Effective Java

Object Equality

- Case Studies -

Angelika Langer
Trainer/Consultant

http://www.AngelikaLanger.com

objective

- study different implementations of `equals()`
- identify and evaluate different techniques

comparison of reference variables

- can mean two things:
  - check for **identity** of referenced objects
  - check for **equality** of referenced objects
- identical objects:
  - occupy same memory location
  - are effectively the "same" object
- equal objects:
  - behave in the same way
  - often means: have same state or content

comparison of reference variables

- check for **identity** via operator `==`
  - yields true if
    - operand values both `null`, or
    - both refer to same object or array
- check for **equality** via method

  ```
  boolean equals(Object o)
  ```

  - inherited from class `Object`
    - can be overridden to implement a check for equality
    - default provided by `Object.equals()`: check for identity !
  - semantics class-specific
    - depends on implementation

example: class-specific semantics of equals()

- class `StringBuffer` does not override `equals()`
- class `String` does

true

false

```
String s = “Hello World !”;
String s1 = new String(s);
String s2 = new String(s);

if ( s1.equals(s2) ) ...

StringBuffer sb1 = new StringBuffer(s);
StringBuffer sb2 = new StringBuffer(s);

if ( sb1.equals(sb2) ) ...
```


which classes must override equals() ?

- fundamental distinction between
  - value types
  - non-value types (sometimes called entity types)
- value types
  - have content and behavior depends vitally on this content
  - examples: `BigDecimal`, `String`, `Date`, `Point`, etc.
- entity types
  - behavior not strictly determined by content
    - service-based types
    - handles to an underlying object
  - examples: `Thread`, `FileOutputStream`, entity beans in EJB

which classes must override `equals()` ?

- entity types
  - do not override `Object.equals()`
  - comparing content is pointless, is not relevant anyway
- value types
  - override `Object.equals()`
  - equality means "equal content"
  - significant difference between identity and equality
- recommendation:

Classes that represent value types must override `Object.equals()`.

requirements

- obvious requirement (to an implementation of `equals()` for a value type)
  - check for equality of objects
- additional requirements imposed by JDK
  - stem from `HashSet` and `HashMap`
  - have certain expectations; do not work properly otherwise
- defined in the so-called `equals()` contract
  - see documentation of Java platform libraries

the `equals()` contract

- reflexivity
  - for any reference value `x`, `x.equals(x)` should return true
- symmetry
  - for any reference values `x` and `y`, `x.equals(y)` should return true if and only if `y.equals(x)` returns true
- transitivity
  - for any reference values `x`, `y`, and `z`, if `x.equals(y)` returns true and `y.equals(z)` returns true, then `x.equals(z)` should return true
- consistency
  - for any reference values `x` and `y`, multiple invocations of `x.equals(y)` consistently return true or consistently return false, provided no information used in equals comparisons on the object is modified
- non-nullity
  - for any non-null reference value `x`, `x.equals(null)` should return false

lack of compliance

- failure to comply to the `equals()` contract
  - leads to subtle bugs
    - difficult to track down because they are conceptual problems
    - conceptual problem are not detected by debugging source code
  - not only hash-based collections rely on reflexivity, symmetry, and transitivity
    - everybody who calls `equals()` does
- recommendation:

> Never provide an implementation of `equals()` that does not comply to the `equals()` contract.

implementing equals()

- different techniques for implementing `equals()`
  - study a number of sample implementations that have been published

[1] "Program Development in Java" by Barbara Liskov

[2] "Effective Java" by Joshua Bloch

[3] "Practical Java" by Peter Haggar

[4] JDK 1.3 source code
(authors: James Gosling, Arthur van Hoff, Alan Liu)

Barbara Liskov, "Program Development in Java", page 182

```
public class Point3 extends Point2 {
  private int z;
  ...
  public boolean equals(Object p) { // overriding definition
    if (p instanceof Point3) return equals((Point3)p);
    return super.equals();
  }
  public boolean equals(Point2 p) { // overriding definition
    if (p instanceof Point3) return equals((Point3)p);
    return super.equals();
  }
  public boolean equals(Point3 p) { // extra definition
    if (p==null || z!=p.z) return false;
    return super.equals();
  }
  ...
}
```

JDK 1.3, package java.util, class Date

```
public class Date implements java.io.Serializable, Cloneable, Comparable {
    private transient Calendar cal;
    private transient long fastTime;

    private static Calendar staticCal = null;
    // ... lots of static fields ...
    ...
    public long getTime() {
        return getTimeImpl();
    }
    private final long getTimeImpl() {
        return (cal == null) ? fastTime : cal.getTimeInMillis();
    }
    ...
    public boolean equals(Object obj) {
        return obj instanceof Date && getTime() == ((Date) obj).getTime();
    }
}
```


Josh Bloch, "Effective Java", item 7 and item 8

```
public final class PhoneNumber {
  private final short areaCode;
  private final short exchange;
  private final short extension;
  ...
  public boolean equals(Object o) {
    if (o==this)
       return true;
    if (!(o instanceof PhoneNumber))
       return false;
    PhoneNumber pn = (PhoneNumber)o;
    return pn.extensions == extension &&
           pn.exchange   == exchange  &&
           pn.areaCode   == areaCode;
  }
  ...
}
```

