CS193J: Programming in Java
Summer Quarter 2003

Lecture 3
Collections and More OOP

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Recap

- Last time (a somewhat jumpy introduction to…)
  - OOP in Java (Student Example)
  - Explore more Java features
    - Primitives
    - Arrays
    - Multi-Dimensional Arrays
    - String Class
    - StringBuffer Class
    - Static keyword
  - OOP Design
    - Encapsulation
      - Interface vs. Implementation
    - Client Oriented Design
- To Dos
  - HW1: Pencil Me In
    - Due before midnight Wednesday July 9th, 2003

Handouts

- 3 Handouts for today!
  - #8: Collections
  - #9: OOP2 - Inheritance
  - #10: OOP3 – Abstract Superclasses

- Next time
  - Complete OOP
    - Probably won't get to all of it today
  - Start Drawing/GUI

Today

- Java Collections
  - ArrayList example
- OOP
  - Inheritance
    - Grad example
  - Abstract Superclasses
    - Account example
- Java Interfaces
- You will have all you need for HW#1
  - By the end of today's lecture.

Collections (Handout #8)

- Built-in support for collections
  - Similar to STL in C++
- Collection type
  - Sequence/Set
  - Example ArrayList
- Map type
  - Hashtable/dictionary
  - Example HashMap
- Collections store pointers to objects!
- Use inheritance and interfaces
- Read
  - http://java.sun.com/docs/books/tutorial/collections

Collection Design

- All classes implement a similar interface
  - add(), size(), iterator()…
  - Easy learning curve for using Collections
  - Possible to swap out the underlying implementation without significant code change
- Implemented as pointer to Object
  - Similar to using a void * in C
  - Require a cast back to the actual type
  - Example
    - String element = (String)arraylist.get(i)
- Java checks all casts at run-time

Collection Messages

- Basic messages
  - constructor()
    - Creates a collection with no elements
  - size()
    - Number of elements in the collection
  - boolean add()
    - Add a new pointer/element at the end of the collection
    - Returns true is the collection is modified.
  - iterator()
    - Returns an Iterator Object

Additional Collection Messages

- Utilities
  - Additional useful methods
  - boolean isEmpty()
  - boolean contains(Object o)
    - Iterative search, uses equals()
  - boolean remove(Object o)
    - Iterative remove(), uses equals()
  - Boolean addAll(Collection c)

Iterators

- Used to iterate through a collection
  - Abstracts away the underlying details of the implementation
    - Iterating through an array is the same as a binary tree
- Responds to
  - hasNext() - Returns true if more elements
  - next() - Returns the next element
  - remove() - removes element returned by previous next() call.

Working with Iterators

- Not valid to modify a collection directly while an iterator is being used!
  - Should not call collection.add() or collection.remove()
- OK to modify the collection using the iterator itself
  - iterator.remove()
- Why?
  - Motivation for concurrency issues later in the course

ArrayList

- Most useful collection
- Replaces the "Vector" class
- Can grow over time
- Methods
  - add()
  - int size()
  - Object get(int index)
    - Index is from 0 to size() -1
    - Must cast to appropriate type when used.
  - iterator()
    - We'll see an ezample!

ArrayList Demo: constructor

```
import java.util.*;

/*
 The ArrayList is replaces the old Vector class.
 ArrayList implements the Collection interface, and also
 the more powerful List interface features as well.
 Main methods:add(), size(), get(i), iterator()
 See the "Collection" and "List" interfaces.
*/
public static void demoArrayList() {
   ArrayList strings = new ArrayList();

…
```

ArrayList Demo: adding/size

```
// add things...
    for (int i= 0; i<10; i++) {
        // Make a String object out of the int
        String numString = Integer.toString(i);
        strings.add(numString);     // add pointer to collection
    }

    // access the length
    System.out.println("size:" + strings.size());
```

ArrayList Demo: looping

```
// ArrayList supports a for-loop access style...
// (the more general Collection does not
   support this)

   for (int i=0; i<strings.size(); i++) {
        String string = (String) strings.get(i);
        // Note: cast the pointer to its actual class
        System.out.println(string);
   }
```

