CS 228: Introduction to Data Structures
Lecture 6
Monday, January 26, 2015

Overriding the `clone()` Method

An alternative to writing our own (ad hoc cloning) method is to override Java's `Object.clone()` method. The default implementation of `clone()` creates a field-by-field copy — that is, a ***shallow copy*** — of its argument. Since shallow copying is not always appropriate, Java intentionally disables `clone()`, by declaring it as `protected`, not `public` — so you have to call it from the subclass using `super` — and by having it throw a `CloneNotSupportedException` when called.
To override `clone()`, you either have to explicitly declare that your class implements `Cloneable` or some superclass of your class must implement `Cloneable`. Thus, the declaration for Point would be

```
public class Point implements Cloneable{…}
```

Your public `clone` method can then call the protected `clone` method to create a shallow copy, if that suffices. For the `Point` class, a shallow copy is enough. The code is:

```
@Override
public Object clone()
{
  Point copy = null;
  try
  {
    // super.clone() creates copies of
    // all fields
    copy = (Point) super.clone();
  }
  catch (CloneNotSupportedException e)
  {
    // Should never happen unless there's
    // a programming error
  }
  return copy;
}
```

Usage:

```
Point p = new Point(1, 2);
q = (Point) p.clone();
```

Shallow versus Deep Copying

A shallow copy suffices for `Point`, because both of its fields, `x` and `y`, are primitive. In general, though, an object may contain references to other objects. In this case, to get a completely independent copy, you have to recursively copy/clone the objects the object references — this is called a ***deep copy***.

Example: The `IntVector` Class

An `IntVector` has a *dimension* `dim` and an array `coords` of coordinates. Its class definition begins like this (the code is posted on BB).

```
public class IntVector implements Cloneable
{
    private int dim;

    private int[] coords;
```

The constructor is

```java
    public IntVector(int dimension)
    {
        if (dimension <= 0)
         throw
           new IllegalArgumentException();
        dim = dimension;
        coords = new int[dim];
    }
```

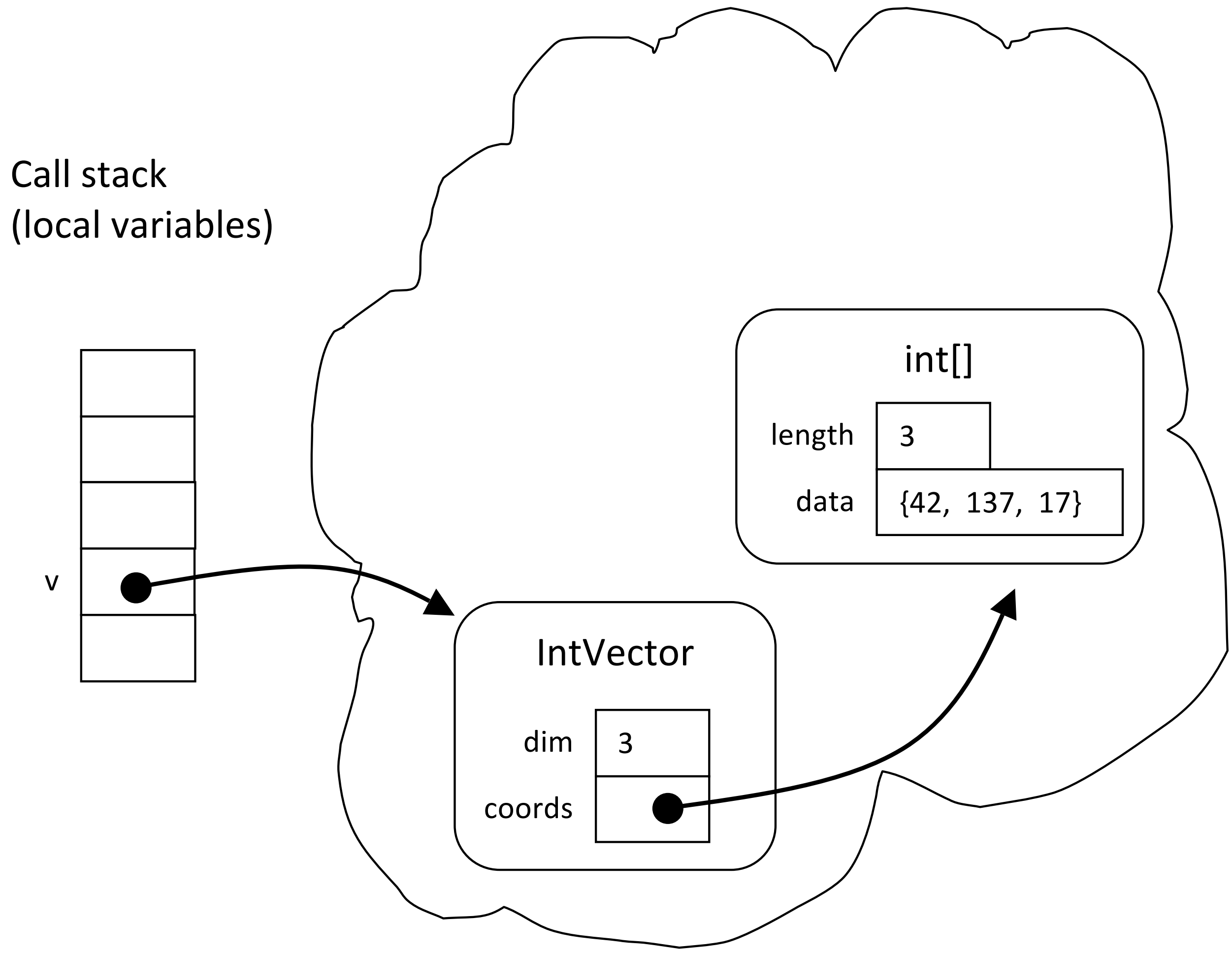
Here is the setter.

```java
    public void set(int index, int value)
    {
        coords[index] = value;
    }
```

