
Lists - I

The List ADT

List ADT

- A list is a dynamic ordered tuple of homogeneous elements

$$A_0, A_1, A_2, \dots, A_{N-1}$$

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
 - printList is $O(n)$
 - findkth, get and set are constant time
 - Insert and delete?
- Also, arrays have a fixed capacity, but can fix with implementation.

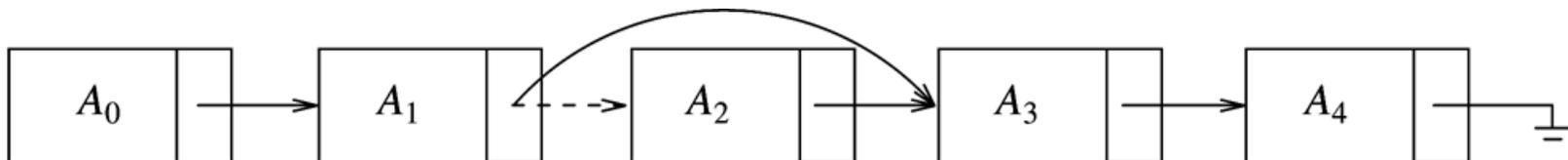
```
int []arr = new int arr[10];
int []newArr = new int[arr.length *2];
for(int i = 0; i < arr.length; i++)
    newArr[i] = arr[i];
arr = newArr;
```

Simple Linked List Implementation

Linked List

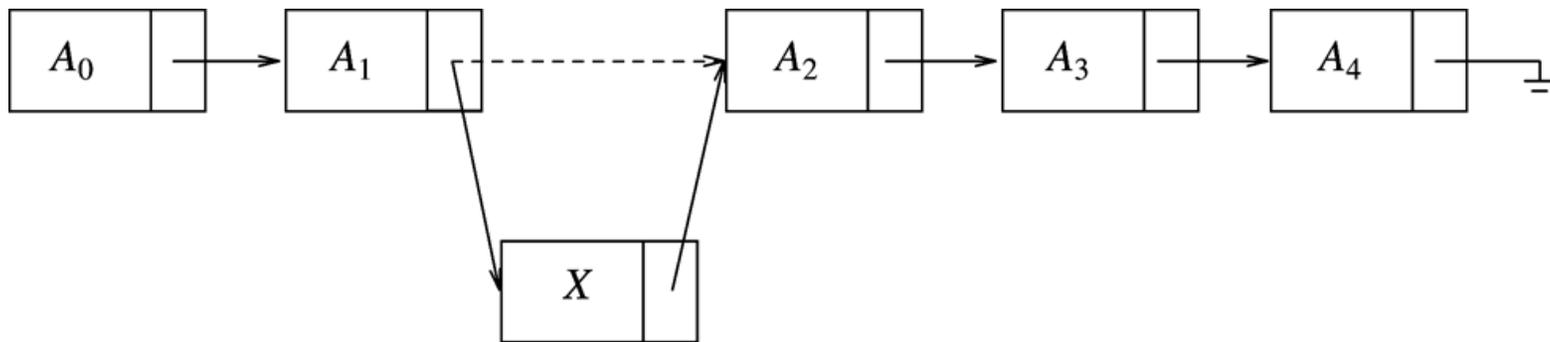


Deletion



Linked List Implementation of a List

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

- Example of using an Iterator object 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>`

