Generic Programming and Inner classes

Goal

- First version of linear search
  - Input was array of int
- More generic version of linear search
  - Input was array of Comparable
- Can we write a still more generic version of linear search that is independent of data structure?
  - For example, work even with 2-D arrays of Comparable

Key ideas in solution

- Iterator interface
- Linear search written once and for all using Iterator interface
- Data class that wants to support linear search must implement Iterator interface
- Implementing Iterator interface
  - We look at three solutions
  - Inner classes provide elegant solution

Recall linear search code

```
boolean linearSearch (Comparable[] a, Object v) {
    for (int i = 0; i < a.length; i++)
        if (a[i].compareTo(v) = = 0)
            return true;
    return false;
}
```

Code in red relies on data being stored in a 1-D array.
For-loop also implicitly assumes that data is stored in 1-D array.

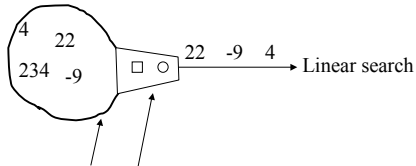
This code will not work if data is stored in a more general data structure such as a 2-D array.

Minor rewrite of linear search

```
boolean linearSearch (Comparable[] a, Object v) {
    int i = 0;
    while (i < a.length)
        if (a[i].compareTo(v) = = 0) return true;
        else i++;
    return false;
}
```

Intuitively, linear search needs to know
- are there more elements to look at?
- if so, get me the next element

Intuitive idea of generic linear search



- Data is contained in some object.
- Object has an adapter that permits data to be enumerated in some order.
- Adapter has two buttons
  - boolean hasNext(): are there more elements to be enumerated?
  - Object Next(): if so, give me a new element that has not been enumerated so far

Iterator interface

```
interface Iterator {
    boolean hasNext();
    Object next();
    void remove(); //we will not use this
}
```

This interface is predefined in Java.
Linear search is written using this interface.
Data class must provide an implementation of this interface.

Generic Linear Search

Iterator version

```
boolean linearSearch(Iterator a, Object v) {
    while (a.hasNext())
        if ((Comparable) a.next()).compareTo(v) = = 0)
            return true;
    return false;
}
```

Compare with Array version

```
boolean linearSearch(Comparable[] a, Object v){
    int i = 0;
    while (i < a.length)
        if (a[i].compareTo(v) = = 0) return true;
    return false;
}
```


How does data class implement Iterator interface?

Let us look at a number of solutions.

1. Adapter code is part of class containing data
2. Adapter is a separate class that is hooked up to data class
3. Adapter is an inner class in class containing data

Adapter (version 1)

```
class Crock1 implements Iterator{
    protected Comparable[] a;
    protected int cursor = 0; //index of next element to be enumerated
    public Crock1() {
      …store data in array a…
    }

    public boolean hasNext() {
      return (cursor < a.length);
    }
    public Object next() {
      return a[cursor++];
    }
    public void remove() {}//unimplementated
}
```


Critique

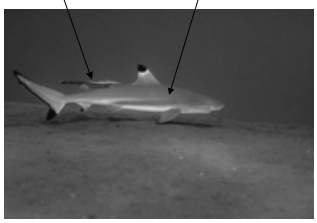
- As shown, client class can only enumerate elements once!
  - How do we reset the cursor?
- Making the data class implement Iterator directly is something of a crock because its concern should be with data, rather than enumeration of data.
- However, this works for other data structures such as 2-D arrays.
  - 2-D arrays: data class can keep two cursors
    - one for row
    - one for column
    - standard orders of enumeration: row-major/column-major

- One solution to resetting the cursor:
  - Data class implement a method void reset() which resets all internal cursor(s)
  - Method must be declared in Iterator interface
- But we still cannot have multiple enumerations of elements going on at the same time
  - Remember: only one cursor….
- Problem: cannot create new cursors on demand
- To solve this problem, cursor must be part of a different class that can be instantiated any number of times for a single data object.

Sharks and remoras

Iterator implementation is like a remora.

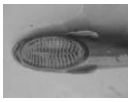
Data class is like shark



Single shark must allow us to hook many remoras to it.