Now, suppose we execute the statements below:

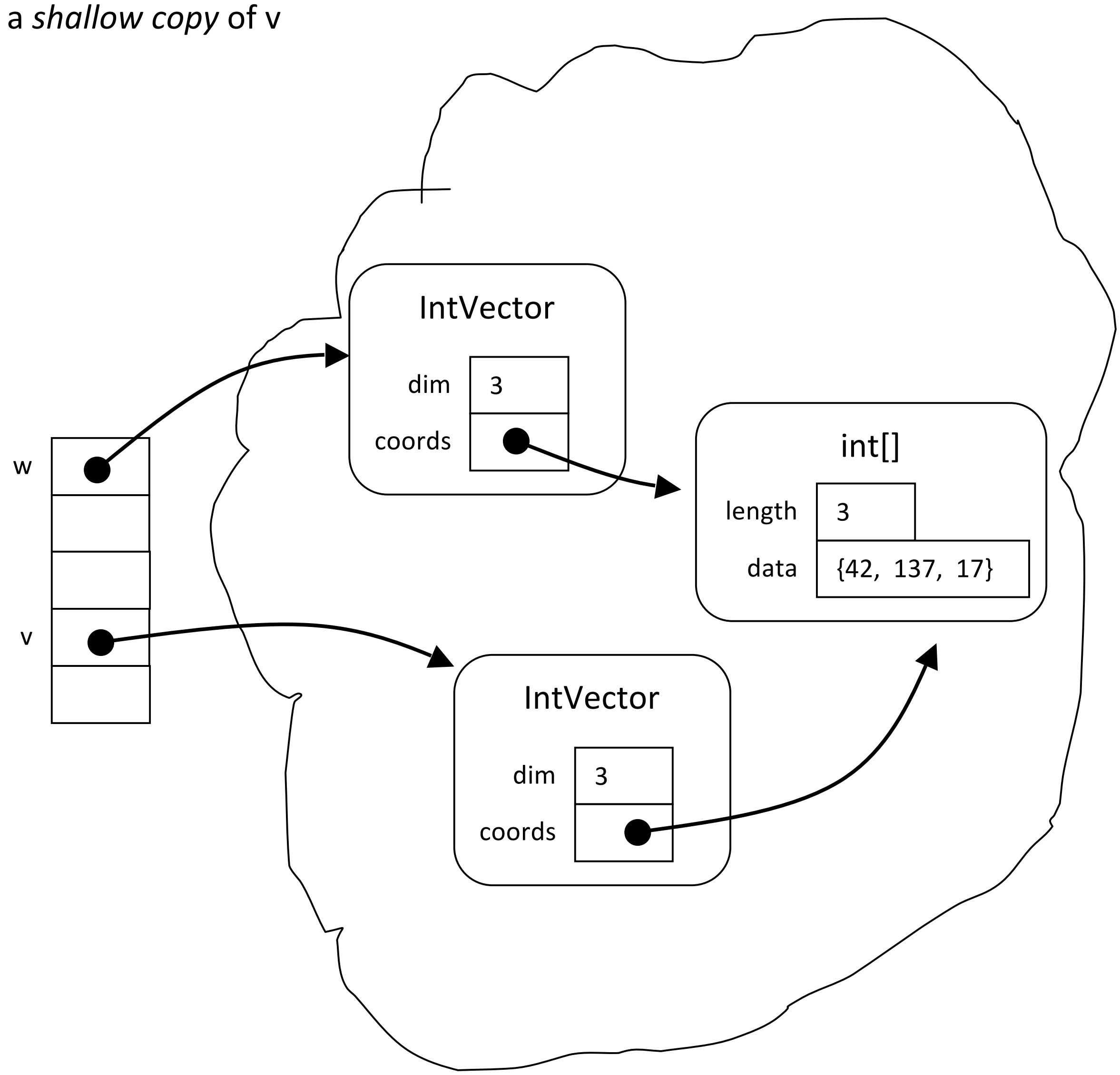
```java
IntVector v = new IntVector(3);
v.set(0, 42);
v.set(1, 137);
v.set(2, 17);
```

