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() \textit{Prints new line.}
  void println(String s) \textit{Prints S.}
  void println(boolean b) \textit{Prints "true" or "false"}
  void println(char c) \textit{Prints single character}
  void println(int i) \textit{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:

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<tr>
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<tbody>
<tr>
<td>byte</td>
<td>Byte</td>
<td>short</td>
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<td>long</td>
<td>Long</td>
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<td>float</td>
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<td></td>
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<td>int</td>
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<td></td>
<td></td>
<td>boolean</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

Boxing and unboxing are 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.

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[]
   |       |         |         |
<nulltype> String[]
```

is a (un)wraps to
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: 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

```java
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
  
  ```java
  class B extends A {
  ... 
  }
  ```

• By default, class \( ... \) extends java.lang.Object.

• The subtype inherits all fields and methods of its direct 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 \( f(\ldots) \) is an instance method, then the call \( x.f(\ldots) \) 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();  | paul.work() ==> collectPay();
TA daniel = new TA();    | daniel.work() ==> doLab(); discuss(); ...  
Worker wPaul = paul,      | wPaul.work() ==> collectPay();
    wDaniel = daniel;      | 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?

```java
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();
Parent pTom = tom;

| tom.x   | --> no |
| tom.y   | --> way |
| tom.f() | --> I wanna! |
| tom.f(1)| --> 2 |
| pTom.x  | --> 0 |
| pTom.y  | --> 1 |
| pTom.f()| --> Ahem! |
| 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.