CS61B Lecture #19

Administrative:

- Review session today 4–6PM in 2 LeConte.
- HKN CS61B review session Saturday 1–3PM in the Woz.
- Need alternative test time? Make sure you send me mail today.

Today:

- Maps
- Generic Implementation
- Array vs. linked: tradeoffs
- Sentinels
- Specialized sequences: stacks, queues, deques
- Circular buffering
- Recursion and stacks
- Adapters

Readings: Data Structures, Chapter 3, 4 (for today), and 5 (next).
Simple Banking I: Accounts

Problem: Want a simple banking system. Can look up accounts by name or number, deposit or withdraw, print.

Account Structure

class Account {
    Account (String name, String number, int init) {
        this.name = name; this.number = number;
        this.balance = init;
    }
    /** Account-holder’s name */
    final String name;
    /** Account number */
    final String number;
    /** Current balance */
    int balance;

    /** Print THIS on STR in some useful format. */
    void print (PrintWriter str) { ... }
}

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Simple Banking II: Banks

class Bank {

  /* These variables maintain mappings of String -> Account. They keep
   * the set of keys (Strings) in "compareTo" order, and the set of
   * values (Accounts) is ordered according to the corresponding keys. */
  SortedMap<String,Account> accounts = new TreeMap<String,Account>() ;
  SortedMap<String,Account> names = new TreeMap<String,Account> () ;

  void openAccount (String name, int initBalance) {
    Account acc =
      new Account (name, chooseNumber (), initBalance);
    accounts.put (acc.number, acc);
    names.put (name, acc);
  }

  void deposit (String number, int amount) {
    Account acc = accounts.get (number);
    if (acc == null) ERROR(...);
    acc.balance += amount;
  }

  // Likewise for withdraw.
}
Banks (continued): Iterating

Printing out Account Data

/** Print out all accounts sorted by number on STR. */
void printByAccount (PrintStream str) {
    // accounts.values () is the set of mapped-to values. Its
    // iterator produces elements in order of the corresponding keys.
    for (Account account : accounts.values ())
        account.print (str);
}

/** Print out all bank accounts sorted by name on STR. */
void printByName (PrintStream str) {
    for (Account account : names.values ())
        account.print (str);
}

A Design Question: What would be an appropriate representation for
keeping a record of all transactions (deposits and withdrawals) against
each account?
Partial Implementations

• Besides interfaces (like List) and concrete types (like LinkedList), Java library provides abstract classes such as AbstractList.

• Idea is to take advantage of the fact that operations are related to each other.

• Example: once you know how to do get(k) and size() for an implementation of List, you can implement all the other methods needed for a read-only list (and its iterators).

• Now throw in add(k, x) and you have all you need for the additional operations of a growable list.

• Add set(k, x) and remove(k) and you can implement everything else.
Example: The java.util.AbstractList helper class

```java
public abstract class AbstractList<Item> implements List<Item> {
    /** Inherited from List */
    // public abstract int size ();
    // public abstract Item get (int k);
    public boolean contains (Object x) {
        for (int i = 0; i < size (); i += 1) {
            if ((x == null && get (i) == null) ||
                (x != null && x.equals (get (i))))
                return true;
        }
        return false;
    }
    return false;
}

/* OPTIONAL: By default, throw exception; override to do more. */
void add (int k, Item x) {
    throw new UnsupportedOperationException ();
}

Likewise for remove, set
```
Example, continued: AListIterator

// Continuing abstract class AbstractList<Item>:
public Iterator<Item> iterator () { return listIterator (); }
public ListIterator<Item> listIterator () { return new AListIterator (this); }

private static class AListIterator implements ListIterator<Item> {
  AbstractList<Item> myList;
  AListIterator (AbstractList<Item> L) { myList = L; }
  /** Current position in our list. */
  int where = 0;

  public boolean hasNext () { return where < myList.size (); }
  public Item next () { where += 1; return myList.get (where-1); }
  public void add (Item x) { myList.add (where, x); where += 1; }
  ... previous, remove, set, etc.
}
...
Example: Using AbstractList

Problem:  Want to create a reversed view of an existing List (same elements in reverse order).

```java
public class ReverseList<Item> extends AbstractList<Item> {
    private final List<Item> L;

    public ReverseList (List<Item> L) { this.L = L; }

    public int size () { return L.size (); }

    public Item get (int k) { return L.get (L.size ()-k-1); }

    public void add (int k, Item x)
        { L.add (L.size ()-k, x); }

    public Item set (int k, Item x)
        { return L.set (L.size ()-k-1, x); }

    public Item remove (int k)
        { return L.remove (L.size () - k - 1); }
}
```
Aside: Another way to do AListIterator

It’s also possible to make the nested class non-static:

```java
public Iterator<Item> iterator () { return listIterator (); }
public ListIterator<Item> listIterator () { return this.new AListIterator (); }

private class AListIterator implements ListIterator<Item> {
    /** Current position in our list. */
    int where = 0;

    public boolean hasNext () { return where < AbstractList.this.size (); }
    public Item next () { where += 1; return AbstractList.this.get (where-1); }
    public void add (Item x) { AbstractList.this.add (where, x); where += 1; }
    ...
    previous, remove, set, etc.
}
```

• Here, AbstractList.this means “the AbstractList I am attached to” and X.new AListIterator means “create a new AListIterator that is attached to X.”