The result is:



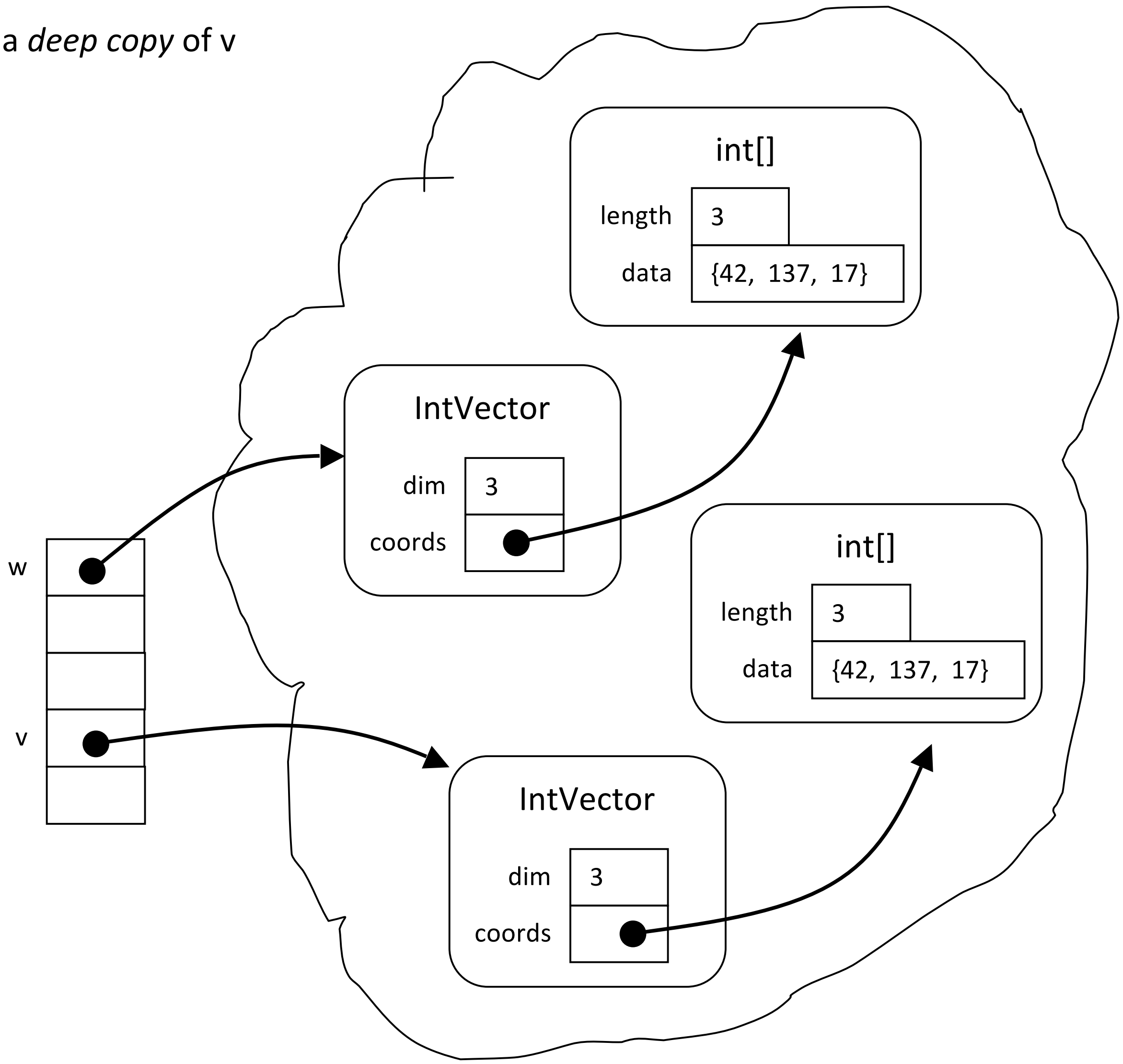
Suppose `w` is a shallow copy of `v`; i.e., `w` is obtained by copying the fields of `w`. Since the `coords` field is a reference, we just copy the reference. Thus, the `coords` fields of `v` and `w` end up referring to the same array.

w is a *shallow copy* of v



This can be dangerous, since any modification to the `coords` array through `w` also affects `v`. What we probably want is, in fact, a completely independent copy — a ***deep copy*** — of this array, like this:

w is a *deep copy* of v



A Copy Constructor for `IntVector`

Here is the code for a copy constructor that builds a deep copy of an `IntVector` object.

```java
public IntVector(IntVector existing)
{
  dim = existing.dim;
  coords = new int[dim];

  for (int i = 0; i < dim; ++i)
  {
    coords[i] = existing.coords[i];
  }
}
```

Note that we could use `System.arraycopy()`[1] instead of the `for` loop.

