CSCI 136
Data Structures &
Advanced Programming

Lecture 8

Fall 2017

Instructors: Bills

Administrative Details

- Lab 3 is now available!
  - Fun with doubly-linked lists!
  - Fun with partners!
    - What does it mean to work collaboratively?
  - Will be modifying existing code in significant ways
    - Make a plan, and bring questions to class
  - Try to answer thought questions before lab

Last Time

- Vector Implementation continued
- Condition Checking
  - Pre- and post-conditions, Assertions List: A general-purpose structure
- Implementing Lists with linked structures
  - Started discussing Singly Linked Lists

Reviewing Important SLL Methods

- How would we implement:
  - get(int index), set(E d, int index)
  - add(E d, int index), remove(int index)
    - removeLast() is just remove(size() - 1)
    - removeFirst() is just remove(0)
- Left as an exercise:
  - contains(E d)
  - clear()
- Note: E is value type

Get and Set

```
public E get(int index) {
   Assert.pre(index < size() - 1, “Index out of range”);
   // or should we return null in above case?
   SLLN finger = head;
   for (int i=0; i<index; i++){
        finger = finger.next();
   }
   return finger.value();
}

public E set(E d, int index) {
   Assert.pre(index < size() - 1, “Index out of range”);
   // Same question!
   SLLN finger = head;
   for (int i=0; i<index; i++){
        finger = finger.next();
   }
   E old = finger.value();
   finger.setValue(d);
   return old;
}
```

Remove

```
public E remove(int index) {
   if(index >= size()) return null;

   E old;

   if (index==0) {              // Special case: remove the head
        old = head.value();
        head = head.next();
        count--;
        return old;
   }

   else {
        SLLN finger = head;
        for (int i=0; i<index - 1; i++) { //stop one before index
               finger = finger.next();
        }
        old = finger.next.value();
        finger.setNext(finger.next().next());
        count--;
        return old;
   }
}
```

Add

```
public void add(E d, int index) {
   if(index > size()) return null;
   E old;

   if (index==0) { addFirst(d); }

   else if (index==size()) { addLast(d); }

   else {
        SLLN finger = head;
        SLLN previous = null;
        for (int i=0; i<index; i++) {
            previous = finger;
            finger = finger.next();
        }
        SLLN elem = new SLLN(d, finger);
        previous.setNext(elem); // new "ith" item added after i-1
        count++;
   }
}
```

Linked Lists Summary

- Recursively defined structures for storing data
- Easy to add to the front of the list
  - Modifying tail/middle of list is not quite as efficient

- Components of SLL (SinglyLinkedList)
  - `SLLN head, int elementCount`
- Components of SLLN (Node):
  - `SLLN next, E value`

Vectors vs. SLL

- Compare performance of
  - size
  - addLast, removeLast, getLast
  - addFirst, removeFirst, getFirst
  - get(int index), set(E d, int index)
  - remove(int index)
  - contains(E d)
  - remove(E d)

More Linked List Summary

- More control over space use than Vectors
  - No empty slots like vectors
  - But keep extra reference for each value
    - overhead proportial to list length
      - (but this is constant and predictable)
- SLL operations are predictable
  - No hidden costs like Vector.ensureCapacity()
  - Avg and worst case are always the same

Food for Thought: SLL Improvements to Tail Ops

- In addition to `Node head`, `int elementCount`, add `Node tail` reference to SLL
- Result
  - addLast and getLast are fast
  - removeLast is not improved
    - We need to know element before tail so we can reset tail pointer
- Side effects
  - We now have three cases to consider in method implementations: empty list, head == tail, head != tail
  - Think about addFirst(E d) and addLast(E d)

CircularlyLinkedLists

- Use *next* reference of last element to reference head of list
- Replace ***head*** reference with ***tail*** reference
- Access head of list via *tail.next*
- ALL operations on head are fast!
- addLast() is still fast
- Only modest additional complexity in implementation
- Can "cyclically reorder" list by changing *tail* node
- Question: What's a circularly linked list of size 1?

