Lists & Trees

Lecture 6
CS211 – Spring 2007

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
- Common operations
  - 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
  - Replace object
  - Size? Empty?
  - Usually sequential access (not random access)
- A Java *interface* corresponds nicely to an ADT

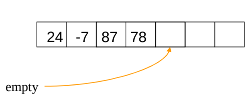
A Simple List Interface

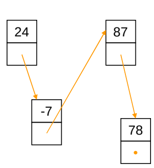
```
public interface List {
    public void insert(Object element);
    public void delete(Object element);
    public boolean contains(Object element);
    public int size();
}
```

- 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

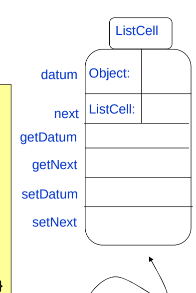




Class ListCell

```
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;}
}
```

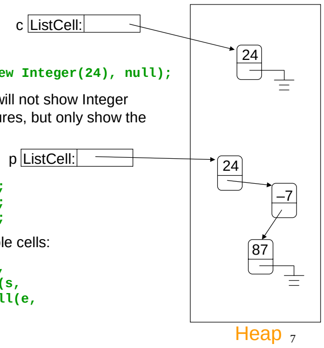


By convention, we will not show the instance methods when drawing cells

Building a List

```
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);
```

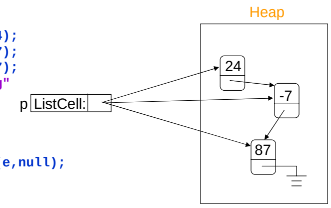
One way to build a list with multiple cells:

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


Building a List (cont'd)

Another way:

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

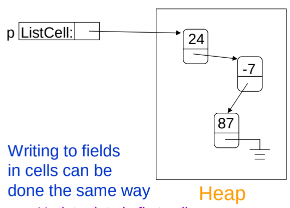



```
ListCell p = new ListCell(e,null);
p = new ListCell(s,p);
p = new ListCell(t,p);
```

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 x, return true if found
public static boolean search(Object x, ListCell c) {
   for (ListCell lc = c; lc != null; lc = lc.getNext()) {
      if (lc.getDatum().equals(x)) return true;
   }
   return false;
}
```

```
//Here is another version. Why does this work?
public static boolean search(Object x, ListCell c) {
   for (; c != null; c = c.getNext()) {
      if (c.getDatum().equals(x)) return true;
   }
   return false;
}
```


A Recursive Version

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

```
public static boolean search(Object x, ListCell c) {
   return c != null &&
      (c.getDatum().equals(x) || search(x, c.getNext()));
}
```


Recursion on Lists

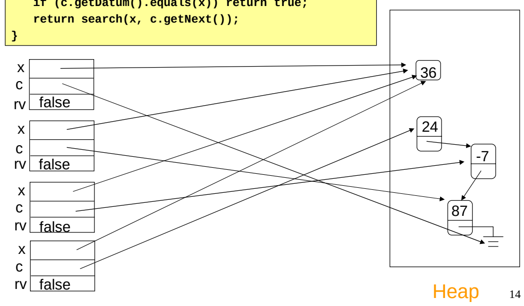
- Recursion can be done on lists
  - Similar to recursion on integers
- Almost always
  - Base case: empty list
  - Recursive case: Assume you can solve problem on (smaller) list obtained by eliminating first cell…
- Many list operations can be implemented very simply by using this idea
  - Although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

Recursive Search

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

Execution of Recursive Program

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



Iteration is Sometimes Better

- Given a list, create a new list with elements in reverse order
- Intuition: think of reversing a pile of coins

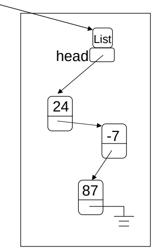
```
public static ListCell reverse(ListCell c) {
   ListCell rev = null;
   for (; c != null; c = c.getNext()) {
      rev = new ListCell(c.getDatum(), rev);
   }
   return rev;
}
```

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

List with Header

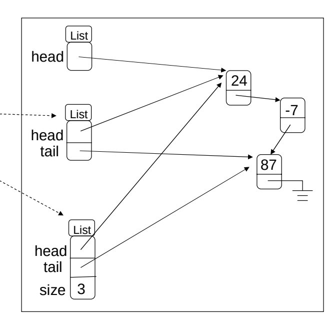
- Some authors prefer to have a List class that is distinct from ListCell class.
- The List object is like a head element that always exists even if list itself is empty.

```
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

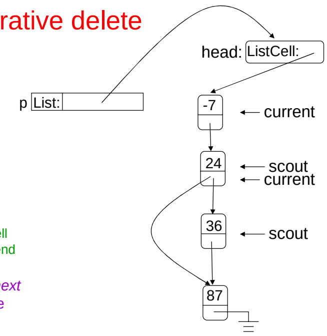
Example: Delete from a List

- Delete *first occurrence* of x from list c
  - Recursive delete
  - Iterative delete
- Intuitive idea of recursive code
  - If list 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

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

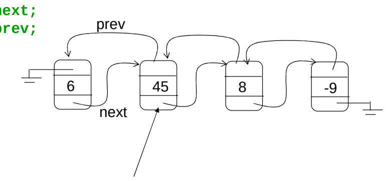
Iterative Code for Delete

```
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 prev;
   …
}
```

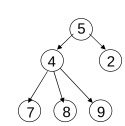


Doubly-linked vs. Singly-linked

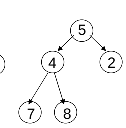
- Advantages of doubly-linked lists over singly-linked lists
  - some things are easier – e.g., reversing a doubly-linked list can be done simply by swapping the previous and next fields of each cell
  - don't need the scout to delete
- Disadvantages
  - doubly-linked lists require more heap space than singly-linked lists
  - insert and delete take more time

Tree Overview

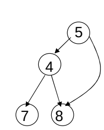
- *Tree*: recursive data structure (similar to list)
  - Each cell may have two or more *successors* (or *children*)
  - Each cell has at most one *predecessor* (or *parent*)
    - Distinguished cell called *root* has no parent
  - All cells reachable from *root*
- *Binary tree*: tree in which each cell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



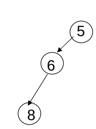
General tree



Binary tree



Not a tree



List-like tree