G51PRG: Introduction to Programming Second semester

Lecture 13

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Previous lecture:networking

How to make your program to make network connections (java.net package)

- Connecting via URLs
- Connecting via ports and sockets
- ChatServer program

This lecture

- Dynamic arrays and lists
- Implementing a dynamic array
- Implementing a very simple linked list in Java
- Inner classes

Next lecture
- Iterators
- Synchronised data structures (back to ChatServer)
- Serialisation (saving objects)

Two kinds of sequential collections

- Array-like collections
- Linked collections
- In what follows, we assume that they all have the following methods:
  - **`Object get(int i)`** - return the ith element
  - **`void add(Object o)`** - add Object o
  - **`boolean remove(Object o)`** - remove the first occurrence of o in the collection; returns true if o was in the collection, and false otherwise.

Array-like collections

- Array itself:
  - Advantages: easy to use, very fast; equally fast access to any index (constant time).
  - Disadvantages: fixed size
- Vector, ArrayList from java.util: generally known as dynamic arrays.
  - Advantages: almost as fast as array, can grow if more items need to be inserted
  - Disadvantages: resizing expensive; still a bit inflexible.

Dynamic arrays: idea

- Has an array inside to store Objects
- If array is not large enough, makes a larger one and copies the values to the new array.
- If an element is removed, the gap is closed by moving subsequent values one place to the left.

Example

- Dynamic array of initial capacity 5 is created:

Example

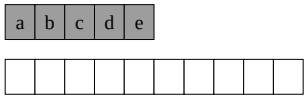
- Adding objects a,b,c,d,e:

Example

- Adding object f:

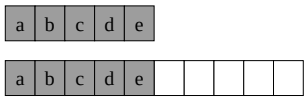
Example

- Double the capacity:



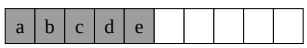
Example

- Copy the contents to the new array:



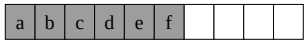
Example

- Make new array the store:



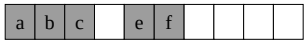
Example

- Add f:



Example

- Remove d:



Example

- Close the gap:

Implementation of “dynamic array”

```
public class DynamicArray {
  Object [] store;
  int capacity;//how many items can store
  int size; // how many items stored
  public DynamicArray() {
    store = new Object[10];
    capacity = 10;
    size = 0;
  }
```


Implementation of “dynamic array”

```
public void add(Object o) {
// if the store has space, insert o
 if (size < capacity){
  store[size] = o;
  size++;
 }
// otherwise need to enlarge the store
```


Implementation of “dynamic array”

```
else {
  capacity = capacity*2;//or whatever
  Object[] newStore = new
                      Object[capacity];
  for (int i = 0; i < size; i++) {
   newStore[i] = store[i];
  }
  store = newStore;
  store[size] = o;
  size++;
 }
}
```

Implementation of “dynamic array”

```
public Object get(int i) {
  // check if i is within bounds
   if ((0 <= i)&&(i < size)) {
      return store[i];
   } else {
   throw new
        ArrayIndexOutOfBoundsException();
   }
```


Implementation of “dynamic array”

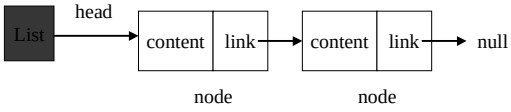
```
public boolean remove(Object o) {
 int index = -1;
// look for o in store
 for (int i = 0; i < size; i++) {
  if (store[i].equals(o)) {
   index = i; break;
  }
// if o not in store, return false
 if (index == -1) return false;
```


Implementation of “dynamic array”

```
// else replace o by the next value and
// shift remaining values to the left
for (int i = index; i < size-1; i++){
  store[i] = store[i+1];
}
size--;
return true;
}
```

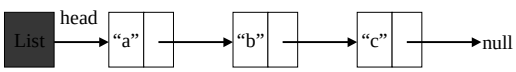

Linked list

- A linked list consists of nodes .
- Each node has a contents fields which stores data (an Object) and a link field which says what the next item in the list is. A list has a head field which refers to the head of the list.



Example: (“a”, “b”, “c”) list

- This list contains three strings (“a”, “b”, “c”).



Linked list

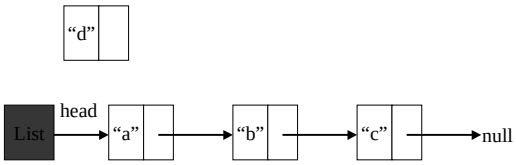
- Really dynamic data structure - don’t have to know initial size at all
- No problems with resizing
- Slow (sequential) access to elements in the middle of the list

Linked list: how to add things

- We add things at the beginning of the list. To add a new node with an object d inside it to the list above, we
  - create a new node with d as its contents
  - link this node to the present head of the list (so that the present head is the next element)
  - make the new node to be the new head of the list

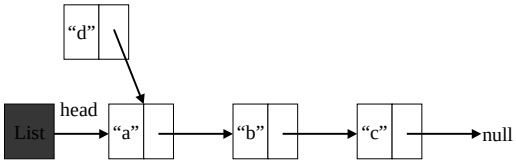
Example: adding “d”

