CS211, LECTURE 17
FOUNDATIONAL DS REVISITED

ANNOUNCEMENTS:

READING:

OVERVIEW:

- Variables
- Arrays
- Lists
- **`ArrayList`**s and **`Vector`**s
- Trees (actually, this happens next lecture)

1. Motivation

- ❒ Introduce more operations
  - so far, mostly searching
  - want to add/delete/reorganize/clone…
- ❒ Rethink design
  - alternative approaches to foundational ADTs

    ex) lists: just head or head & tail?
  - more practice!
- ❒ Generic Programming
  - clean up, standardize code
  - demonstrate API again
- ❒ Implement Other ADTs
  - ADTs will use foundational data structures

    ex) **`StackAsArray`**, **`StackAsList`**

2. Variables

- Simplest Data Structure

```
PrimitiveType var = primitive
ClassType var = object
```

- Time and Space?
  - constant
- Not really an ADT
  - ADT is info and its operations
  - So, is an entire program an ADT?
- API
  - Collection interface

3. Arrays

❒ Syntax

***type*[][].... *var* = new *type*[*size1*][*size2*]....**

❒ Aspects

- static structure, so space is linear
- time to access an element: constant

❒ Some API info

- build array with reflection: see **`Array`** in **`java.lang.reflect`**
- predefined array operations: see **`Arrays`** in **`java.util.Arrays`**:

  `asList`: convert to API's **`List`**

  `binarySearch`: binary search (many types)

  `equals`: tests if 2 arrays are "deeply" equal

  `fill`: put a value in specified places in array

  `sort`: modified merge sort, stable

3.1 Using `java.lang.Object` and `java.lang.System` (Arrays1)

```
   int[] x1 = {1,2,3};
   int[] x2 = (int[]) x1.clone();
   int[] x3 = {1,2,3};
   int[] x4 = new int[3];
   System.arraycopy(x1,0,x4,0,3);

   System.out.println("Test 1: "+x1.equals(x1));
   System.out.println("Test 2: "+x1.equals(x2));
   System.out.println("Test 3: "+x1.equals(x3));
   System.out.println("Test 4: "+x1.equals(x4));

   System.out.println("Test 5: "+x1);
   System.out.println("Test 6: "+x2);
   System.out.println("Test 7: "+x3);
   System.out.println("Test 8: "+x4);

   System.out.println("Test 9: "+x1.getClass());

/* output:
   Test 1: true
   Test 2: false
   Test 3: false
   Test 4: false
   Test 5: [I@1ba34f2
   Test 6: [I@1ea2dfe
   Test 7: [I@17182c1
   Test 8: [I@13f5d07
   Test 9: class [I
*/
```

3.2 Using `java.util.Arrays` (Arrays2)

```
import java.util.Arrays;

   int[] x1 = {1,2,3};
   int[] x2 = (int[]) x1.clone();
   int[] x3 = {1,2,3};
   int[] x4 = new int[3];
   System.arraycopy(x1,0,x4,0,3);
   Integer[] x5 = { new Integer(3), new Integer(1),
                    new Integer(2)};

   System.out.println("Test 1: "+Arrays.equals(x1,x1));
   System.out.println("Test 2: "+Arrays.equals(x1,x2));
   System.out.println("Test 3: "+Arrays.equals(x1,x3));
   System.out.println("Test 4: "+Arrays.equals(x1,x4));
   System.out.println("Test 5: "+Arrays.asList(x5));
   System.out.println("Test 6: "+
            Arrays.binarySearch(x5,new Integer(1)));

   Arrays.sort(x5);
   for (int i=0;i<x5.length;i++)
       System.out.print(x5[i]+" ");
   System.out.println();

/* output:
   Test 1: true
   Test 2: true
   Test 3: true
   Test 4: true
   Test 5: [3, 1, 2]
   Test 6: 1
   1 2 3
*/
```

4. Lists

❒ Motivation/Issues

- arrays are great, but are only static
- need dynamic structure, which changes size
- random access (only linear search)