Rest of Today: DLLs & Inheritance

- Note: Storing `null` values in Lists
- Details of Doubly-Linked Lists
  - Lab this week: Doubly Linked Lists with dummy nodes
- Abstract Classes and Inheritance
  - Return of the Card Classes!
- The Structure5 Universe to date

DoublyLinkedLists

- Keep reference/links in **both** directions
  - previous and next
- DoublyLinkedListNode instance variables
  - `DLLN next`, `DLLN prev`, `E value`
- Space overhead is proportional to number of elements
- ALL operations on tail (including removeLast) are fast!
- Additional complexity in each list operation
  - Example: `add(E d, int index)`
  - Four cases to consider now: empty list, add to front, add to tail, add in middle

```java
public class DoublyLinkedNode<E>
{
	protected E data;
	protected DoublyLinkedNode<E> nextElement;
	protected DoublyLinkedNode<E> previousElement;

// Constructor inserts new node between existing nodes
public DoublyLinkedNode(E v,
		DoublyLinkedNode<E> next,
		DoublyLinkedNode<E> previous)
{
	data = v;
	nextElement = next;
	if (nextElement != null)  // point next back to me
		nextElement.previousElement = this;
	previousElement = previous;
	if (previousElement != null) // point previous to me
		previousElement.nextElement = this;
}
```

DoublyLinkedList Add Method

```
public void add(int i, E o) {
       Assert.pre((0 <= i) && (i <= size()),
              "Index in range.");
       if (i == 0) addFirst(o);
       else if (i == size()) addLast(o);
       else {
              // Find items before and after insert point
              DoublyLinkedNode<E> before = null;
              DoublyLinkedNode<E> after = head;
              // search for ith position
              while (i > 0) {
                 before = after;
                 after = after.next();
                 i--;
              }
       // before, after refer to items in slots i-1 and i
       // continued on next slide
```

DoublyLinkedList Add Method

```
        // Note: Still in “else” block!
        // before, after refer to items in slots i-1 and i

        // create new value to insert in correct position
        // Use DLN constructor that takes parameters
        // to set its next and previous instance variables
        DoublyLinkedNode<E> current =
              new DoublyLinkedNode<E>(o,after,before);

        count++; // adjust size

        // make after and before value point to new value
        // Note: These lines aren’t needed---why?
        before.setNext(current);
        after.setPrevious(current);
    }
}
```

```
public E remove(E value) {
       DoublyLinkedNode<E> finger = head;
       while ( finger != null &&
               !finger.value().equals(value) )
              finger = finger.next();
       if (finger == null) return null;

       // fix next field of previous element
       if (finger.previous() != null)
              finger.previous().setNext(finger.next());
       else head = finger.next();

       // fix previous field of next element
       if (finger.next() != null)
              finger.next().setPrevious(finger.previous());
       else tail = finger.previous();
       count--;
       return finger.value();
}
```

Class Specialization

- Classes can *extend* other classes
  - Inherit **fields** and **method bodies**
- By extending other classes, we can create specialized sub-classes
- Java supports class extension/specialization
- Java enforces *type-safety*: Objects behave according to their type
  - Some checks are made at compile-time
  - Some checks are made at run-time
- We'll first use this feature to factor out code

Abstract Classes

- Note: All of our Card implementations code `toString()` in identical fashion.
- It's good to be able to "factor out" common code so that it only has to be maintained in one place
- *Abstract classes* to the rescue….
- An abstract class allows for a *partial* implementation
- We can then *extend* it to a complete implementation
- Let's do this with our cards.
  - Examine CardAbstract.java....

Abstract Classes

Notes from `CardAbstract` class example

- `CardAbstract` *implements* `Card` (partially)
- `CardAbstract` is declared to be *abstract*
  - It contains the implementation of `toString()`

How do the full implementations (`CardRankSuit`, etc) change?

- They are declared to *extend* `CardAbstract`
- They don't need to say "`implements Card`"
- They don't contain the `toString()` method
  - They *inherit* that method from `CardAbstract`
  - But could *override* that method if desired

Extending Concrete Classes

Let's call a class *concrete* if it is not abstract

We can extend concrete classes

Example: Adding a point count to a `Card`

- Suppose we wanted to add a point value to each of the playing cards in `CardRankSuit`
- We *extend* that class

```
class CardRankSuitPoints extends CardRankSuit {… }
```

- This new class can now contain additional instance variables and methods
- Let's look at the code for CardRankSuitPoints.java….

