- Semantics: *Including a mixin makes its methods part of the class*
  - Extending or overriding in the order mixins are included in the class definition
  - More powerful than helper methods because mixin methods can access methods (and instance variables) on **self** not defined in the mixin

Example

```
module Doubler
  def double
    self + self # assume included in classes w/ +
  end
end
class String
  include Doubler
end
class AnotherPt
  attr_accessor :x, :y
  include Doubler
  def + other
    ans = AnotherPt.new
    ans.x = self.x + other.x
    ans.y = self.y + other.y
    ans
end
```


Lookup rules

Mixins change our lookup rules slightly:

- When looking for receiver **obj**'s method **m**, look in **obj**'s class, then mixins that class includes (later includes shadow), then **obj**'s superclass, then the superclass' mixins, etc.
- As for instance variables, the mixin methods are included in the same object
  - So usually bad style for mixin methods to use instance variables since a name clash would be like our **CowboyArtist** pocket problem (but sometimes unavoidable?)

The two big ones

The two most popular/useful mixins in Ruby:

- Comparable: Defines **<**, **>**, **==**, **!=**, **>=**, **<=** in terms of **<=>**
- Enumerable: Defines many iterators (e.g., **map**, **find**) in terms of **each**

Great examples of using mixins:
- Classes including them get a bunch of methods for just a little work
- Classes do not "spend" their "one superclass" for this
- Do not need the complexity of multiple inheritance

- See the code for some examples

Replacement for multiple inheritance?

- A mixin works pretty well for **ColorPt3D**:
  - Color a reasonable mixin except for using an instance variable

```
module Color
 attr_accessor :color
end
```

- A mixin works awkwardly-at-best for **ArtistCowboy**:
  - Natural for **Artist** and **Cowboy** to be **Person** subclasses
  - Could move methods of one to a mixin, but it is odd style and still does not get you two pockets

```
module ArtistM …
class Artist < Person
  include ArtistM
class ArtistCowboy < Cowboy
  include ArtistM
```

Statically-Typed OOP

- Now contrast multiple inheritance and mixins with Java/C#-style interfaces
- Important distinction, but interfaces are about static typing, which Ruby does not have
- So will use Java code after quick introduction to static typing for class-based OOP…
  - Sound typing for OOP prevents "method missing" errors

Classes as Types

- In Java/C#/etc. each class is also a type
- Methods have types for arguments and result

```
class A {
  Object m1(Example e, String s) {…}
  Integer m2(A foo, Boolean b, Integer i) {…}
}
```

- If `C` is a (transitive) subclass of `D`, then `C` is a *subtype* of `D`
  - Type-checking allows subtype anywhere supertype allowed
  - So can pass instance of `C` to a method expecting instance of `D`

Interfaces are (or were) JustTypes

```
interface Example {
  void   m1(int x, int y);
  Object m2(Example x, String y);
}
```

- An interface is not a class; it is [er, used to be] only a type
  - Does not contain method *definitions*, only their *signatures* (types)
    - Unlike mixins
    - (Changed in Java 8, makes them more like mixins!)
  - Cannot use `new` on an interface
    - Like mixins

Implementing Interfaces

- A class can explicitly implement any number of interfaces
  - For class to type-check, it must implement every method in the interface with the right type
    - More on allowing subtypes later!
  - Multiple interfaces no problem; just implement everything
- If class type-checks, it is a subtype of the interface

```
class A implements Example {
  public void m1(int x, int y) {…}
  public Object m2(Example e, String s) {…}
}
class B implements Example {
  public void m1(int pizza, int beer) {…}
  public Object m2(Example e, String s) {…}
}
```


Multiple interfaces

- Interfaces provide no methods or fields
  - So no questions of method/field duplication when implementing multiple interfaces, unlike multiple inheritance
- What interfaces are for:
  - "Caller can give any instance of any class implementing `I`"
    - So callee can call methods in `I` regardless of class
  - So much more flexible type system
- Interfaces have little use in a dynamically typed language
  - Dynamic typing *already* much more flexible, with trade-offs we studied

Connections

Let's now answer these questions:

- What does a statically typed OOP language need to support "required overriding"?
- How is this similar to higher-order functions?
- Why does a language with multiple inheritance (e.g., C++) not need Java/C#-style interfaces?

[Explaining Java's abstract methods / C++'s pure virtual methods]

Required overriding

Often a class expects all subclasses to override some method(s)
- The purpose of the superclass is to abstract common functionality, but some non-common parts have no default

A Ruby approach:
- Do not define must-override methods in superclass
- Subclasses can add it
- Creating instance of superclass can cause method-missing errors

```
# do not use A.new
# all subclasses should define m2
class A
  def m1 v
    … self.m2 e …
  end
end
```


Static typing

- In Java/C#/C++, prior approach fails type-checking
  - No method `m2` defined in superclass
  - One solution: provide error-causing implementation

```
class A
  def m1 v
    … self.m2 e …
  end
  def m2 v
    raise "must be overridden"
  end
end
```

  - Better: Use static checking to prevent this error…

Abstract methods

- Java/C#/C++ let superclass give signature (type) of method subclasses should provide
  - Called *abstract methods* or *pure virtual methods*
  - Cannot creates instances of classes with such methods
    - Catches error at compile-time
    - Indicates intent to code-reader
    - Does *not* make language more powerful

```
abstract class A {
  T1 m1(T2 x) { … m2(e); … }
  abstract T3 m2(T4 x);
}
class B extends A {
  T3 m2(T4 x) { … }
}
```


Passing code to other code

- Abstract methods and dynamic dispatch: An OOP way to have subclass "pass code" to other code in superclass

```
abstract class A {
  T1 m1(T2 x) { … m2(e); … }
  abstract T3 m2(T4 x);
}
class B extends A {
  T3 m2(T4 x) { … }
}
```

- Higher-order functions: An FP way to have caller "pass code" to callee

```
fun f (g,x) = … g e …
fun h x = … f((fn y => …),…)
```


No interfaces in C++

- If you have multiple inheritance and abstract methods, you do not also need interfaces
- Replace each interface with a class with all abstract methods
- Replace each "implements interface" with another superclass

So: Expect to see interfaces only in statically typed OOP without multiple inheritance
- Not Ruby
- Not C++