Topic Notes: Iterators

Interfaces and Abstract classes

Before we discuss `Iterators`, we need to think about the design of abstract data types in Java. So far, we have seen interfaces and regular classes. There is a level between these called an *abstract class*.

The abstractions provided by interfaces and abstract classes are important for the development of reusable and modular software.

We want to be able to define *what* an abstract data type does without committing to *how* it does it.

The biggest example we've seen so far is a `Vector`. As the user of a `Vector`, we know we can create them, add, retrieve, remove, and modify elements in them, and query information like their size. All of these are independent of how the `Vector` is implemented.

This separation of the public interface from the implementation allows programmers to make use of `Vectors` without needing to know how things work on the inside. It also allows the implementers of `Vectors` to make internal changes without affecting other code that uses it, so long as the public interface does not change.

Java has language constructs to support the development of abstract data types.

- *Interfaces* describe the public functionality of an abstract data type. This includes:

  - method signatures
  - constants

  An interface may extend another interface.

  We have seen and used interfaces already, including things like `Comparators` and `Comparables`.

- *Abstract base classes* describe a partial implementation. An abstract class can define method bodies for some of the methods required by interfaces it implements.

  This can be useful for:

  - methods that can be implemented in terms of other methods

  It is possible for a class that extends an abstract class to override methods defined in the abstract class, in case there is a more efficient way to do some of these things when an actual implementation is developed.

  A frequent use of an abstract class is to "factor out" implementation of methods that happen to be the same for multiple implementations of an interface.

- Full implementations (classes that you can instantiate, *i.e.*construct instances of with `new`) may implement interfaces, and/or extend at most one abstract or fully implemented class.

We will see many examples using interfaces and abstract classes throughout the rest of the course.

Bailey has examples using "generators" and the design of playing card classes to motivate interfaces and abstract classes, and you are encouraged to read them.

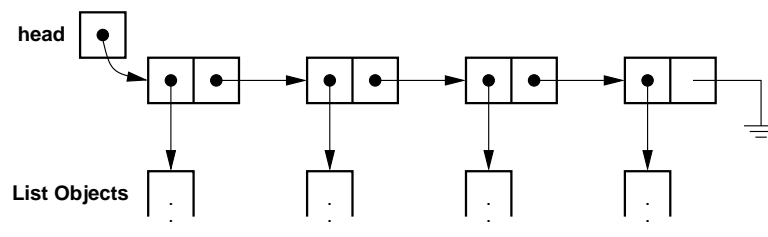However, we consider them in the context of `Iterators`.

Iterators

How do we "visit" each item in a collection? With a `Vector`, or an array, it's easy. We can write a `for` loop:

```
public <T> void traverse(Vector<T> v) {
  int i;

  for (i=0; i<v.size(); i++) {
    T visitme = v.get(i);
    // do something with visitme
  }
}
```

But imagine if someone has changed the internal implementation of `Vector`. It no longer has an array, but a linked structure.

Without worrying about the details of linked lists yet, we can notice that to get access to the nth element, we need to visit the first $n - 1$ elements. If our `Vector` contained one of these linked structures instead of an array, our traverse method above suddenly becomes very inefficient.

This is not good. What is the complexity of `get()`? In order to get the item at position i, we have to start at the beginning and we have to follow links until we find the right element.

What we want to do is to use the previous value returned, and take the one pointed to by the list element we just used to get that previous value. But how? We don't have that information!

We often need a way of cycling through all of the elements of a data structure. Java has an interface that provides exactly what we need: `java.util.Iterator<E>`

A data structure can create an object of a type that implements the `Iterator`, which can be used to cycle through the elements. For example, built-in Java classes `Vector` and `ArrayList` each have a method:

```
public Iterator<E> iterator()
```

that we can use to visit all of the elements in the `Vector` or `ArrayList`. For example, to print out the elements of `Vector<E> v` we could use the iterator as follows:

```
for (Iterator<E> iter=v.iterator(); iter.hasNext(); ) {
    System.out.println(iter.next());
}
```

or formulated as a `while` loop:

```
Iterator<E> iter=v.iterator()
while (iter.hasNext()) {
    System.out.println(iter.next());
}
```

Notice the similarity to the way we would read a series of words from the keyboard or from a file with a `Scanner`.

In modern Java versions, if our class implements the `Iterable interface` (which simply requires the method `iterator`) we can use an enhanced for loop as a shorthand for the above:

```
for (E item: v) {
  System.out.println(item);
}
```

See Example: Iterables

Important Notes:

- Never change the state of a data structure with an active works, or you may end up in an infinite loop!

- There is also a `remove()` method in Java's `Iterator` interface, but we will ignore that for now, as not all iterators provide it.

- `Iterators` guarantee a predictable and consistent order of the elements returned.

The structure package defines an abstract class called `AbstractIterator` that `implements` both `java.util.Enumeration` (an older, iterator-like interface) and `java.util.Iterator`.

Notes about `AbstractIterators`:

- it adds two methods that are not part of either enumerations or iterators in Java:

  - `reset()` – start the iteration over without constructing a brand new `Iterator`
  - `get()` – retrieve the "current value" without advancing the `Iterator`

  Both of these are declared as `abstract` methods, meaning that they are essentially adding to the `interface` defined by the `AbstractIterator` without defining them.

- The `AbstractIterator` also provides *implementations* of the two methods required by enumeration. The fact that these are implemented is what requires that we declare this as an `abstract` class rather than just another `interface`. Note that these are also declared as `final` meaning that classes that extend this class may not override their definitions. This ensures that the `Enumeration` and `Iterator` methods of any class that `extends` `AbstractIterator` must be identical.

The data structures in the structure package typically return an `AbstractIterator` rather than a `java.util.Iterator`.

See Structure Source:
`structure5/VectorIterator.java`

We can see the standard `VectorIterator` in action and a couple of custom iterators in this example:

See Example: Iterators