CS61B Lecture #8: Object-Oriented Mechanisms

Today:

• New in this lecture: the bare mechanics of “object-oriented programming.”

• The general topic is: Writing software that operates on many kinds of data.
Overloading

Problem: How to get `System.out.print(x)` to print `x`, regardless of type of `x`?

- In Scheme or Python, one function can take an argument of any type, and then test the type (if needed).
- In Java, methods specify a single type of argument.
- Partial solution: overloading—multiple method definitions with the same name and different numbers or types of arguments.
- E.g., `System.out` has type `java.io.PrintStream`, which defines
  ```java
  void println() Prints new line.
  void println(String s) Prints S.
  void println(boolean b) Prints "true" or "false"
  void println(char c) Prints single character
  void println(int i) Prints I in decimal
  etc.
  ```
- Each of these is a different function. Compiler decides which to call on the basis of arguments’ types.
Generic Data Structures

**Problem:** How to get a “list of anything” or “array of anything”?

- Again, no problem in Scheme or Python.
- But in Java, lists (such as `IntList`) and arrays have a single type of element.
- First, the short answer: any `reference` value can be converted to type `java.lang.Object` and back, so can use `Object` as the “generic (reference) type”:

```java
Object[] things = new Object[2];
things[0] = new IntList(3, null);
things[1] = "Stuff";
// Now ((IntList) things[0]).head == 3;
// and ((String) things[1]).startsWith("St") is true
// things[0].head Illegal
// things[1].startsWith("St") Illegal
```
And Primitive Values?

- Primitive values (ints, longs, bytes, shorts, floats, doubles, chars, and booleans) are not really convertible to `Object`.

- Presents a problem for “list of anything.”

- So Java introduced a set of wrapper types, one for each primitive type:

<table>
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<tbody>
<tr>
<td>byte</td>
<td>short</td>
<td>int</td>
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<tr>
<td>Byte</td>
<td>Short</td>
<td>Integer</td>
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<td>long</td>
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<td>Long</td>
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<td>float</td>
<td>double</td>
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<tr>
<td>Float</td>
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</tbody>
</table>

- One can create new wrapper objects for any value (boxing):

  ```java
  Integer Three = new Integer(3);
  Object ThreeObj = Three;
  ```

  and vice-versa (unboxing):

  ```java
  int three = Three.intValue();
  ```
**Autoboxing**

In recent versions, boxing and unboxing is automatic (in many cases):

```java
Integer Three = 3;
int three = Three;
int six = Three + 3;

Integer[] someInts = { 1, 2, 3 };
for (int x : someInts) {
    System.out.println(x);
}

System.out.println(someInts[0]);  // Prints Integer 1, but NOT unboxed.
```
Dynamic vs. Static Types

- Every value has a type—its **dynamic type**.
- Every container (variable, component, parameter), literal, function call, and operator expression (e.g. \(x+y\)) has a type—its **static type**.
- Therefore, every expression has a static type.

```java
Object[] things = new Object[2];
things[0] = new IntList(3, null);
things[1] = "Stuff";
```
Type Hierarchies

- A container with (static) type T may contain a certain value only if that value “is a” T—that is, if the (dynamic) type of the value is a subtype of T. Likewise, a function with return type T may return only values that are subtypes of T.

- All types are subtypes of themselves (& that’s all for primitive types)

- Reference types form a type hierarchy; some are subtypes of others. null’s type is a subtype of all reference types.

- All reference types are subtypes of Object.
Java Library Type Hierarchy (Partial)

```
int  double  boolean  ...  Object

Integer  Double  Boolean  String  IntList  int[]  Object[]

<String>  <nulltype>
```

-is a-

(un)wraps to

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The Basic Static Type Rule

- Java is designed so that any expression of (static) type T always yields a value that “is a” T.
- Static types are “known to the compiler,” because you declare them, as in
  
  ```java
  String x;      // Static type of field
  int f(Object s) { // Static type of call to f, and of parameter
      int y;     // Static type of local variable
  }
  ```

  or they are pre-declared by the language (like 3).
- Compiler insists that in an assignment, \( L = E \), or function call, \( f(E) \), where

  ```java
  void f(SomeType L) { ... };
  ```

  E’s static type must be subtype of L’s static type.
- Similar rules apply to \( E[i] \) (static type of E must be an array) and other built-in operations.
Coercions

• The values of type short, for example, are a subset of those of int (shorts are representable as 16-bit integers, ints as 32-bit integer)

• But we don’t say that short is a subtype of int, because they don’t quite behave the same.

• Instead, we say that values of type short can be coerced (converted) to a value of type int.