❒ List

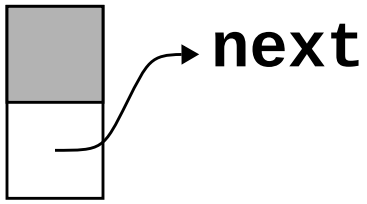
- linear DS, collections of linked cells
- cells contain info (Object) and link(s) to other cells

❒ Related Types

- ***singly-linked***: link to another cell (**`prev`** or **`next`**)
- ***doubly-linked***: link to both **`prev`** and **`next`** (easier to work with costs more heap storage)
- ***circular***: head connects to tail
- ***degenerate tree*** (tree with only 1 "side")
- related ADTs: ***set*** (no order, all unique), ***bag*** (also called ***multiset***: no order, maybe repeats)

4.1 List Node

- "Standard" Node or Cell

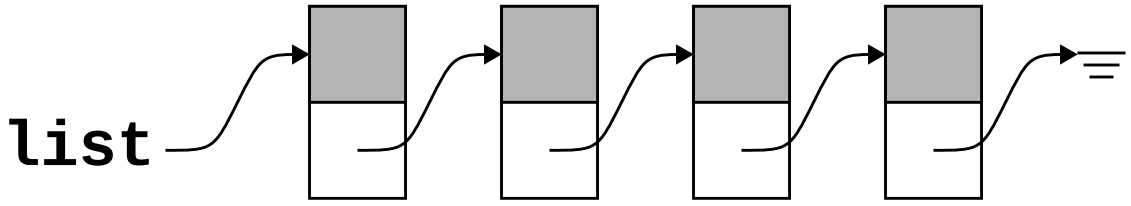


- Node Code (see **`TestListNode`**)

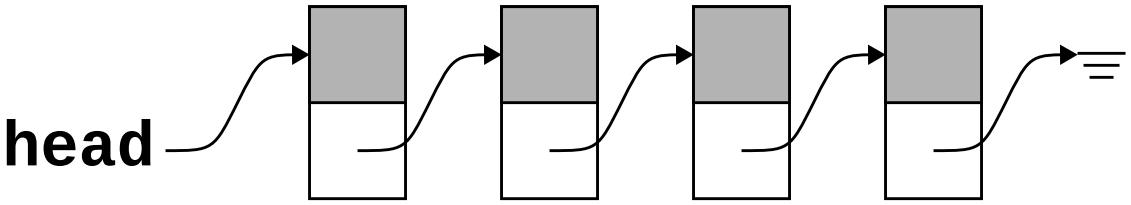
```
public class ListNode {

   private Object item;
   private ListNode next;

   public ListNode(Object o, ListNode n) {
      item = o;
      next = n;
   }

   public Object getItem() { return item; }
   public ListNode getNext() { return next; }
   public void setItem(Object o) { item = o; }
   public void setNext(ListNode n) { next = n;  }
   public String toString() {
      String temp = item.toString();
      if (next != null)
         temp += " " + next.toString();
      return temp;
      }
}
```

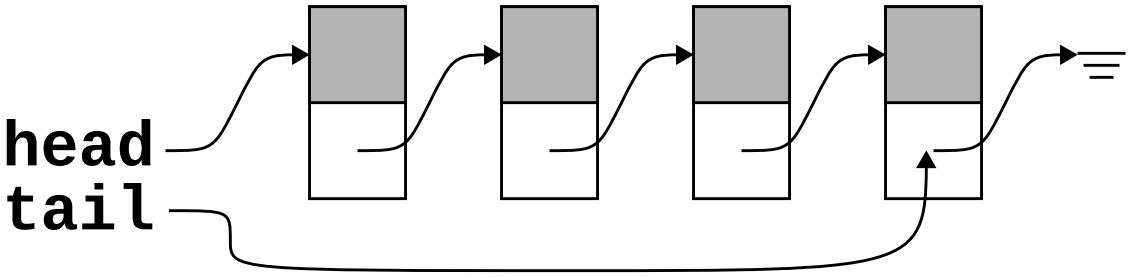
4.2 Singly-Linked Lists

- The Gist



- Variations (see DS&A, 4.3 for more)



