CS 635 Advanced Object-Oriented Design & Programming
Spring Semester, 2005
Doc 3 Iterators

Contents

References

Design Patterns: Elements of Reusable Object-Oriented Software, Gamma, Helm, Johnson, Vlissides, 1995, pp. 257-271

Reading

Design Patterns: pp. 257-271

Future Readings

Composite & Visitor patterns

Iterator

Provides a way to access elements of an aggregate object sequentially without exposing its underlying representation

Java Example

Enumeration, Iterator, and Streams in Java are iterators

```
Vector listOfStudents = new Vector();

// code to add students not shown

Iterator list = listOfStudents.iterator();
while ( list.hasNext() )
   {Student x = list.next();
   System.out.println( x );
   }
```

C# Example

```
Student[ ] listOfStudent;
// code to add students not shown
foreach (Student x in listOfStudent )
   {
   Console.WriteLine(x.ToString());
   }
```

Smalltalk Examples

Streams, do:, select:, reject:, collect:, detect:, inject:into: are iterators in Smalltalk

```
| sum  |
sum := 0.
#( 1 7 2 3 9 3 50) do: [:each | sum := sum + each squared].
^sum
```

```
#( 1 7 2 3 9 3 50) inject: 0 into:
   [:partialSum :number | partialSum + number squared]
```

```
'this is an example' select: [:each |  each isVowel ]
```

What's The Big Deal?

```
void print(ArrayList list)
   {
   for( int k = 0; k < list.size(); k++ )
      System.out.println( list.get(k) );
   }

void print(LinkedList list )
   {
   Node current = list.first();
   System.out.println( current );
   while (current.hasNext() )
      {
      current = current.next();
      System.out.println( current );
      }
   }

void print(Collection list )
   {
   Iterator items = list.iterator();
   while (items.hasNext() )
      {
      System.out.println( items.next() );
      }
   }

print: aCollection
   aCollection do:
      [:each |
      Transcript
         show: each;
         cr]
```

What's The Big Deal?

Iterator abstracts out underlying representation of collection

Programmer does not have to know implementation details of each type of collection

Can write code that works for wide range of collects

Do not have to change code if change the type of collection used

Design Principle 1

Program to an interface, not an implementation

Use abstract classes (and/or interfaces in Java) to define common interfaces for a set of classes

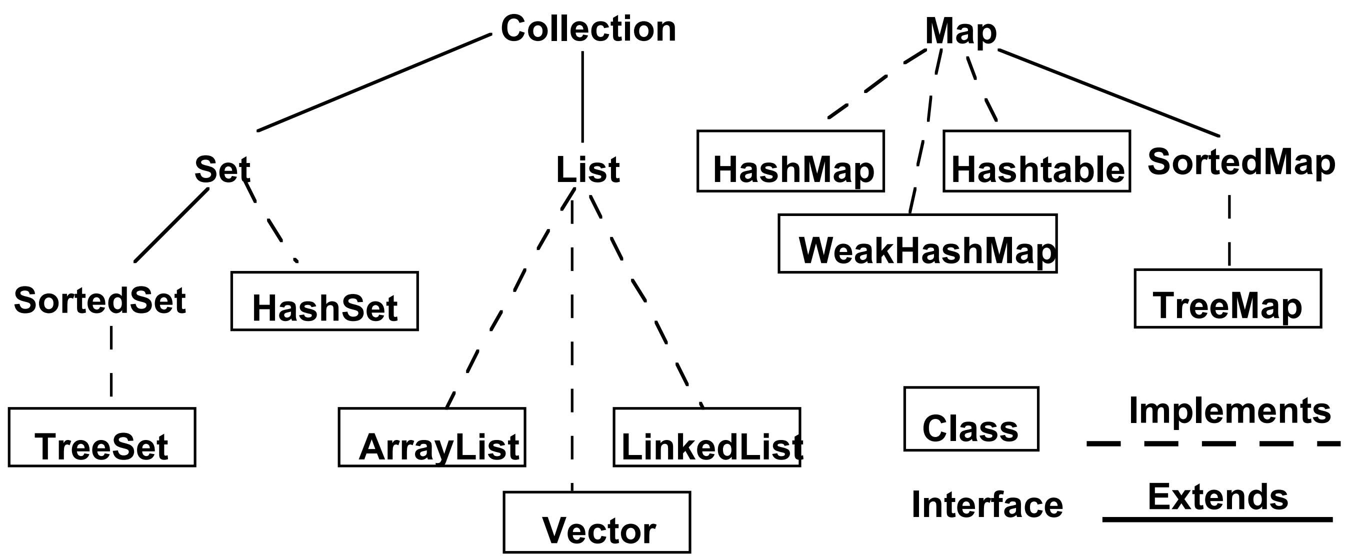
Declare variables to be instances of the abstract class not instances of particular classes

Benefits of programming to an interface

Client classes/objects remain unaware of the classes of objects they use, as long as the objects adhere to the interface the client expects

Client classes/objects remain unaware of the classes that implement these objects. Clients only know about the abstract classes (or interfaces) that define the interface.

