CSE 331
Software Design & Implementation

James Wilcox

Autumn 2021

Identity, `equals`, and `hashCode`

Overview

- Using the libraries reduces bugs in most cases
  - take advantage of code already inspected & tested

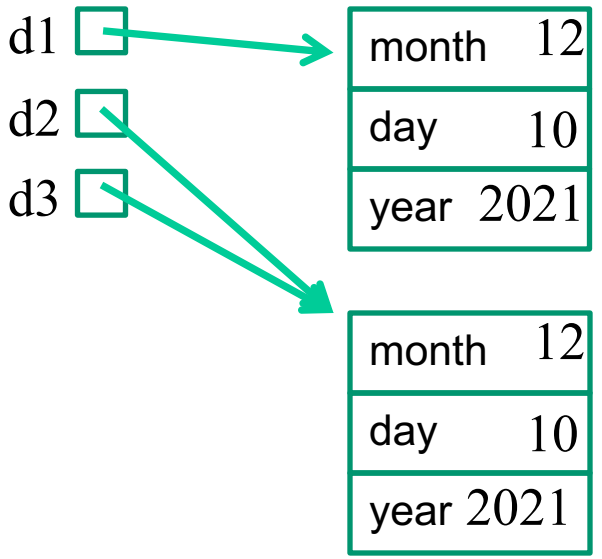
- In Java, collection classes depend on `equals` and `hashCode`
  - EJ 47: "Know and use the libraries"
    - "every programmer should be familiar with the contents of java.lang and java.util"
  - e.g., `List` may not work properly if `equals` is wrong
  - e.g., `HashSet` may not work properly of `hashCode` is wrong

- You will need to use these for HW5 (pt 2) – HW7

- Same concepts exist in other languages

What might we want?

```
Date d1 = new Date(12,10,2021);
Date d2 = new Date(12,10,2021);
Date d3 = d2;
// d1==d2 ?
// d2==d3 ?
// d1.equals(d2) ?
// d2.equals(d3) ?
```



- Sometimes want equivalence relation bigger than ==
  - Java takes OOP approach of letting classes *override* **`equals`**
  - (can also be defined by a `Comparator`)

Expected properties of equality

Reflexive `a.equals(a) == true`

- Confusing if an object does not equal itself

Symmetric `a.equals(b)` **iff** `b.equals(a)`

- Confusing if order-of-arguments matters

Transitive `a.equals(b) && b.equals(c) => a.equals(c)`

- Confusing again to violate centuries of logical reasoning

A relation that is reflexive, transitive, and symmetric is an *equivalence relation*

Reference equality

- Reference equality means an object is equal only to itself
  - `a == b` only if `a` and `b` refer to (point to) the same object

- Reference equality is an equivalence relation
  - Reflexive
  - Symmetric
  - Transitive

- Reference equality is the *smallest* equivalence relation on objects
  - "Hardest" to show two objects are equal (must be same object)
  - Cannot be smaller without violating reflexivity
  - Sometimes but not always what we want

`Object.equals` method

```
public class Object {
  public boolean equals(Object o) {
    return this == o;
  }
  …
}
```

- Implements reference equality
- Subclasses can override to implement a different equality
- But library includes a *contract* **`equals`** should satisfy
  - Reference equality satisfies it
  - So should *any* overriding implementation
  - Balances flexibility in notion-implemented and what-clients-can-assume even in presence of overriding

`equals` specification

`public boolean equals(Object obj)` should be:

- *reflexive*: for any reference value `x`, `x.equals(x) == true`
- *symmetric*: for any reference values `x` and `y`, `x.equals(y) == y.equals(x)`
- *transitive*: for any reference values `x`, `y`, and `z`, if `x.equals(y)` and `y.equals(z)` are `true`, then `x.equals(z)` is `true`
- *consistent*: for any reference values `x` and `y`, multiple invocations of `x.equals(y)` consistently return `true` or consistently return `false` (provided neither is mutated)
- For any *non-null* reference value `x`, `x.equals(null)` should return `false`

Why all this?

