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

• This is straightforward because we know exactly how an array works!
Motivation

• What if we want to traverse a collection of objects?
  • Like a list
  • 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

| 5 | 9 | 23 | 34 |
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..
// 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];
}
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..
}
// ..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;
}
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`:

  ```java
  // 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 `LinkedListIterator`
/**
 * 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);
}
/**
 * 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 LinkedListIterator<T>(contents, count);
}
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

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

and then had items added to it…

```java
// 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:

```java
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!