ArrayList: iterating

```
// ArrayList also supports the "iterator" style...

    Iterator it = strings.iterator();
    while (it.hasNext()) {
        String string = (String) it.next();  // get and cast
    pointer
        System.out.println(string);
    }

// Calling toString()
    System.out.println("to string:" + strings.toString());
```

ArrayList Demo: removing

```
// Iterate through and remove elements
// get a new iterator (at the beginning again)

    it = strings.iterator();
    while (it.hasNext()) {
        it.next();              // get pointer to elem
        it.remove();            // remove the above elem
    }

    System.out.println("size:" + strings.size());
}
```

ArrayList Demo: output

```
/* Output...
    size:10
    0
    1
    2
    3
    4
    5
    6
    7
    8
    9
    to string:[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
    size:0
*/
```

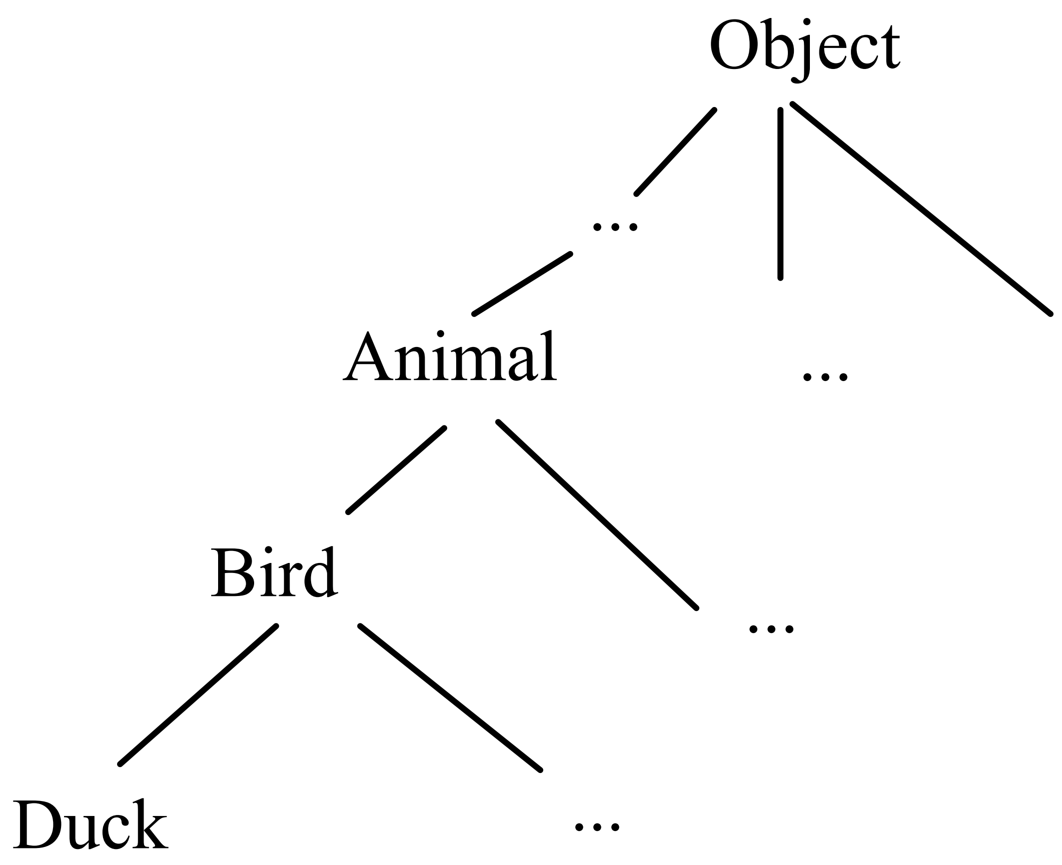
OOP – Inheritance (Handout #9)

- OOP so far
  - Modularity
  - Encapsulation
- Today
  - Open Pandora's box
    - Inheritance
    - Abstract Super Classes
- Warning
  - True good uses of inheritance are rare
  - Use it only where it is really appropriate.

