CS61B Lecture #9: Abstract Classes and All That

Public Service Announcement:

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Abstract Methods and Classes

- Instance method can be *abstract:* No body given; must be supplied in subtypes.
- One good use is in specifying a pure interface to a family of types:

```
/** A drawable object. */
public abstract class Drawable {  // "abstract" = "can't say new Drawable"
  /** Expand THIS by a factor of SIZE */
  public abstract void scale (double size);
  /** Draw THIS on the standard output. */
  public abstract void draw ();
}
```

  Now a `Drawable` is something that has *at least* the operations `scale` and `draw` on it. *Can't create* a `Drawable` because it's abstract—in particular, it has two methods without any implementation.

- *BUT,* we can write methods that operate on `Drawables`:

```
void drawAll (Drawable[] thingsToDraw) {
   for (int i = 0; i < thingsToDraw.length; i += 1)
     thingsToDraw[i].draw ();
}
```

- But `draw` has no implementation! How can this work?

Concrete Subclasses

- Can define kinds of `Drawable`s that are non-abstract. To do so, must supply implementations for all methods:

```
public class Rectangle extends Drawable {
  public Rectangle (double w, double h) { this.w = w; this.h = h; }
  public void scale (double size) { w *= size; h *= size; }
  public void draw () { draw a w x h rectangle }
  private double w,h;
}
```

Any `Circle` or `Rectangle` is a Drawable.

```
public class Circle extends Drawable {
  public Circle (double rad) { this.rad = rad; }
  public void scale (double size) { rad *= size; }
  public void draw () { draw a circle with radius rad }
  double rad;
}
```

- So, writing

```
Drawable[] things = { new Rectangle (3, 4), new Circle (2) };
drawAll (things);
```

draws a 3×4 rectangle and a circle with radius 2.

Interfaces

- In *generic* use, an *interface* is a "point where interaction occurs between two systems, processes, subjects, etc." (*Concise Oxford Dictionary*).
- In programming, often use the term to mean a *description* of this generic interaction, specifically, a description of the functions or variables by which two things interact.
- Java uses the term to refer to a slight variant of an abstract class that contains only abstract methods (and static constants).
- Idea is to treat Java interfaces as the public specifications of data types, and classes as their implementations:

```
public interface Drawable {
  void scale (double size);   // Automatically public abstract.
  void draw ();
}

public class Rectangle implements Drawable { ... }
```

- Interfaces are automatically abstract: can't say `new Drawable();` can say `new Rectangle(...)`.

Multiple Inheritance

- Can *extend* one class, but *implement* any number of interfaces.
- Contrived Example:

```
interface Readable {                    |   void copy (Readable r,
  Object get ();                        |              Writable w)
}                                       |   {
                                        |     w.put (r.get ());
interface Writable {                    |   }
  void put (Object x);                  |
}                                       |
                                        |
class Source implements Readable {      |  class Sink implements Writable {
  public Object get () { ... }          |    public void put (Object x) { ... }
}                                       |  }

              class Variable implements Readable, Writable {
                public Object get () { ... }
                public void put (Object x) { ... }
              }
```

- The first argument of `copy` can be a `Source` or a `Variable`. The second can be a `Sink` or a `Variable`.

Review: Higher-Order Functions

- In Scheme, you had *higher-order functions* like this (adapted from *SICP*)

```
(define (map    proc          items)
;              function      list
  (if (null? items)
      nil
      (cons (proc (car items)) (map proc (cdr items)))))
```

  and could write

```
(map abs (list -10 2 -11 17))
  ====> (10 2 11 17)
(map (lambda (x) (* x x)) (list 1 2 3 4))
  ====> (1 4 9 16)
```

- Java does not have these directly, but can use abstract classes or interfaces and subtyping to get the same effect (with more writing)

Map in Java

```
/** Function with one integer argument */ | IntList map (IntUnaryFunction proc,
                                          |                IntList items) {
public interface IntUnaryFunction {       |   if (items == null)
  int apply (int x);                      |     return null;
}                                         |   else return new IntList (
                                          |       proc.apply (items.head),
                                          |       map (proc, items.tail)
                                          |     );
                                          | }
```

- It's the use of this function that's clumsy. First, define class for absolute value function; then create an instance:

```
class Abs implements IntUnaryFunction {
  public int apply (int x) { return Math.abs (x); }
}
----------------------------------------------
map (new Abs (), some list);
```

- Or, we can write a lambda expression (sort of):

```
map (new IntUnaryFunction () {
        public int apply (int x) { return x*x; }
     }, some list);
```