- Create a new node:



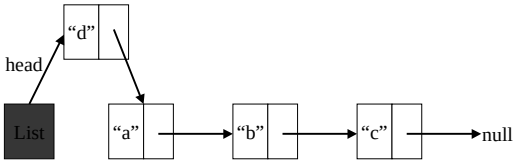
Example: adding “d”

- Link it to the head of the list:



Example: adding “d”

- Make it the new head of the list:

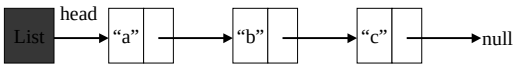


Linked list: how to remove things

- We find the first node which has the object to be removed as contents, and bypass it: get the node which was linked to the removed node to link to the o-node's successor in the list.
- No other object now has a reference to the removed node so it will be garbage-collected by Java's garbage collector eventually. You don't have to destroy it yourself.

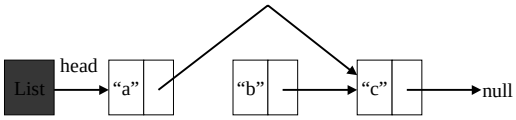
Example: removing a node

- To remove “b”...



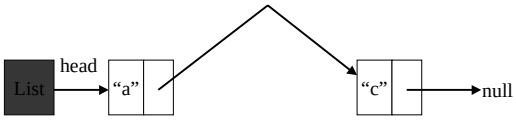
Example: removing a node

- Get “a” to link to “c”:



Example: removing a node

- Eventually “b” will be garbage collected:



Linked list implementation

- Need a class to represent nodes in a list
- Need a list class to store the head of the list and **`add(Object o), remove(Object o), get(int i)`** methods.

Node class

```
class Node {
  Object contents;
  Node link;

  public Node(Object o, Node next) {
   this.contents = o;
   this.link = next;
  }
}
```


List class

```
public class List{
  Node head;

  public List() {
   this.head = null;
  }
  public void add(Object o){
   Node newHead = new Node (o, head);
   head = newHead;
  }
```


List class

```
 public boolean remove(Object o){
  if (head == null) return false;
  if (head.contents.equals(o)){
   head = head.link;
   return true;
  }
// otherwise look for o in the list
```

List class: remove() continued

```
Node checkNode = head;
 while(checkNode.link != null){
  if (checkNode.link.contents.equals(o)){
   checkNode.link = checkNode.link.link;
   return true;
  } else {
   checkNode = checkNode.link;
  }
 } // end while
 return false;
}
```


Access to element at index i

- Access to element at index i comes less naturally to lists than to dynamic arrays.
- We'll postpone implementing **`get(int i)`** method until the next lecture, when we look at Iterators.
- Intuitively, Iterators are objects which know how to walk or iterate along the list. A bit like Tokenizers, they have **`boolean hasNext()`** and **`Object next()`** methods.
- We will implement **`get(int i)`** using an Iterator: get it to produce **`i`** items in order, and then return the **`i`**th item.

Digression: inner classes

- This is really a bit of a digression; but the List and Node classes are a good illustration of the use of inner classes.
- Another good illustration are graphical user interfaces, which we will see later in the course.

Inner, or nested, classes

- Classes can be members of other classes. Just like other members, they can be declared public or private, static etc. Why would one do this?
  - one class is auxiliary and only makes sense in the context of the other class (like the Node class)
  - convenience
  - encapsulation

Two kinds of nested classes

- top-level nested classes (static)
- inner classes (non-static)

- Static inner classes have the same status as top-level (ordinary) classes. They just tucked away in another class to keep the code tidy and readable.
- Static nested classes exist relative to the class where they are defined.
- Non-static nested classes exist relative to an object of the class.

Static nested classes

- Example from Arnold and Gosling:

```
public class BankAccount {
 private long number;
 private long balance;
 public static class Permissions {
   public boolean canDeposit,
                  canWithdraw,
                  canClose;
 }
 // class BankAccount continued
```

Inner classes

- Non-static nested classes are called inner classes. (In Java Gently they are called member classes).
- They cannot have static members.
- They have access to enclosing instance of other class, even to private fields and methods; **`this`** is used to refer to the inner class members, **`this`** prefixed by the outer class name to the outer class members.

Example

```
public class List {
  class Node {
      Object contents;
      Node link;
      Node(Object o, Node next) {
         this.contents = o;
         this.link = next;
      }
  }// end of Node class
  Node head;    // List continued
```


Example

- When the List class is compiled, so is the inner class Node. Instead of **`Node.class`**, we get

`List$Node.class`

- In general, when an nested (static or non-static) class A of class B is compiled, its name is given as B$A.class

Summary

- For nested classes, see Sun tutorial

http://java.sun.com/docs/books/tutorial/java/javaOO/nested.html

- For various linked lists and flexible arrays, any textbook with data structures in it, and Java API classes.
- Will see more of it in the Algorithms and Data Structures course next year.
- Good exercise: implement a recursive list in Java (like a list in Haskell).
- Snag to watch for: empty list not the same as null; probably will need a special empty list class.