• In this case you can abbreviate this.new as new and can leave off the AbstractList.this parts, since meaning is unambiguous.
Getting a View: Sublists

**Problem:** \( L\.\) sublist\((\text{start}, \text{end}) \) is a full-blown List that gives a view of part of an existing list. Changes in one must affect the other. How? Here's part of AbstractList:

```java
List sublist (int start, int end) {
    return new this.Sublist (start, end);
}

private class Sublist extends AbstractList<Item> {
    // NOTE: Error checks not shown
    private int start, end;
    Sublist (int start, int end) { obvious }

    public int size () { return end-start; }

    public Item get (int k)
    { return AbstractList.this.get (start+k); }

    public void add (int k, Item x) {
        AbstractList.this.add (start+k, x); end += 1; }
    ...
}
```

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What Does a Sublist Look Like?

- Consider $SL = L\text{.sublist}(3, 5)$;

```
L:

List object

SL:

AbstractList.this

<table>
<thead>
<tr>
<th>start</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>end</td>
<td>5</td>
</tr>
</tbody>
</table>
```
Arrays and Links

- Two main ways to represent a sequence: array and linked list
- In Java Library: ArrayList and Vector vs. LinkedList.
- Array:
  - Advantages: compact, fast ($\Theta(1)$) random access (indexing).
  - Disadvantages: insertion, deletion can be slow ($\Theta(N)$)
- Linked list:
  - Advantages: insertion, deletion fast once position found.
  - Disadvantages: space (link overhead), random access slow.
Implementing with Arrays

- Biggest problem using arrays is insertion/deletion in the middle of a list (must shove things over).

- Adding/deleting from ends can be made fast:
  - Double array size to grow; amortized cost constant (Lecture #15).
  - Growth at one end really easy; classical stack implementation:
    
    ```
    S.push ("X");
    S.push ("Y");
    S.push ("Z");
    ```

    - To allow growth at either end, use **circular buffering**:
      
    ```
    F IHG
    ```

    - Random access still fast.
Linking

• Essentials of linking should now be familiar

• Used in Java LinkedList. One possible representation:

```java
L = new LinkedList<String>();
L.add("axolotl");
L.add("kludge");
L.add("xerophyte");
I = L.listIterator();
I.next();
```
Clever trick: Sentinels

- A *sentinel* is a dummy object containing no useful data except links.
- Used to eliminate special cases and to provide a fixed object to point to in order to access a data structure.
- Avoids special cases ('if' statements) by ensuring that the first and last item of a list always have (non-null) nodes—possibly sentinels—before and after them:

```java
// To delete list node at p:  // To add new node N before p:
p.next.prev = p.prev;      N.prev = p.prev;  N.next = p;
p.prev.next = p.next;      p.prev.next = N;
p.prev = N;
```

Initially p: ![Diagram of list before change](image1)

p: ![Diagram of list after change](image2)
Specialization

- Traditional special cases of general list:
  - **Stack**: Add and delete from one end (LIFO).
  - **Queue**: Add at end, delete from front (FIFO).
  - **Dequeue**: Add or delete at either end.

- All of these easily representable by either array (with circular buffering for queue or deque) or linked list.

- Java has the **List** types, which can act like any of these (although with non-traditional names for some of the operations).

- Also has **java.util.Stack**, a subtype of **List**, which gives traditional names ("push", "pop") to its operations. There is, however, no "stack" interface.
Stacks and Recursion

- Stacks related to recursion. In fact, can convert any recursive algorithm to stack-based (however, generally no great performance benefit):

  - Calls become “push current variables and parameters, set parameters to new values, and loop.”
  - Return becomes “pop to restore variables and parameters.”

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findExit(start):
  if isExit(start)
    FOUND
  else if (! isCrumb(start))
    leave crumb at start;
    for each square, x,
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        if legalPlace(x)
          findExit(x)

Call: findExit(0)
Exit: 16
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Design Choices: Extension, Delegation, Adaptation

- The standard `java.util.Stack` type extends `Vector`:
  ```java
class Stack<Item> extends Vector<Item> {
    void push (Item x) { add (x); } ...
  }
```
- Could instead have delegated to a field:
  ```java
class ArrayStack<Item> {
    private ArrayList<Item> repl = new ArrayList<Item> ();
    void push (Item x) { repl.add (x); } ...
}
```
- Or, could generalize, and define an adapter: a class used to make objects of one kind behave as another:
  ```java
public class StackAdapter<Item> {
  private List repl;
  /** A stack that uses REPL for its storage. */
  public StackAdapter (List<Item> repl) { this.repl = repl; }
  public void push (Item x) { repl.add (x); } ...
}
```
```
class ArrayStack<Item> extends StackAdapter<Item> {
  ArrayStack () { super (new ArrayList<Item> ()); }
}
```