Equality and Copying

Context

- Although much of our discussion will use the OpenList class as an example, the concepts extend to a wide variety of other classes.

Equality

- Suppose we want to test two OpenLists for equality.
- From earlier discussions we could use the following rules, if in rex:
  - equals([ ], [ ]) => 1;
  - equals([ ], _) => 0;
  - equals(_, [ ]) => 0;
  - equals([A | L], [B | M]) => A == B && equals(L, M);

Transcription to Java

- We could easily transcribe those rules using recursion.
- So let's do it with iteration instead.

Iterative OpenList equals in Java

```
public static boolean equals(OpenList L1, OpenList L2)
  {
  while( L1.nonEmpty() && L2.nonEmpty() )
    {
    if( !(L1.first().equals(L2.first())) )
      {
      return false;
      }

    L1 = L1.rest();
    L2 = L2.rest();
    }
  return L1.isEmpty() && L2.isEmpty();
  }
```

Comments

- Our version of equals assumes that elements are to be compared using .**equals**, not ==.
- Does it matter? YES!
  - == compares references only
  - .equals compares content
  - equal reference *implies* equal content, but NOT conversely

Defining instance .equals

- In order to properly over-ride the .equals that is found in the base class Object, we need the following form:
  - equals(Object Ob)
- rather than the form
  - equals(OpenList L)
- Otherwise, when comparing Objects that happen to be OpenLists, the wrong equals will get used, and we will end up with ==, which is not what we want.

Nomenclature

- == can be said to provide a "**shallow**" test for equality.
- The intent of .equals is to provide a "**deep**" test for equality.
- What actually happens is up to the programmer or library designer.
- More on this later.

Copying OpenLists: Related to Equality

- Is there ever really a need to copy an OpenList for sake of just having a copy?

OpenList elements

- Even if OpenList *structure* is immutable,
- OpenList *elements* can be any *Object*, immutable or mutable.
- We can't stop this, and sometimes it might be useful.

Choices in copying

- Suppose we want to copy an OpenList that contains some mutable Objects.
- There may be preferences involved:
  - We want to make new copies of the mutable objects.
- vs.
  - We want to keep the mutable objects the same in both the original and the copy.

Cloning

- A reasonable convention is that if a Class *wants* objects to be copiable, it provides a clone() method do so, and conversely.
- The class of things being copied should implement the **Cloneable** interface.

Recall the Interface Idea

- **Obligations**:
  - A class implementing the Cloneable interface must:
    - Declare that it is implementing the interface.
    - Provide a clone() method.
- **Privileges**:
  - Objects in a class impementing the Cloneable interface can be passed to any method declaring the argument type as Cloneable.

OpenLists of Cloneable's

- Assume for the moment that we are only going to construct OpenLists out of Cloneable objects.
- Then we can make a clone of an OpenList itself as follows:

Cloning an OpenList: 1st approx.

```
public Object clone()
 {
 if( isEmpty() )
  {
  return nil;
  }
 return cons(first().clone(), (OpenList)rest().clone());
 }
```

- Notes:
  - **Object** rather than OpenList is the **required** return type for clone()
  - Object is not publicly cloneable, so first().clone() is **illegal**.

Fixing the Illegality

- Regarding the first() of a list, we'd like to:
  - Return a clone if the Object is cloneable.
  - Return the next best thing if not:
    - i.e. return the object itself.
- This will help make our definition work.
- We still need to be careful when using it.

This Captures the Idea

```
public Object clone()
 {
 if( isEmpty() )
  {
  return nil;
  }
 return cons(maybeClone(first()),
             (OpenList)rest().clone());
 }
```

Java Difficulty

- Java provides a way to test if something is cloneable:
  - Ob instanceof Cloneable
- Unfortunately, Java provides ***no*** nice way to **cast** an object known to be Cloneable such the clone() method can be applied. The target of a cast is a class, not an interface.

