

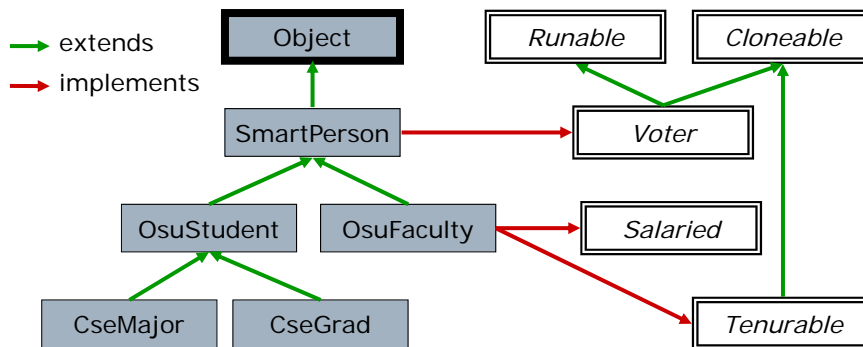
java.lang.Object: Equality

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Lecture 14

Class and Interface Hierarchies

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java.lang.Object

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- The root of all class hierarchies
 - This is a *class* called “Object”
 - There is also a class in java.lang called “Class”!
- Provides several useful methods
 - getClass()
 - Returns Class of the object instance
 - String toString()
 - Returns String representing object value
 - boolean equals(Object)
 - Returns true iff argument is equal to object
 - int hashCode()
 - Returns an int “hash value” for object
 - Object clone()
 - Creates and returns a copy (here be dragons...)

The getClass() Method

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- Returns an instance of java.lang.Class
 - Generic class: Class<T>
 - String getName()
 - Name of the class as a string, eg “CseMajor”
- Think of it as representing the object’s class

```
Student s1 = new OsuStudent();
Student s2 = new CseMajor();
System.out.println(s1.getClass().getName());
System.out.println(s2.getClass().getName());
if (s1.getClass() == s2.getClass()) { . . .
```
- Of course (?) java.lang.Class extends Object!
 - Try not to think about this too hard

Good Practice: Core Methods

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- ❑ Always override `toString()`
 - Default implementation gives class name + `@` + a meaningless hex number
 - ❑ eg `"BankAccount@3d4606bf"`
- ❑ Always override `equals()`
 - Default implementation checks object *references* for equality

```
Pencil p1 = new LedgedPencil();
Pencil p2 = new LedgedPencil();
assert(!p1.equals(p2));
```
- ❑ Always override `hashCode()`
 - Default implementation is memory address
 - What is a hashCode? Stay tuned...
- ❑ Resist the temptation to override `clone()`
 - Things get very dicey here

Overriding `toString()`

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- ❑ Spec in `java.lang.Object`
 - "A concise but informative representation that is easy for a person to read."
- ❑ Automatically called when String needed

```
System.out.println(myAccount);
String msg = "Cell phone: " + phoneNumber;
```
- ❑ Ideally provides *complete* information
 - Can be at odds with being "concise"
 - Information about *abstract* (ie interface) state
- ❑ Design decision: How specific to make spec?
 - Whatever is in spec, the client can use/exploit
 - Specific toString info ==> most useful to client
 - Vague toString info ==> most flexibility for future

Good Practice: String Conversion

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- Provide matching constructor to create object from a String
 - `String toString(): object --> String`
 - `Pencil(String): String --> new object`
- Especially common for immutables
 - See `java.lang.Integer`
 - Notice how carefully `toString()` is documented
 - Caveat: Factory methods are better than constructors here (we'll talk about these later)

Overriding equals()

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- Spec requires it to be an equivalence relation
 - Should also be consistent with `compareTo`
- 1. Reflexive
 - `x.equals(x) == true`
- 2. Symmetric
 - `x.equals(y) <==> y.equals(x)`
- 3. Transitive
 - `x.equals(y) && y.equals(z) ==> x.equals(z)`
- 4. Consistent (ie over time)
 - `x.equals(y) == x.equals(y) == x.equals(y) ...`
- 5. Robust to null
 - `x.equals(null) == false`

Naïve approach

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```
class SmartPerson {
    private String firstName;
    private String lastName;

    public boolean equals (SmartPerson p) {
        return (firstName.equals(p.firstName) &&
                lastName.equals(p.lastName) );
    }
}
```

.

Many Problems with Naïve Solution

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- On the surface, it looks promising
 - Reflexive, symmetric, transitive, consistent
- But (1): Not robust to null
 - if (p1.equals(null)) {... //*run-time error*
- But (2): Wrong argument type
 - equals() has argument type Object
 - This implementation overloads (not overrides) equals() in java.lang.Object

Another Attempt

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```
class SmartPerson {
    private String firstName;
    private String lastName;

    @Override
    public boolean equals (Object o) {
        if (o == null) return false;
        SmartPerson p = (SmartPerson)o;
        return (firstName.equals(p.firstName) &&
                lastName.equals(p.lastName) );
    }
}
```