Peter Haggar, "Practical Java", praxis 8 thru praxis 14

```
class Golfball {
   private String brand;
   private String make;
   private int compression;
   ...
   public String brand() {
     return brand;
   }
   ...
   public boolean equals(object obj) {
     if (this == obj)
        return true;
     if (obj!=null && getClass() == obj.getClass())
     {
        Golfball gb = (Golfball)obj; // Classes are equal, downcast.
        if (brand.equals(gb.brand())  &&  // Compare atrributes.
            make.equals(gb.make()) &&
            compression == gb.compression())
          return true;
     }
     return false;
   }
}
```


Peter Haggar (cont.)

```
class MyGolfball extends Golfball {
  public final static byte TwoPiece = 0;
  public final static byte ThreePiece = 1;
  private byte ballConstruction;
  ...
  public byte constuction() {
    return ballConstruction;
  }
  ...
  public boolean equals(Object obj) {
    if (super.equals(obj))
    {
      MyGolfball bg = (MyGolfball)obj;  // Classes equal, downcast.
      if (ballConstruction == gb.construction())
        return true;
    }
    return false;
  }
}
```

different techniques

- signature
  - disagreement:
    - overriding in combination with overloading
      - several versions of `equals()` method (Listing 1)
    - just one signature
      - namely `Object.equals(Object o)`
- comparing fields
  - agreement:
    - `equals()` must compare fields defined in the class
      - if fields contribute to state of object
      - transient and static fields are not considered (see Listing 2)

different techniques

- delegation to super
  - agreement:
    - `super.equals()` should be invoked
    - if class has a superclass other than `Object`
- type check and downcast
  - agreement:
    - check that other object is of a type to which this object can be compared
  - disagreement regarding the actual check:
    - use `instanceof` operator
    - use `getClass()` method (see Listing 4)

agenda

- check for type match
- delegation vs. inheritance
- signature of `equals()`
- slice comparison yes/no
- correct slice comparison methods
- guidelines for practitioners

listing 1 - an incorrect implementation

```
public class Point3 extends Point2 {
  private int z;
  ...
  public boolean equals(Object p) { // overriding definition
    if (p instanceof Point3) return equals((Point3)p);
    return super.equals();
  }
  public boolean equals(Point2 p) { // overriding definition
    if (p instanceof Point3) return equals((Point3)p);
    return super.equals();
  }
  public boolean equals(Point3 p) { // extra definition
    if (p==null || z!=p.z) return false;
    return super.equals();
  }
  ...
}
```

- not transitive

mixed-type comparison

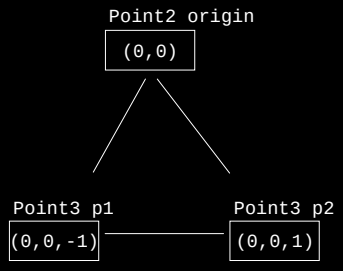
```
Point2 origin(0,0);
Point3 p1(0,0,-1);
point3 p2(0,0,1);

System.out.println(p1.equals(origin));  // calls Point3.equals(Point2)
System.out.println(origin.equals(p2));  // calls Point2.equals(Point2)
System.out.println(p1.equals(p2));      // calls Point3.equals(Point3)
```

should print:

```
true
true
true
```

instead prints:

```
true
true
false
```



lack of transitivity - reason

- `equals()` methods in `Point2` and `Point3` perform semantically different comparisons

- mixed-type comparison
  - involving a superclass and a subclass object
  - slice comparison: comparing only superclass part
- same-type comparison
  - involving two subclass objects
  - whole-object comparison

conceptual problem in class hierarchies

- `equals()` must be transitive
- `equals()` must compare for equality of objects

- objects in a class hierarchy have a different structure:
  - subclass objects have more fields than superclass objects
  - subclass must implement `equals()`
    - take subclass-specific fields into account
  - subclass `equals()` semantically different from superclass version
- if `equals()` permits mixed-type comparison
  - it is non-transitive (and incorrect)
- alternatives:
  - do not allow slice comparison of superclass and subclass objects
  - `equals()` method is final in the superclass

listing 2 - a debatable implementation

```
public class Date implements java.io.Serializable, Cloneable, Comparable {
    private transient Calendar cal;
    private transient long fastTime;

    private static Calendar staticCal = null;
    // ... lots of static fields ...
    ...
    public long getTime() {
        return getTimeImpl();
    }
    private final long getTimeImpl() {
        return (cal == null) ? fastTime : cal.getTimeInMillis();
    }
    ...
    public boolean equals(Object obj) {
        return obj instanceof Date && getTime() == ((Date) obj).getTime();
    }
}
```

- subclasses are in trouble

a subclass - example

- implementation of subclass and its `equals()`:

```
public class NamedDate extends Date {
  private String name;
  public boolean equals(Object other) {
    if (other instanceof NamedDate &&
        !name.equals(((NamedDate)other).name))
       return false;
    return super.equals(other));
  }
}
```