Programming to an Interface
Java Collections



Java Iterators & Arrays?

Arrays are common collections

How can one get an iterator on a Java array?

How would you pass an array to the following function?

```
void print(Collection list )
    {
    Iterator items = list.iterator();
    while (items.hasNext() )
        {
        System.out.println( items.next() );
        }
    }
```

Java Iterators in Practice

```
void printA(Collection list )
   {
   Iterator items = list.iterator();
   while (items.hasNext() )
      System.out.println( items.next() );
   }

void printB(String[] list)
   {
   for (int k = 0; k < list.length; k++)
      System.out.println( list[k]);
   }
```

Programmers are not used to programming to an interface

printA requires as much typing as printB

So iterators are not used as much

Java Iterators & JDK 1.5

JDK 1.5 (Java 5) has C# like syntax for iteration

```
void printName(Collection list )
  {
  for (Object element : list)
    {
    Student aStudent = (Student) element;
    System.out.println( aStudent.name());
    }
  }

void printName(Collection<Student> list )
  {
  for (Student element : list)
    {
    System.out.println( element.name());
    }
  }
```

Smalltalk/C# Iterators in Practice

```
printA: aCollection
  1 to: aCollection size do: [:index |
  Transcript
    show: (aCollection at: index);
    cr.

printB: aCollection
  aCollection do: [:each |
    Transcript
      show: each;
      cr.

Print(IEnumerable list )
  {
  foreach (Object x in list)
    {
    Console.WriteLine( x.ToString());
    }
  }
```

printB requires less typing than printB

Iterators are part of the C# language

Programmers use iterators just to avoid extra work

Sample Implementation of Java Enumerator

```
class VectorIterator implements Enumeration {
  Vector iteratee;
  int count;

  VectorIterator(Vector v) {
    iteratee = v;
    count = 0;
  }

  public boolean hasMoreElements() {
    return count < iteratee.elementCount;
  }

  public Object nextElement() {
    synchronized (iteratee) {
      if (count < iteratee.elementCount)
        return iteratee.elementData[count++];
    }
  throw new NoSuchElementException("VectorIterator");
  }
}
```

The iterator is using privileged access to Vectors fields

Issues
Concrete vs. Polymorphic Iterators
Concrete

Use Explicit Iterator Type

```
Reader iterator = new StringReader( "cat");
int c;
while (-1 != (c = iterator.read() ))
        System.out.println( (char) c);
```

Polymorphic

Actual type of iterator is not known

```
Vector listOfStudents = new Vector();

// code to add students not shown

Iterator list = listOfStudents.iterator();
while ( list.hasNext() )
   Console.println( list.next() );
```

Polymorphic iterators can cause problems with memory leaks in C++ because they are on the heap!

Who Controls the iteration?
External (Active)

```
Vector listOfStudents = new Vector();

// code to add students not shown

Iterator list = listOfStudents.iterator();

while ( list.hasNext() )
   Console.println( list.next() );
```

Iteration control code is repeated for each use of the iterator

Who Controls the iteration?
Internal (Passive)

```
'this is an example' select: [:each |  each isVowel ]
```

Control code is inside the iterator

Programmer

- Does not repeat control code
- Can focus on what to do not how to do it

Who Defines the Traversal Algorithm?
Object being Iterated

Iterator can store where we are

In a Vector this could mean the index of the current item

In a tree structure it could mean a pointer to current node and stack of past nodes

```
BinaryTree searchTree = new BinaryTree();

// code to add items not shown

Iterator aSearch = searchTree.getIterator();
Iterator bSearch = searchTree.getIterator();
Object first = searchTree.nextElement( aSearch );
Object stillFirst = searchTree.nextElement( bSearch );
```

Iterator

Makes it easier to have multiple iterator algorithms on same type

On Vector class, why not have a reverseIterator which goes backwards?

In a complex structure the iterator may need access to the iteratee's implementation

How Robust is the iterator?

What happens when items are added/removed from the iteratee while an iterator exists?

```
Vector listOfStudents = new Vector();

// code to add students not shown

Enumeration list = listOfStudents.elements();
Iterator failFastList = listOfStudents.iterator();

listOfStudents.add( new Student( "Roger") );

list.hasMoreElements();
failFastList.hasNext();        //Exception thrown here
```

Additional Iterator Operations

Augmenting basic iteration operations may improve their usefulness

previous()
    back up one location

add(Object item)
    add item to the iteratee at current location

remove()
    remove the current item from the iteratee

skipTo(some location, item or condition)
    go to the location indicated

mark()
    mark current location for future return

Iterators and Privileged Access

An iterator may need privileged access to the aggregate structure for traversal

Iterators for Composites

Traversing a complex structure like a graph, tree, or composite can be difficult

An internal iterator can use recursion to keep track of where to go next

For example using a depth-first search algorithm on graph

If each element in the aggregate “knows” how to traverse to the next element and previous element, than an external iterator can be used

Null Iterator

A Null iterator for the empty aggregates can be useful
of each.