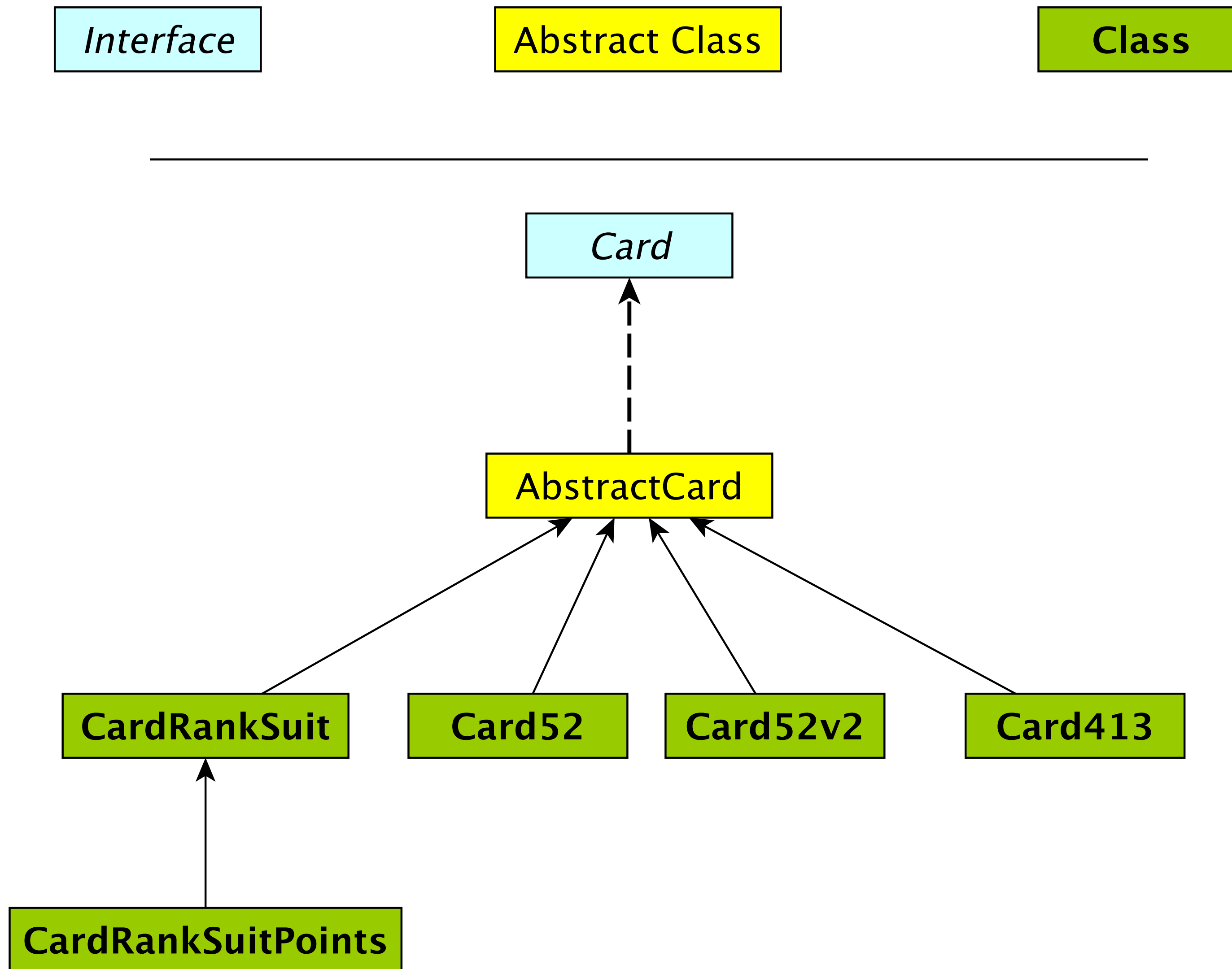
CardRankSuitPoints Notes

- Constructor calls `CardRankSuit` constructor using *super*
- We can override methods---e.g., `toString()`
- Can use a `CardRankSuitPoints` object wherever we use a `Card`
  - But! Can only use new features (`getPoints()`) if the object is declared to be of type `CardRankSuitPoints`

```
CardRankSuitPoints c1 = new CardRankSuitPoints(
    Rank.ACE, Suit.CLUBS, 4);
int p1 = c1.getPoints(); // Legal
Card c2 = new CardRankSuitPoints(Rank.ACE,
    Suit.CLUBS, 4);
int p2 = c2.getPoints(); // Bad! c2 is of type Card
int p3 = ((CardRankSuitPoints) c2).getPoints(); // Legal
```