Hierarchy

- Classes are arranged in a tree hierarchy
  - A class' "superclass" is the class above it in the hierarchy
  - Classes below is are "subclasses"
- Classes have all the properties of their superclasses
  - General – towards the root (top)
  - More specific – towards the leaves (down)
    - NB: In Computer Science trees grow upside down!

Example



Inheritance

- The process by which a class inherits the properties of its superclasses
  - Methods
  - Instance variables
- Message-Method resolution revisited
  - Receive message, check for method in class
  - If found, execute
  - Check for method in superclass
  - If found, execute, if not, repeat this procedure
  - Basic idea: Travel up the tree.
- **Result:**
  - **A class automatically responds to all the messages and has all the storage of superclasses**

"Overriding"

- When an object receives a message
  - It checks it own methods first
  - Then check the superclass' methods
- The first method in the hierarchy takes precedence
  - We can add a method with the same name as in the superclass in the class
  - The code of the superclass will not be executed
    - It is effectively "overridden" i.e. intercepted
- In C++ runtime overriding is an option invoked by the "virtual" keyword.

Polymorphism

- Do not be intimidated by the big word
  - It's a simple concept
  - Basic idea: "it does the right thing"
- An Object always knows its true class at runtime
  - The MOST specific method found for the object is executed.

Polymorphism example

- Shape is a superclass of Rectangle
  - Shape.drawSelf() and Rectangle.drawSelf()
- Code:

```
Shape s;
Rectangle r = new Rectangle();
s = r;
s.drawSelf()
```

- Which method will get execute? Shape.drawSelf() or Rectangle.drawSelf()?

OOP Glossary

- OOP Class Hierarchy
- Superclass
- Subclass
- Inheritance
- Overriding
- isA
  - the subclass is a instance of the superclass

Horse/Zebra Example

- Hierarchy of all the animals
  - Need to add in Zebra
- Options
  - Define zebra from scratch
    - Bad idea – mutlitpe copies of code.
  - Locate the Horse class and subclass it to create the Zebra class
    - Zebra will inherit most of the characteristics of a horse
    - Override or add additional features as needed

Grad Example

- Add Grad as an extension to the Student class from previous lecture.
  - yearsOnThesis – a count of the number of years worked on the thesis
  - getStress() – overridden to be different
    - 2 * the Student stress + yearsOnThesis
- Grad is everything that a student is
  - Has additional or some different properties
- Grad is “more specific”
  - Grad (subclass) has more properties, and is more constrained that Student (superclass)

Student/Grad Design Diagram

Student
- units
- ctor
- get/set Units
- getStress

Grad
- yearsOnThesis
- ctor
- get/set YOT
- getStress (override)

Simple Inheritance Client Code

- Instantiation
  - Student s = new Student(10);
  - Grad g = new Grad(10, 2); // ctor takes units and yot
- Usage (normal)
  - s.getStress(); // (100) goes to Student.getStress()
- Usage (inheritance)
  - g.getUnits(); // (10) goes to Student.getUnits()
- Usage (overriding)
  - g.getStress(); // (202) goes to Grad.getStress()

Clarifications and Reminders

- An Object never forgets it's Class
  - The receiver always knows it's most specific class
- Student s; in the face of inheritance
  - No: "s points to a Student object"
  - Yes: "s points to an object that responds to all the messages that Students respond to"
  - Yes: "s points to a Student, or a subclass of Student"

OOP Pointer Substitution

- A subclass *isA* superclass
  - A subclass object can be used when you are expecting a superclass
  - The subclass has everything the superclass has and more (not less!)
- Compile time error checking
  - Compiler will only allow code in which the receiver respond to the given message
  - Implemented as loose checking since sometimes the exact class is not known (Student or Grad both work)
- Run time error checking
  - More strict. Receiver knows exactly which class it is.

