rex to Java
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Imperative languages often permit the use of functional programming.

Sometimes just say “no” to side-effects.

Otherwise use functions and side-effects articulately.

Best of both worlds!
The analog to function in rex is method in Java. Functions are applied as aFunction(x, y, z), while methods are applied like x.aMethod(y, z).

Argument and return types must be declared in Java, not in rex.

Both allow recursion.

All of the underlying functionality in rex is implementable.

Think of rex lists as your abstraction, use Java to implement it.
Our initial foray into Java will be to implement the concepts of rex, particularly lists.

Think of rex lists as your abstraction, use Java to implement them.
Java brief review
The empty Java program

class Empty
{
    public static void main(String arg[])
    {
    }
}
The empty Java program

```java
class Empty {
    public static void main(String arg[]) {
    }
}
```

- The one and only class of this program
- The main method for this class (called at start-up)
- Makes this method accessible from the outside
- External arguments for this method
- Result type of this method (none)
- Says that this method depends only on the class, not any specific object
The “Hello, world” program in Java

class Hello {
    
    public static void main(String arg[]) {
        System.out.println("Hello, world!");
    }
}


The “Hello, world” program in Java

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```

The "System" class.

The standard output stream object, pre-defined in the System class.

The print-with-end-of-line method for object System.out.

The empty program + one line.
Running Java on turing

- Current version is 1.4
- To compile:  
  ` javac Hello.java `  
  UNIX convention for compiler, e.g. javac, cc
- To execute:  
  ` java Hello `  
  No “.class” here.
Running Java on turing

turing 101> ls Hello.*
Hello.java

Check what's there.

Compile it.

Check what's there now.

Be astounded by results.

turing 102> javac Hello.java

Run it.

turing 103> ls Hello.*
Hello.class   Hello.java

Be astounded by results.

turing 104> java Hello
Hello, world!
HMC Shortcuts

Since java is a prefix of javac, this tends to confound using command completion (e.g. !j in the Cshell).

In your .cshrc should be the following command definitions:

```bash
alias jc 'javac \!$.java' #compile java
alias je 'java' #execute
alias jx 'javac \!$.java ; java \!$' #compile and execute
```

Example usage:

```bash
jc Hello # same as javac Hello.java
je Hello # same as java Hello
jx Hello # same as javac Hello.java; java Hello
```

Then use !jc, !je, or !jx to re-do previous commands of same type.
Java Data Items

- Java data items are either:
  - **Primitives**, such as
    - int, long, float, double, char
  - **Objects**, such as
    - String, Long, Double
    - Objects you define
    - Arrays are essentially Objects too.
Purposes of Objects

- **Aggregate** various data objects together
- **Allow** mutation of the **state** of data objects
- **Control** use and access of data according to specific **disciplines**
- and other good stuff, such as inheritance and delegation
Immutable Objects

- An Object is **immutable** if its state never changes once it is created.

- **Functional programming** deals with immutable objects *almost* exclusively
  - (exception: delayed evaluation)

- The aggregating and disciplined access properties of Objects are still very useful.
OpenList class

- This is a class you will construct and own.

- It will allow you to solve problems for which rex is suitable in Java, as well as problems for which rex is less suitable.

- Think of rex lists as the abstraction. Use Java to implement.
Object Creation

- Objects are created using constructors.

- For a given Class of Objects, there can be multiple types of constructors, each providing different types of parameters to define the creation of an object.

- In Java, constructors always take the same name as their Class.
The Class “Object” in Java

- In Java, all objects are derived from an ancestral class called Object.

- For example, if we define a class OpenList, an object of that class is still an Object as well.
Class Hierarchy:
Abstraction, not Containment

Object's

String's

OpenList's

Number's

Integer's

Float's
Purpose of Hierarchical Abstraction

- Group classes with similar properties into super-classes.
- e.g. Number is a super-class of:
  - Integer
  - Float
  - Double
  - Long
  - BigInteger
  - BigDecimal
  - Byte
  - Short

- Objects in these classes share some properties, but are distinct in others.
- The bottom line: intellectual economy.
One OpenList Constructor

To create an OpenList, we need to give values to two internal variables, First and Rest:

```java
public class OpenList {
    private Object First;
    private OpenList Rest;

    public OpenList(Object _First, OpenList _Rest) {
        First = _First;
        Rest = _Rest;
    }

    // ... more stuff to come ...
}
```
Getters

- Attributes of objects should usually not be accessed within an object simply by referring to them:
  ```java
  OpenList x = new OpenList(...);
  ...
  System.out.println(x.First);
  ```
- **except** possibly for debugging purposes.
- Instead, use a **getter** method:
  ```java
  Object first()
  {
  return First;
  }
  ...
  System.out.println(x.first());
  ```
In Java, a method’s action may or may not depend on the Object on which the method is called:

- methods that do not depend on an Object should be annotated as static
Example of Static

