Announcements:

- Programming Contest coming up: 29 September. Watch for details.
Object-Based Programming

Basic Idea.

- **Function-based programs** are organized primarily around the functions (methods, etc.) that do things. Data structures (objects) are considered separate.

- **Object-based programs** are organized around the types of objects that are used to represent data; methods are grouped by type of object.

- Simple banking-system example:

  Function-based

<table>
<thead>
<tr>
<th>account</th>
<th>account</th>
</tr>
</thead>
<tbody>
<tr>
<td>deposit</td>
<td>withdraw</td>
</tr>
<tr>
<td>account</td>
<td>account</td>
</tr>
</tbody>
</table>

  Object-based

<table>
<thead>
<tr>
<th>Account</th>
</tr>
</thead>
<tbody>
<tr>
<td>deposit</td>
</tr>
<tr>
<td>withdraw</td>
</tr>
<tr>
<td>balance: 1420</td>
</tr>
</tbody>
</table>

  Exported methods

  Exported field
Philosophy

- Idea (from 1970s and before): An abstract data type is
  - a set of possible values (a domain), plus
  - a set of operations on those values (or their containers).
- In IntList, for example, the domain was a set of pairs: (head,tail), where head is an int and tail is a pointer to an IntList.
- The IntList operations consisted only of assigning to and accessing the two fields (head and tail).
- In general, prefer a purely procedural interface, where the functions (methods) do everything—no outside access to fields.
- That way, implementor of a class and its methods has complete control over behavior of instances.
- In Java, the preferred way to write the “operations of a type” is as instance methods.
You Saw It All in CS61A: The Account class

(define-class (account balance0)
  (instance-vars (balance 0))
  (initialize
    (set! balance balance0))

  (method (deposit amount)
    (set! balance (+ balance amount))
    balance)

  (method (withdraw amount)
    (if (< balance amount)
      (error "Insufficient funds")
      (begin
        (set! balance (- balance amount))
        balance))))

(define my-account
  (instantiate account 1000))
(ask my-account 'balance)
(ask my-account 'deposit 100)
(ask my-account 'withdraw 500)

public class Account {
  public int balance;
  public Account (int balance0) {
    balance = balance0;
  }
  public int deposit (int amount) {
    balance += amount; return balance;
  }
  public int withdraw (int amount) {
    if (balance < amount)
      throw new IllegalStateException
        ("Insufficient funds");
    else balance -= amount;
    return balance;
  }
}

Account myAccount = new Account (1000);
myAccount.balance
myAccount.deposit (100);
myAccount.withdraw(500);
You Saw It All in CS61A: Python Version

class Account:
    balance = 0
    def __init__(self, balance0):
        self.balance = balance0
    def deposit(self, amount):
        self.balance += amount
        return balance
    def withdraw(self, amount):
        if balance < amount:
            raise ValueError("Insufficient funds")
        else:
            self.balance -= amount
        return balance

my_account = Account(1000)
my_account.balance
my_account.deposit(100)
my_account.withdraw(500)

public class Account {
    public int balance;
    public Account (int balance0) {
        balance = balance0;
    }
    public int deposit (int amount) {
        balance += amount; return balance;
    }
    public int withdraw (int amount) {
        if (balance < amount)
            throw new IllegalStateException("Insufficient funds");
        else balance -= amount;
        return balance;
    }
}

Account myAccount = new Account (1000);
myAccount.balance
myAccount.deposit (100);
myAccount.withdraw(500);
The Pieces

- Class declaration defines a **new type of object**, i.e., new type of structured container.

- **Instance variables** such as `balance` are the simple containers within these objects (**fields** or **components**).

- **Instance methods**, such as `deposit` and `withdraw` are like ordinary (static) methods that take an invisible extra parameter (called **this**).

- The **new** operator creates (**instantiates**) new objects, and initializes them using constructors.

- **Constructors** such as the method-like declaration of `Account` are special methods that are used only to initialize new instances. They take their arguments from the **new** expression.

- **Method selection** picks methods to call. For example,

  ```java
  myAccount.deposit(100)
  ```

  tells us to call the method named `deposit` that is defined for the object pointed to by `myAccount`. 
Getter Methods

• Slight problem with Java version of Account: anyone can assign to the balance field

• This reduces the control that the implementor of Account has over possible values of the balance.

• Solution: allow public access only through methods:

    public class Account {
        private int balance;
        ...
        public int balance () { return balance; }
        ...
    }

• Now the balance field cannot be directly referenced outside of Account.

