Lists

The List ADT

Reading: Textbook Sections 3.1 – 3.5

List ADT

- A list is a **dynamic ordered** tuple of **homogeneous** elements

  $A_o, A_1, A_2, \ldots, A_{N-1}$

  where A_i is the i-th element of the list
- The *position* of element A_i is i; positions range from 0 to N-1 inclusive
- The *size* of a list is N (a list with no elements is called an “empty list”)

Generic Operations on a List

- create an empty list
- printList() – prints all elements in the list
- construct a (deep) copy of a list
- find(x) – returns the position of the first occurrence of x
- remove(x) – removes x from the list if present
- insert(x, position) – inserts x into the list at the specified position
- isEmpty( ) – returns true if the list has no elements
- makeEmpty( ) – removes all elements from the list
- findKth(int k) – returns the element in the specified position

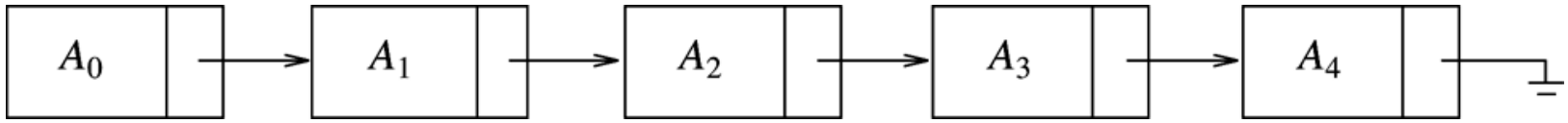
Simple Array Implementation of a List

- Use an array to store the elements of the list
  - Complexity for printList:
  - findkth,get and set:
- Also, arrays have a fixed capacity, but can fix with implementation.

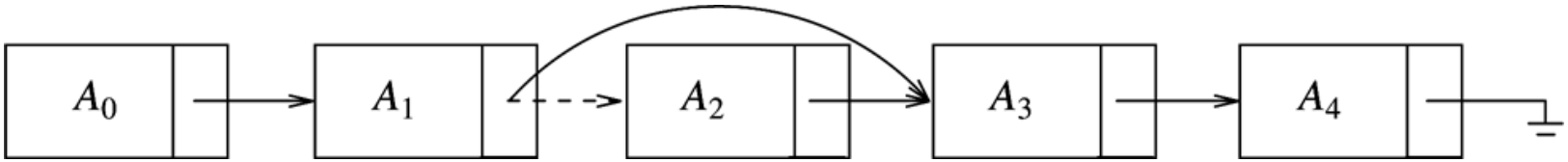
```
int arr[] = new int arr[10];
int newArr[] = new int[arr.length *2];
for(int i = 0; i < arr.length; i++)
  newArr[i] = arr[i];
arr = newArr;
```

Deletion

Linked List



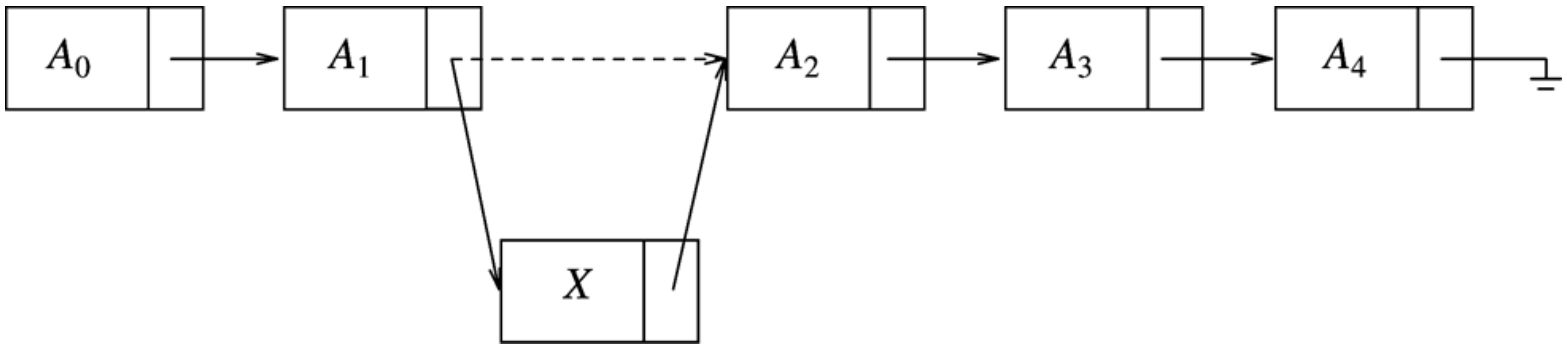
Deletion



A1 -> next =A2-> next;

Insertion

Insertion



Notice insert and delete can be constant time if node is inserted at beginning of List; however, findkth is now O(i).