A Puzzle

```
class A {                                                | class B extends A {
  void f ()        { System.out.println ("A.f"); } |   void f ()        {
  void g () { f (); /* or this.f()  */ }                 |     System.out.println ("B.f");
//static void g (A y) { y.f(); }                         |   }
}                                                        | }
```

```
class C {
  static void main (String[] args) {
    B aB = new B ();
    h (aB);
  }

  static void h (A x) { x.g() }
//static void h (A x) { A.g(x); }
}
```

x.g(x) also legal here

1. What is printed?
2. What if we made `g` static?
3. What if we made `f` static?
4. What if `f` were not defined in A?

Choices:

a. `A.f`

b. `B.f`

c. Some kind of error

A Puzzle

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class A {                                                 | class B extends A {
  void f ()        { System.out.println ("A.f"); } |   void f ()        {
  void g () { f (); /* or this.f()  */ }              |     System.out.println ("B.f");
//static void g (A y) { y.f(); }                      |   }
}                                                         | }
```

```
class C {
  static void main (String[] args) {
    B aB = new B ();
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class A {                                              | class B extends A {
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//void g () { f (); /* or this.f()  */ }               |     System.out.println ("B.f");
  static void g (A y) { y.f(); }                       |   }
}                                                      | }
```

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class C {
  static void main (String[] args) {
    B aB = new B ();
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class A {                                                  | class B extends A {
  void f ()          { System.out.println ("A.f"); } |   void f ()        {
//void g () { f (); /* or this.f()  */ }                  |     System.out.println ("B.f");
  static void g (A y) { y.f(); }                          |   }
}                                                          | }
```

```
class C {
  static void main (String[] args) {
    B aB = new B ();
    h (aB);
  }

//static void h (A x) { x.g() }
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class A {                                                | class B extends A {
  static void f () { System.out.println ("A.f"); }      |   static void f () {
  void g () { f (); /* or this.f()  */ }                 |     System.out.println ("B.f");
//static void g (A y) { y.f(); }                         |   }
}                                                        | }
```

```
class C {
  static void main (String[] args) {
    B aB = new B ();
    h (aB);
  }

  static void h (A x) { x.g() }
//static void h (A x) { A.g(x); } x.g(x) also legal here
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A Puzzle

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class A {                                              | class B extends A {
  static void f () { System.out.println ("A.f"); }     |   static void f () {
  void g () { f (); /* or this.f()  */ }               |     System.out.println ("B.f");
//static void g (A y) { y.f(); }                       |   }
}                                                      | }
```

```
class C {
  static void main (String[] args) {
    B aB = new B ();
    h (aB);
  }

  static void h (A x) { x.g() }
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```

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A Puzzle

```
class A {                                                | class B extends A {
                                                         |   void f ()        {
  void g () { f (); /* or this.f()  */ }                 |     System.out.println ("B.f");
//static void g (A y) { y.f(); }                         |   }
}                                                        | }
```

```
          class C {
            static void main (String[] args) {
              B aB = new B ();
              h (aB);
            }

            static void h (A x) { x.g() }
          //static void h (A x) { A.g(x); } x.g(x) also legal here
          }
```

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Choices:

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A Puzzle

```
class A {                                          | class B extends A {
                                                   |   void f ()        {
  void g () { f (); /* or this.f()  */ }           |     System.out.println ("B.f");
//static void g (A y) { y.f(); }                   |   }
}                                                  | }
```

```
class C {
  static void main (String[] args) {
    B aB = new B ();
    h (aB);
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  static void h (A x) { x.g() }
//static void h (A x) { A.g(x); } x.g(x) also legal here
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Choices:

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Answer to Puzzle

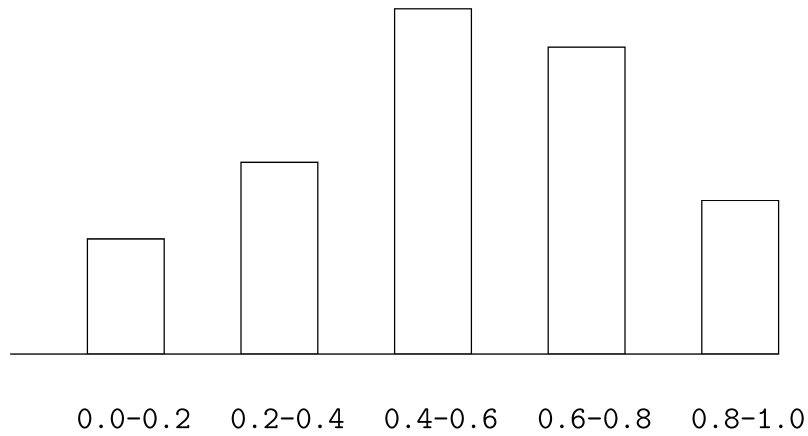
1. Executing `java C` prints ___, because
   1. `C.main` calls `h` and passes it `aB`, whose dynamic type is `B`.
   2. `h` calls `x.g()`. Since `g` is inherited by `B`, we execute the code for `g` in class `A`.
   3. `g` calls `this.f ()`. Now `this` contains the value of `h`'s argument, whose dynamic type is `B`. Therefore, we execute the definition of `f` that is in `B`.
   4. In calls to `f`, in other words, static type is ignored in figuring out what method to call.
2. If `g` were static, we see ___; selection of `f` still depends on dynamic type of `this`.
3. If `f` were static, would print ___ because then selection of `f` would depend on static type of `this`, which is `A`.
4. If `f` were not defined in `A`, we'd get ____________________.