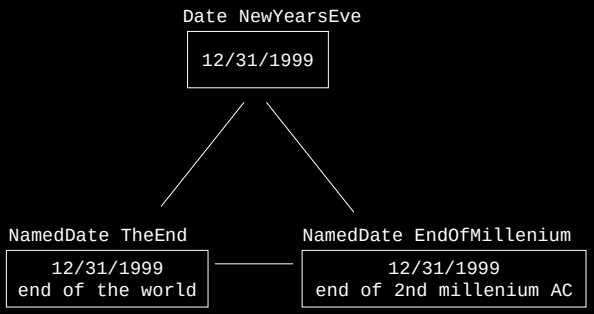
- implementation of superclass `equals()`:

```
public class Date implements ... {
    public boolean equals(Object obj) {
        return obj instanceof Date &&
               getTime() == ((Date) obj).getTime();
    }
}
```


mixed-type comparison

```
NamedDate EndOfMillenium = new NamedDate(99,11,31,"end of 2nd millenium AC");
NamedDate TheEnd         = new NamedDate(99,11,31,"end of the world");
Date      NewYearsEve    = new Date(99,11,31);

EndOfMillenium.equals(NewYearsEve)   // slice comparison: true
NewYearsEve.equals(TheEnd)           // slice comparison: true
EndOfMillenium.equals(TheEnd)        // whole-object comparison: false
```

not transitive



evaluation

- same transitivity problem as before
  - `Date.equals()` allows for slice comparison
  - overriding versions in a subclass performs semantically different comparison
  - incorrect non-transitive behavior
- class `Date` can avoid pitfall
  - by declaring `equals()` method final
  - by declaring entire class final

another common mistake

- another implementation of a subclass:

```
public class NamedDate extends Date {
  private String name;
  public boolean equals(Object other) {
    if ( !(other instanceof NamedDate) )
      return false;
    else if ( !name.equals(((NamedDate)other).name) )
      return false;
    else if ( !super.equals(other) )
      return false;
    else
      return true;
  }
}
```

asymmetry

- mixed-type comparison
  - compare `Date` to `NamedDate` via `Date.equals()`
    - `NamedDate` passes `instanceof` test
    - comparison is performed; result can be false or true
  - swap the two objects:
    - compare `NamedDate` to `Date` via `NamedDate.equals()`
    - `Date` object does *not* pass `instanceof` test
    - these two objects will never compare equal
- violates the symmetry requirement
  - fairly common in Java platform library classes before JDK 1.3

listing 3 - a correct implementation

```
public final class PhoneNumber {
  private final short areaCode;
  private final short exchange;
  private final short extension;
  ...
  public boolean equals(Object o) {
    if (o==this)
       return true;
    if (!(o instanceof PhoneNumber))
       return false;
    PhoneNumber pn = (PhoneNumber)o;
    return pn.extensions == extension &&
           pn.exchange   == exchange  &&
           pn.areaCode   == areaCode;
  }
  ...
}
```

evaluation

- `equals()` uses `instanceof` test
- class `PhoneNumber` is final
  - no subclasses can ever exists
  - transitivity problem can never come up
- flawless solution, but restricted to final classes

listing 4 - another correct implementation

```
class Golfball {
   private String brand;
   private String make;
   private int compression;
   ...
   public String brand() {
     return brand;
   }
   ...
   public boolean equals(object obj) {
     if (this == obj)
        return true;
     if (obj!=null && getClass() == obj.getClass())
     {
        Golfball gb = (Golfball)obj; // Classes are equal, downcast.
        if (brand.equals(gb.brand())  &&  // Compare atrributes.
            make.equals(gb.make()) &&
            compression == gb.compression())
          return true;
     }
     return false;
   }
}
```

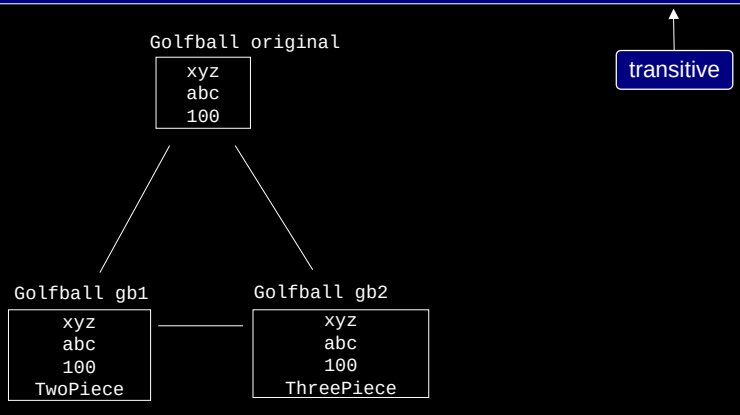
listing 4 (cont.)

```
class MyGolfball extends Golfball {
  public final static byte TwoPiece = 0;
  public final static byte ThreePiece = 1;
  private byte ballConstruction;
  ...
  public byte constuction() {
    return ballConstruction;
  }
  ...
  public boolean equals(Object obj) {
    if (super.equals(obj))
    {
      MyGolfball bg = (MyGolfball)obj;  // Classes equal, downcast.
      if (ballConstruction == gb.construction())
        return true;
    }
    return false;
  }
}
```

