CSE 143 Lecture 20

Advanced List Implementation (ADTs; interfaces; abstract classes; inner classes; generics; iterators)

read 11.1, 9.6, 15.3-15.4, 16.4-16.5

slides adapted from Marty Stepp http://www.cs.washington.edu/143/

Our list classes

- We have implemented the following two list collection classes:
 - ArrayIntList

index	0	1	2
value	42	-3	17

- LinkedIntList

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$$\rightarrow$$
42 \rightarrow -3 \rightarrow 17

- Problems:

- We should be able to treat them the same way in client code.
- Some methods are implemented the same way (redundancy).
- Linked list carries around a clunky extra node class.
- They can store only int elements, not any type of value.
- It is inefficient to get or remove each element of a linked list.

Common code

- Notice that some of the methods are implemented the same way in both the array and linked list classes.
 - add (**value**)
 - contains
 - isEmpty
- Should we change our interface to a class? Why / why not?
 - How can we capture this common behavior?

Abstract classes (9.6)

- abstract class: A hybrid between an interface and a class.
 - defines a superclass type that can contain method declarations (like an interface) and/or method bodies (like a class)
 - like interfaces, abstract classes that cannot be instantiated (cannot use new to create any objects of their type)
- What goes in an abstract class?
 - implementation of common state and behavior that will be inherited by subclasses (parent class role)
 - declare generic behaviors that subclasses must implement (interface role)

Abstract class syntax

// declaring an abstract class
public abstract class name {

}

// declaring an abstract method
// (any subclass must implement it)
public abstract type name(parameters);

- A class can be abstract even if it has no abstract methods
- You can create variables (but not objects) of the abstract type
- Exercise: Introduce an abstract class into the list hierarchy.

Abstract and interfaces

• Normal classes that claim to implement an interface must implement all methods of that interface:

public class Empty implements IntList {} // error

• Abstract classes can claim to implement an interface without writing its methods; subclasses must implement the methods.
public abstract class Empty implements IntList {} // ok
public class Child extends Empty {} // error

An abstract list class

```
// Superclass with common code for a list of integers.
public abstract class AbstractIntList implements IntList {
    public void add(int value) {
        add(size(), value);
    public boolean contains(int value) {
        return indexOf(value) >= 0;
    public boolean isEmpty() {
        return size() == 0;
```

public class ArrayIntList extends AbstractIntList { ...
public class LinkedIntList extends AbstractIntList { ...

Abstract class vs. interface

- Why do both interfaces and abstract classes exist in Java?
 - An abstract class can do everything an interface can do and more.
 - So why would someone ever use an interface?
- Answer: Java has single inheritance.
 - can extend only one superclass
 - can implement many interfaces
 - Having interfaces allows a class to be part of a hierarchy (polymorphism) without using up its inheritance relationship.

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Recall: Inner classes

```
// outer (enclosing) class
public class name {
    ...
    // inner (nested) class
    private class name {
        ...
    }
}
```

- Only this file can see the inner class or make objects of it.
- Each inner object is associated with the outer object that created it, so it can access/modify that outer object's methods/fields.
- Exercise: Convert the linked node into an inner class.

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Implementing generics

// a parameterized (generic) class
public class name<Type> {

}

- Forces any client that constructs your object to supply a type.
 - Don't write an actual type such as String; the client does that.
 - \bullet Instead, write a type variable name such as ${\tt E}$ or ${\tt T}.$
 - You can require multiple type parameters separated by commas.
- The rest of your class's code can refer to that type by name.
- Exercise: Convert our list classes to use generics.

Generics and arrays (15.4)

- You cannot create objects or arrays of a parameterized type.
- You can create variables of that type, accept them as parameters, return them, or create arrays by casting from Object[].

Comparing generic objects

public class ArrayList<E> {

```
public int indexOf(E value) {
    for (int i = 0; i < size; i++) {
        // if (elementData[i] == value) {
            if (elementData[i].equals(value)) {
                return i;
            }
        }
        return -1;
    }
</pre>
```

- When testing objects of type E for equality, must use equals

Generic interface (15.3, 16.5)

```
// Represents a list of values.
public interface List<E> {
    public void add(E value);
    public void add(int index, E value);
    public E get(int index);
    public int indexOf(E value);
    public boolean isEmpty();
    public void remove(int index);
    public void set(int index, E value);
    public int size();
}
```

public class ArrayList<E> implements List<E> { ...
public class LinkedList<E> implements List<E> { ...

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Linked list iterator

• The following code is particularly slow on linked lists: List<Integer> list = new LinkedList<Integer>();

```
...
for (int i = 0; i < list.size(); i++) {
    int value = list.get(i);
    if (value % 2 == 1) {
        list.remove(i);
    }
}</pre>
```

- Why?
- What can we do to improve the runtime?

Recall: Iterators (11.1)

- **iterator**: An object that allows a client to traverse the elements of a collection, regardless of its implementation.
 - Remembers a position within a collection, and allows you to:
 - get the element at that position
 - advance to the next position
 - (possibly) remove or change the element at that position
 - A common way to examine *any* collection's elements.



Iterator methods

hasNext()	returns true if there are more elements to examine
next()	returns the next element from the collection (throws a NoSuchElementException if there are none left to examine)
remove()	<pre>removes from the collection the last value returned by next() (throws IllegalStateException if you have not called next() yet)</pre>

- every provided collection has an iterator method

```
Set<String> set = new HashSet<String>();
...
Iterator<String> itr = set.iterator();
...
```

- Exercise: Write iterators for our linked list and array list.
 - You don't need to support the remove operation.

Array list iterator

```
public class ArrayList<E> extends AbstractIntList<E> {
    // not perfect; doesn't forbid multiple removes in a row
    private class ArrayIterator implements Iterator<E> {
        private int index; // current position in list
        public ArrayIterator() {
            index = 0;
        public boolean hasNext() {
            return index < size();</pre>
        public E next() {
            index++;
            return get(index - 1);
        public void remove() {
            ArrayList.this.remove(index - 1);
            index--;
```

Linked list iterator

```
public class LinkedList<E> extends AbstractIntList<E> {
    // not perfect; doesn't support remove
    private class LinkedIterator implements Iterator<E> {
        private ListNode current; // current position in list
        public LinkedIterator() {
            current = front;
        public boolean hasNext() {
            return current != null;
        public E next() {
            E result = current.data;
            current = current.next;
            return result;
        public void remove() { // not implemented for now
            throw new UnsupportedOperationException();
    }
```

for-each loop and Iterable

• Java's collections can be iterated using a "for-each" loop: List<String> list = new LinkedList<String>();

```
for (String s : list) {
    System.out.println(s);
}
```

- Our collections do not work in this way.
- To fix this, your list must implement the Iterable interface.
 public interface Iterable<E> {
 public Iterator<E> iterator();
 }

Final List interface (15.3, 16.5)

```
// Represents a list of values.
public interface List<E> extends Iterable<E> {
    public void add(E value);
    public void add(int index, E value);
    public E get(int index);
    public int indexOf(E value);
    public boolean isEmpty();
    public Iterator<E> iterator();
    public void remove(int index);
    public void set(int index, E value);
    public int size();
}
```