CS61B Lecture #18

Announcements:

• *Programming Contest Saturday!* See
  
  [http://inst.eecs.berkeley.edu/~ctest/contest/](http://inst.eecs.berkeley.edu/~ctest/contest/)

  for details and registration.
Topics

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

New Concept: A view is an alternative presentation of (interface to) an existing object.

- For example, the sublist method is supposed to yield a “view of” part of an existing list:

  ```java
  List<String> L = new ArrayList<String>();
  L.add("at"); L.add("ax"); ...
  List<String> SL = L.sublist(1, 4);
  ```

  - Example: after `L.set(2, "bag")`, value of `SL.get(1)` is "bag", and after `SL.set(1, "bad")`, value of `L.get(2)` is "bad".
  
  - Example: after `SL.clear()`, `L` will contain only "at" and "cat".
  
  - Small challenge: “How do they do that?!"
A Map is a kind of “modifiable function:”

```java
package java.util;
public interface Map<Key, Value> {
    Value get(Object key); // Value at KEY.
    Object put(Key key, Value value); // Set get(KEY) -> VALUE
...
}
```

Map<String,String> f = new TreeMap<String,String>();
f.put("Paul", "George"); f.put("George", "Martin");
f.put("Dana", "John");
// Now f.get("Paul").equals("George")
//    f.get("Dana").equals("John")
//    f.get("Tom") == null
public interface Map<Key, Value> { // Continuation

    /* Views of Maps */

    /** The set of all keys. */
    Set<Key> keySet();

    /** The multiset of all values that can be returned by get. 
     * (A multiset is a collection that may have duplicates). */
    Collection<Value> values();

    /** The set of all(key, value) pairs */
    Set<Map.Entry<Key, Value>> entrySet();
}
View Examples

Using example from a previous slide:

Map<String, String> f = new TreeMap<String, String>();
f.put("Paul", "George"); f.put("George", "Martin");
f.put("Dana", "John");

we can take various views of f:

for (Iterator<String> i = f.keySet().iterator(); i.hasNext();)
    i.next() ===> Dana, George, Paul
// or, more succinctly:
for (String name : f.keySet())
    name ===> Dana, George, Paul

for (String parent : f.values())
    parent ===> John, Martin, George

for (Map.Entry<String, String> pair : f.entrySet())
    pair ===> (Dana,John), (George,Martin), (Paul,George)

f.keySet().remove("Dana");  // Now f.get("Dana") == null
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(PrintStream str) {
        ... 
    }
}
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: Throws 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 some AbstractList.this parts, since meaning is unambiguous.
```
**Getting a View: Sublists**

**Problem:** `L.sublist(start, 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<Item> sublist(int start, int end) {
    return new this.Sublist(start, end);
}
```

```java
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;
    }

    ...
}
```
What Does a Sublist Look Like?

- Consider $SL = L.sublist(3, 5);$
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  I  H  G
    add here
    ```
  - Random access still fast.
Linking

- Essentials of linking should now be familiar
- Used in Java LinkedList. One possible representation for linked list and an iterator object over it:

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

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:

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

Initially

\[\text{p: } \square \quad \cdots \]
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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,
      adjacent to start:
        if legalPlace(x) && !isCrumb(x)
          findExit(x)

Call: findExit(0)
Exit: 16
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```plaintext
12 11 8 9 10
4 7
3 6
1 2 5
```

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  - Return becomes “pop to restore variables and parameters.”

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

Call: `findExit(0)`
Exit: 16

```
findExit(start):
  S = new empty stack;
  push start on S;
  while S not empty:
    pop S into start;
    if isExit(start)
      FOUND
    else if (!isCrumb(start))
      leave crumb at start;
      for each square, x,
        adjacent to start (in reverse):
          if legalPlace(x) && !isCrumb(x)
            push x on S
```

Stacks and Recursion

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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>()); }
  }
  ```