CS1007: Object Oriented Design and Programming in Java

Lecture #14

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Outline

- Java implementation of Objects
- Types
- wrappers
- Testing types
- Object class
- Hashes
- Copy
- Reading 7-7.4
  - next time 7.4-7.8

Mistake

- I meant to skip chap 6, and do 7-7.4 last class.
- Oops, still need to know 6-6.4
- Will cover 7-7.4 today.

Announcement

- Homework 3 was released
- Due Nov 27 midnight
- Open ended….please adopt it to your needs
  - Need to document design
  - Need to fulfill basic requirements of assignment

Types

- A set of values and operations with those values.

Strongly typed language

- Strongly typed language: compiler and run-time system check that no operation can execute that violates type system rules
- Compile-time check

```
Employee e = new Employee();
e.clear(); // ERROR
```

- Run-time check:

```
e = null;
e.setSalary(200); // ERROR
```

Java view of Types

- Primitive types:

```
int short long byte
char float double boolean
```

- Class types
- Interface types
- Array types
- The null type
- Note:
  - void is not a type

Values

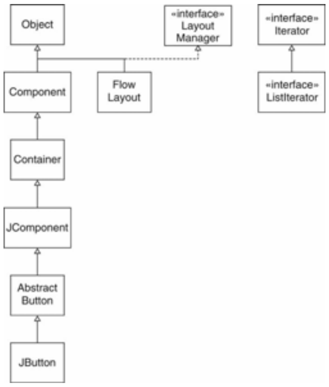
- value of primitive type
- reference to object of class type
- reference to array
- null
- Note: Can't have value of interface type

Subtypes

- S is a subtype of T if:
- S and T are the same type
- S and T are both class types, and T is a direct or indirect superclass of S
- S is a class type, T is an interface type, and S or one of its superclasses implements T
- S and T are both interface types, and T is a direct or indirect superinterface of S
- S and T are both array types, and the component type of S is a subtype of the component type of T
- S is not a primitive type and T is the type Object
- S is an array type and T is Cloneable or Serializable
- S is the null type and T is not a primitive type

Examples

- Container is a subtype of Component
- JButton is a subtype of Component
- FlowLayout is a subtype of LayoutManager
- ListIterator is a subtype of Iterator
- Rectangle[] is a subtype of Shape[]
- int[] is a subtype of Object
- int is not a subtype of long
- long is not a subtype of int
- int[] is not a subtype of Object[]



Exception!

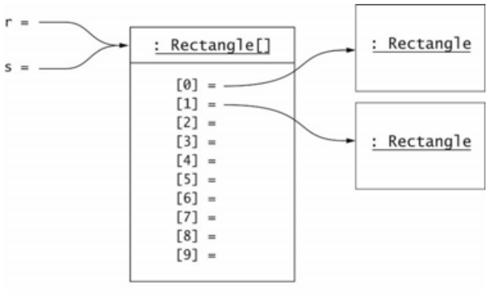
- Rectangle[] is a subtype of Shape[]
- Can assign Rectangle[] value to Shape[] variable:

```
Rectangle[] r = new Rectangle[10];
Shape[] s = r;
```

- Both r and s are references to the same array
- That array holds rectangles
- The assignment

```
s[0] = new Polygon();
```

- compiles
- Throws an ArrayStoreException at runtime
- Each array remembers its component type



Wrapping

- Primitive types aren't classes
- Use wrappers when objects are expected
- Wrapper for each type:

```
Integer Short Long Byte
Character Float Double Boolean
```

Before java 1.5

```
Integer A = new Integer(5);
…
Int x = A.intValue();
```

1.5

- Auto-boxing and auto-unboxing
- `Integer X = 5;`

```
ArrayList<Integer> numbers = new
  ArrayList<Integer>();
numbers.add(13);
int n = numbers.get(0);
```

Enumerated

- Finite set of values
- Example: enum Size { SMALL, MEDIUM, LARGE }
- Typical use:

Size imageSize = Size.MEDIUM;

if (imageSize == Size.SMALL) . . .