Within class OpenList:

```java
public class OpenList {
    public static OpenList nil;
    private Object First;
    private OpenList Rest;
    ...
}
```

The One, True, Empty List
Static Methods can only call static

- A static method can only depend on:
  - variables declared as static
  - other static methods

- A static method, therefore, *cannot* depend on:
  - variables *not* declared as static
  - other methods *not* declared as static unless those methods are applied to some static object

- Any other way just doesn’t make sense.
- The compiler will tell you, but sometimes in a cryptic way.
Example

class myBad
{
    int x;

    myBad(int x)
    {
        this.x = x;
    }

    int getX()
    {
        return x;
    }

    static boolean test()
    {
        return getX() > 0;
    }
}
class myGood
{
    static MyOb myOb = new MyOb();

    static boolean test()
    {
        return myOb.getX() > 0;
    }
}

OK, depends on an object
An Open List

- Each list element begins a list in its own right.
- A list is identified with a reference to its first element.
- The empty list is identified with a special value, which we are calling **nil**.
- In the text, we used null for the empty list, but we’re changing this now!
Open Lists Identified with References

The list [a, b, c, d]
The list [b, c, d]
The list [c, d]
The list [d]
Stands for the empty list, nil
Sharing in Open Lists

Display the list identified with each reference.

Why is list mutation discouraged?
Passing an Open List as an Argument to a Function

- To pass an open list as an argument in, we simply pass its reference.
- The list is not literally copied.
Open List Consing

- To “cons” an element to an open list, we simply put the element in a new cell and hook the cell to the original list:

- consing x to the front \([x \mid [a, b, c, d]]\)

  yields

  caution: rex, not Java, notation!
cons, the pseudo-constructor

- cons constructs OpenLists, but is not technically a Constructor in the sense of Java.
- I call it a pseudo-constructor, as it really is a method.
- It can also be called a “factory method” because it produces new objects.
The static cons

- The typical use of cons is static:

```java
public class OpenList {
    public static OpenList nil;

    private Object First;
    private OpenList Rest;

    public static OpenList cons(_First, _Rest) {
        return new OpenList(_First, _Rest);
    }
    . . .
}
```
The definition of nil:

- nil is defined to be some OpenList.

```java
public class OpenList
{
    public static OpenList nil = cons(null, null);

    private Object First;
    private OpenList Rest;

    public static OpenList cons(_First, _Rest)
    {
        return new OpenList(_First, _Rest);
    }
}
```
What is null?

- null is built into Java.
- It is the reference that refers to NO object.
- It has a value, but we cannot apply a method to it:

  ```java
  Object A = null;
  A.myMethod();
  ```

Bad: syntactically OK
Why \texttt{cons(null, null)} for \texttt{nil}?

- Actually, \texttt{cons(anything, anything)} would work.
- \texttt{cons(null, null)} is just the simplest \texttt{OpenList} we can create
- We agree never to look at the First and Rest of \texttt{nil}. 
References are values.

They can be compared.

Checking whether an OpenList is nil will be done by comparing its reference to the reference to nil.

As long as there is only one nil, we are safe.
Two distinct objects can have identical “content”, but their references will compare `!=`.

Two references only compare `==` if they are the same object.
Implementing isEmpty()

```java
public class OpenList {
    public static OpenList nil = cons(null, null);

    . . .

    public static boolean isEmpty(OpenList L) {
        return L == nil;
    }

    public boolean isEmpty() {
        return isEmpty(this);
    }
}
```

Keyword this means “The current object”
Using isEmpty()

Inside class `OpenList`:

```java
OpenList L = ...;

isEmpty(L);
L.isEmpty();
```

Inside a different class:

```java
OpenList L = ...;

OpenList.isEmpty(L);
L.isEmpty();
```

Less Convenient
The customary way to compare for content is to use
Ob1.equals(Ob2)
not
Ob1 == Ob2.

Our list nil is not based on content, but rather absolute reference.
Non-static cons?

- Non-static cons would have to add a new Object to an OpenList.
- Outside the OpenList class it would be applied as:

  ```
  OpenList L = ...;
  OpenList M;
  
  M = L.cons(Ob2).cons(Ob1);
  
  or
  
  M = OpenList.cons(Ob1, OpenList.cons(Ob2, M));
  ```
list methods

- Define methods named `list` of various numbers of arguments, e.g.

  \[ M = \text{OpenList.list}(\text{Ob1}, \text{Ob2}, \text{Ob3}, \ldots, \text{ObN}); \]

- More convenient than using a bunch of `OpenList.cons`.

