Data Structures

Iterators and Chain Linear List

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August 18, 2016

Outline

1. Iterators
   - The Method
   - Interface
   - Separate and Inner Class Iterator
     - Separate Class Iterator
     - Inner Class Iterator

2. Linked Representation
   - Introduction
   - Memory Layout
   - Operations
     - IsEmpty()
     - size()
     - Get(Index)
     - Remove
     - Add
   - Can we simplify the code?

3. Other data structures based in the Linked List
   - Circular List
   - Doubly Linked List
   - Where are all these things?

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Iterator Method

Scenario

We often want to access every item in a data structure or collection in turn...

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int listSize = SomeList.size();
for (int i = 0; i < listSize; i++)
        System.out.println(SomeList.get(i));
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For example the get in a Chain List

We will see that it has complexity $O(n)$!!!

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Something Notable

Iteration is such a common operation that we could include it as part of the ADT list.

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We do not want to add another operation to the ADT each time we think of another way to use an iteration.

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In Java at java.util we have the interface Iterator

Interface

```
package java.util;
public interface Iterator<Item> {

public boolean hasNext();

public Item next();

// Optional method
public void remove();

} // end Iterator
```

Explanation

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- It removes from the collection of data the last entry that next() returned.

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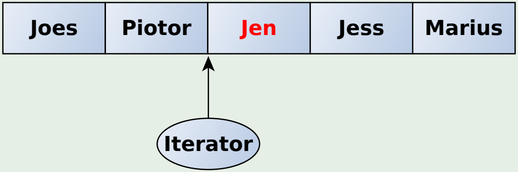
Effect in a list

The List Before Any Operation with the Iterator



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After the next() operation

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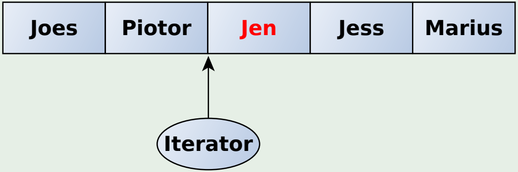

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Iterator

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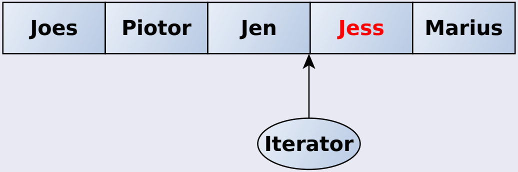

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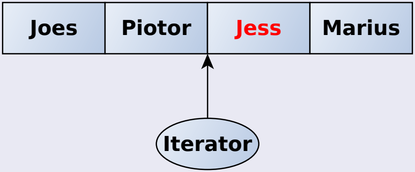
Iterator

Effect in a list

Now, we issue a remove()



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Iterator

NO FREE LUNCH!!!

Remark

Some details of using an iterator depend on the approach used to implement the iterator methods.

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We can do the following

- A possible, but not optimal, way to provide an ADT with traversal operations is to define them as ADT operations.
  - For example, if **ListInterface extends Iterator**, a list object would have iterator methods as well as list methods.
  - PROBLEM!!! What if you want to have two or more iterators over the object list making different things at the same time!!!

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Iterator<String> nameIterator = new SeparateIterator<String>(nameList);

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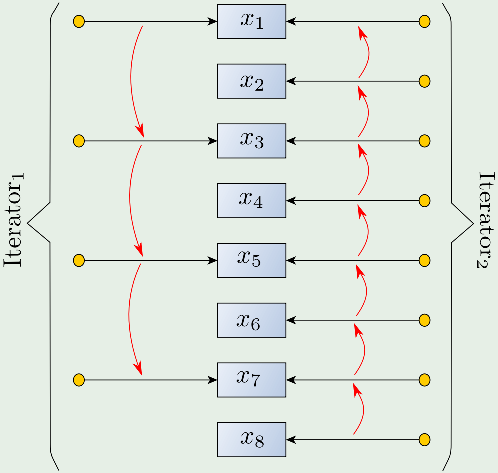
Example

This allows us to build iterators that go slower of faster over the list



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Multiple Iterators

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External Iterators provides a solution to multiple iterators

However

Huge Problem

We can only access the list through the public methods:

- What if they are not enough?

