Announcements

- See Piazza post @459 to sign up for one-on-one tutoring next week.

Recreation

Given that

$$\log(1 + x) = x - \frac{1}{2} x^2 + \frac{1}{3} x^3 - \ldots$$

why is it not the case that

$$\log 2 = 1 - \frac{1}{2} + \frac{1}{3} - \frac{1}{4} + \frac{1}{5} - \frac{1}{6} + \frac{1}{7} - \frac{1}{8} + \frac{1}{9} - \ldots$$

$$= (1 + \frac{1}{3} + \frac{1}{5} + \frac{1}{7} + \frac{1}{9} + \ldots) - (\frac{1}{2} + \frac{1}{4} + \frac{1}{6} + \frac{1}{8} + \ldots)$$

$$= (1 + \frac{1}{3} + \frac{1}{5} + \frac{1}{7} + \frac{1}{9} + \ldots) + (\frac{1}{2} + \frac{1}{4} + \frac{1}{6} + \frac{1}{8} + \ldots)$$

$$- 2(\frac{1}{2} + \frac{1}{4} + \frac{1}{6} + \frac{1}{8} + \ldots)$$

$$= (1 + \frac{1}{2} + \frac{1}{3} + \frac{1}{4} + \ldots) - (1 + \frac{1}{2} + \frac{1}{3} + \frac{1}{4} + \ldots)$$

$$= 0?$$
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:
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, we prefer a purely procedural interface, where the functions (methods) do everything—no outside access to the internal representation (i.e., instance variables).

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

myAccount = Account(1000)
print(myAccount.balance)
myAccount.deposit(100)
myAccount.withdraw(500)

public class Account {
    public int balance;
    public Account(int balance0) {
        this.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);
print(myAccount.balance)
myAccount.deposit(100);
myAccount.withdraw(500);
(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);
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:

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

• Now Account._balance = 1000000 is an error outside Account.

• (I use the convention of putting '_' at the start of private instance variables to distinguish them from local variables and non-private variables. Could actually use balance for both the method and the variable, but please don’t.)
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
public class Account {
    ...
    private static int _funds = 0;
    public int deposit(int amount) {
        _balance += amount;
        _funds += amount; // or this._funds or Account._funds
        return _balance;
    }
    public static int funds() {
        return _funds; // or Account._funds
    }
    ...
    // Also change withdraw.
}
```

- From outside, can refer to either `Account.funds()` or to `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.”)
Calling Instance Method

```java
/** (Fictional) equivalent of deposit instance method. */
static int deposit(final Account this, int amount) {
    this._balance += amount;
    _funds += amount;
    return this._balance;
}
```

- Likewise, the instance-method call `myAccount.deposit(100)` is like a call on this fictional static method:
  ```java
  Account.deposit(myAccount, 100);
  ```
- Inside a real instance method, as a convenient abbreviation, one can leave off the leading 'this.' on field access or method call if not ambiguous. (Unlike Python)
'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 (or use no qualification inside the class, as we’ve been doing).
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

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

• All classes have constructors. In the absence of any explicit constructor, get default constructor, as if you had written:

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

• Multiple overloaded constructors possible, and they can use each other (although the syntax is odd):

```java
public class IntList {
    public IntList(int head, IntList tail) {
        this.head = head; this.tail = tail;
    }

    public IntList(int head) {
        this(head, null); // Calls first constructor.
    }

    ...
}
```
Constructors and Instance Variables

- Instance variables initializations are moved inside constructors that don’t start with `this(...)`.

```java
class Foo {
    int x = 5;

    Foo(int y) {
        DoStuff(y);
    }

    Foo() {
        this(42);
    }
}
```

```java
class Foo {
    int x;

    Foo(int y) {
        x = 5;
        DoStuff(y);
    }

    Foo() {
        this(0); // Assigns to x
    }
}
```
## Summary: Java vs. Python

<table>
<thead>
<tr>
<th>Java</th>
<th>Python</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>class Foo {</code></td>
<td><code>class Foo: ...</code></td>
</tr>
<tr>
<td><code>int x = ...;</code></td>
<td><code>x = ...</code></td>
</tr>
<tr>
<td><code>Foo(...)</code></td>
<td><code>def __init__(self, ...)</code>:</td>
</tr>
<tr>
<td><code>{ ... }</code></td>
<td><code>...</code></td>
</tr>
<tr>
<td><code>int f(...)</code></td>
<td><code>def f(self, ...)</code>:</td>
</tr>
<tr>
<td><code>{ ... }</code></td>
<td><code>...</code></td>
</tr>
<tr>
<td><code>static int y = 21;</code></td>
<td><code>y = 21</code> # Referred to as Foo.y</td>
</tr>
<tr>
<td><code>static void g(...)</code></td>
<td><code>@staticmethod</code></td>
</tr>
<tr>
<td><code>{ ... }</code></td>
<td><code>def g(...):</code></td>
</tr>
<tr>
<td><code>}</code></td>
<td><code>...</code></td>
</tr>
</tbody>
</table>

- `aFoo.f(...)`  
- `aFoo.x`  
- `new Foo(...)`  
- `this`  

- `aFoo.f(...)`  
- `aFoo.x`  
- `Foo(...)`  
- `self` # (typically)