• Leads to a slight fudge: compiler will silently coerce “smaller” integer types to larger ones, float to double, and (as just seen) between primitive types and their wrapper types.

• So,

  short x = 3002;
  int y = x;

  works without complaint.
Consequences of Compiler’s “Sanity Checks”

• This is a conservative rule. The last line of the following, which you might think is perfectly sensible, is illegal:

```java
int[] A = new int[2];
Object x = A;    // All references are Objects
A[i] = 0;       // Static type of A is array...
x[i+1] = 1;     // But not of x: ERROR
```

Compiler figures that not every Object is an array.

• Q: Don’t we know that x contains array value!?

• A: Yes, but still must tell the compiler, like this:

```java
(((int[])) x)[i+1] = 1;
```

• Defn: Static type of cast (T) E is T.

• Q: What if x isn’t an array value, or is null?

• A: For that we have runtime errors—exceptions.
Overriding and Extension

• Notation so far is clumsy.

• Q: If I know Object variable \( x \) contains a String, why can’t I write, \( x \).startsWith("this")?

• A: \( \text{startsWith} \) is only defined on Strings, not on all Objects, so the compiler isn’t sure it makes sense, unless you cast.

• But, if an operation were defined on all Objects, then you wouldn’t need clumsy casting.

• Example: .toString() is defined on all Objects. You can always say \( x \).toString() if \( x \) has a reference type.

• The default .toString() function is not very useful; on an IntList, would produce string like "IntList@2f6684"

• But for any subtype of Object, you may override the default definition.
Overriding toString

• For example, if s is a String, s.toString() is the identity function (fortunately).

• For any type you define, you may supply your own definition. For example, in IntList, could add

   public String toString()
   {
      StringBuffer b = new StringBuffer();
      b.append("[");
      for (IntList L = this; L != null; L = L.tail)
         b.append(" "+L.head);
      b.append("]");
      return b.toString();
   }

• If x = new IntList(3, new IntList(4, null)), then x.toString() is ":[3 4]"

• Conveniently, the "+" operator on Strings calls .toString when asked to append an Object, and so does the "%s" formatter for printf.

• With this trick, you can supply an output function for any type you define.
Extending a Class

• To say that class B is a direct subtype of class A (or A is a direct superclass of B), write

        class B extends A {
            ...
        }

• By default, class ... extends java.lang.Object.

• The subtype inherits all fields and methods of its superclass (and passes them along to any of its subtypes).

• In class B, you may override an instance method (not a static method), by providing a new definition with same signature (name, return type, argument types).

• I'll say that a method and all its overridings form a dynamic method set.

• The Point: If $f(...)$ is an instance method, then the call $x.f(...)$ calls whatever overriding of $f$ applies to the dynamic type of $x$, regardless of the static type of $x$. 
Illustration

class Worker {
    void work() {
        collectPay();
    }
}

class Prof extends Worker {
    // Inherits work()
}

class TA extends Worker {
    void work() {
        while (true) {
            doLab(); discuss(); officeHour();
        }
    }
}

Prof paul = new Prof();
TA daniel = new TA();
Worker wPaul = paul,
    wDaniel = daniel;

paul.work() ==> collectPay();
daniel.work() ==> doLab(); discuss(); ...
wPaul.work() ==> collectPay();
wDaniel.work() ==> doLab(); discuss(); ...

Lesson: For instance methods (only), select method based on dynamic type. Simple to state, but we’ll see it has profound consequences.
What About Fields and Static Methods?

class Parent {
    int x = 0;
    static int y = 1;
    static void f() {
        System.out.printf("Ahem!\n");
    }
    static int f(int x) {
        return x+1;
    }
}

class Child extends Parent {
    String x = "no";
    static String y = "way";
    static void f() {
        System.out.printf("I wanna!\n");
    }
}

Child tom = new Child();  // tom.x ==> no  pTom.x ==> 0
Parent pTom = tom;         // tom.y ==> way  pTom.y ==> 1
// tom.f() ==> I wanna!  pTom.f() ==> Ahem!
// tom.f(1) ==> 2          pTom.f(1) ==> 2

Lesson:  Fields hide inherited fields of same name; static methods hide methods of the same signature.
Real Lesson: Hiding causes confusion; so understand it, but don’t do it!
What's the Point?

• The mechanism described here allows us to define a kind of *generic* method.

• *A superclass* can define a set of operations (methods) that are common to many different classes.

• *Subclasses* can then provide different implementations of these common methods, each specialized in some way.

• All subclasses will have at least the methods listed by the superclass.

• So when we write methods that operate on the superclass, they will automatically work for all subclasses with no extra work.