Final Exam: Thur., Dec. 11, 2:30, here
- Review Wed., Dec 10, 4:30, CSE 403
- Old exams on website now
  - Ignore details no longer part of the course, but several of the old compiler questions are really about parsing & grammars, which is fair game
- In-class review & topic list this Friday

Assignment 7 due Thursday night 11 pm
- Printouts due in class Friday
- NO LATE ASSIGNMENTS – even if you didn’t use all of your late days
Overview

- Object-oriented programming: essence is inheritance, overriding, dynamic-dispatch
- What about multiple inheritance (>1 superclass)?
  - When does it make sense?
  - What are the issues?
Models

- Multiple Inheritance: >1 superclass
  - Useful, but has issues (e.g., C++)
- Java-style interfaces: >1 type
  - Doesn’t apply to dynamically-typed languages; fewer problems than multiple inheritance
- Mixins: >1 “source of methods”
  - Similarities to multiple inheritance – many of the goodies with fewer(?) problems
Multiple Inheritance

- If single inheritance is so useful, why not allow multiple superclasses?
  - Semantic and implementation complexities
  - Typing issues w/static typing
- Is it useful? Sure:
  - Color3DPoint extends 3DPoint, ColorPoint
- Naïve view: subclass has all fields and methods of all superclasses
Trees, DAGs, and Diamonds

- Class hierarchy forms a graph
  - Edges from subclasses to superclasses
  - Single inheritance: a tree
  - Multiple inheritance: a DAG

- Diamonds
  - With multiple inheritance, may be multiple ways to show that A is a (transitive) subclass of B
  - If all classes are transitive subclasses of e.g. Object, multiple inheritance always leads to diamonds
Multiple Inheritance: Semantic Issues

- What if multiple superclasses define the same message $m$ or field $f$?
  - Classic example: Artists, Cowboys, ArtistCowboys

- Options for method $m$:
  - Reject subclass as ambiguous – but this is too restrictive (esp. w/diamonds)
  - “Left-most superclass wins” – too restrictive (want per-method flexibility) + silent weirdness
  - Require subclass to override $m$ (can use explicitly qualified calls to inherited methods)
Multiple Inheritance: Semantic Issues

Options for field $f$: One copy of $f$ or multiple copies?

- Multiple copies: what you want if Artist::draw and Cowboy::draw use inherited fields differently
- Single copy: what you want for Color3dPoint $x$ and $y$ coordinates

C++ provides both kinds of inheritance

- Either two copies always, or one copy if field declared in same (parent) class
Java-Style Interfaces

- In Java we can define *interfaces* and classes can *implement* them
  - Interface describes methods and types
  - Interface *is* a type – can have variables, parameters, etc. with that type
  - If class C implements interface I, then instances of C have type I but must define everything in I (directly or via inheritance)
Interfaces are all about Types

- In Java, we can have 1 immediate superclass and implement any number of interfaces
- Interfaces provide no methods or fields – no duplication problems
  - If I1 and I2 both include some method \( m \), implementing class must provide it somehow
- But this doesn’t allow what we want for Color3DPoints or ArtistCowboys
  - No code inheritance/reuse possible
Java Interfaces and Ruby

- Concept is totally irrelevant for Ruby
  - We can already send any message to any object (dynamic typing)
  - We need to get it right (can always ask an object what messages it responds to)
Interfaces vs Abstract Classes

- Interfaces are not needed in C++. Why?
- C++ allows methods and classes to be abstract
  - Specified in class declaration but not provided in implementation (same as Java)
  - Called pure virtual methods in C++
- So a class can extend multiple abstract classes
  - Same as implementing interfaces
- But if that’s all you need, you don’t need multiple inheritance
  - Point to multiple inheritance is not just typing
Mixins

- A mixin is a collection of methods
  - No fields, constructors, instances, etc.
- Typically a language with mixins allows 1 superclass and any number of mixins
  - We’ve already seen this in Ruby
- Bad news: less powerful than multiple inheritance (what is in a class, what is in a mixin?)
- Good news: Clear semantics, great for certain idioms (Enumerable, Comparable using each, <=>)