- Remember the goal is a contract:
  - weak enough to allow different useful overrides
  - strong enough so clients can assume equal-ish things
    - example: to implement a set
  - this gives a good balance in practice

- In summary:
  - equivalence relation on non-null objects
  - consistency, but allow for mutation to change the answer
  - asymmetric with **`null`** (other way raises exception)
    - final detail: argument of **`null`** must return **`false`**
    - weird but useful
    - often see, e.g., "left".equals(direction) – false for null

An example

A class where we may want **`equals`** to mean equal contents

```
public class Duration {
    private final int min; // RI: min>=0
    private final int sec; // RI: 0<=sec<60
    public Duration(int min, int sec) {
        assert min>=0 && sec>=0 && sec<60;
        this.min = min;
        this.sec = sec;
    }
}
```

- Should be able to implement what we want and satisfy the **`equals`** contract…

How about this?

```
public class Duration {
    …
  public boolean equals(Duration d) {
      return this.min==d.min && this.sec==d.sec;
  }
}
```

Two bugs:

1. Violates contract for **`null`** (not that interesting)
   - Can add **`if(d==null) return false;`**
     - But our fix for the other bug will make this unnecessary
2. Does not override **`Object`**'s **`equals`** method (more interesting)

Overloading versus overriding

In Java:

- A class can have multiple methods with the same name and different parameters (number or type)
- A method *overrides* a superclass method only if it has the same name and exact same argument types

So **`Duration`**'s **`boolean equals(Duration d)`** does *not* override **`Object`**'s **`boolean equals(Object d)`**

- Sometimes useful to avoid having to make up different method names
- Sometimes confusing since the rules for what-method-gets-called are complicated

Example: *no* overriding

```
public class Duration {
  public boolean equals(Duration d) {…}
  …
}
Duration d1 = new Duration(10,5);
Duration d2 = new Duration(10,5);
Object o1 = d1;
Object o2 = d2;
d1.equals(d2); // true
o1.equals(o2); // false(!)
d1.equals(o2); // false(!)
o1.equals(d2); // false(!)
d1.equals(o1); // true [using Object's equals]
```

Example fixed (mostly)

```
public class Duration {
  public boolean equals(Object d) {…}
  …
}
Duration d1 = new Duration(10,5);
Duration d2 = new Duration(10,5);
Object o1 = d1;
Object o2 = d2;
d1.equals(d2); // true
o1.equals(o2); // true [overriding]
d1.equals(o2); // true [overriding]
o1.equals(d2); // true [overriding]
d1.equals(o1); // true [overriding]
```

But wait!

This doesn't actually compile:

```
public class Duration {
    …
   public boolean equals(Object o) {
      return this.min==o.min && this.sec==o.sec;
   }
}
```

Really fixed now

```
public class Duration {
   public boolean equals(Object o) {
      if (!(o instanceof Duration))
        return false;
      Duration d = (Duration) o;
      return this.min==d.min && this.sec==d.sec;
   }
}
```

- Cast cannot fail
- We want equals to work on *any* pair of objects
- Gets **`null`** case right too (**`null instanceof C`** always **`false`**)
- So: rare use of cast that is correct and idiomatic
  - This is what you should do (cf. *Effective Java*)

Satisfies the contract

```
public class Duration {
   public boolean equals(Object o) {
      if (!(o instanceof Duration))
        return false;
      Duration d = (Duration) o;
      return this.min==d.min && this.sec==d.sec;
   }
}
```

- Reflexive: Yes
- Symmetric: Yes, even if `o` is not a **`Duration`**!
  - (Assuming `o`'s **`equals`** method satisfies the contract)
- Transitive: Yes, similar reasoning to symmetric

Even better

- Defensive Tip: use the **`@Override`** annotation when overriding

```
public class Duration {
    @Override
    public boolean equals(Object o) {
        …
    }
}
```

- *Compiler warning* if not actually an override
  - Catches bug where argument is **`Duration`** or **`String`** or ...
  - Alerts reader to overriding
    - Concise, relevant, *checked* documentation