`clone()` for `IntVector`

By default, `Object.clone()` creates shallow copies. That is OK for `Point`, but not for `IntVector`. Here is how to make a deep copy.

[1] See http://docs.oracle.com/javase/8/docs/api/java/lang/System.html.

```java
@Override
public IntVector clone()
{
  try
  {
    IntVector copy
        = (IntVector) super.clone();

    // Object.clone() copies fields, now
    // make it into deep copy

    copy.coords = new int[dim];
    for (int i = 0; i < dim; ++i)
    {
      copy.coords[i] = coords[i];
    }
    return copy;
  }
  catch (CloneNotSupportedException e)
  {
    // should never happen...
    return null;
  }
}
```

Shallow versus Deep Comparison

The shallow versus deep issue also arises when implementing `equals()`. For example, `ArrayList`'s `equals()` method does a shallow comparison of two `ArrayLists`: they are "equal" if they have the same length and contain identical values in the same order. To implement `IntVector`'s `equals()` properly, we must do a deep comparison:

```
@Override
public boolean equals(Object obj)
{
  if (obj == null ||
        obj.getClass() !=
           this.getClass()) return false;
  IntVector other = (IntVector) obj;
```

```
    if (dim == other.dim)
    {
      // Check whether all coordinates are
      // the same
      for (int i = 0; i < dim; ++i)
      {
        if (coords[i] != other.coords[i])
        {
          return false;
        }
      }
      return true;
    }
    else
    {
      return false;
    }
  }
```

Note. For comparing the `int` arrays, you could also use the utility

```
Arrays.equals(coords, other.coords).
```

However, since the class `int[]` does not override `equals()`, the following will ***not*** work:

```
coords.equals(other.coords)
```

Comments on Overriding Methods

Notice that the return type in `IntVector.clone()` is `IntVector`, while the return type in `Point.clone()` is `Object`. Either way is correct. The potential advantage of the former is that we can avoid the cast we needed with `Point`.

Here are some additional things you can and cannot do when you override a method.

- You ***cannot*** change the method's name or parameter types.

- You ***can*** change the return type, as long as the new type is ***compatible*** with the original.

- You ***can*** change a method from protected to public, but you ***cannot*** make the access more restrictive.

- You ***can*** omit a `throws` declaration, but you ***cannot*** add a `throws` declaration.

`static` Fields and Methods

The keyword **`static`** in Java means “associated with the class as a whole, not with an instance”. Fields and methods can be static.

A ***static field*** is a single variable shared by a whole class of objects; its value does not vary from object to object. Thus, static fields are also called ***class variables***. If we declare a field `static`, there is just one field for the whole class. One common use of static fields is to define constants, such as `Math.PI`, that are **`static`** and **`final`**. Here is another example.

Example. Suppose we want to keep track of the number of `Person` objects that we have constructed. It does not make sense for each object to have its own copy of this number: we would have to update every `Person`’s number whenever a new `Person` is created. It makes more sense to have a single variable, a static field, for the entire class that counts the number of people created thus far. The constructor increments this static field, called `numberOfPeople`, by one.

```
class Person {
  public static int numberOfPeople;
  public String name;
  public Person(String name) {
    this.name = name;
    numberOfPeople++;
  }
}
```

If we want to look at the variable `numberOfPeople` from another class, we write it in the usual notation, but we prefix it with the class name rather than the name of a specific object. For example,

```
  int kids = Person.numberOfPeople / 4;
```

The following works too, but has nothing to do with `joe` specifically.

```
  int kids = joe.numberOfPeople / 4;
```

Don't do this; it is bad (confusing) style.

A ***static method*** does not implicitly pass an object as a parameter — in contrast, for example, the call `p.foo(q)` implicitly passes p as a parameter to `foo`. Thus, a static method can be used without creating an instance of the class. One example is `Math.cos()`. Here's another one.

```
class Person {
  ...
  public static void printPopulation() {
    System.out.println(numberOfPeople);
  }
}
```

Now, we can call "`Person.printPopulation()`" from another class. We can also call "`joe.printPopulation()`", and it works, but it is bad style, and `joe` will NOT be passed along as "`this`".

The `main()` method is always `static`, because when we run a program, we are not passing it an object.

Important: In a `static` method, there is no "`this`"! Any attempt to reference "`this`" will cause a compile-time error.