New Problems

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- ❑ Narrowing cast may fail

```
Person p = new SmartPerson();
IceCreamFlavor i = new SaltyCaramel();
if (p.equals(i)) {... //run-time error
```
- ❑ We could keep patching it
 - Add *instanceof* test of run-time type
- ❑ It would keep breaking
 - Inheritance complicates the analysis
 - Can an OsuStudent be equal to a CseMajor?
- ❑ Bottom line: You can not do both
 1. Have behavioral subtypes, and
 2. Satisfy all the equivalence relation requirements

Standard Solution

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```
class SmartPerson {
    private String firstName;
    private String lastName;

    @Override
    public boolean equals (Object o) {
        if (o == this) return true;
        if (o == null) return false;
        if (!o.getClass().equals(this.getClass()))
            return false;

        SmartPerson p = (SmartPerson)o;
        return (firstName.equals(p.firstName) &&
                lastName.equals(p.lastName) );
    }
}
```

Complication: Extensions

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```
class OsuStudent extends SmartPerson {
    private BuckID identity;

    @Override
    public boolean equals (Object o) {
        if (o == this) return true;
        if (!super.equals(o)) return false;

        OsuStudent s = (OsuStudent)o;
        return identity.equals(s.identity);
    }
}
```

Notes on equals()

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- Initial comparison (ie $o == this$)
 - Used only for performance reasons (a “shortcut”)
- Objects must be of *exactly* the same class
 - Subclass instance never equal to superclass instance
 - So much for “is a”!
 - For CseMajor c , and OsuStudent s ,
`assert(!c.equals(s))`
 - Different classes that implement the same interface can never be equal
 - For SlowBigNatural $b1$, and FastBigNatural $b2$
`assert(!b1.equals(b2))`
- Two recipes for implementing equals()
 - Version 1 when overriding equals for the first time
 - Version 2 when some parent overrides equals

Overriding hashCode()

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- This method returns an *arbitrary* int
 - Must be consistent (ie repeatable)
 - Default implementation: memory address
- Equal objects must have equal hashes
 - $x.equals(y) ==> x.hashCode() == y.hashCode()$
- Must distinct objects have distinct hashes?
 - Not required for correctness
 - But helps performance when using collections
- Rule: If you override equals(), override hashCode()
- Immutable objects can pre-compute and then cache their hashcode value

Recipe for hashCode()

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1. Initialize with a non-zero constant integer
`int result = 17; //must be non-zero`
2. For each field f that figures into equals:
 - a. Compute int hash code c for f
 - For primitive f , use f 's value
 - For reference f , recurse
 - For array f , examine each element`c = (f ? 0 : 1); //for boolean f`
`c = (int)f; //for byte/char/short/int f`
`c = Float.floatToIntBits(f); //for long f`
`c = f.hashCode(); //for reference f`
 - b. Combine c into $result$ through multiplication
`result = 37*result + c; //use an odd prime`
3. Return result

Basic Example

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```
class SmartPerson {
    private String firstName;
    private String lastName;
    private int age;

    @Override
    public int hashCode () {
        int result = 17;
        result = 37*result + firstName.hashCode();
        result = 37*result + lastName.hashCode();
        result = 37*result + age;
        return result;
    }
}
```

Notes on hashCode Recipe

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- ❑ Good: uses entire representation to (hopefully) spread hashCode values
- ❑ Bad: uses entire representation and can be inefficient
- ❑ Worse: if implementation allows different representations for the same abstract value, might violate $x.equals(y) \implies x.hashCode() == y.hashCode()$
- ❑ E.g., if BigInteger implementation uses a String representation and allows leading 0's, "123", "0123", "00123", etc. might all end up with different hashCode's

Example: hashCode for Immutable

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```
class SmartPerson {
    private Integer cachedHashCode; // == null

    @Override
    public int hashCode () {
        if (cachedHashCode == null) {
            int result = 17;
            . . . //code to compute hash from fields
            cachedHashCode = result;
        }
        return cachedHashCode;
    }
}
```

Supplemental Reading

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- Bloch's "Effective Java", chapter 3
 - See Safari Books Online link
 - Warning: favors instanceof over getClass
 - Better for behavioral subtyping
 - Worse for creating an equivalence relation
- IBM developerWorks paper
 - "Java Theory and practice: Hashing it out"
 - <http://www.ibm.com/developerworks/java/library/j-jtp05273.html>
- Various blogs (all slightly broken)
 - <http://www.geocities.com/technofundo/tech/java/equalhash.html>

Summary

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- java.lang.Object
 - Root of all class hierarchies
 - Contains useful methods
 - Several core ones should be overridden
- toString()
 - Concise, complete, informative
- equals()
 - Spec: An equivalence relation
 - Default implementation compares references
 - Comparing values is subtle because of inheritance
 - Overriding helps with JUnit
- hashCode()
 - Equal objects must return equal hashes