Topics

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

Readings:  *Data Structures*, Chapter 2, 3 (for today), and 4 (Friday).
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:

```
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?!“
Maps

- 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
    ...
}
```

```java
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
```
Map Views

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(PrintWriter str) { ... }
}

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**

```java
/** 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: \texttt{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; }  
... \texttt{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
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(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);
}

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

    - 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:

```
L = new LinkedList<String>();
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:

  // 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:

p:

p:
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.”

```java
findExit(start):
  if isExit(start)
    FOUND
  else if (! isCrumb(start))
    leave crumb at start;
    for each square, x, adjacent to start:
      if legalPlace(x)
        findExit(x)
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Call: findExit(0)
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```

```
1 2 3 4
5 6
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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); } ...
}
```

  ```java
class ArrayStack<Item> extends StackAdapter<Item> {
    ArrayStack() { super(new ArrayList<Item>()); }
}
```