- Safer than integer constants

public static final int SMALL = 1;

public static final int MEDIUM = 2;

public static final int LARGE = 3;

Typesafe Enumeration

- enum equivalent to class with fixed number of instances

```
public class Size
{
   private /* ! */ Size() {  }
   public static final Size SMALL = new Size();
   public static final Size MEDIUM = new Size();
   public static final Size LARGE = new Size();
}
```

- enum types are classes; can add methods, fields, constructors
- Enum API

Object testing

- Object O = ????
- How do we figure out what we are dealing with?

Type Inquiry

- Test whether e is a Shape:

if (e instanceof Shape) . . .

- Common before casts:

Shape s = (Shape) e;

- Don't know exact type of e
- Could be any class implementing Shape
- If e is null, test returns false (no exception)

Plain old class

- getClass method gets class of any object
- Returns object of type **Class**
- Class object describes a type

```
Object e = new Rectangle();
Class c = e.getClass();
System.out.println(c.getName()); // prints
   java.awt.Rectangle
```

- Class.forName method yields Class object:

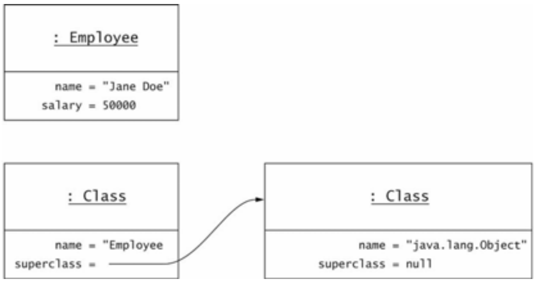
```
Class c = Class.forName("java.awt.Rectangle");
```

- .class suffix yields Class object:

```
Class c = Rectangle.class; // java.awt prefix not needed
```

- Class is a misnomer, since also works for primitives
  int.class
  void.class
  Shape.class

An Employee Object vs. the Employee.class Object



Checking Type

- Test whether e is a Rectangle:

if (e.getClass() == Rectangle.class) . . .

- Ok to use ==
- A unique Class object for every class
- Test fails for subclasses
- Use instanceof to test for subtypes:
  - if (e instanceof Rectangle) . . .

Array Types

- Can apply getClass to an array
- Returned object describes an array type

```
double[] a = new double[10];
Class c = a.getClass();
if (c.isArray())
   System.out.println(c.getComponentType());
```

- getName produces strange names for array types

```
[Z for boolean[]
[D for double[])
[[java.lang.String; for String[][]
```

SUPERclass

- All classes extend Object
- Most useful methods:
  - String toString()
  - boolean equals(Object otherObject)
  - Object clone()
  - int hashCode()

toString

- Returns a string representation of the object
- Useful for debugging
- Example: Rectangle.toString returns something like

java.awt.Rectangle[x=5,y=10,width=20,height=30]

- toString used by concatenation operator
- aString + anObject

means

aString + anObject.toString()

- Object.toString prints class name and object address System.out.println(System.out) yields

java.io.PrintStream@d2460bf

- Implementor of PrintStream didn't override toString:

Overriding toString

- Format all fields:

```
public class Employee
{
   public String toString()
   {
      return getClass().getName()
         + "[name=" + name
         + ",salary=" + salary
         + "]";
   }
   ...
}
```

- Typical string:

Employee[name=Harry Hacker,salary=35000]

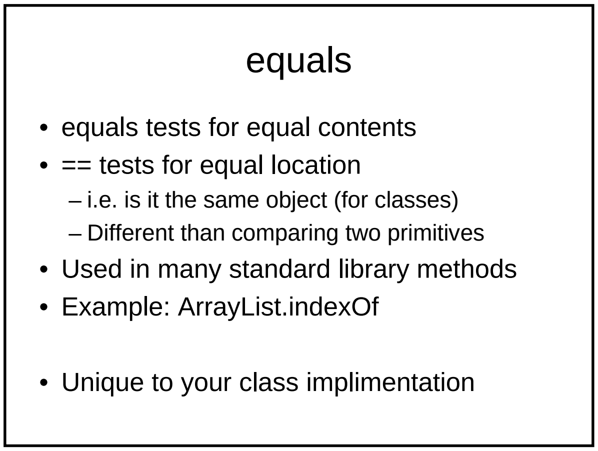
Subclass toString

- Format superclass first

```
public class Manager extends Employee
{
   public String toString()
   {
      return super.toString()
         + "[department=" + department +
  "]";
   }
   ...
}
```