Pointer Substitution Example

- A pointer to a Grad object be assigned to Student pointer.
  - Student s = new Student(10);
  - Grad g = new Grad(10,2);
  - s = g; // ok -- subclass may be used in place of superclass
- The reverse is not allowed however
  - Student s = new Student(10);
  - Grad g = new Grad(10,2);
  - g = s; // NO, does not compile

Example of method calls

```
Student s = new Student(10);
Grad g = new Grad(10, 2);

s = g;  // ok

s.getStress();
// (202) ok -- goes to Grad.getStress() (overriding)

s.getUnits();
// (10) ok -- goes to Student.getUnits (inheritance)

s.getYearsOnThesis();
// NO -- does not compile (s is compile time type Student)
```

Downcast

- Sometimes the programmer can give the compiler more information
  - Done by providing a more specific cast around a less specific object
  - ((Grad)s).getYearsOnThesis();
- Downcast
  - Makes a more specific claim
- All casts are checked at runtime
  - Will throw ClassCastException if there is a problem
  - In C, the program would crash unpredictably
- In general: Downcasting is bad style!

Student/Grad Memory Layout

- Implementation detail
  - In memory, instance variables of the subclass are layers on top of the instance variables of the subclass
- Result
  - A pointer to the base instance of the subclass can be treated as if it were a superclass object
  - A Grad object looks like a Student object

Inheritance Client Code

```
Student s = new Student(10);
Grad g = new Grad(15, 2);
Student x = null;

System.out.println("s " + s.getStress());
System.out.println("g " + g.getStress());

// Note how g responds to everything s responds to
// with a combination of inheritance and overriding...
g.dropClass(3);

System.out.println("g " + g.getStress());

/*
 OUTPUT...
      s 100
      g 302
      g 242
*/
```

Inheritance Client Code

```
// s.getYearsOnThesis();       // NO does not compile

g.getYearsOnThesis();          // ok

// Substitution rule -- subclass may play the role of superclass
x = g;       // ok

// At runtime, this goes to Grad.getStress()
// Point: message/method resolution uses the RT class of the receiver,
// not the CT class in the source code.
// This is essentially the objects-know-their-class rule at work.
x.getStress();

// g = x;    // NO -- does not compile,
// substitution does not work that direction
// x.getYearsOnThesis();       // NO, does not compile

((Grad)x).getYearsOnThesis();            // insert downcast
// Ok, so long as x really does point to a Grad at runtime
```

isIrate() example

- isIrate() method in the Student Class
  - Returns true is stress > 100
- In the Student Class:

```
public boolean isIrate() {
   return (getStress() > 100);
}
```

- What happens with the following client code:

```
Student s = new Student(...);
Grad g = new Grad(....);
s.isIrate();
g.isIrate();
```

How g.isIrate() works…

- g *known* that is a Grad Object
- It looks for an isIrate method
  - Not found, so climbs up the tree to the Student class
  - Method found in Student class
- isIrate() has a call to getStress()
  - Since g knows it is a Grad Object (*and it doesn't forget this!*) it will call the Grad.getStress()
  - Grad.getStress() in turn calls Student.getStress()!!
    - We will see this when we examine the implementation code!
- Bottom line: it does the right thing!

"Pop-Down" rule

- The reciever knows it's class
- The flow of control jumps around different classes
- No matter where there code is executing the receiver knows its class and does the message→method mapping correctly for each message!
- Example
  - Receiver is the subclass (Grad), executing a method in the superclass(Student)
  - A message send that Grad overrides will "pop-down" to the Grad definition as in the case of getStress())

super.getStress()

- The “super” keyword is used in methods and constructors to refer to code in the superclass
  - Calling super.getStress() in the Grad class would execute the code for getStress() in the Student Class
  - Think of super as a directive to the message→method resolution process.
    - Start searching one level higher.
- Allows the subclass to not have to rewrite the code
  - Re-use the code in the superclass and add to the functionality

Continue on Lecture 4…

- Continued on Lecture 4…

Summary

- Today
  - Java Collections
    - ArrayList example
  - OOP
    - Inheritance
      - Grad example
- Assigned Work Reminder:
  - HW #1: Pencil Me In
    - Due before midnight Wednesday, July 9th, 2003