What We'd Like, But Can't Do

```
Object maybeClone(Object Ob)
  {
  if( Ob instanceof Cloneable )
    return ((Cloneable)Ob).clone();
  else
    return Ob;
  }
```

A Way I Devised: using java.lang.reflect magic

```
class Copier
{
static Class[] noArgs = new Class[0];
static Object[] args = new Object[0];

static Object maybeClone(Object ob)
{
 if( ob instanceof Cloneable )
    {
    try
      {
      // If Cloneable, clone it.

      return ob.getClass().getMethod("clone", noArgs).invoke(ob, args);
      }
    catch( Exception e)
      {
      }
    }
  return ob;      // Otherwise just return the argument.
  }
```

Possible Approaches to Copying

- **clone**() method: returns copy of **this**
- **copy constructor**: constructs a copy from original
- static **copy method**: copies argument
- Only the first of these really extends robustly across the Java language. The others can be used on an ad hoc basis.

Copy constructor

- Add constructor

```
MyClass(MyClass orig)
  {
  …
  }
```

- Use constructor

```
MyClass newObj = new MyClass(orig);
```

static copy method

- Add method

```
static MyClass copy(MyClass orig)
   {
   …
   }
```

- Use method

```
MyClass newObj = MyClass.copy(orig);
```

Deep vs. Shallow Copying

- Think of object as a tree
  - **The object is the root**
  - **The components are the children.**
- **Deep** copy: Copy all the way down to the leaves.
- **Shallow** copy: Copy references to components only.
- A spectrum of copies lies in between deep and shallow.

Shallow Copy

```
class MyClass
{
OpenList List1;
OpenList List2;


MyClass(MyClass orig)
     {
     List1 = orig.List1;
     List2 = orig.List2;
     }
}
```

- This copy **shares** the lists with the original.

Deep Copy

```
class MyClass
{
OpenList List1;
OpenList List2;


MyClass(MyClass orig)
     {
     List1 = orig.List1.clone();
     List2 = orig.List2.clone();
}
```

- This copy **has copies of** the original lists, ***provided*** that clone() makes such copies.

Equality Revisited

- Defining `equals()` is at programmer's discretion
- By analogy with copying:
  - Equality checking can be deep, shallow, or in-between.
- *Semantic* equality may be taken into account:
  - e.g. allowing an integer value to be *equal* to a floating value.

Interning principle: Making == function as equals

- Suppose we could guarantee that two objects are semantically equal only if they are the *same* object.
- Then computing equals would be very fast: only need to compare references.
- Such a guarantee can be made if we **intern** all of the objects in the class.
- It is common to do this for strings.

Interning principle

- To *intern* objects in a class, we need a way to get to all objects in that class that were ever created.
- The client does not use the constructor, but rather uses a **factory method** that returns objects.
- The factory method checks to see whether the prescribed object has already been created
  - If so, it returns the existing object's reference.
  - If not, it creates a new object (using the constructor) and returns the reference to that object.

Interning Example: an Interning `cons`

```
OpenList cons(Object F, OpenList R)
  {
  OpenList found = find(F, R); // exists already?
  if( found == null )
    {
    found = new OpenList(new Cell(F, R));
    remember(found);
    }
  return found;
  }
```

Clearly, sharing is intended.

`find` and `remember` must be implemented.

Implementing `find` and `remember`

- We must store every OpenList ever produced (sharing tails, etc.)
- We must be able to find a list with equal firsts and rests.
- A naïve implementation would store an internal list of all OpenLists (not itself a OpenList) and search the list with `find`.
- This process can become slow.

Faster Implemention of `find` and `remember`

- Use the concept of **hashing**.
- Hashing computes a numeric signature for the proposed new item.
- It then uses the signature to access an **array** (called a hash table) of "equivalence classes" of items.
- Each equivalence class **ideally** has a relatively *small* number of items in it.
- The only searching needed is that of searching the small equivalence class, not the whole universe.

How Java Helps

- Java provides method `hashCode()` of `Object`.
- This gives a (generally large) integer value for any object.
- By **dividing** the hash code by the hash table size, equivalence classes are thereby formed.
- All objects with the same hash code *modulo* the table size are considered equivalent.
- Java also provides a class `HashSet` that can be used to implement `find` and `remember`.

Further Investigation

- Examine these classes/*interfaces* on the Java API web page:
  - `Exception`
  - `Object`
  - *`Cloneable`*
  - `HashSet`
  - *`Collection`*
  - `HashMap`