- Typical string

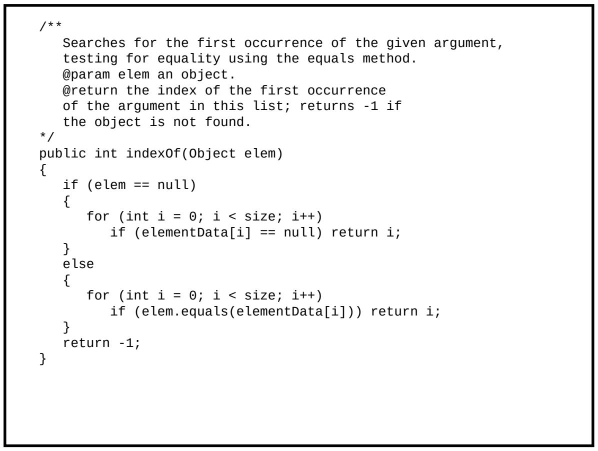
Manager[name=Dolly Dollar,salary=100000][department=Finance]



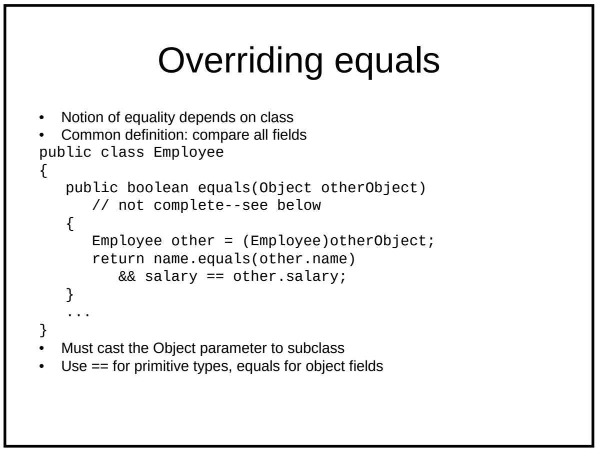
equals

- equals tests for equal contents
- == tests for equal location
  - i.e. is it the same object (for classes)
  - Different than comparing two primitives
- Used in many standard library methods
- Example: ArrayList.indexOf

- Unique to your class implimentation



```
/**
   Searches for the first occurrence of the given argument,
   testing for equality using the equals method.
   @param elem an object.
   @return the index of the first occurrence
   of the argument in this list; returns -1 if
   the object is not found.
*/
public int indexOf(Object elem)
{
   if (elem == null)
   {
      for (int i = 0; i < size; i++)
         if (elementData[i] == null) return i;
   }
   else
   {
      for (int i = 0; i < size; i++)
         if (elem.equals(elementData[i])) return i;
   }
   return -1;
}
```

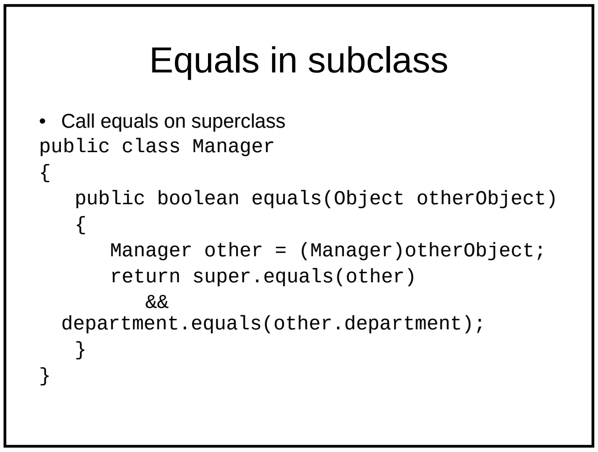


Overriding equals

- Notion of equality depends on class
- Common definition: compare all fields

```
public class Employee
{
   public boolean equals(Object otherObject)
      // not complete--see below
   {
      Employee other = (Employee)otherObject;
      return name.equals(other.name)
         && salary == other.salary;
   }
   ...
}
```