- Java enforces *type-safety*: An variable of type X can only be assigned a value of type X or of a type that extends X

The Card Classes Hierarchy



Access Levels

- public, private, and protected variables/methods
- What's the difference?
  - public – accessible by all classes, packages, subclasses, etc.
  - protected – accessible by all objects in same class, same package, and all subclasses (stay tuned)
  - private – only accessible by objects in same class
- Generally want to be as "strict" as possible

Access Modifiers

	Class	Package	Subclass	World
public	Y	Y	Y	Y
protected	Y	Y	Y	N
none	Y	Y	N	N
private	Y	N	N	N

A package is a named collection of classes.

- Structure5 is Duane's package of data structures
- Java.util is the package containing Random, Scanner and other useful classes
- There's a single "unnamed" package

Duane's Structure Hierarchy

The structure5 package has a similar structure

- A collection of *interfaces* that describe---but do not implement---the functionality of one or more data structures
- A collection of *abstract classes* provide partial implementations of one or more data structures
  - To factor out common code or instance variables
- A collection of concrete (fully implemented) classes to provide full functionality of a data structure

AbstractList Superclass

```
abstract class AbstractList<E> implements List<E> {
    public void addFirst(E element) { add(0, element); }
    public E getLast() { return get(size()-1);}
    public E removeLast() { return remove(size()-1); }
}
```

- AbstractList provides *some* of the list functionality
  - Code is shared among all sub-classes (see Ch. 7 for more info)

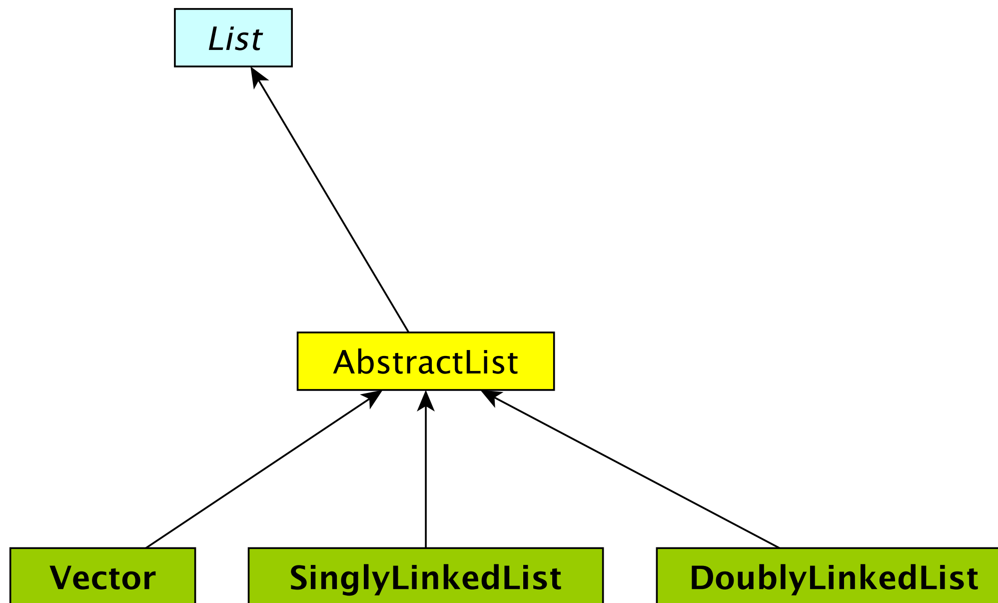
    ```
    public boolean isEmpty() { return size() == 0; }
    ```

  - Concrete classes (SLL, DLL) can override the code implemented in AbstractList
- Abstract classes in general do not implement every method
  - For example, size() is not defined although it is in the List interface
- Can't create an "AbstractList" directly
- Other lists extend AbstractList and implement missing functionality as needed

```
class Vector extends AbstractList {
    public int size() { return elementCount; }
}
```

The Structure5 Universe (almost)

Interface | Abstract Class | **Class**



The Structure5 Universe (so far)