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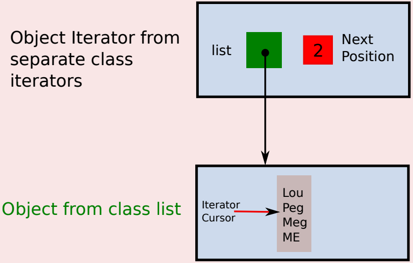

Huge Problem

We can only access the list through the public methods:

- What if they are not enough?

Separate Iterator Code

Code

```
import java.util.Iterator;
import java.util.NoSuchElementException;

public class SeparateIterator<Item>
                 implements Iterator<Item> {

private LinearList<Item> list;
// position of entry last returned by next()
private int nextPosition;
// needed by remove
private boolean wasNextCalled;

public SeparateIterator(ListList<Item> aList) {
// All that it implies
} // end constructor

< Implementations of the methods hasNext ,...
next , and remove go here > . . .
} // end SeparateIterator
```

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We need a better solution!!!

Declare a inner class

So you can have direct access to the protected or private elements in the object!!!

Actually you have something like this

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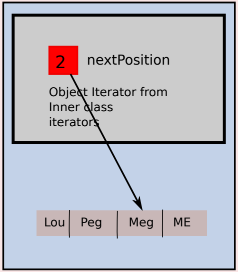
Object from class array list



Inner Class Code

Code

```
import java.util.Iterator;
import java.util.NoSuchElementException;

public class ArrayListWithIterator<T>
             implements ListWithIteratorInterface<T> {

// ALL the code for array linear list

private class IteratorForArrayList
             implements Iterator<T> {
private int nextIndex;
private boolean wasNextCalled;

private IteratorForArrayList() {
        nextIndex = 0;
        wasNextCalled = false;
} // end default constructor

< Implementations of the methods in the
interface Iterator go here > . . . }
// end IteratorForArrayList

} // end  ArrayListWithIterator
```

So, we have...

Advantages

- It is a way of logically grouping classes that are only used in one place.
- It increases encapsulation
- It can lead to more readable and maintainable code.

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Linked Representation

Storage

List elements are stored, in memory, in an arbitrary order.

How you move through it

Explicit information (called a link) is used to go from one element to the next.

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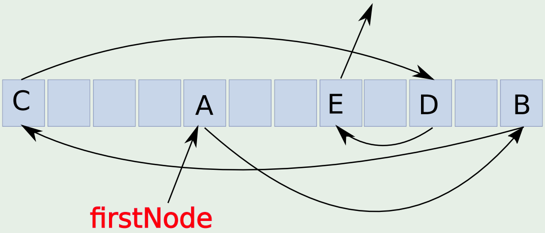

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Last pointer (or link) from E is null

Thus

You can use a variable firstNode to get to the first element in the Linked List.

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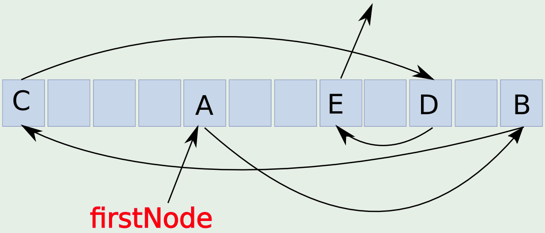

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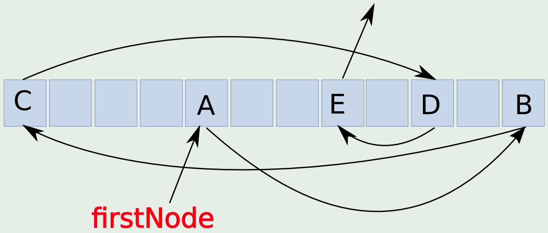

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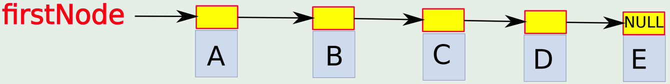
Normal Way To Draw A Linked List

Example



🟨 Link or pointer field of node

▭ Data field of node

Actually, we know this as a Chain

First

A chain is a linked list in which each node represents one element.

