Topic 13

Iterators

Motivation

- We often want to access every item in a data structure or collection in turn
  - We call this ***traversing*** or ***iterating over*** or ***stepping through*** or ***visiting every item in*** the data structure or collection
- Example with a data structure (array):

```
for (int i = 0; i < arr.length(); i++)
    /*  do something to arr[i]   */
```

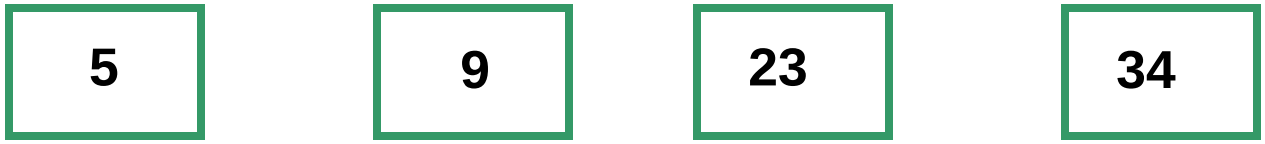
  - This is straighforward because we know exactly how an array works!

Motivation

- What if we want to traverse a *collection* of objects?
  - A list, a stack, a queue …
  - Its underlying implementation may not be known to us
- Java provides a *common scheme* for stepping through all elements in *any* collection, called an ***iterator***

What is an Iterator?

- An ***iterator*** is a mechanism used to step through the elements of a collection one by one
  - Each element is "***delivered*** " exactly once
- ***Example***
  - Iterate through an ordered list and print each element in turn



Iterator Interface

- The Java API has a generic interface called Iterator<T> that specifies what methods are required of an iterator
  - **public boolean hasNext( );**
    returns true if there are more elements in the iteration
  - **public T next( );**
    returns the next element in the iteration
  - **public void remove( );**
    removes the last element returned by the iterator (*optional operation*)
- It is in the java.util package of the Java API

Array Iterator

- If we had a collection with an array implementation, we would need an ***array implementation*** of the **Iterator** interface
  - See ***ArrayIterator.java***:
    - Its attributes
    - Its constructor
    - The code for the methods hasNext and next
      - In what order does it deliver the items?

- ***Note:*** ***ArrayIterator.java*** *can be used by an array implementation of* ***any*** *collection!*

```
// Represents an iterator over the elements of an array

import java.util.*;

public class ArrayIterator<T> implements Iterator<T> {

    // Attributes
    private int count;   // number of elements in collection
    private int current; // current position in the iteration
    private T[ ] items;   // items in the collection

    // Constructor: sets up this iterator using the
    // specified items
    public ArrayIterator (T[ ] collection, int size) {
        items = collection;
        count = size;
        current = 0;
    }
    // cont'd..
```

ArrayIterator.java

```
    // cont'd..
    // Returns true if this iterator has at least one
    // more element to deliver in the iteration
    public boolean hasNext( )  {
          return (current < count);
    }

    // Returns the next element in the iteration.
    // If there are no more elements in this iteration,
    // throws an exception.
    public T next( )  {
        if (! hasNext( ))
          throw new NoSuchElementException( );
      current++;
      return items[current - 1];
     }
}
```

ArrayIterator.java (cont'd)

Linked Iterator

- If we had a collection with a linked implementation, we would need a ***linked implementation*** of the **Iterator** interface
  - See ***LinkedIterator.java***
    - Its attributes
    - Its constructor
    - The code for the methods hasNext and next
      - In what order does it deliver the items?