- slice comparison is not permitted

mixed-type comparison

```
Golfball original = new Golfball("xyz", "abc",100);
MyGolfball gb1 = new MyGolfball("xyz", "abc", 100, MyGolfball.TwoPiece);
MyGolfball gb2 = new MyGolfball("xyz", "abc", 100, MyGolfball.ThreePiece);

gb1.equals(original)  // mixed-type comparison: yields false
original.equals(gb2)  // mixed-type comparison: yields false
gb1.equals(gb2)       // same-type comparison:  yields false
```



evaluation

- slice comparison is not permitted in the sense that:
  - mixed-type comparison is allowed,
  - but a `Golfball` does never compare equal to `MyGolfball`
- type check via `getClass()` yields false for all attempts of mixed-type comparison
  - only correct approach in class hierarchies of value types
  - where `equals()` must be overridden

revisiting listing 2

- can we solve problem with subclass of `Date` ?
  - using `getClass()` instead of `instanceof`
- NO: leads to asymmetry
  - superclass `Date` permits mixed-type comparison
  - asymmetric behavior if subclass treats mixed-type comparison differently
    - for symmetry any subclass must also allow mixed-type comparison

example - incorrect asymmetric equals()

```
public class Date {   // as before
  ...
  public boolean equals(Object obj) {
    return obj instanceof Date
        && getTime() == ((Date) obj).getTime();
} }
```

```
public class NamedDate extends Date {
  private String name;
  public boolean equals(Object other) {
    if (other!=null && getClass() == other.getClass()) {
      if (!super.equals(other))  return false;
      return name.equals(((NamedDate)other).name));
    }
} }
```

```
NamedDate EndOfMillenium = new NamedDate(99,11,31,"end of 2nd millenium AC");
Date      NewYearsEve    = new Date(99,11,31);

EndOfMillenium.equals(NewYearsEve)   // slice comparison: false
NewYearsEve.equals(EndOfMillenium)   // slice comparison: true
```

not symmetric

cannot mix strategies

- if superclass uses `instanceof` test
  - subclass cannot switch to `getClass()` test
  - violates symmetry requirement
- if superclass uses `getClass()` test
  - subclass cannot allow mixed-type comparison via `instanceof`
  - symmetry requirement violated
- conclusion:

> The strategy chosen for a superclass's `equals()` method determines the implementation of `equals()` for the entire class hierarchy.
> All classes in the hierarchy either allow slice comparison and use `instanceof` or they disallow it and use `getClass()`.

wrap-up

- two substantially different checks for type match
  - allow mixed-type comparison between super- and subclass objects via `instanceof`
  - treat objects of different type as non-equal via `getClass()`
- implementations using `getClass()` are more robust than those using `instanceof`

wrap-up

- `instanceof` test correct only for final classes
  - or if at least method `equals()` is final in a superclass
- a subclass must not extend the superclass's state
  - but can only add functionality or
  - fields that are irrelevant for the object's state and behavior
    - such as transient or static fields

wrap-up

- implementations using `getClass()` test always comply to the `equals()` contract
  - correct and robust
- semantically very different from `instanceof` test
  - prohibits comparison of sub- with superclass objects
  - even for "trivial" class extension
    - when subclass does not add any fields and would not override `equals()`

agenda

- check for type match
- delegation vs. inheritance
- signature of `equals()`
- slice comparison yes/no
- correct slice comparison methods
- guidelines for practitioners

avoiding inheritance

- why not simply avoid inheritance at all ?
  - problems with non-transitive `equals()` only come up in class hierarchies
- habitually declare every new class a final class
  - unless it is supposed to be a superclass
  - effort of providing a robust and correct implementation of a superclass is substantially higher
- recommendation:

> Keep it simple; try out a final class before you consider implementing a non-final class.

inheritance vs. delegation

- inheritance can be replaced by delegation
  - instead of implementing new class as subclass of existing class
  - new class is implemented as unrelated class that holds reference to object of existing class
  - implements same methods as existing class by delegation

delegation - example

- re-implement class `NamedDate`

does *not* extend Date

Date field

delegation

```
public class NamedDate {
  private String name;
  private Date   date;
  ...
  public boolean equals(Object other) {
    if (other!=null && getClass()==other.getClass()) {
       if(date.equals(((NamedDate)other).date)
          && name.equals(((NamedDate)other).name))
          return true;
    }
    return false;
  }
  ...
  public boolean before(Date when) {
    return date.before(when);
  }
  ...
}
```


evaluation

- tedious typing required
  - public interface must be repeated
- sensible and robust alternative to inheritance

- delegation is similar to `getClass()` approach
  - `NamedDate` not considered compatible with `Date`

limitations

- delegation cannot always replace inheritance

- example:
  - protected parts of superclass must be accessed by subclass
  - Template Method pattern from GOF book
- example:
  - frameworks in which superclass also serves as marker interface
  - class hierarchy of standard exceptions (`Throwable`, `Error`, `Exception`, and `RuntimeException`)
    - user-defined domain-specific exception must derive
    - delegation is not an option here

agenda

- check for type match
- delegation vs. inheritance
- signature of `equals()`
- slice comparison yes/no
- correct slice comparison methods
- guidelines for practitioners