- Alas, need a different definition for each number of arguments.
Appending Open Lists

What happens when we append one open list to another, as in

\[
\text{append}(L, M)\?
\]

```plaintext
a → b → c → d
x → y → z
```
Recall definition of append

- append([], M) => M;
- append([A | L], M) => [A | append(L, M)];
Reversing an Open List

What happens when we reverse an open list?

reverse(L)

\[ \text{a} \rightarrow \text{b} \rightarrow \text{c} \rightarrow \text{d} \]
Recall definition of reverse

- \( \text{reverse}(L) = \text{reverse}(L, []) \);
- \( \text{reverse}([], M) \Rightarrow M \);
- \( \text{reverse}([A \mid L], M) \Rightarrow \text{reverse}(L, [A \mid M]) \);
Mapping an Open List

- What happens when we map over an open list?

\[ \text{L.map(fun)} \]

\[ \begin{array}{c}
\text{a} \\
\text{b} \\
\text{c} \\
\text{d} \\
\end{array} \]
Wrappers for Primitives

- Items in a OpenList must be Objects.
- Primitives (ints, longs, floats, doubles, chars ...) are **not** Objects in Java.
- The constructor `Long()` makes an Object for any long by creating a “wrapper” which is an object.
- Other wrappers: `Integer()`, `Float()`, `Double()`, `Boolean()`, Snoop, Queen Latiffa, Ice-T, ...
Strings

- In contrast to long, int, float, etc., strings are already objects.

- Consequently, strings do not need extra wrappers.

- OpenLists are also Objects.
Getters for Wrappers

- These can be applied to any Object derived from class `Number`, which includes `Long`, `Integer`, ...:
  
  ```java
  longValue(), intValue(), ...
  ```

- Use the on-line javadoc pages on the web to find info:

  `http://java.sun.com/j2se/1.3/docs/api/`
Conversion to String

- **Class `String`** includes the following static methods (not constructors):

  ```java
  valueof(double d)
  valueof(long x)
  ...
  ```

- Each returns a `String`. 
Cheap Conversion to String

“Adding” a number to a string will convert the number to a string, then concatenate it:

String s = "" + 31415;
Conversion from String

- Use the appropriate static method in the class to which you wish to convert, e.g.
  - `Long.parseLong(String s)`
  - `Double.parseDouble(String s)`

- (Don’t use `getLong`, which has a different meaning entirely.)
Type Discrimination

- The type of an Object can be discriminated using the `instanceof` operator:

  ```java
  Object ob = L.first();
  if( ob instanceof Long ) ...
  if( ob instanceof OpenList ) ...
  ```
Equality Checking

- To check whether two Objects are equal, DO NOT USE `==`. This only checks whether the references to those objects are identical. The Objects could be equal, but be different Objects. This applies for strings, for example.

- **DO USE** `equals`:
  ```java
  if( ob1.equals(ob2) )
  ```
A Recursive List Pattern
(without using map)

- ad-hoc map-like operations, build list outside-in, using recursion:

```java
static OpenList scale(long factor, OpenList L)
{
    if( L.isEmpty() )
        return OpenList.nil;

    long first = ((Long)L.first()).longValue();
    Long result = new Long(factor*first);
    return cons(result, scale(factor, L.rest());
}
```

- unwrap
- wrap
- recurse
An Iterative List Pattern

- **build list inside-out**, using ordinary iteration and an accumulator

```java
static OpenList scaleAndReverse(long factor, OpenList L) {
    OpenList result = OpenList.nil;

    for( ; L.nonEmpty(); L = L.rest() ) {
        long first = ((Long)L.first()).longValue();
        result = cons(new Long(factor*first), result);
    }
    return result;
}
```
An Iterative Reduce Pattern

- collapse list into a value using ordinary iteration

```java
static long sum(OpenList L)
{
    long result = 0;

    for( ; L.nonEmpty() ; L = L.rest() )
    {
        long first = ((Long)L.first()).longValue();

        result += first;
    }

    return result;
}
```
An Recursive Merge Pattern

- **merge two lists of Longs in increasing order**

```java
static OpenList merge(OpenList L, OpenList M) {
    if( L.isEmpty() )
        return M;
    if( M.isEmpty() )
        return L;
    long firstL = ((Long)L.first()).longValue();
    long firstM = ((Long)M.first()).longValue();
    if( firstL <= firstM )
        return merge(L.rest(), M).cons(L.first());
    else
        return merge(L, M.rest()).cons(M.first());
}
```
Try this

- determine whether an Object occurs in an OpenList

    static boolean member(Object Ob, OpenList L)
    {
    }
If you used recursion, try it with iteration, and vice-versa

- determine whether an Object occurs in a OpenList

```java
static boolean member(Object Ob, OpenList L)
{

```

Give a non-static method

- determine whether an Object occurs in this OpenList

```java
boolean member(Object Ob)
{
}
```
Open vs. Closed Lists

Two list models are described in the text:

- Open lists:
  - Elements and sublists can be shared
  - Mutation of lists is discouraged
  - Mathematically elegant

- Closed lists:
  - Sharing generally not done
  - Mutation of lists is ok, because they are encapsulated
  - Mathematically less attractive

Closed lists can be built by wrapping open lists