- ***Note:*** ***LinkedIterator.java*** *can be used by a linked implementation of* ***any*** *collection!*

```
import java.util.*;
public class LinkedIterator<T> implements Iterator<T> {

  // Attributes
   private int count;              // number of elements in collection
   private LinearNode<T> current; // current position

   //  Constructor: Sets up this iterator using the specified items
   public LinkedIterator (LinearNode<T> collection, int size){
            current = collection;
            count = size;
    }    //cont'd..
```

LinkedIterator.java

```
   // ..cont'd..
   //  Returns true if this iterator has at least one more element
   //  to deliver in the iteration.
   public boolean hasNext( ) {
      return (current!= null);
   }
   //  Returns the next element in the iteration. If there are no
   //  more elements in this iteration, throws an exception.
   public T next( ) {
      if (! hasNext( ))
         throw new NoSuchElementException( );
      T result = current.getElement( );
      current = current.getNext( );
      return result;
   }
}
```

LinkedIterator.java (cont'd)

Iterators for a Collection

So how do we set up an iterator for a collection?

- Recall that the ListADT interface has an ***operation*** called iterator :

```
//  Returns an iterator for the elements in this list
    public Iterator<T> iterator( );
```

- (In fact, any of our collections could have had an iterator operation … *later*)

The iterator Operation in the ListADT

- Note that the return type of the iterator operation is Iterator<T>
  - But Iterator<T> is an interface, not a class!
  - When the return type of a method is an *interface name*, the method actually returns an object from *a class that implements the interface*
    - The iterator operation in ArrayList will use the class ArrayIterator
    - The iterator operation in LinkedList will use the class LinkedIterator

iterator method for ArrayList

```
/**
* Returns an iterator for the elements currently in this list.
*
* @return  an iterator for the elements in this list
*/
   public Iterator<T> iterator()
   {
      return new ArrayIterator<T> (list, rear);
   }
```

iterator method for LinkedList

```
/**
* Returns an iterator for the elements currently in this list.
*
* @return  an iterator for the elements in this list
*/
public Iterator<T> iterator( )
{
   return new LinkedIterator<T> (contents, count);
}
```

The only difference from the iterator method in ArrayList is the class from which the iterator object is being created!

Using an Iterator

- When the iterator() method in a collection is invoked, it returns an "iterator object"
- We can then invoke the methods hasNext() and next() on that object, to iterate through the collection
    - (Those are the methods that are specified in the Iterator<T> interface)

Using an Iterator in an Application

Example: Suppose we had an unordered list that was created by

```
ArrayUnorderedList<Person> myList =
                        new ArrayUnorderedList<Person>();
```

and then had items added to it…

```
// Use iterator to display contents of list
   Iterator<Person> iter = myList.iterator();
   while(iter.hasNext() )
   {
        System.out.println(iter.next());
   }
```

// cont'd

Using an Iterator in an Application

```
// Print just the email addresses now
// Note that we have to start a new iteration!

    iter = myList.iterator();  // start new iteration
    while(iter.hasNext() )
    {
        System.out.println(iter.next().getEmail());
    }
```

Example: Using an Iterator within a Class Definition

- Rewrite the toString() method of ArrayList using its iterator:

```
public String toString() {
    String result = "";

    Iterator<T> iter  =  this.iterator();

    while ( iter.hasNext() )
       result = result  +  iter.next().toString() +  "\n";

    return result;
}
```

Discussion

- Could we use the *very same code* from the previous slide for the toString() method of LinkedList?
- If we had an iterator operation in the StackADT, could we use this very same code for the toString() methods of the StackADT implementations?

Exercises

- Add an iterator operation to the StackADT
  - Implement it in ArrayStack
    - In what order will it deliver the items if we use ArrayIterator.java to implement the Iterator<T> interface?
  - Implement it in LinkedStack
    - In what order will it deliver the items if we use LinkedIterator.java to implement the Iterator<T> interface?
  - Rewrite the toString method of the StackADT implementations to use its iterator
- Ditto for the QueueADT

Discussion

- Note that the order of the iteration is determined by the design of the class that implements the Iterator<T> interface
- If we wanted an iterator that delivered the items in a stack in the opposite order from ArrayIterator, what would we have to do?

Why use Iterators?

- Traversing through the elements of a collection is very common in programming, and iterators provide a *uniform* way of doing so
- Advantage? Using an iterator, we don't need to know how the collection is implemented!