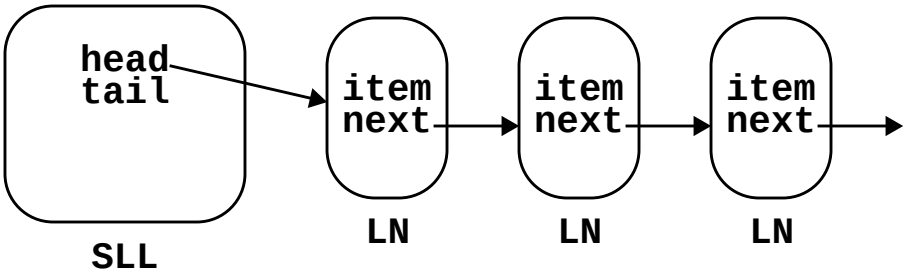


- How to choose?
  - space considerations
  - time consideration

4.3 List Class

❒ Structure

- List class: contain links to **`head`** and/or **`tail`**, sentinels
- List node: represent each item in list



❒ Choice of list class?

- DS&SD: see Figs 7.9, 7.10; DS&A: see 4.3.1

❒ Code Snippet

```
public class SLL {

   private ListNode head;
   private ListNode tail;

   public SLL() { }

   // getters, setters
   // operations (remove, add, … )
}
```

4.4 List Operations

- List as ADT…
- Common operations from API:

`void add(int index, Object o)`
Inserts the specified element at the specified position in this list

`boolean add(Object o)`
Appends the specified element to the end of this list

`void clear()`
Removes all of the elements from this list

`boolean contains(Object o)`
Returns true if this list contains the specified element.

`boolean equals(Object o)`
Compares the specified object with this list for equality.

`Object get(int index)`
Returns the element at the specified position in this list.

`int indexOf(Object o)`
Returns the index in this list of the first occurrence of the specified element, or -1 if this list does not contain this element.

`boolean isEmpty()`
Returns true if this list contains no elements.

`Object remove(int index)`
Removes the element at the specified position in this list

`boolean remove(Object o)`
Removes the first occurrence in this list of the specified element

`int size()`
Returns the number of elements in this list.

4.5 Example Code (SLL)

```
public class SLL {
   // see other code from (10)

   // Add elem to end of list:
   public boolean add(Object o) {
      ListNode tmp = new ListNode(o, null);
      if (head==null) head = tmp;
      else tail.setNext(tmp);
      tail = tmp;
      return true;
   }

   // Remove 1st occurrence of o:
   public boolean remove(Object o) {
      ListNode current = head;
      ListNode prev = null;
      while(current != null &&
            !o.equals(current.getItem())) {
         prev = current;
         current = current.getNext();
      }

      if (current==null)
         return false;
      if (current==head)
         head = current.getNext();
      else
         prev.setNext(current.getNext());
      if (current == tail)
         tail = prev;
      return true;
   }
```

```
// Purge all elements from list:
public void clear() {
   head = tail = null;
}

// Check if a node contains o:
public boolean contains(Object o) {
   ListNode current = head;
   while (current != null) {
      if (o.equals(current.getItem()))
         return true;
      else
         current = current.getNext();
   }
return false;
}

// Return number of nodes:
public int size() {
   int count = 0; // start as empty
   ListNode current = head;
   while (current != null) {
      count++;
      current = current.getNext();
   }
   return count;
}

// Check if list is empty:
public boolean isEmpty() {
   return (head==null);
}
```

4.6 Using SLL (TestSLL)

```
public class TestSLL {
public static void main(String[] args) {

SLL list = new SLL();
list.add("D");
list.add("C");
list.add("B");
list.add("A");

System.out.println("List:  " + list);
System.out.println("Size:  " + list.size());
System.out.println("E?     " + list.contains("E"));
System.out.println("A?     " + list.contains("A"));
System.out.println("Del A: " + list.remove("A"));
System.out.println("List:  " + list);
System.out.print  ("Gone!  ");
                          list.clear(); list.display();
System.out.println("Empty? " + list.isEmpty());
}
}

/* Output:
   List:  D C B A
   Size:  4
   E?     false
   A?     true
   Del A: true
   List:  D C B
   Gone!  null
   Empty? true
*/
```

