Objects and Classes

March 28, 2001

CS 131: Programming Languages

Questions to Think About

- What is an object?
- What is a class?
- What is a method?
- What makes a language object-oriented?

Extensibility

- Frequently a problem domain consists of
  - A collection of sorts of data item
  - Operations on data items
- Extensibility can be a problem.
  - How hard is it to add new sorts of data?
  - How hard is it to add new operations?

SML vs. OOP approaches

- Example:
  - Geometric shapes (circles, squares, ...)
  - Operations on shapes (translate, rotate, scale, ...)
- SML
  - Create a single datatype `shape`
  - Operations pattern-match on the sort of shape
- OOP
  - Create subclass of `shape` class for each shape
  - Operations become methods of the class

Prototypical Class

```
class Cell is
   field contents : int = 0;
   method get() : int is
      return this.contents;
   end;
   method set(n:int) is
      this.contents := n;
   end;
end;
```

Prototypical Usage of a Class

```
mycell = new Cell;
mycell.contents := 7;
mycell.set(12);
x = mycell.get();

procedure double(c:Cell) is
   c.set(2 * c.get());
end;

double(mycell);
```

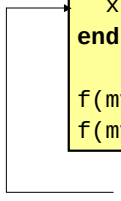
Prototypical Subclass

```
subclass ReCell of Cell is
   field backup : int = 0
   override set(n:int) is
     this.backup := this.contents;
     super.set(n);
   end;
   method restore() is
     this.contents := this.backup;
   end;
end;
```

Prototypical Usage of a Subclass

```
mycell = new Cell;
myrecell = new ReCell;
procedure f(x:Cell) is
  x.set(3);
end;

f(mycell);
f(myrecell);
```



Subclassing vs. Subtyping

Is it safe to conclude that every circle is a shape?

```
class shape is
  ...
  method clone() : shape;
end;

subclass circle of shape is
  ...
  override clone() : circle
end;
```

Subclassing vs. Subtyping

Assume `Vegetables` $\preccurlyeq$ `Food`. Is it safe to conclude that every vegetarian is a person?

```
class person is
  ...
  method eat(food : Food);
end;

subclass vegetarian of person is
  ...
  override eat(food : Vegetables);
end;
```

Subclassing vs. Subtyping

Assume `Vegetables` $\preccurlyeq$ `Food`. Is it safe to conclude that every omnivorous cow is a cow?

```
class cow is
  ...
  method eat(food : Vegetables) {
  ...
end;
subclass omnivorouscow of cow is
  ...
  override eat(food : Food) {
  ...
end;
```

Subclassing vs. Subtyping

Is it safe to conclude that every colored point is a point?

```
class point is
  field x : int = 0;
  method equal(other : point) : bool
  ...
end;
subclass cpoint of point is
  field c : color = red;
  overload equal(other : cpoint) : bool
end;
```

Subclassing vs. Subtyping

Example usage

```
function f(p1:point, p2:point):bool {
  return p1.equal(p2);
}

p1 = new point;
p2 = new point;
x1 = f(p1,p2);
cp1 = new cpoint;
cp2 = new cpoint;
x2 = f(cp1,cp2);
```

Subclassing vs. Subtyping

Now, is it safe to conclude that every colored point is a point?

```
class point is
  field x : int = 0;
  method equal(other : point) : bool
  ...
end;
subclass cpoint of point is
  field c : color = red;
  override equal(other : cpoint) : bool
end;
```

Subclassing vs. Subtyping

Example usage

```
function f(p1:point, p2:point):bool {
  return p1.equal(p2);
}

p1 = new point;
p2 = new point;
x1 = f(p1,p2);
cp1 = new cpoint;
cp2 = new cpoint;
x2 = f(cp1,cp2);
```

Subclassing vs. Subtyping

- Summary: When overriding methods it's safe to
  - Make the arguments of methods less specific
  - Make the return types of methods more specific
- Java permits neither
- C++ permits only the latter.
- Eiffel permits "wrong" overriding.

What Do Classes Provide?

- Abstract types
  - Plus ways to create values of this type (constructors)
- Subtyping hierarchy
- Inheritance (code reuse)
- Modularity?
  - Collects related code
  - Classes with only static methods awfully like modules
  - Visibility restrictions (`public`, `private`, etc.)
  - But what do you need to know to use a class?

Mixins

- Some people argue for a finer-grained notion of inheritance than classes.
- A mixin is a collection of facilities that we would like to add to several classes.
  - Sort of a partial class
  - Can create a whole class by combining mixins
  - Can be simulateded in C++ with templates or multiple inheritance

```
template <class Super>
class Mixin : public Super {
  ...
}
```

Mixin Example [Booch]

```
class Rose: public Plant, public FlowerMixin ...

class Carrot: public Plant,
              public FruitVegetableMixin ...

class Cherry: public Plant,
              public FruitVegetableMixin,
              public FlowerMixin ...
```

Is SML Object-Oriented?

```
fun cell() =
  let
     val r = ref 0
  in
     {contents = r,
      get = (fn() => !r),
      set = (fn n => (r:=n))}
  end

val mycell = cell()
val x = (#set cell)((#get cell)() * 2)
```

Object-Based Languages

- Some object-oriented languages don't have a built-in notion of class.
  - Objects are just ordinary values, like integers or pairs in SML
  - Objects are created by:
    - Listing all the values for the fields and methods
    - Or, adding new fields and methods to an empty object. (Usually, but not always, untyped.)

Example: JavaScript

```
function cell_get() {
   return this.contents;
};
function cell_set(n) {
   this.contents = n;
};

var mycell = new Object();
mycell.contents = 0;
mycell.get = cell_get;
mycell.set = cell_set;
```

Example: JavaScript

```
function Cell {
   this.contents = 0;
   this.get = cell_get;
   this.set = cell_set;
};

var mycell = new Cell();
```

Delegation

- Subclassing without classes
- Each object may have a "parent"
  - If we fail to find a field or method in an object, try looking in the object's parent, the parent's parent, etc.
  - Efficiency: many objects can share the same parent, so they don't have to each have a copy of the parent's fields and methods.
  - Parent can be changed at run-time
    - Nice implementation for mode-switching (e.g., a shape's drawing operations must work for iconified and open modes.)

CLOS: Common Lisp Object System

- Class-based, but classes specify only fields ("slots")

```
(defclass figure ())

(defclass circle (figure)
     ((center :initform 0)
      (radius :initform 1)))

(defclass square (figure)
     ((lowerleft :initform (0 0))
      (upperright initform (1 1)))
```

CLOS

- Q: If objects contain only fields, what's the point?
- A: Dynamic dispatch via *multimethods* ("generic functions")
  - Functions where we can keep adding new cases
  - True dynamic dispatch, not just overloading!

```
(defmethod draw ((f circle) window)
      ...draw the circle f in the given window...)

(defmethod draw ((f square) window)
      ...draw the square f in the given window...)
```

Multimethods

- C++ or Java are called *single-dispatch* languages because the code invoked depends on the class of a single object: `mycell.set(3)`
- CLOS supports *multiple-dispatch*:

```
(defmethod intersect ((c1 circle) (c2 circle))
      ...find the intersection of circles f1 and f2...)

(defmethod intersect ((c circle) (f figure))
      ...find the intersection of circle c and
         arbitrary figure f...)
```