Recreation

Show that for any polynomial with a leading coefficient of 1 and integral coefficients, all rational roots are integers.

CS61B Lecture #9: Interfaces and Abstract Classes

Announcements

- Berkeley Programming Contest: Sat., 3 October at 10:00 AM.
- Summary of readings on current topic up to now: Chapters 7–9 of *Head-First Java*.
- **Reminder:** Projects are individual efforts:

> "The four projects are individual efforts in this class (no partnerships). Feel free to discuss projects or pieces of them before doing the work. But you must complete and write up each project yourself. That is, feel free to discuss projects with each other, but be aware that we expect your work to be substantially different from that of all your classmates (in this or any other semester)."

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.

Methods on Drawables

```
/** 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();
}
```

- Can't write `new Drawable()`, because it would have unimplemented methods.
- *BUT*, we can write methods that operate on `Drawables` in `Drawable` or in other classes:

```
void drawAll(Drawable[] thingsToDraw) {
   for (Drawable thing : thingsToDraw)
     thing.draw();
}
```

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

Concrete Subclasses

- Regular classes can extend abstract ones to make them "less abstract" by overriding their abstract methods.
- Can define kinds of Drawables that are *concrete*, in that all methods have implementations and one can use **new** on them:

```
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 }
  private double rad;
}
```


Using Concrete Classes

- We *can* create new Rectangles and Circles.
- Since these classes are subtypes of Drawable, we can put them in any container whose static type is Drawable, ...
- ... and therefore can pass them to any method that expects Drawable parameters:
- Thus, 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), like this:

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

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

Implementing Interfaces

- Idea is to treat Java interfaces as the public specifications of data types, and classes as their implementations:

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

- Can use the interface as for abstract classes:

```
void drawAll(Drawable[] thingsToDraw) {
   for (Drawable thing : thingsToDraw)
     thing.draw();
}
```

- Again, this works for Rectangles and any other implementation of Drawable.

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 Python, you had *higher-order functions* like this:

```
def map(proc,      items):
      function      list
   if items is None:
       return None
   else:
       return IntList(proc(items.head), map(proc, items.tail))
```

and could write

```
zmap(abs, makeList(-10, 2, -11, 17))
  ====> makeList(10, 2, 11, 17)
map(lambda x: x * x, makeList(1, 2, 3, 4))
  ====> makeList(t(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); }
}
----------------------------------------------
R = map(new Abs(), some list);
```


Lambda Expressions

- In Java 7, one can create classes likes `Abs` on the fly with *anonymous classes*:

```
R = map(new IntUnaryFunction() { public int apply(int x) { return Math.abs(x); } }
        some list);
```

- This is sort of like declaring

```
class Anonymous implements IntUnaryFunction {
    public int apply(int x) { return x*x; }
}
```

and then writing

```
R = map(new Anonymous(), some list);
```

- In Java 8, this is even more succinct:

```
R = map((int x) -> Math.abs(x), some list);
    or even better, when the function already exists:
R = map(Math::abs, some list);
```

- These figure out you need an anonymous `IntUnaryFunction` and create one.

Review: 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

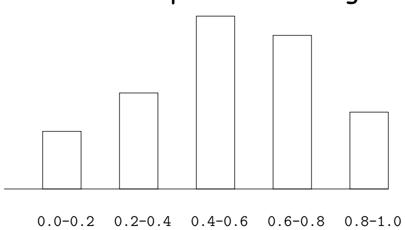
c. Some kind of error

Answer to Puzzle

1. Executing `java C` prints ___, because
   A. `C.main` calls `h` and passes it `aB`, whose dynamic type is `B`.
   B. `h` calls `x.g()`. Since `g` is inherited by `B`, we execute the code for `g` in class `A`.
   C. `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`.
   D. 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*, (*aka* APIs) 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.