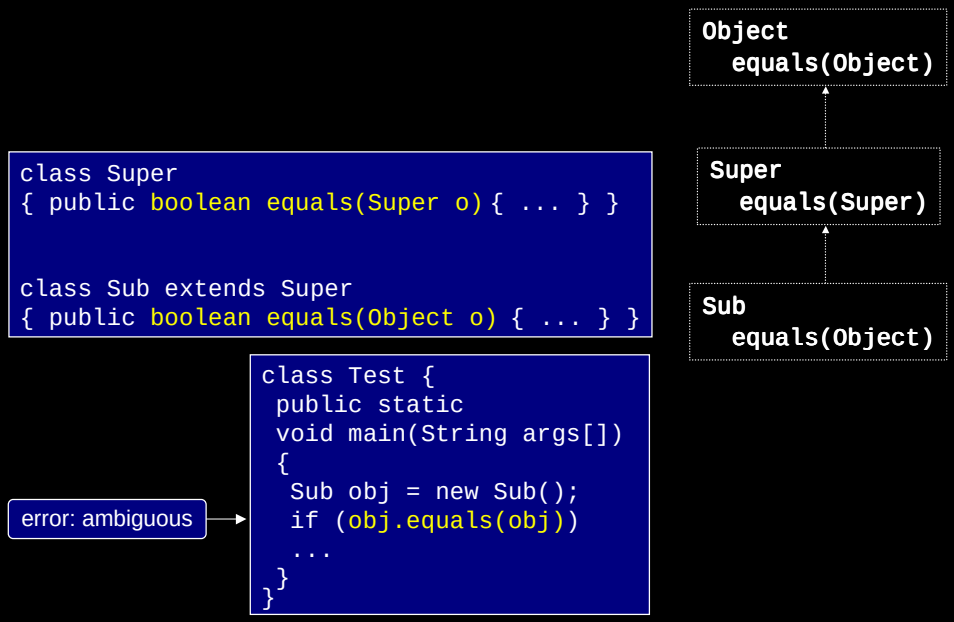
signature of `equals()`

- all implementations of `equals()` in a class hierarchy have the same signature
  - namely the one defined in class `Object`

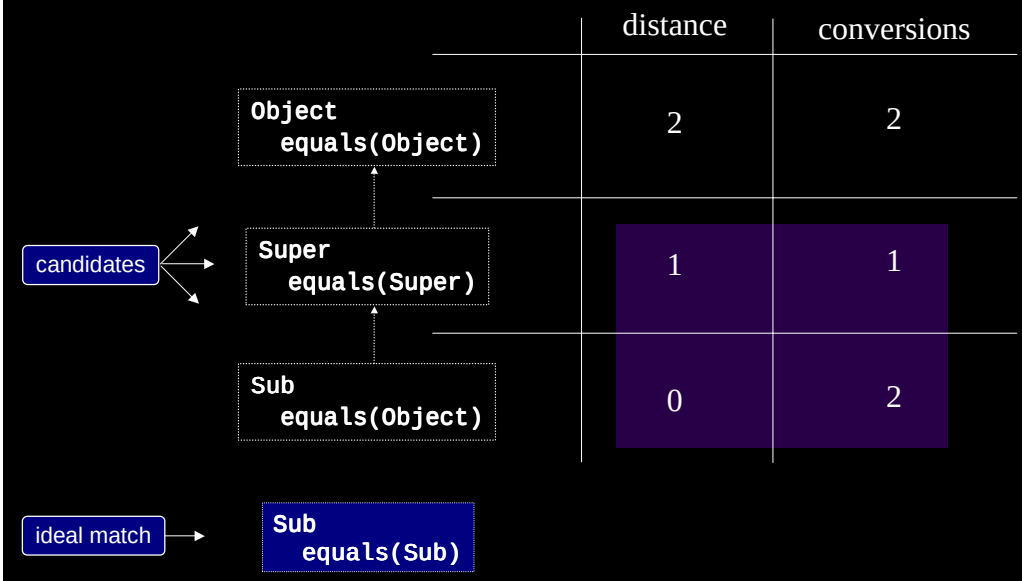
```
boolean equals(Object other)
```

- reason:
  - avoid ambiguities

ambiguous `equals()` - example



ambiguity analysis



Barbara Liskov, "Program Development in Java", page 182

```
public class Point3 extends Point2 {
  private int z;
  ...
  public boolean equals(Object p) { // overriding definition
    if (p instanceof Point3) return equals((Point3)p);
    return super.equals();
  }
  public boolean equals(Point2 p) { // overriding definition
    if (p instanceof Point3) return equals((Point3)p);
    return super.equals();
  }
  public boolean equals(Point3 p) { // extra definition
    if (p==null || z!=p.z) return false;
    return super.equals();
  }
  ...
}
```

overriding and overloading

- upside
  - can omit check for type match in one of the versions
  - all other versions uniformly delegate to `super.equals()`
- downside
  - *all* subclasses must override *all* overloaded versions in order to avoid ambiguities

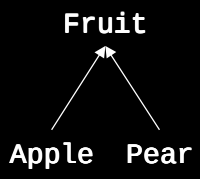
agenda

- check for type match
- delegation vs. inheritance
- signature of `equals()`
- slice comparison yes/no
- correct slice comparison methods
- guidelines for practitioners

slice comparison

- slice comparison is a problem in class hierarchies
  - leads to non-transitive implementations of `equals()`
- when is it needed ? when can it be avoided?