The List ADT in Java Collections

- The List ADT is one of the data structures implemented in the Java Collections API.
- A list is abstracted using an inheritance hierarchy that stems from the Collection<E> interface , List<E>Interface in the java.util package and from the Iterable<E> interface in the java.lang package.
- The combination of these interfaces provides a uniform public interface for all Lists in Java

Methods from the Collections List ADT

```
//from Collection interface
 int size( );
boolean isEmpty( );
void clear( );
boolean contains( AnyType x );
boolean add( AnyType x );
boolean remove( AnyType x );
java.util.Iterator<AnyType> iterator( );
//from List interface
AnyType get( int idx );
AnyType set( int idx, AnyType newVal );
void add( int idx, AnyType x );
void remove( int idx );
ListIterator<AnyType> listIterator(int pos);
```

The Iterator<E> Interface

- The Collections framework provides two very useful interfaces for traversing a *Collection*. The first is the Iterator<E> interface.
- When the *iterator* method is called on a *Collection*, it returns an *Iterator* object which has the following methods for traversing the Collection.

```
boolean hasNext( );
AnyType next( );
void remove( );
```

Using an Iterator to Traverse a Collection

```
public static <AnyType>
void print( Collection<AnyType> coll )
{
    Iterator<AnyType> itr = coll.iterator( );
    while( itr.hasNext( ) ){
          AnyType item = itr.next( );
          System.out.println( item );
    }
}
```

The Enhanced for Loop

- The enhanced for loop in Java actually calls the *iterator* method when traversing a *Collection* and uses the *Iterator* to traverse the *Collection* when translated into byte code.

```
public static <AnyType> void
print( Collection<AnyType> coll )
{
      for( AnyType item : coll )
          System.out.println( item );
}
```

The ListIterator<E> Interface

- The second interface for traversing a *Collection* is the ListIterator<E> interface. It allows for the bidirectional traversal of a *List*.

```
boolean hasPrevious( );
AnyType previous( );
void add( AnyType x );
void set( AnyType newVal );
```

- A *ListIterator* object is returned by invoking the *listIterator* method on a *List*.

Concrete Implementations of the List ADT in the Java Collections API

- Two concrete implementations of the List API in the Java Collections API with which you are already familiar are:
  - java.util.ArrayList
  - java.util.LinkedList
- Let's examine the methods of these concrete classes that were developed at Sun.

List Operations on an ArrayList<E>

- Supports constant time for
  - insertion at the "end" of the list using

    ```
    void add(E element)
    ```
  - deletion from the "end" of the list using

    ```
    E remove(int index)
    ```
  - access to any element of the list using

    ```
    E get(int index)
    ```
  - changing value of any element of the list using

    ```
    E set(int index, E element)
    ```

List Operations on an **ArrayList**<E> (cont.)

- What is the growth rate for the following?
  - insertion at the "beginning" of the list using

    ```
    void add(int index, E element)
    ```

    O(N)

    Insertion at the "end" of the list

    O(C)
  - deletion from the "beginning" of the list using

    ```
    E remove(int index)
    ```

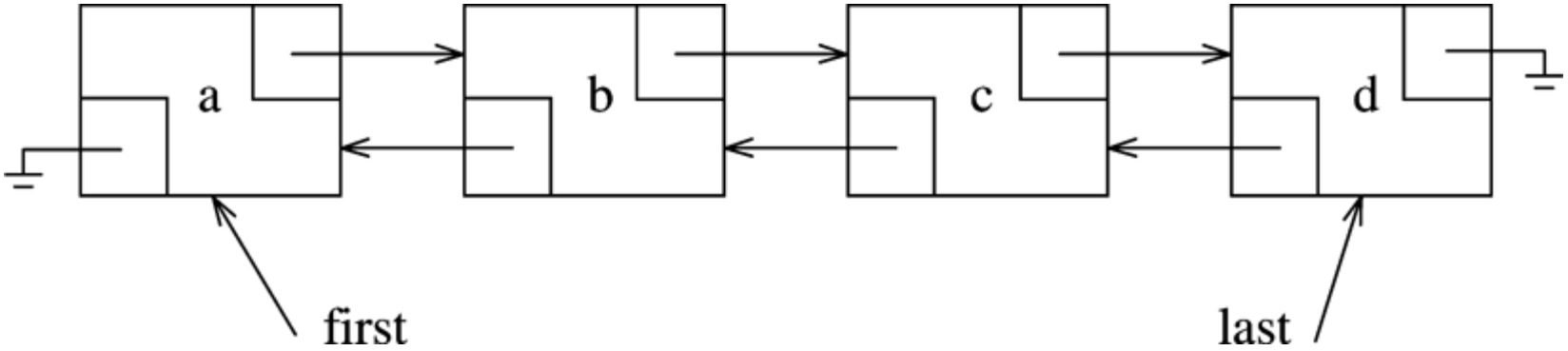
    O(N)

