

CS61B Lectures #7:

- If you feel you can do the labs at home, make arrangements with your TA to get them checked off.
- Programming Contest: September 25th. Links are on our web page.

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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?

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Concrete Subclasses

- Can define kinds of Drawables 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.

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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(...).

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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.

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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)

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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);
```

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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

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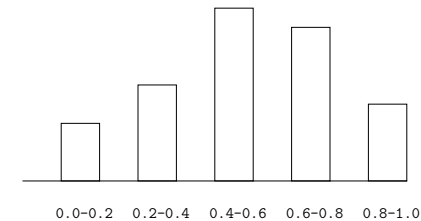
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Answer to Puzzle

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 _____.

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 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;
    }
}
```

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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*.

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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];
    }
}
```

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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.

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