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:

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<tr>
<td>byte</td>
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<td>long</td>
<td>Long</td>
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<td>float</td>
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<td>int</td>
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<td></td>
<td></td>
<td>boolean</td>
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</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.
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,

  ```java
  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 \textit{x} contains a String, why can’t I write, \textit{x.startsWith("this")}?

• A: \textit{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 \textit{were} defined on all Objects, then you \textit{wouldn’t} need clumsy casting.

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

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

• But for any subtype of Object, you may \textit{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

        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 overrides 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.
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.