    Deletion from the "end" of the list

    O(C)

List Operations on a LinkedList<E>

- Provides doubly linked list implementation



List Operations on a LinkedList<E>

- Supports constant time for
  - insertion at the "beginning" of the list using
    `void addFirst(E o)`
  - insertion at the "end" of the list using
    `void addLast(E o)`
  - deletion from the "beginning" of the list using
    `E removeFirst()`
  - deletion from the "end" of the list using
    `E removeLast()`
  - Accessing first element of the list using
    `E getFirst()`
  - Accessing first element of the list using
    `E getLast()`

List Operations on a **LinkedList**<E>

- What is the running time for the following?
  - access to the "middle" element of the list using

```
E get(int index)
```

LinkedList: O(N)

ArrayList: O(1)

Example 1 –ArrayList vs. LinkedList

- What is the average running time for an ArrayList versus a LinkedList?

```
public static void
makeList1(List<Integer> list, int N)
{
  list.clear();
  for(int i = 0; i < N; i++)
     list.add(i);
}
```

ArrayList:O(N); LinkedList: O(N)

Example 2 –ArrayList vs. LinkedList

- What is the average running time for an ArrayList versus a LinkedList?

```
public static void
makeList2(List<Integer> list, int N)
{
      list.clear();
      for(int i = 0; i < N; i++)
          list.add(0,i);
}
```

ArrayList: O(N^2); LinkedList: O(N)

Example 3 –ArrayList vs. LinkedList

- What is the running time for an ArrayList versus a LinkedList?

```
public static
int sum(List<Integer> list, int N)
{
    int total = 0;
    for(int i = 0; i < N ; i++)
        total += list.get(i);
    return total;
}
```

ArrayList: O(N), LinkedList: O(N^2)

- How can we change this code so the running time for both is the same?: use iterator in LinkedList.

Example 4 –ArrayList vs. LinkedList

- What is the running time for an ArrayList versus a LinkedList?

```
public static void
removeEvensVer3(List<Integer> lst )
{
      Iterator<Integer> itr = lst.iterator( );

      while( itr.hasNext( ) )
          if( itr.next( ) % 2 == 0 )
              itr.remove( );
}
```

ArrayList: O(N^2): LinkedList: O(N)

Implementing Your Own **ArrayList**

- What do you need?
  1. Store elements in a parameterized array
  2. Track number of elements in array (size) and capacity of array

```
public class MyArrayList<AnyType>
implements Iterable<AnyType>
{
  private static final int DEFAULT_CAPACITY=10;
  private int theSize;
  private AnyType [ ] theItems;
```

3. Ability to change capacity of the array

```
public void ensureCapacity( int newCapacity )
{
        if( newCapacity < theSize )
            return;

        AnyType [ ] old = theItems;
        theItems = (AnyType []) new Object[
    newCapacity];
        for( int i = 0; i < size( ); i++ )
            theItems[ i ] = old[ i ];
}
```

4. get and set Methods

```
public AnyType get( int idx )
{
    if( idx < 0 || idx >= size( ) )
       throw new ArrayIndexOutOfBoundsException();
    return theItems[ idx ];
}

public AnyType set( int idx, AnyType newVal )
{
    if( idx < 0 || idx >= size( ) )
      throw new ArrayIndexOutOfBoundsException( );
    AnyType old = theItems[ idx ];
    theItems[ idx ] = newVal;
    return old;
}
```

5. size, isEmpty, and clear Methods

```
public void clear( ){
    theSize = 0;
    ensureCapacity( DEFAULT_CAPACITY );
}
public int size( ){
    return theSize;
}
public boolean isEmpty( ){
    return size( ) == 0;
}
// constructor invokes the clear method
public MyArrayList( ){
    clear( );
}
```

6. add Methods

/** Add to the end of the list */

```
public boolean add( AnyType x ){
        add( size( ), x );
        return true;
}
```