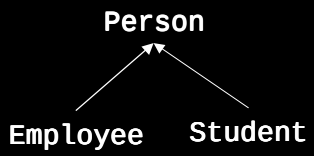
is slice comparison sensible ?



comparison of `Fruit` slices

- `Fruit` is an abstraction
  - should be an abstract class
- comparing `Fruit` part of apples and pears is meaningless

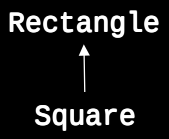
is slice comparison sensible ?



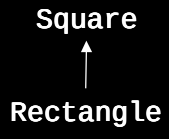
comparison of `Person` slices

- `Employee` and `Student` are roles
  - do not determine characteristics of a `Person`
- comparing `Person` part of employees and students makes sense

is slice comparison sensible ?



- comparison of `Rectangle` slices
  - design violates LSP (Liskov Substitution Principle)
    - a Square cannot be used in all places where a Rectangle can be used
    - example: stretch by doubling one of the edges



- comparison of `Square` slices
  - abuse of inheritance
    - inheritance of structure only
    - instead of inheritance of behavior
  - highly questionable design
    - a Rectangle is not a Square

conclusion

- whether or not slice comparison makes sense
  - depends on semantics of class
- if we want to provide slice comparison in hierarchies of value types
  - how do we do it?

agenda

- check for type match
- delegation vs. inheritance
- signature of `equals()`
- slice comparison yes/no
- correct slice comparison methods
- guidelines for practitioners

final slice comparison

- implement `equals()` as slice comparison and make `final`

  - `Point.equals()`
    - compares Point slices
    - uses `instanceof` check
      - to make sure that other instance has a `Point` part
  - `ColoredPoint` cannot override `equals()`
    - transitive:
      - comparison is always slice comparison

final slice comparison - example

```
class Point {
  final boolean equals(Object other) {
    ...
    if (!(other instanceOf Point))
       return false;
    ...
  }
}
class ColoredPoint extends Point { ... }

Point origin = new Point(0,0);
ColoredPoint p1 = new ColoredPoint(0,0,0xFFFF);
ColoredPoint p2 = new ColoredPoint(0,0,0x0000);

p1.equals(origin);
origin.equals(p2);

p1.equals(p2);
```

true

Point.equals()

evaluation

- no subclass can ever define `equals()` again
  - semantically correct?
  - attributes of subclasses will never be considered for comparison
- in our example:
  - color is irrelevant for comparison of (colored) points

named slice-comparison method

- different names for slice comparison and full comparison
  - `Point.equals()`
    - compares only Point instances
    - uses check for exact type match
  - `ColoredPoint.equals()`
    - compares only ColoredPoint instances
    - no slice comparison
    - uses check for exact type match
  - `MyPoint.isSameLocationAs()`
    - compares Point part of ColoredPoints
    - uses instanceof check
    - is transitive, because it considers only the Point part in *all* cases

named slice-comparison - example

slice comparison

```
class Point {
  boolean equals(Object other) {
    ...
    if (!(other.getClass() == getClass()))
       return false;
    ...
  }
  final boolean isSameLocationAs(Object other) {
    ...
    if (!(other instanceof Point))
       return false;
    ...
  }
}
class ColoredPoint extends Point {
  boolean equals(Object other) {
    ...
    if (!super.equals(other))
       return false;
    ...
  }
}
```


named slice-comparison - example

```
Point origin = new Point(0,0);
ColoredPoint p1 = new ColoredPoint(0,0,0xFFFF);
ColoredPoint p2 = new ColoredPoint(0,0,0x0000);


p1.equals(origin);
origin.equals(p2);

p1.equals(p2);


p1.isSameLocationAs(origin);
origin.isSameLocationAs(p2);

p1.isSameLocationAs(p2);
```

false: type mismatch

false: different content

true: same point part

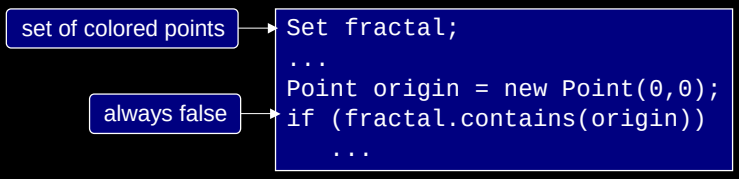
Point.equals()

ColoredPoint.equals()

Point.isSameLocationAs()

evaluation

- collections use `equals()` method of element type for finding elements
  - example:
    - cannot find Point origin in collection of ColoredPoints
    - search would use Point.equals()
      ➔ yields false because of type mismatch



note

- The next 13 slides are not contained in your handouts.