- Must cast the Object parameter to subclass
- Use == for primitive types, equals for object fields



Equals in subclass

- Call equals on superclass

```
public class Manager
{
   public boolean equals(Object otherObject)
   {
      Manager other = (Manager)otherObject;
      return super.equals(other)
         &&
  department.equals(other.department);
   }
}
```

Not so easy

- Two **sets** are equal if they have the same elements in some order

```
public boolean equals(Object o)
{
   if (o == this) return true;
   if (!(o instanceof Set)) return false;
   Collection c = (Collection) o;
   if (c.size() != size()) return false;
   return containsAll(c);
}
```

Object.equals

- Object.equals tests for identity:

```
public class Object
{
   public boolean equals(Object obj)
   {
      return this == obj;
   }
   ...
}
```

- Override equals if you don't want to inherit that behavior

Requirements

- reflexive: x.equals(x)
- symmetric: x.equals(y) if and only if y.equals(x)
- transitive: if x.equals(y) and y.equals(z), then x.equals(z)
- x.equals(null) must return false

Employee.equals

- What does it mean ?

simple

- Check for same name and salary?

- Check for id?

fixing

- Violates two rules
- Add test for null:

if (otherObject == null) return false

- What happens if otherObject not an Employee
- Should return false (because of symmetry)
- Common error: use of instanceof

if (!(otherObject instanceof Employee)) return false;
   // don't do this for non-final classes

- Violates symmetry: Suppose e, m have same name, salary

e.equals(m) is true (because m instanceof Employee)
m.equals(e) is false (because e isn't an instance of Manager)

- Remedy: Test for class equality

if (getClass() != otherObject.getClass()) return false;

Best practice

- Start with these three tests:

```
public boolean equals(Object otherObject)
{
   if (this == otherObject) return true;
   if (otherObject == null) return false;
   if (getClass() != otherObject.getClass())
  return false;
   ...
}
```

- First test is an optimization

Hashing

Hashing Components

- Hash table
- Hash function
- Collision
- Load

Hashing

- hashCode method used in HashMap, HashSet
- Computes an int from an object
- Example: hash code of String

```
int h = 0;
for (int i = 0; i < s.length(); i++)
   h = 31 * h + s.charAt(i);
```

- Hash code of "eat" is 100184
- Hash code of "tea" is 114704

Hashing

- Must be compatible with equals:

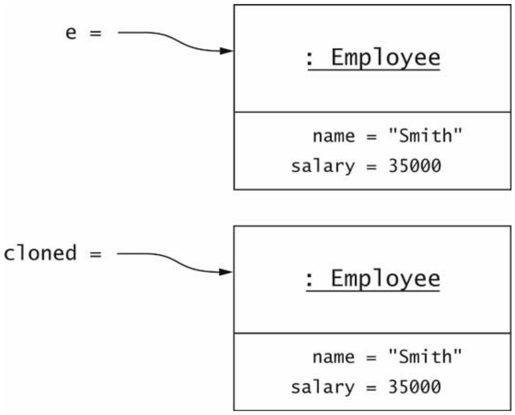
if x.equals(y), then x.hashCode() == y.hashCode()

- Object.hashCode hashes memory address
- NOT compatible with redefined equals
- Remedy: Hash all fields and combine codes:

```
public class Employee
{
   public int hashCode()
   {
      return name.hashCode()
         + new Double(salary).hashCode();
   }
   ...
}
```

Shallow vs. Deep Copy

- Assignment (copy = e) makes shallow copy
- Clone to make deep copy
- Employee cloned = (Employee)e.clone();



Cloning

- Object.clone makes new object and copies all fields
- Cloning is subtle
- Object.clone is protected
- Subclass must redefine clone to be public

```
public class Employee
{
   public Object clone()
   {
      return super.clone(); // not complete
   }
   ...
}
```

Cloneable Interface

- Object.clone is nervous about cloning
- Will only clone objects that implement Cloneable interface

```
public interface Cloneable
{
}
```