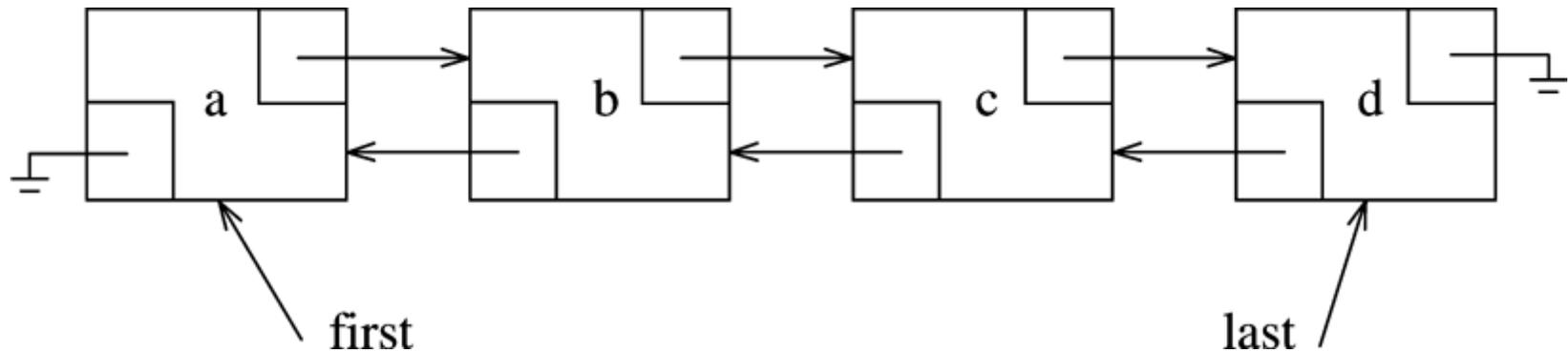
- Supports constant time for
 - insertion at the “end” of the list using
`void add(int index, E element)`
 - deletion from the “end” of the list using
`E remove(int index)`
 - access to any element of the list using
`E get(int index)`
 - changing value of any element of the list using
`E set(int index, 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)`
 - deletion from the “beginning” of the list using
`E remove(int index)`

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 last element of the list using
E getLast()

List Operations on a LinkedList<E>

- What is the growth rate for the following?
 - access to the “middle” element of the list using
E get(int index)

Example 1 –ArrayList vs. LinkedList

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

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

Example 2 –ArrayList vs. LinkedList

- What is the 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);
}
```

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;
}
```

- How can we change this code so the running time for both is the same?

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( );
}
```

Implementing Your Own ArrayList

- What do you need?

1. Store elements in a parametrized 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

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

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

```
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<AnyType>( );
}
```

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 ); }
}
}
```

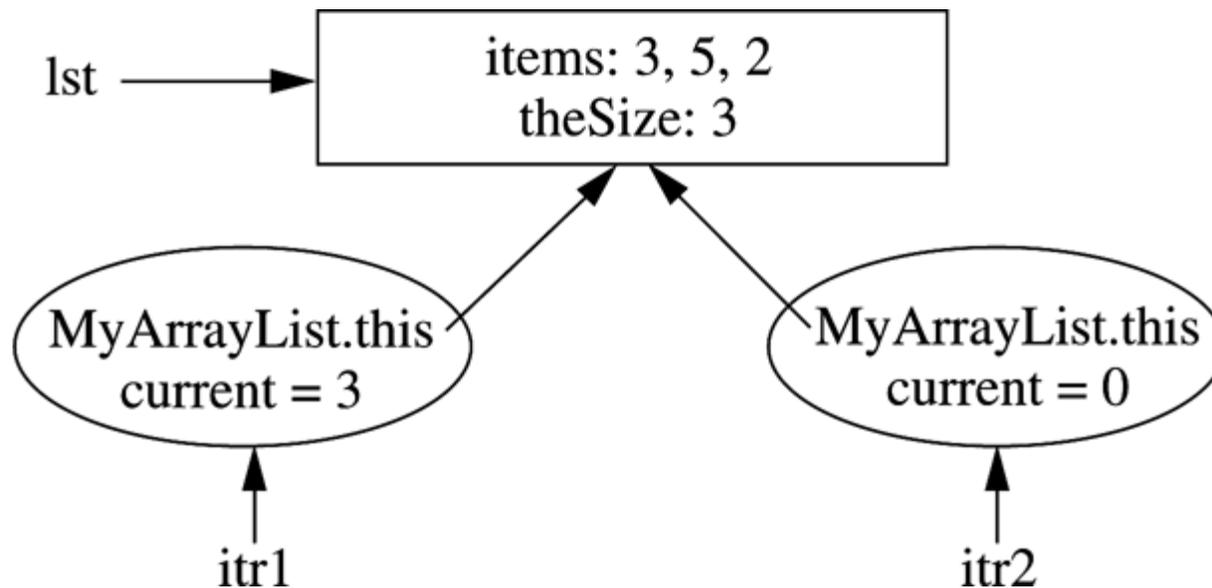
Implicit reference to outer class method

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.
- How would the sorted order be determined?
- What List code would need to be changed?
- How would sorting the data affect the performance of
 - Finding an element in the list
 - Inserting an element into the list
 - Removing an element from the list
 - other List functions