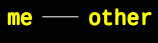
full-blown tree traversal

- key idea to solve the conceptual transitivity problem
  - mixed-type comparison only succeeds if
    - superclass slice is equals and
    - subclass fields have “default” values
- example:
  - `Point2(1,2)` is equal to `Point3(1,2,0)`
  - but is *not* equal to `Point3(1,2,3)`
- implementation is a non-trivial task
  - lots of issues to consider
    - how do we compare objects from different branches?
    - how do we avoid recursive calls to superclass equals?
    - how much of a burden do we impose on future subclasses?

principles

4 possible cases:

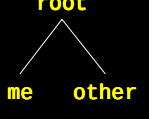
[a] other is an instance of my class



[b] other is an instance of a superclass of mine

[c] other is an instance of a subclass of mine

[d] other is none of the above (a side branch)



[a] other is of same type

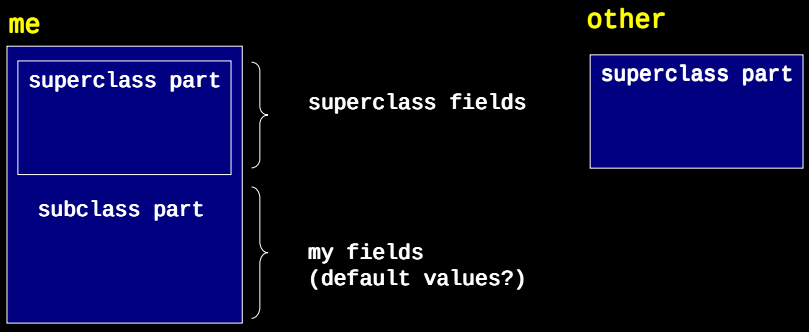
me — other

- just compare my fields and
- call my super to compare the superclass fields

[b] other is an instance of a superclass

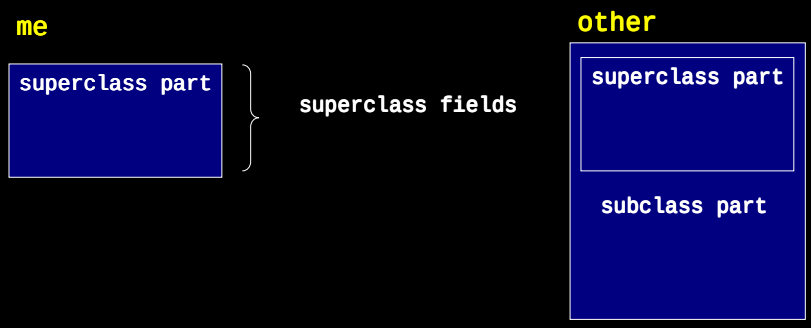
other
|
me

- check whether my fields have default values
- call my super to compare the superclass fields



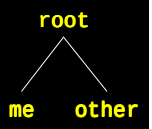
[c] other is an instance of a subclass

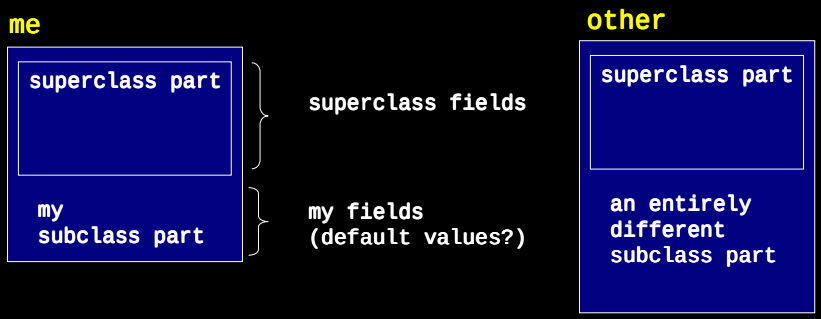
- same as [b] if roles are switched
- reverses the order of the operands
  - return `other.equals(this)`



[d] other is from a side branch

- check for default values in both `this` and `other`
  - traverse both branches
- identify superclass that they have in common
  - straight up the hierarchy from then on





implementation - field comparison

```
public class Point {
    ...

    private boolean _compareFields(Object other) {
        if (other instanceof Point) {
            Point myType = (Point)other;
            if (x != myType.x || y != myType.y)
               return false;
        } else {
            if (x != 0 || y != 0)
               return false;
        }
        return true;
    }
}
```

my class or lower; compare fields

higher type or side branch; check defaults

implementation - equals()

```
public class Point {
    ...
    public boolean equals(Object other) {

        if (other == null) return false;


        if (other == this) return true;


        if (!(other instanceof Point)) return false;


        return _navigate(other,false);
    }
  ...
}
```

null reference

identical objects

incomparable types

start tree traversal

implementation - tree traversal

```
public class ColoredPoint extends Point {
    ...
    protected boolean _navigate(Object other, boolean reversed) {
    if (other instanceof ColoredPoint && !reversed)
        {
          return ((ColoredPoint)other)._navigate(this,true);
        }

        else
        {
          if(!_compareFields(other)) return false;


          return super._navigate(other,reversed);
        }
    }
    ...
}
```