/** Add item ***x*** to the index of ***idx*** in the list */

```
public void add( int idx, AnyType x ){
        if( theItems.length == size( ) )
            ensureCapacity( size( ) * 2 + 1 );
        for( int i = theSize; i > idx; i-- )
            theItems[ i ] = theItems[ i - 1 ];
        theItems[ idx ] = x;
        theSize++;
}
```

7. remove and iterator Method

```
 /** Remove by index */
public AnyType remove( int idx ){
    AnyType removedItem = theItems[ idx ];
    for( int i = idx; i < size( ) - 1; i++ )
              theItems[ i ] = theItems[ i + 1 ];
    theSize--;
    return removedItem;
}

/**required by Iterable<E> interface */
 public java.util.Iterator<AnyType> iterator( ){
     return new ArrayListIterator(  );
 }
```

8. Iterator class

```
// private inner class for iterator
private class ArrayListIterator implements
  java.util.Iterator<AnyType>
    {
        private int current = 0;

        public boolean hasNext( )
          { return current < size( ); }
        public AnyType next( )
          { return theItems[ current++ ]; }
        public void remove( )
          { MyArrayList.this.remove( --current ); }
    }
}
```

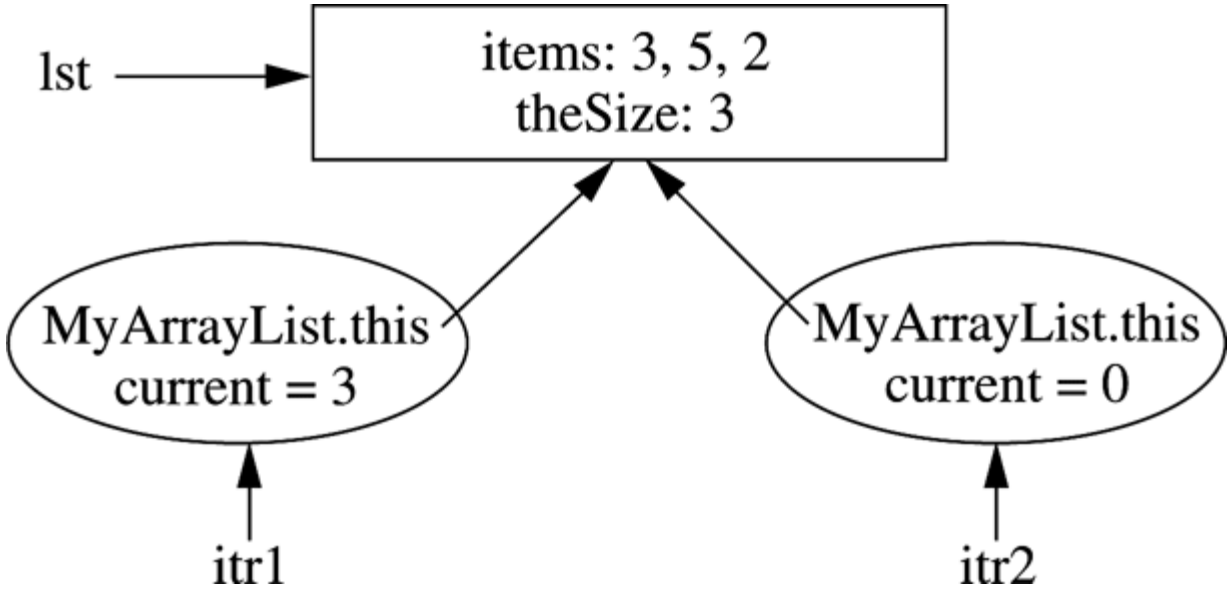
Implicit reference to outer class method

Implicit ref. to outer class data

Explicit reference to outer class method

The Iterator and Java Inner classes

- The implementation of the Iterator class required an inner class to allow one or more instances of Iterator for one outer class.



Sorted Lists

- Suppose we decided that the data in the lists should be stored in sorted order.
- What List code would need to be changed?
- How would sorting the data affect the performance of
  - Finding an element in the list: yes: best O(lgn)
  - Inserting an element into the list: yes new: O(n); old: O(1)
  - Removing an element from the list: yes; depends on the find()
  - other List functions

- Supl. Material: Inner class

```
class OuterClass {
    private String     someString = “this belongs to the outerClass”;

    class InnerClass {
       private  String someString2 = “this belongs to the innerClass”;

       public doSomethingHere
       {
          System.println(someString2);
       }
    }
}
Class MyTest {
   main ()
   {
        OuterClass   myOC;
        // will this compile?     - yes
        InnerClass myIC:
        // will this compile?  - no
        OuterClass.InnerClass myIC2; // yes this works.
        myIC2.doSomethingHere();
    }
}
```