Programming Languages and Techniques (CIS120)

Lecture 24

Mar. 16, 2012

Subtyping and Extension

Announcements

- HW08 (Adventure game) posted soon
  - Objects with mutable state
  - Due Monday, Mar 26th
- Midterm 2 is Friday, Mar. 30th in class
  - Mutable state (in OCaml and Java)
  - Objects (in OCaml and Java)
  - Reactive programming
  - Arrays

Types and Subtyping

Why Static Types?

- Types stop you from using values incorrectly
  - `3.m()`
  - `if (3) { return 1; } else { return 2; }`
  - `3 + true`
  - `(new Counter()).m()`
- All *expressions* have types
  - `3 + 4` has type `int`
  - `"A".toLowerCase()` has type `String`
  - `new ResArray()` has type `ResArray`
- How do we know if `x.m()` is correct? or `x+3`?
  - depends on the type of `x`
  - variable declarations specify types of variables
- Type restrictions preserve the types of variables
  - assignment "x = v" must be to values with compatible types
  - methods "o.m(3)" must be called with compatible argument types
- HOWEVER: in Java, values can have *multiple* types....

Subtyping

- **Definition**: Type A is a *subtype* of type B if A can do anything that B can do. Type B is called the *supertype* of A.
- **Example**: A class that implements an interface is a subtype of the interface

```
interface Area {
    public double getArea ();
}
public class Circle implements Area {
    private double r;
    private Point p;
    public Circle (double x0, double y0, double r0) {
       r = r0; p = new Point(x0,y0);
    }
    public double getArea ()  {
       return 3.14159 * r * r;
    }
    public double getRadius () { return r; }
}
```

Subtyping and Variables

- A a *variable* declared with type A can store any *object* that is a subtype of A

```
Area a = new Circle(1, new Point(2,3));
```

supertype of Circle

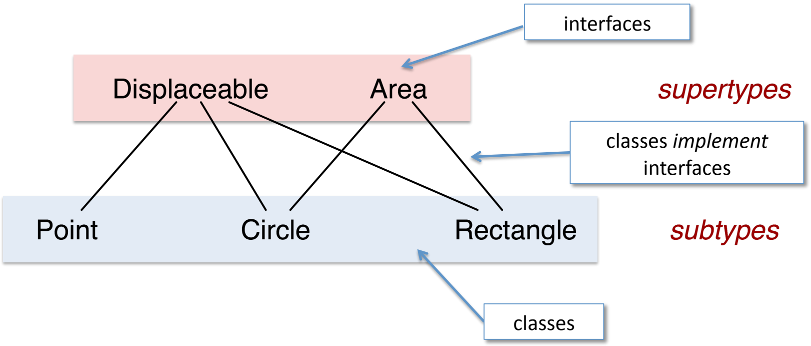
subtype of Area

- Methods with *parameters* of type A must be called with *arguments* that are subtypes of A

```
static void double m (Area x) {
   return x.getArea() * 2;
}
...
C.m( new Circle(1, new Point(2,3)) );
```

Subtypes and Supertypes

- An interface represents a *point of view* about an object
- Classes can implement *multiple* interfaces



Types can have many different supertypes / subtypes

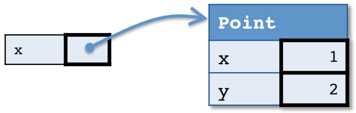
"Static" types vs. "Dynamic" classes

- The **static type** of an *expression* is a type that describes what we (and the compiler) know about the expression at compile-time (without thinking about the execution of the program)

```
Displaceable x;
```

- The **dynamic class** of an *object* is the class that it was constructed from at run time

```
x = new Point(1,2)
```



- In OCaml, we only had static types
- In Java, we also have dynamic classes because of objects
  - The dynamic class will always be a *subtype* of its static type

Static type vs. Dynamic class quiz

```
public Area asArea (Area s) {
   return s;
}
…
Rectangle r =
  new Rectangle (1,2,1,1);
Circle c = new Circle (1,1,3);
Area s1 = r;  // A
Area s2 = c;  // B
s2 = r;       // C

__D__ x = asArea (r);
__E__ y = asArea (s1);

s1 = c;   // F
s1 = s2;  // G
r = c;    // H
r = s1;   // I
```

- What is the static type of s1 on line A?
- What is the dynamic class of s1 when execution reaches A?
- What is the static type of s2 on line B?
- What is the dynamic class of s2 when execution reaches B?
- What type should we declare for x (in blank D)?
- What is the dynamic class of x?
- What type should we declare for y (in blank E)?
- What is the dynamic class of y?
- Which of the assignments on lines F-I are well typed?