• (OK to use name balance for both the field and the method. Java can tell which is meant by syntax: A.balance vs. A.balance().)
Class Variables and Methods

• Suppose we want to keep track of the bank's total funds.
• This number is not associated with any particular Account, but is common to all—it is class-wide.
• In Java, "class-wide" ≡ static

```java
class Account {
    private static int funds = 0;
    public int deposit (int amount) {
        balance += amount; funds += amount;
        return balance;
    }
    public static int funds () {
        return funds;
    }
    ...
}
```

• From outside, can refer to either `Account.funds()` or `myAccount.funds()` (same thing).
Instance Methods

• Instance method such as

```java
int deposit (int amount) {
    balance += amount; funds += amount;
    return balance;
}
```

behaves sort of like a static method with hidden argument:

```java
static int deposit (final Account this, int amount) {
    this.balance += amount; funds += amount;
    return this.balance;
}
```

• NOTE: Just explanatory: Not real Java (not allowed to declare 'this'). (final is real Java; means "can't change once set.")

• Likewise, the instance-method call `myAccount.deposit (100)` is like a call on this fictional static method:

```java
Account.deposit (myAccount, 100);
```

• Inside method, as a convenient abbreviation, can leave off leading 'this.' on field access or method call if not ambiguous.
'Instance' and 'Static' Don't Mix

- Since real static methods don't have the invisible `this` parameter, makes no sense to refer directly to instance variables in them:

  ```java
  public static int badBalance (Account A) {
      int x = A.balance;  // This is OK (A tells us whose balance)
      return balance;     // WRONG! NONSENSE!
  }
  ```

- Reference to `balance` here equivalent to `this.balance`,

- But this is meaningless (whose balance?)

- However, it makes perfect sense to access a static (class-wide) field or method in an instance method or constructor, as happened with `funds` in the `deposit` method.

- There's only one of each static field, so don't need to have a 'this' to get it. Can just name the class.
Constructors

• To completely control objects of some class, you must be able to set their initial contents.

• A constructor is a kind of special instance method that is called by the **new** operator right after it creates a new object, as if:

\[
L = \text{new IntList}(1, \text{null}) \implies \begin{cases} 
\text{tmp = pointer to 0}; \\
\text{tmp.IntList}(1, \text{null}); \\
L = \text{tmp};
\end{cases}
\]

• Instance variables initializations are moved inside constructors:

```java
class Foo {
    int x = 5;
    Foo () {
        DoStuff ();
    }
    ...
}
```

```java
class Foo {
    int x;
    Foo () {
        x = 5;
        DoStuff ();
    }
    ...
}
```

• In absence of any explicit constructor, get **default constructor**:

```java
public Foo() {
}
```

• Multiple **overloaded** constructors possible (different parameters).
### Summary: Java vs. CS61A OOP in Scheme

<table>
<thead>
<tr>
<th>Java</th>
<th>CS61A OOP</th>
<th>Python</th>
</tr>
</thead>
<tbody>
<tr>
<td>class Foo ...</td>
<td>(define-class (Foo args)...)</td>
<td>class Foo: ...</td>
</tr>
<tr>
<td>int x = ...;</td>
<td>(instance-vars (x ...))</td>
<td>x = ...</td>
</tr>
<tr>
<td>Foo(args) {...}</td>
<td>(initialize ...)</td>
<td>def <strong>init</strong>(self, args):...</td>
</tr>
<tr>
<td>int f(...) {...}</td>
<td>(method (f ...) ...)</td>
<td>def f(self, ...) :...</td>
</tr>
<tr>
<td>static int y = ...;</td>
<td>(class-vars (y ...))</td>
<td>y = ...</td>
</tr>
<tr>
<td>static void g(...) {...}</td>
<td>(define (g...)...)</td>
<td>(refer to with Foo.y)</td>
</tr>
<tr>
<td>aFoo.f (...)</td>
<td>(ask aFoo 'f ...)</td>
<td>def g(...): ... or</td>
</tr>
<tr>
<td>aFoo.x</td>
<td>(ask aFoo 'x)</td>
<td>@staticmethod</td>
</tr>
<tr>
<td>new Foo (...)</td>
<td>(initialize Foo ...)</td>
<td>def g(...): ...</td>
</tr>
<tr>
<td>this</td>
<td>self</td>
<td>aFoo.f(...)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>aFoo.x</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Foo(...)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>self</td>
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</tbody>
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