4.7 Alternative (`ListRecursion`)

```
class List2 {
   private ListNode head;
   public List2() { }
   public String toString() { return head.toString(); }

   public void add(Object o) { head = add(o, head); }
   private ListNode add(Object o, ListNode n) {
      if (n == null) return new ListNode(o, n);
      else { n.next = add(o, n.next); return n; }
   }

   public void del(Object o) { head = del(o, head); }
   private ListNode del(Object o, ListNode n) {
      if (n == null) return n;
      if (o.equals(n.item)) return n.next;
      else { n.next=del(o,n.next); return n;}
   }

   private class ListNode {
      public Object item;
      public ListNode next;
      public ListNode(Object o, ListNode n) {
         item = o;
         next = n;
      }
      public String toString() {
         String temp = item.toString();
         if (next != null) temp+=" "+next.toString();
         return temp;
      }
   }
}
```

```
public class ListRecursion {
   public static void main(String[] args) {

      List2 list = new List2();
      list.display();

      list.add("A"); System.out.println(list);
      list.add("B"); System.out.println(list);
      list.add("C"); System.out.println(list);

      list.del("A"); System.out.println(list);
      list.del("B"); System.out.println(list);
      list.del("C"); System.out.println(list);
   }
}

/* Output:
   null
   A
   A B
   A B C
   B C
   C
   null
*/
```

4.8 API for Lists

- package? import **`java.util.*`**
- Interfaces
  - **`Collection`**, **`List`**

  - see also **`ListIterator`**
- Abstract classes
  - **`AbstractList`** (partially implements **`List`** interface)
  - **`AbstractSequentialList`** (extends A.L.)
- Concrete Classes
  - **`LinkedList`** (extends A.S.L.)
  - **`ArrayList`**, **`Vector`** (extends A.L.)
  - see API for complete specs

5. ArrayLists and Vectors

❒ Motivation

- want something with dynamic size of lists
- want something with random access of arrays

❒ `ArrayList` vs. `Vector`

- **`Vector`** is synchronized, **`ArrayList`** isn't
- huh? see threads; prevent chaotic access to data structure

❒ API

- **`Vector`** and **`ArrayList`** implement **`List`**
  so, refer there for method headers
- Why bother with Vector?
  Legacy code: early concept of collection in Java

❒ Example

- see Lecture 3

6. Strings

- **`String`** as ADT?
- Object: **`toString`**
  - default: **`getClass().getName() + '@' + Integer.toHexString(hashCode())`**
  - **`hashCode`**: coming up in Search Structures
- **`CharSequence`** interface
  - implemented by String
  - **`charAt(index)`**, **`length()`**, **`toString()`**, **`subSequence(start, end)`**
- **`String`**
  - **`java.lang`**
  - implements **`Comparable`**, **`CharSequence`**
- **`StringBuffer`**
  - mutable **`String`**s
  - **`insert`**, **`append`** are common operations

❒ `StringTokenizer`

- **`java.util`**
- breaks **`String`** into collection of substrings
- uses ***delimiters***: special characters to indicate breaks
- default delimiters: **`" \t\r\n\f"`**
- see also **`StreamTokenizer`**

```
// TestTokenizer example:
String s = "abc2de fg.hi";
String delims = "1234567890.\"\\ ";

StringTokenizer st1 = new StringTokenizer(s);
StringTokenizer st2 = new StringTokenizer(s,delims);
while (st1.hasMoreTokens())
   System.out.println(st1.nextToken());
while (st2.hasMoreTokens())
   System.out.println(st2.nextToken());
```

❒ `StringCharacterIterator`

- **`java.text`**
- iterator for **`String`**s

❒ IO

- **`StringBuffer`**, **`StringWriter`**, …

7. Suggested Exercises

Write a class that implements a singly-linked list as an array.

Write list classes for variations (a), (c), and (d) in DS&A, 4.3.

Implement the API's **`List`** interface methods for the given **`SLL`** class. See if you can write recursive and iterative versions for the methods instead of using just one approach.

Write a binary search method for an **`ArrayList`** and/or **`Vector`**.

Create a **`MyArray`** class (see previous notes) that includes a useful **`toString`** method.

Write a program that takes a body of text and counts the number of letters (without spaces, numbers, and punctuation), words, and sentences.