

CS61B Lecture #9: Interfaces and Abstract Classes

- HW #3 should be posted.
- Project #1 will be posted by the end of Thursday. Due 9 October.
- First test in class 17 October.
- **Readings for today:** §5.5 of *A Java Reference*.

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 (Drawable thing : thingsToDraw)
        thing.draw ();
}
```

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

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.

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(...)`.

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);
```

Review: A Puzzle

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

class B extends A {
    void f ()          {
        System.out.println ("B.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

Review: A Puzzle

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

class B extends A {
    void f ()          {
        System.out.println ("B.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

Review: A Puzzle

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

class B extends A {
    void f ()          {
        System.out.println ("B.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

Review: A Puzzle

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

class B extends A {
    void f ()          {
        System.out.println ("B.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

Review: A Puzzle

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

class B extends A {
    static void f () {
        System.out.println ("B.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

Review: A Puzzle

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

class B extends A {
    static void f () {
        System.out.println ("B.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

Review: A Puzzle

```
class A {  
    void g () { f (); /* or this.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  
}
```

```
| class B extends A {  
|     void f ()      {  
|         System.out.println ("B.f");  
|     }  
| }
```

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

Review: A Puzzle

```
class A {  
    void g () { f (); /* or this.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  
}
```

```
| class B extends A {  
|     void f ()      {  
|         System.out.println ("B.f");  
|     }  
| }
```

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

Answer to Puzzle

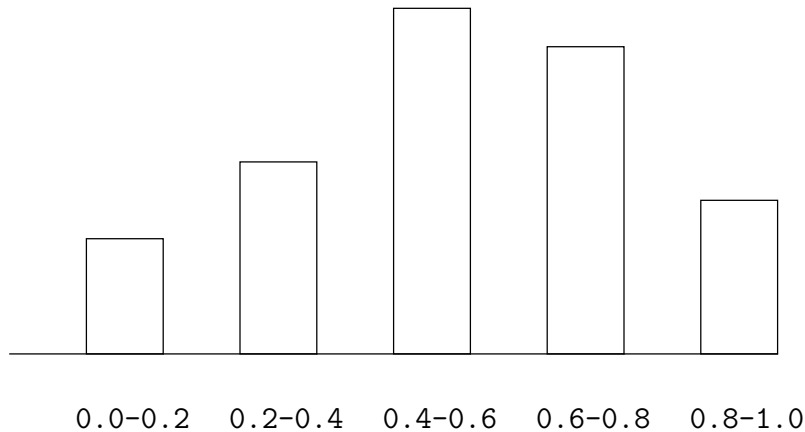
1. Executing `java C` prints ____, because
 1. `C.main` calls `h` and passes it `aB`, whose dynamic type is `B`.
 2. `h` calls `x.g()`. Since `g` is inherited by `B`, we execute the code for `g` in class `A`.
 3. `g` calls `this.f()`. Now `this` contains the value of `h`'s argument, whose dynamic type is `B`. Therefore, we execute the definition of `f` that is in `B`.
 4. `h` 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(\dots) 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.