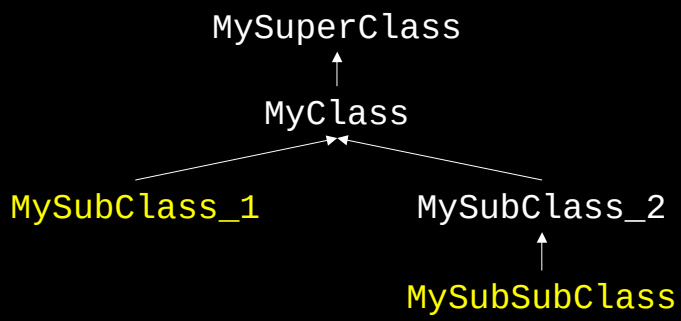
switch roles

process own fields

recursive tree traversal

implementation - avoid infinite loop

- process first branch
  - start at `MySubClass_1` and ascend to `MyClass` (common superclass)
- process second branch bottom up
  - switch roles of `this` and `other`; start at `MySubSubClass`; ascend to `MyClass`
- do NOT process the first branch again



implementation - the boolean flag

```
public class ColoredPoint extends Point {
    ...
    protected boolean _navigate(Object other, boolean reversed) {

    if (other instanceof ColoredPoint && !reversed)
        {
          return ((ColoredPoint)other)._navigate(this,true);
        }

        else
        {
          if(!_compareFields(other)) return false;


          return super._navigate(other,reversed);
        }
    }
    ...
}
```

check value

flip value

pass flag on

boilerplate code

- *all* subclasses must use this mechanism
- boilerplate code
  - trivial modification for root class
  - trivial modification for new subclass

```
public class Point {
    ...
    protected boolean _navigate(Object other, boolean reversed) {
        if (other instanceof Point && !reversed)
        {
          return ((Point)other)._navigate(this,true);
        }
        else
        {
          if(!_compareFields(other)) return false;
          return true;
        }
    }...
}
```

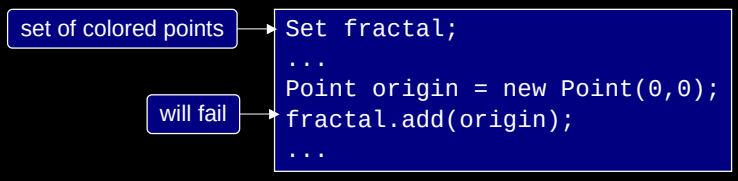
root class

no delegation to superclass

evaluation

- collections use `equals()` method of element type for adding elements
  - example:
    - cannot add Point origin to collection of ColoredPoints
      - if a “origin with default color” is contained in the collection
      - no duplicates allowed in a `Set`
    - add would use Point.equals()

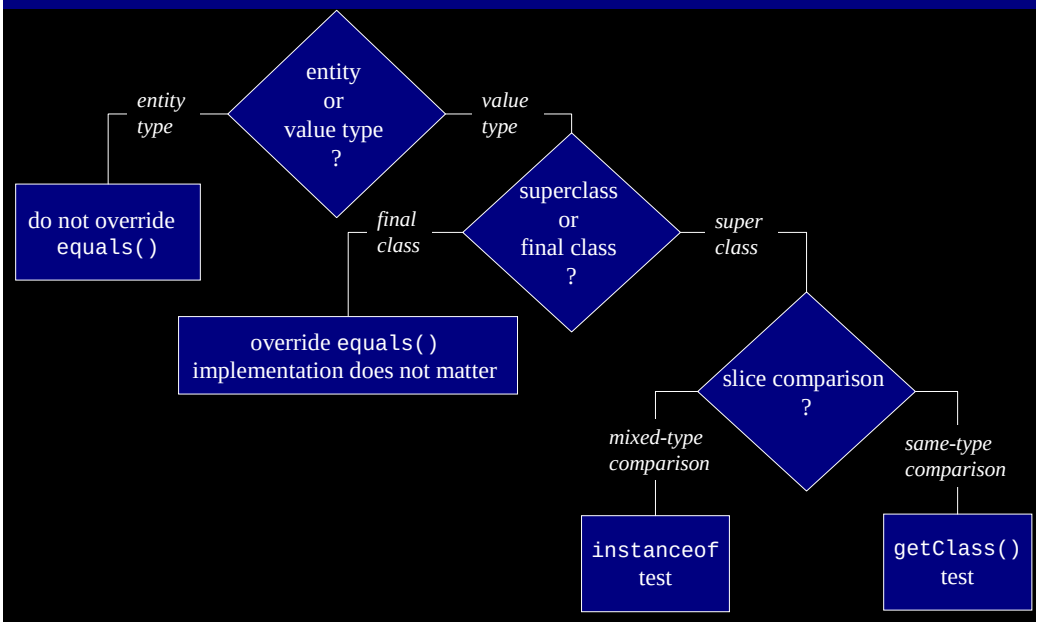
      ➔ yields true because of slice comparison



agenda

- check for type match
- delegation vs. inheritance
- signature of `equals()`
- slice comparison yes/no
- correct slice comparison methods
- guidelines for practitioners

check list



references

- Joshua Bloch
  Effective Java
  Addison Wesley, 2001
- Peter Haggar
  Practical Java
  Addison Wesley, 2000
- Barbara Liskov with John Guttag
  Program Development in Java
  Addison Wesley 2001
- Klaus Kreft & Angelika Langer
  Secrets of equals
  Java Solutions, April 2002
  www.cuj.com/java/articles/a19.htm?topic=java
- Mark Davis
  Liberté, Egalité, Fraternité
  Java Report, 1999/2000
  www.macchiato.com/columns/Durable5.html

contact info

Angelika Langer

Training & Mentoring

Object-Oriented Software Development in C++ & Java

Munich, Germany

http: **//www.AngelikaLanger.com**

Klaus Kreft

Siemens Business Services, Munich, Germany

Email: **klaus.kreft@siemens.com**