Extension

1. Interface extension
2. Class extension (Simple inheritance)
3. `Object` – the root of the type hierarchy

Interface Extension

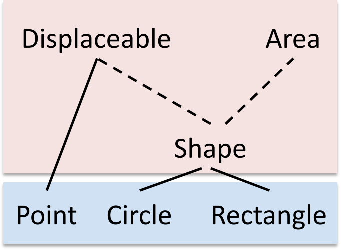
- Build richer interface hierarchies by *extending* existing interfaces.

```
public interface Displaceable {
  double getX();
  double getY();
  void move(double dx, double dy);
}

public interface Area {
  double getArea();
}

public interface Shape extends Displaceable, Area {
   Rectangle getBoundingBox();
}
```

The Shape type includes all the methods of Displaceable and Area, plus the new getBoundingBox method.

Note the use of the "extends" keyword.

Interface Hierarchy



```
class Point implements Displaceable {
  … // omitted
}
class Circle implements Shape {
  … // omitted
}
class Rectangle implements Shape {
  … // omitted
}
```

- Shape is a *subtype* of both Displaceable and Area.
- Circle and Rectangle are both subtypes of Shape, and, by *transitivity*, both are also subtypes of Displaceable and Area.
- Note that one interface may extend *several* others.
  - Interfaces do not necessarily form a tree, but the hierarchy has no cycles.

Interface Extension Demo

See: Main1.java

Class Extension: Inheritance

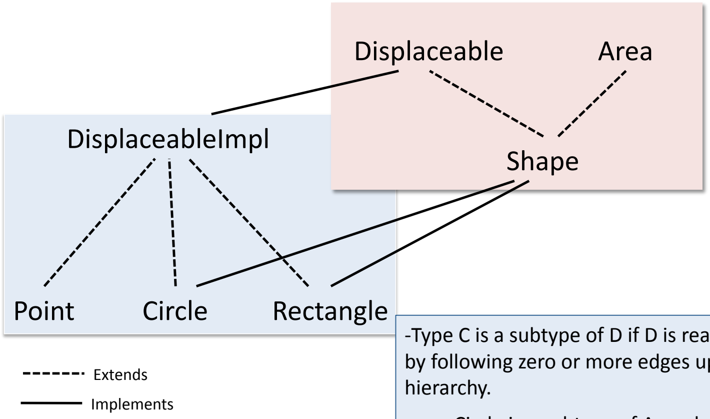
- Classes, like interfaces, can also extend one another.
  - Unlike interfaces, a class can extend only *one* other class.
- The extending class *inherits* all of the fields and methods of its *superclass*, and may include additional fields or methods.
  - This captures the “is a” relationship between objects (e.g. a Car is a Vehicle).
  - Class extension should *never* be used when “is a” does not relate the subtype to the supertype.

```
class D {
  private int x;
  private int y;
  public int addBoth() { return x + y; }
}

class C extends D {     // every C is a D
  private int z;
  public int addThree() {return (addBoth() + z); }
}
```

Simple Inheritance

- In *simple inheritance*, the subclass only *adds* new fields or methods.
- Use simple inheritance to *share common code* among related classes.
- Example: Point, Circle, and Rectangle have *identical* code for getX(), getY(), and move() methods when implementing Displaceable.

Subtyping with Inheritance



-Type C is a subtype of D if D is reachable from C by following zero or more edges upwards in the hierarchy.

- e.g. Circle is a subtype of Area, but Point is not

Example of Simple Inheritance

See: Main2.java

Inheritance: Constructors

- Contructors *cannot* be inherited (they have the wrong names!)
  - Instead, a subclass invokes the constructor of its super class using the keyword ‘super’.
  - Super *must* be the first line of the subclass constructor, unless the parent class constructor takes no arguments, in which it is OK to omit the call to super (it is called implicitly).

```
class D {
  private int x;
  private int y;
  public D (int initX, int initY) { x = initX; y = initY; }
  public int addBoth() { return x + y; }
}

class C extends D {
  private int z;
  public C (int initX, int initY, int initZ) {
    super(initX, initY);
    z = initZ;
  }
  public int addThree() {return (addBoth() + z); }
}
```

Other forms of inheritance

- Java has other features related to inheritance (some of which we will discuss later in the course):
  - A subclass might *override* (re-implement) a method already found in the superclass.
  - A class might be *abstract* – i.e. it does not provide implementations for all of its methods (its subclasses must provide them instead)
- These features are hard to use properly and the need for them arises in special cases
  - Making reusable libraries
  - Special methods: equals and toString
- We recommend avoiding all forms of inheritance (even “simple inheritance”) when possible – prefer interfaces and composition (see Main3.java).

  Especially avoid overriding.