CMSC 330: Organization of Programming Languages

Functional Programming in
Object-Oriented Languages

The Stack Class

```
class Stack {
  class Entry {
    Object elt; Entry next;
    Entry(Object e, Entry n) { elt = e; next = n; }
  };
  private Entry theStack;
  void push(Object e) {
    theStack = new Entry(e, theStack);
  }
  Object pop() {
    if (theStack == null) throw new NoSuchElementException();
    Object temp = theStack.elt;
    theStack = theStack.next;
    return temp;
  }
}
```


Writing a "Stack" in OCaml: Take 1

```
module type STACK =
  sig
    type 'a stack
    val new_stack : unit -> 'a stack
    val push : 'a stack -> 'a -> unit
    val pop : 'a stack -> 'a
  end

module Stack : STACK =
  struct
    type 'a stack = 'a list ref
    let new_stack () = ref []
    let push s x = s := (x::!s)
    let pop s = match !s with
      [] -> failwith "Empty stack"
    | (h::t) -> s := t; h
  end
```


Writing a "Stack" in OCaml: Take 2

```
let new_stack () =
  let this = ref [] in
    let push x = this := (x::!this) in
    let pop () = match !this with
        [] -> failwith "Empty stack"
      | (h::t) -> this := t; h
    in
    (push, pop)
```

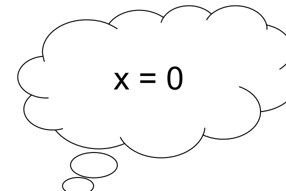
```
# let s = new_stack ();;
val s : ('_a -> unit) * (unit -> '_a) = (<fun>, <fun>)
# fst s 3;;
- : unit = ()
# snd s ();;
- : int = 3
```

Relating Objects and Closures

- An object...
  - Is a collection of fields (data)
  - ...and methods (code)
  - When a method is invoked, it is passed an implicit *this* parameter it can use to access fields
- A closure...
  - Is a pointer to an environment (data)
  - ...and a function body (code)
  - When a closure is invoked, it is passed its environment it can use to access variables

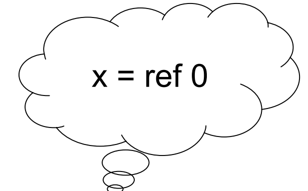
Relating Objects and Closures (cont'd)

```
class C {
  int x = 0;
  void set_x(int y) { x = y; }
  int get_x() { return x; }
}
```




```
C c = new C();
c.set_x(3);
int y = c.get_x();
```

```
let make () =
 let x = ref 0 in
   ( (fun y -> x := y),
     (fun () -> !x) )
```



fun y -> x := y	fun () -> !x

```
let (set, get) = make();;
set 3;;
let y = get ();;
```


Encoding Objects with Lambda

- We can apply this transformation in general

```
class C { f1 ... fn; m1 ... mn; }
```

  - becomes

```
let make () =
 let f1 = ... in
 ...
 let fn = ... in
 ( fun ... , (* body of m1 *)
   ...
   fun ...,  (* body of mn *)
 )
```

  - make () is like the constructor
  - the closure environment contains the fields

Recall a Useful Higher-Order Function

```
let rec map f = function
  [] -> []
| (h::t) -> (f h)::(map f t)
```

- Can we encode this in Java?

A Map Method for Stack

- To write a map method, we need some way of passing a function into another function
  - We can do that with an object with a known method

```
public interface Function {
  Object eval(Object arg);
}
```


A Map Method for Stack, cont'd

- Here are two classes which both implement this Function interface:

```
class AddOne implements Function {
  Object eval(Object arg) {
    Integer old = (Integer) arg;
    return new Integer(old.intValue() + 1);
  }
}
```

```
class MultTwo implements Function {
  Object eval(Object arg) {
    Integer old = (Integer) arg;
    return new Integer(old.intValue() * 2);
  }
}
```


A Map Method for Stack, cont'd

```
class Stack {
  class Entry {
      Object elt; Entry next;
      Entry(Object x, Entry n) { elt = x; next = n; }
      Entry map(Function f) {
        if (next == null) return new Entry(f.apply(elt), null);
        else return new Entry(f.apply(elt), next.map(f));
      }
  }
  Entry theStack;
  ...

  Stack map(Function f) {
    Stack s = new Stack();
      s.theStack = theStack.map(f);
      return s;
  }
}
```


A Map Method for Stack, con't.

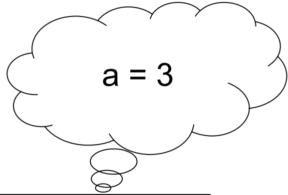
- Then to apply the function, we just do

```
Stack s = ...;
Stack t = s.map(new AddOne());
Stack u = s.map(new MultTwo());
```

  - We make a new object that has a method that performs the function we want
  - This is sometimes called a *callback*, because map "calls back" to the object passed into it
  - But it's really just a higher-order function, written more awkwardly

Relating Closures and Objects

```
let app f x = f x
```



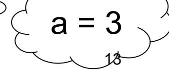

```
fun b -> a + b
```

```
let add a b = a + b;;
let f = add 3;;
app f 4;;
```

```
interface F {
  Object eval(Object y);
}
class C {
   static Object app(F f, Object x) {
     return f.eval(x);
   }
}
```

```
class G implements F {
  int a;
  G(int a) { this.a = a; }
  Object eval(Object y) {
    return
      new Integer(a +
           ((Integer) y).intValue());
  }
}
```

```
F adder = new G(3);
C.app(adder, 4);
```



Encoding Lambda with Objects

- We can apply this transformation in general

```
...(fun x -> (* body of fn *)) ...
let h f ... = ...f y...
```

  - becomes

```
interface F { Object eval(Object x); }
class G implements F {
  Object eval(Object x) { /* body of fn */ }
}
class C {
  Typ h(F f, ...) {
     ...f.eval(y)...
  }
}
```

  - F is the interface to the callback
  - G represents the particular function

Code as Data

- The key insight in all of these examples is to treat *code* as if it were *data*
  - Higher-order functions allow code to be passed around the program
  - As does object-oriented programming
- This is a powerful programming technique
  - And it can solve a number of problems quite elegantly
- Closures and objects are related
  - Both of them allow data to be associated with higher-order code as its passed around (but we can even get by without this)