Lists & Trees

Lecture 6
CS211 – Fall 2006

Announcements

- If you're curious
  - The best bonus-point solution to the stock problem from A1 is posted on the website
  - There is also a separate discussion of the meaning of "choose at random"
- A2 is online (since Friday)
  - Due Sept 20

List Overview

- Arrays
  - Random access: :)
  - Fixed size: cannot grow on demand after creation: : >((
- Characteristics of some applications:
  - Do not need random access
  - Require a data structure that can grow and shrink dynamically to accommodate different amounts of data

  Lists satisfy these requirements
- Let us study
  - List creation
  - Accessing elements in a list
  - Inserting elements into a list
  - Deleting elements from a list

List Operations

- An ADT (Abstract Data Type):
  - Specifies public functionality
  - Hides implementation detail from users
  - Allows us to improve/replace implementation
  - Forces us to think about fundamental operations (i.e., the *interface*) separately from the implementation
- List Operations:
  - Create
  - Insert object
  - Delete object
  - Find object
  - Size?, Full?, Empty?, Replace Object, …
  - Usually sequential access (not random access)
- A Java *interface* corresponds nicely to an ADT

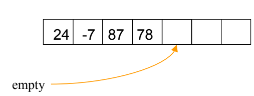
A Simple List Interface

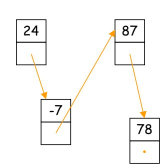
```
public interface List {

   public void insert (Object element);

   public void delete (Object element);

   public boolean contains (Object element);

   public int size ();

}
```

- Methods are specified, but *no* implementation

List Data Structures

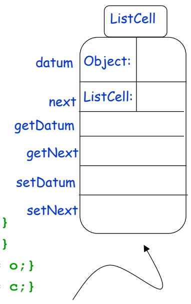
- Can use an array
  - Need to specify array size
  - Inserts & Deletes require moving elements
  - Must copy array (to a larger array) when it gets full
- Can use a sequence of linked cells
  - We'll focus on this kind of implementation
  - We define a class ListCell from which we build lists





Class ListCell

```
class ListCell {
    private Object datum;
    private ListCell next;

    public ListCell(Object d, ListCell n){
        datum = d;
        next = n;
    }
    public Object getDatum() {return datum;}
    public ListCell getNext() {return next;}
    public void setDatum(Object o) {datum = o;}
    public void setNext(ListCell c) {next = c;}
}
```



By convention,
we will not show
the instance methods
when drawing cells

Building a List

c ListCell

ListCell c = new ListCell(new Integer(24), null);

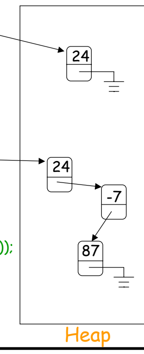
To keep things simple, we will not show Integer objects explicitly in our pictures, but only show the value contained in them.

Integer t = new Integer(24);
Integer s = new Integer(-7);
Integer e = new Integer(87);

p ListCell

One way to build a list with multiple cells:

ListCell p = new ListCell(t, new ListCell(s, new ListCell(e,null)));

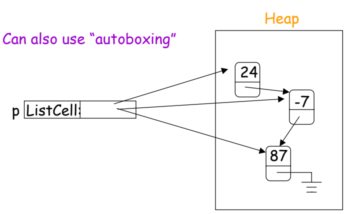


Building a List (Cont'd)

Another way:

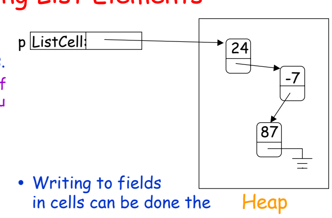
Integer t = new Integer(24); // Can also use "autoboxing"
Integer s = new Integer(-7);
Integer e = new Integer(87);

ListCell p = new ListCell(e,null);
p = new ListCell(s,p);
p = new ListCell(t,p);



Note: assignment of form p = new ListCell(s,p); does *not* create a circular list

Accessing List Elements



- Lists are sequential-access data structures.
  - To access contents of cell n in sequence, you must access cells 0..n-1
- Accessing data in first cell: p.getDatum()
- Accessing data in second cell: p.getNext().getDatum()
- Accessing next field in second cell: p.getNext().getNext()
- Writing to fields in cells can be done the same way
  - Update data in first cell: p.setDatum(new Integer(53));
  - Update data in second cell: p.getNext().setDatum(new Integer(53));
  - Chop off third cell: p.getNext().setNext(null);

Access Example: Linear Search

```
// Scan list looking for object o and return true if found
public static boolean search (Object x, ListCell c) {
    for (ListCell current = c; current != null; current = current.getNext())
        if (current.getDatum().equals(x)) return true;
    return false;
}
...
ListCell p = new ListCell("hello", new ListCell("dolly", new ListCell("polly", null)));
search("dolly", p);           //returns true
search("molly", p);           //returns false
search("dolly", null);        //returns false
...
// Here is another version. Why does this work? Draw stack picture to understand.
public static boolean search(Object x, ListCell c) {
    for (; c != null; c =c.getNext())
        if (c.getDatum().equals(x)) return true;
    return false;
}
```

Recursion on Lists

- Recursion can be done on lists
  - Similar to recursion on integers
- Almost always
  - Base case: empty list
  - Recursive case: Assume you can solve problem on (smaller) list obtained by eliminating first cell…
- Many list operations can be implemented very simply by using this idea
  - Some operations though are easier to implement using iteration

