

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, dequeues
- 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) { ... }
}
```

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

```
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;
    }
    /* 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).

```
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:

```
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.

Last modified: Mon Oct 22 15:34:05 2007

CS61B: Lecture #19 9

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`:

```
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); }

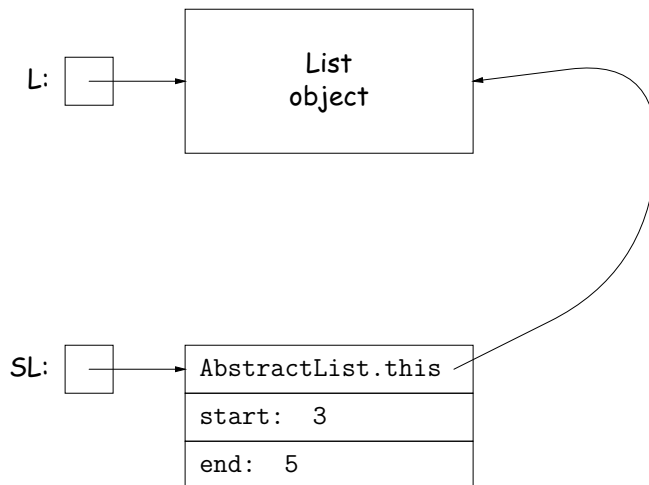
    public void add (int k, Item x) {
        { AbstractList.this.add (start+k, x); end += 1; }
        ...
    }
}
```

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CS61B: Lecture #19 10

What Does a Sublist Look Like?

- Consider `SL = L.sublist (3, 5);`



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CS61B: Lecture #19 11

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.

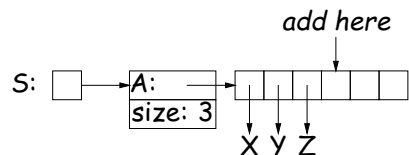
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CS61B: Lecture #19 12

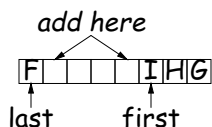
Implementing with Arrays

- 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");
```



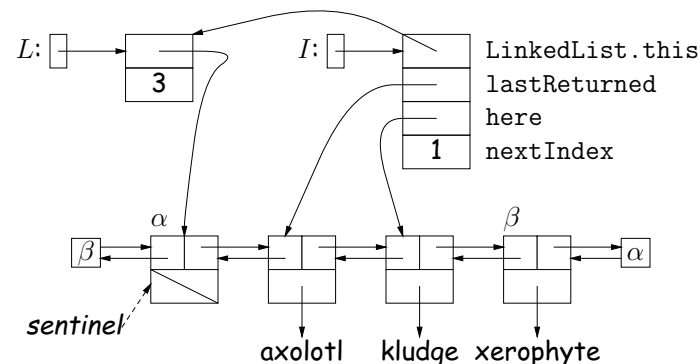
- To allow growth at either end, use *circular buffering*:



- Random access still fast.

Linking

- Essentials of linking should now be familiar
- Used in Java `LinkedList`. One possible representation:

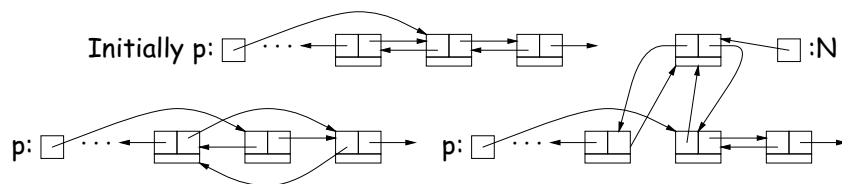


```
L = new LinkedList<String>();
L.add("axolotl");
L.add("kludge");
L.add("xerophyte");
I = L.listIterator();
I.next();
```

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:
- // 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;
```



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."

```
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)
```

Call: findExit(0)

Exit: 16

12	11	8	9	10
13	4	7	15	16
14	3	6		
1	2	5		

```
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)
          push x on S
```

Design Choices: Extension, Delegation, Adaptation

- The standard `java.util.Stack` type *extends* `Vector`:

```
class Stack<Item> extends Vector<Item> { void push (Item x) { add (x); } ... }
```

- Could instead have *delegated* to a field:

```
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:

```
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> ()); }
}
```