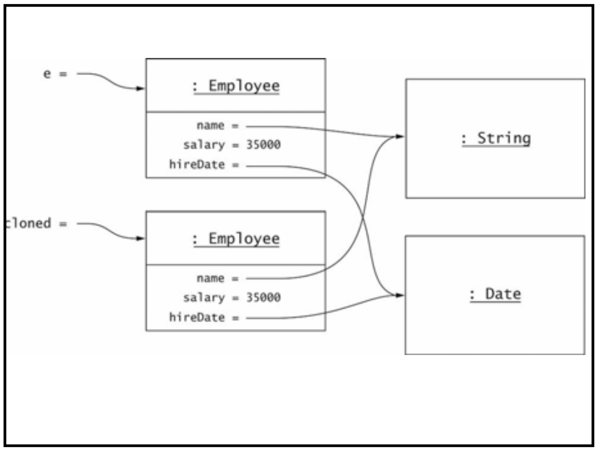
- Interface has no methods!
- Tagging interface--used in test

if x implements Cloneable

- Object.clone throws CloneNotSupportedException
- A checked exception

clone

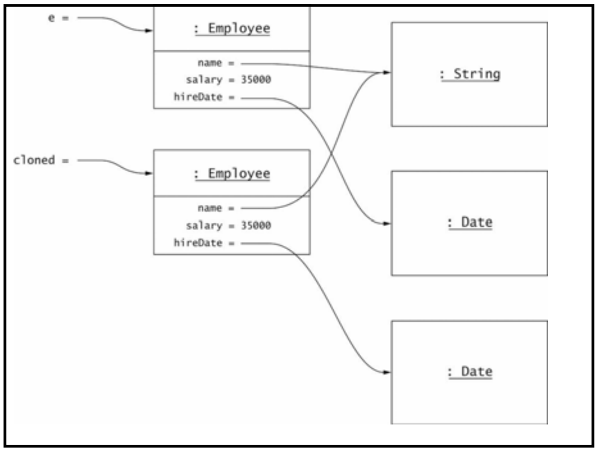
```
public class Employee
  implements Cloneable
{
   public Object clone()
   {
      try
      {
         return super.clone();
      }
      catch(CloneNotSupportedException e)
      {
         return null; // won't happen
      }
   }
   ...
}
```



Deep cloning

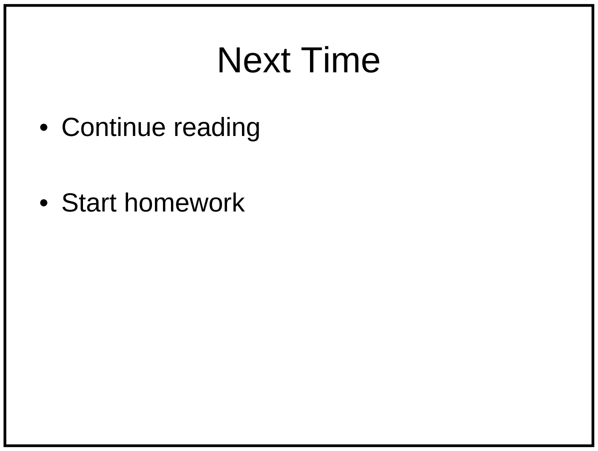
- Why doesn't clone make a deep copy?
- Wouldn't work for cyclic data structures
- Not a problem for immutable fields
- You must clone mutable fields

```
public class Employee
  implements Cloneable
{
   public Object clone()
   {
      try
      {
         Employee cloned = (Employee)super.clone();
         cloned.hireDate = (Date)hiredate.clone();
         return cloned;
      }
      catch(CloneNotSupportedException e)
      {
         return null; // won't happen
      }
   }
   ...
}
```



Cloning and Inheritance

- Object.clone is paranoid
  - clone is protected
  - clone only clones Cloneable objects
  - clone throws checked exception
- You don't have that luxury
- Manager.clone must be defined if Manager adds mutable fields
- Rule of thumb: if you extend a class that defines clone, redefine clone
- Lesson to learn: Tagging interfaces are inherited. Use them only to tag properties that inherit



Next Time

- Continue reading
- Start homework