Answer to Puzzle

1. Executing `java C` prints `B.f`, because
   1. `C.main` calls `h` and passes it `aB`, whose dynamic type is `B`.
   2. `h` calls `x.g()`. Since `g` is inherited by `B`, we execute the code for `g` in class `A`.
   3. `g` calls `this.f ()`. Now `this` contains the value of `h`'s argument, whose dynamic type is `B`. Therefore, we execute the definition of `f` that is in `B`.
   4. In calls to `f`, in other words, static type is ignored in figuring out what method to call.
2. If `g` were static, we see `B.f`; selection of `f` still depends on dynamic type of `this`.
3. If `f` were static, would print `A.f` because then selection of `f` would depend on static type of `this`, which is `A`.
4. If `f` were not defined in `A`, we'd get a compile-time error.

Example: Designing a Class

Problem: Want a class that represents histograms, like this one:



Analysis: What do we need from it? At least:

- Specify buckets and limits.
- Accumulate counts of values.
- Retrieve counts of values.
- Retrieve numbers of buckets and other initial parameters.

Specification Seen by Clients

- The *clients* of a module (class, program, etc.) are the programs or methods that *use* that module's exported definitions.
- In Java, intention is that exported definitions are designated **public**.
- Clients are intended to rely on *specifications*, not code.
- *Syntactic specification:* method and constructor headers—syntax needed to use.
- *Semantic specification:* what they do. No formal notation, so use comments.
  - Semantic specification is a *contract*.
  - Conditions client must satisfy (*preconditions*, marked "Pre:" in examples below).
  - Promised results (*postconditions*).
  - Design these to be *all the client needs!*
  - Exceptions communicate errors, specifically failure to meet pre-conditions.

Histogram Specification and Use

```
/** A histogram of floating-point values */
public interface Histogram {
  /** The number of buckets in THIS. */
  int size ();

  /** Lower bound of bucket #K. Pre: 0<=K<size(). */
  double low (int k);

  /** # of values in bucket #K. Pre: 0<=K<size(). */
  int count (int k);

  /** Add VAL to the histogram. */
  void add (double val);
}
```

Sample output:

```
>=  0.00 |   10
>= 10.25 |   80
>= 20.50 |  120
>= 30.75 |   50
```

```
void fillHistogram (Histogram H,
                    Scanner in)
{
    while (in.hasNextDouble ())
       H.add (in.nextDouble ());
}
```

```
void printHistogram (Histogram H) {
    for (int i = 0; i < H.size (); i += 1)
       System.out.printf
           (">=%5.2f | %4d%n",
            H.low (i), H.count (i));
}
```

An Implementation

```
public class FixedHistogram implements Histogram {
  private double low, high; /* From constructor*/
  private int[] count; /* Value counts */

  /** A new histogram with SIZE buckets recording values >= LOW and < HIGH. */
  public FixedHistogram (int size, double low, double high)
  {
    if (low >= high || size <= 0) throw new IllegalArgumentException ();
    this.low = low; this.high = high;
    this.count = new int[size];
  }

  public int size () { return count.length; }
  public double low (int k) { return low + k * (high-low)/count.length; }

  public int count (int k) { return count[k]; }

  public void add (double val) {
     int k = (int) ((val-low)/(high-low) * count.length);
     if (k >= 0 && k < count.length) count[k] += 1;
  }
}
```

Let's Make a Tiny Change

Don't require *a priori* **bounds:**

```
class FlexHistogram implements Histogram {
  /** A new histogram with SIZE buckets. */
  public FlexHistogram (int size) {
    ?
  }
  // What needs to change?
}
```

- How would you do this? Profoundly changes implementation.
- But *clients* (like `printHistogram` and `fillHistogram`) still work with no changes.
- Illustrates the power of *separation of concerns*.

Implementing the Tiny Change

- Pointless to pre-allocate the `count` array.
- Don't know bounds, so must save arguments to `add`.
- Then recompute `count` array "lazily" when `count(···)` called.
- Invalidate `count` array whenever histogram changes.

```
class FlexHistogram implements Histogram {
   private List<Double> values = ...; // Java library type (later)
   int size;
   private int[] count;

   public FlexHistogram (int size) { this.size = size; this.count = null;  }

   public void add (double x) { count = null; values.add (x); }

   public int count (int k) {
     if (count == null) { compute count from values here.  }
     return count[k];
   }
}
```

Advantages of Procedural Interface over Visible Fields

By using public method for `count` instead of making the array `count` visible, the "tiny change" is transparent to clients:

- If client had to write `myHist.count[k]`, would mean

  "The number of items currently in the k^{th} bucket of histogram `myHist` (and by the way, there is an array called `count` in `myHist` that always holds the up-to-date count)."

- Parenthetical comment *useless* to the client.
- But if `count` array had been visible, after "tiny change," *every use* of `count` in client program would have to change.
- So using a method for the public `count` decreases what client *has* to know, and (therefore) has to change.