Adapter (version 2)

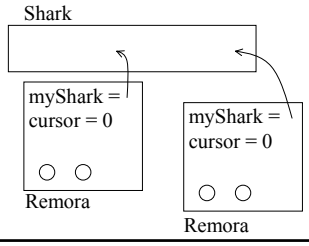
```
class Shark{
   protected Comparable[] a;
   public Shark() {…get data into a…}
}

class Remora implements Iterator{
   int cursor;
   Shark myShark;
   public Remora(Shark s) {
      myShark = s;
      cursor = 0;
   }
   public boolean hasNext() {
       return (cursor < myShark.a.length);}//a in Shark is protected,so accessible
   public Object next() {
       return myShark.a[cursor++];}
   public void remove() {} //unimplemented
}
```



Remora teeth

Client code:

```
…..
Shark s = new Shark(); //object containing data
…new Remora(s)….
Object v = ….;
boolean b = linearSearch( new Remora(s), v);
…..
```



Critique

- Good:
  - Shark class focuses on data, Remora class focuses on enumeration
- Bad:
  - Remora code relies on being able to access Shark variables such as array a
    - What if a was declared private?
    - Protected access is less secure than private.
  - Remora is specialized to Shark but code appears outside Shark class
    - 2-D array Shark will require a different Remora
    - We may change Shark class and forget to update Remora.

Slightly better code: Shark object creates Remoras in request

```
class Shark{
   protected Comparable[] a;
   public Shark() {…get data into a…}
   public Iterator makeRemora(){
       return new Remora(this);//Shark code contains mention of Remora class
 }
class Remora implements Iterator{
   int cursor;
   Shark myShark;
   public Remora(Shark s) {
      myShark = s;
      cursor = 0;
   }
   public boolean hasNext() {
       return (cursor < myShark.a.length);}//a in Shark is protected,so accessible
   public Object next() {
       return myShark.a[cursor++];}
   public void remove() {} //unimplemented
}
```


Client code

```
…..
Shark s = new Shark(); //object containing data
…s.makeRemora()…
Object v = ….;
boolean b = linearSearch(s.makeRemora(), v);
…..
```

Critique

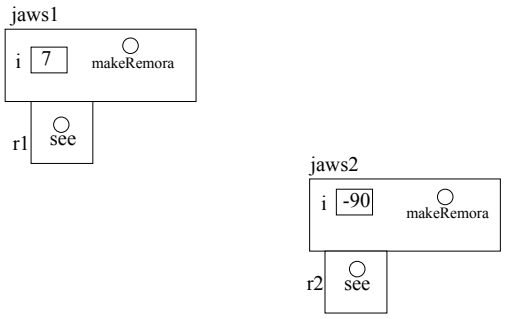
- Good:
  - Shark code mentions Remora, so person modifying Shark code is at least aware that Remora code depends on this class.
- Bad:
  - Clients can still create Remoras without invoking makeRemora method
    - Better to have language construct to enforce such a convention

Better solution: inner classes

- Inner class: Java allows you declare a class within another class.
- Inner classes can occur at many levels within another class.
  - Member-level
    - Inner class defined as if it were another field or method
  - Statement-level
    - Inner class defined as if it were a statement in a method
  - Expression-level
    - Inner class defined as it were part of an expression
    - Called anonymous classes
- Let us focus on member-level inner classes.

Example of inner class

```
class Shark{
        private int i;
        public Shark(int arg){
                i = arg;
        }
        //make a new instance of inner class
        public Remora makeRemora(){
                return new Remora();
        }
        //inner class
        public class Remora{
                public void see(){
                        System.out.println(i);//inner class has access to i
                }
        }
}
class Client{
        public static void main(String[] args){
                Shark jaws1 = new Shark(7);
                Shark jaws2 = new Shark(-90);
                Shark.Remora r1 = jaws1.makeRemora();//create instance of inner class
                Shark.Remora r2 = jaws2.new Remora();//alternate syntax
                r1.see();//should print 7
                r2.see();//should print -90
                jaws1.makeRemora().see();//should print 7
        }
}
```