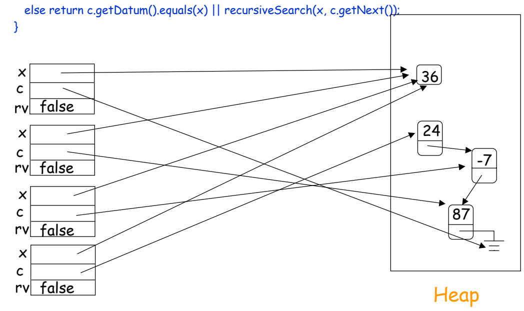
Recursion Example: Linear Search

- Base case: empty list
  - return false
- Recursive case: non-empty list
  - if data in first cell equals object o, return true
  - else return result of doing linear search on rest of list

```
public static boolean recursiveSearch(Object x, ListCell c) {
   if  (c == null) return false;
   else return c.getDatum().equals(x) || recursiveSearch(x, c.getNext());
}
```

Execution of Recursive Program

```
public static boolean recursiveSearch (Object x, ListCell c) {
   if  (c == null) return false;
   else return c.getDatum().equals(x) || recursiveSearch(x, c.getNext());
}
```



Iteration is Sometimes Better

- Given a list, create a new list with elements in reverse order from input list

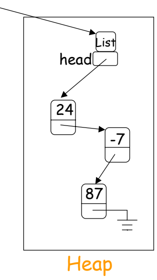
```
// Intuition: think of reversing a pile of coins
public static ListCell reverse (ListCell c) {
    ListCell rev = null ;
    for (  ; c != null; c = c.getNext())
        rev = new ListCell(c.getDatum(), rev);
    return rev;
 }
```

- It is not obvious how to write this simply using a recursive style

List with Header

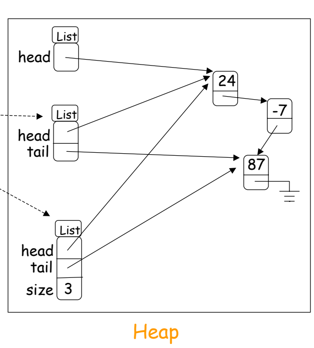
- Some authors prefer to have a List class that is distinct from ListCell class.
- The List object is like a head element that always exists even if list itself is empty.

```
class List {
    protected ListCell head;
    public List (ListCell c) {
      head = c;
    }
    public ListCell getHead()
    ........
   public void setHead(ListCell c)
    ........
}
```



Variations on List with Header

- Header can also keep other info
  - Reference to last cell of list
  - Number of elements in list
  - Search/insertion/ deletion as instance methods
  - …



Special Cases to Worry About

- Empty list
  - add
  - find
  - delete?(!)
- Front of list
  - insert
- End of list
  - find
  - delete
- Lists with just one element

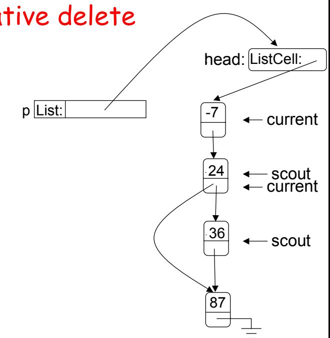
Example: Delete from a List

- Delete first occurrence of object x from list c
  - Recursive delete
  - Iterative delete
- Intuitive idea of recursive code
  - If list c is empty, return null
  - If first element of c is x, return rest of list c
  - Otherwise, return list consisting of
    - First element of c, and
    - List that results from deleting x from rest of list c

```
public static ListCell deleteRecursive (Object x, ListCell c) {
  if (c == null) return null;
  if (c.getDatum().equals(x)) return c.getNext();
  c.setNext(deleteRecursive(x, c.getNext()));
  return c;
}
```

Iterative delete

- Two steps:
  - Locate cell that is the *predecessor* of cell to be deleted (i.e., the cell containing x)
    - Keep two cursors, *scout* and *current*
    - *Scout* is always one cell ahead of *current*
    - Stop when *scout* finds cell containing x, or falls off end of list
  - If *scout* finds cell, update *next* field of *current* cell to splice out object x from list
- Note: Need special case for x in first cell



delete 36 from list

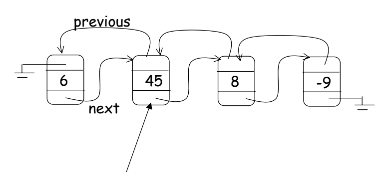
Iterative Code for Delete

```
public void delete (Object x) {
    if (head == null) return;
    if (head.getDatum().equals(x)) {          // x in first cell
        head = head.getNext();
        return;
    }
    ListCell current = head;
    ListCell scout = head.getNext();
    while ((scout != null) && !scout.getDatum().equals(x)) {
        current = scout;
        scout = scout.getNext();
    }
    if (scout != null) current.setNext(scout.getNext());
    return;
}
```

Doubly-Linked Lists

- In some applications, it is convenient to have a ListCell that has references to both its predecessor and its successor in the list.

```
class DLLCell {
   private Object datum;
   private DLLCell next;
   private DLLCell previous;
   .....
}
```

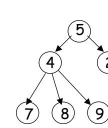


Doubly-Linked vs. Singly-Linked

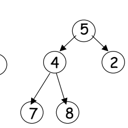
- In some cases it is easier to work with doubly-linked lists than with (singly-linked) lists
  - For example, reversing a DLL can be done simply by swapping the previous and next fields of each cell
- Trade-off: DLLs require more heap space than singly-linked lists

Tree Overview

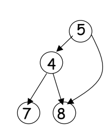
- *Tree*: recursive data structure (similar to list)
  - Each cell may have two or more successors (children)
  - Each cell has at most one predecessor (parent)
    - Distinguished cell called *root* has no parent
  - All cells are reachable from *root*
- *Binary tree*: tree in which each cell can have at most two children: a left child and a right child



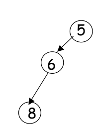
General tree



Binary tree



Not a tree



List-like tree