Points to note

- Inner class can be declared to be public, private, or protected
  - Inner class name is visible accordingly
- Inner class is instantiated by invoking method of containing class or by outerObj.new InnerClass()
  - new jaws1.Remora() does not work
- Instances of inner class have access to all members of containing outer class instance
  - In our example, member i of jaws1 is visible to r1 even though it is private

- Keyword this in Remora class refers to Remora object, not the outer Shark object.
- How do we get a reference to Shark object from Remora? Here's one way:

```
class Shark {
   private kahuna;
   public Shark() {
      kahuna = this;//constructor of outer object initializes variable
     …..;
   }
    class Remora{//inner class
      … kahuna….}//inner class simply accesses variable
}
```

Back to linear search: Data class with inner class

```
class Shark{
   protected Comparable[] a;
   public Shark() {…get data into a…}
   public Iterator makeRemora(){
      return new Remora();
   }
   protected class Remora implements Iterator{
      int cursor = 0;
      public boolean hasNext() {
        return (cursor < a.length);
      }
      public Object next() {
        return a[cursor++];
      }
      public void remove() {} //unimplemented
  }
}
```


Client code: same as before

```
…..
Shark s = new Shark(); //object containing data
…s.makeRemora()…
Object v = ….;
boolean b = linearSearch(s.makeRemora(), v);
…..
```


Adapter classes

- Inner class is like an adapter that permits client code to work with class containing data without modifying the data class itself.
- This is a very general design pattern that shows up in many contexts.
  - Adapter class
- To permit programmers to write adapters compactly, Java permits programmers to write anonymous classes.
  - Class does not have a name
  - Must be instantiated at the point where it is defined

Intuitive idea

```
import java.util.*;

class Shark{
        private int i;
        public Shark(int arg){
                i = arg;
        }
        //make a new instance of inner class
        public Remora makeRemora(){
                return new Remora();
        }
        //inner class
        public class Remora{
                public void see(){
                        System.out.println(i);//inner class has access to i
                }
        }
}
class Client{
        public static void main(String[] args){
                Shark jaws1 = new Shark(7);
                Shark jaws2 = new Shark(-90);
                Shark.Remora r1 = jaws1.makeRemora();//create instance of inner class
                Shark.Remora r2 = jaws2.new Remora();//alternate syntax
                r1.see();//should print 7
                r2.see();//should print -90
                jaws1.makeRemora().see();//should print 7
        }
}
```


Anonymous classes

- Class declaration has usual body but
  - inner class
  - no name
  - no access specifier: public/private/protected
  - no explicit extends or implements:
    - it either extends one class or implements one interface
  - no constructor

- Creating an instance of anonymous class A:
  - If class A is extending a superclass P
    - new P {body of A}; //creates instance of anon class
    - Can invoke appropriate constructor of P by passing arguments to P as in new P(79) {body of A};
    - Assignment: P x = new P {body of A};
    - Think: anonymous class should only override methods of superclass and not define any other methods.
      - If it did, how would you invoke these methods?
        - » Something like x.coolMethod(); //???
      - What would the type checker do??
  - If class A is implementing interface I
    - new I {body of A}
    - Assignment: I foo = new I{body of A};
    - Think: anonymous class should only implement interface methods, and not any other methods.

Anonymous class

```
interface IRemora{
        void see();
}

class Shark{
        private int i;
        public Shark(int arg){
                i = arg;
        }
        //make a new instance of anonymous class
        public IRemora makeRemora(){
                return  new IRemora(){
                        public void see(){
                                System.out.println(i);
                        }
                        };

        }
}
class Client{
        public static void main(String[] args){
                Shark jaws1 = new Shark(7);
                Shark jaws2 = new Shark(90);
                IRemora r1 = jaws1.makeRemora();//one way to instantiate inner class
                IRemora r2 = jaws2.makeRemora();
                r1.see();//should print 7
                r2.see();//should print 90
                jaws1.makeRemora().see();//should print 7
        }
}
```


Conclusions

- Generic code:
  - works on data collections without much regard to type of data elements or type of data structure
- Writing generic code:
  - Iterator interface is very useful
  - use inner classes to implement Iterator
- C++ Standard Template Library:
  - more complex iterators