Second

There is a link or pointer from one element to the next.

Third

The last node has a null pointer.

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The last node has a null pointer.

Code for ChainNode

Code

```
package LinearList;
//Using Generic in Java
class ChainNode<Item>{
   // package data members
   protected Item element;
   protected ChainNode next;
   // constructors and methods come here
}
```

The Constructors for ChainNode

A classic one

```
package LinearList;
//Using Generic in Java
public ChainNode(){
   // Set the next node
   this.element = null;
   this.next = null;
}

public ChainNode(Item elem){
   // Set element
    this.element = elem;
    this.next = null;
}
```

What about the Class Chain?

Code

```
/** linked implementation of LinearList */
package infrastructures;
import java.util.*;  // has Iterator
public class Chain<Item> implements LinearList<Item>
{
// data members
protected ChainNode<Item> firstNode;
protected int size;

// methods of Chain come here
}
```

In addition!!! Constructors!!!

Code

```
public Chain<Item> (int initialCapacity)
{

// the default initial values of firstNode and size
// are null and 0, respectively

}
```

A simple example

```
public Chain<Item> ()
    {
        this.firstNode = new ChainNode<Item>();
        this.size = 0;
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IsEmpty()

Really Simple Code

```
/** @return true iff list is empty */
   public boolean isEmpty()
      {return size == 0;}
```

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size()

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/** @return current number of elements in list */
    public int size()
        {return size;}
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Operations: Get

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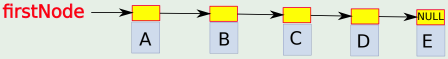

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What to do to implement Get

1. Check Index
2. Move to the correct position
   - For example: TempNode = firstNode.next.next.next.
   - You actually use a loop.
3. return TempNode.element

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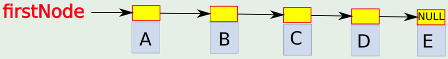

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Check Index

$$0 \leq index \leq size - 1 \tag{1}$$

Negate the statement to use it

How?

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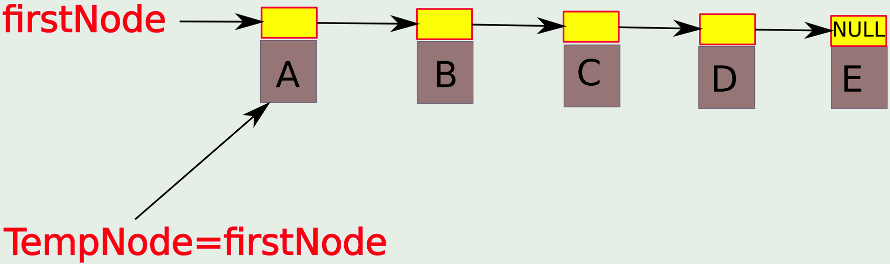


firstNode

NULL

A

B

C

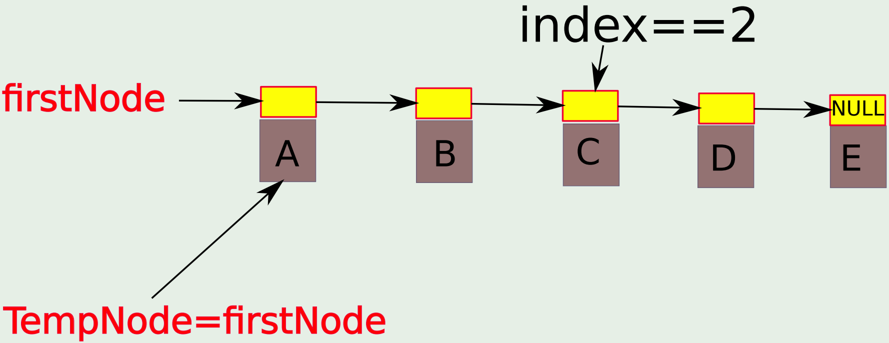
D

E

TempNode=firstNode

Move to the correct place

Index == 2



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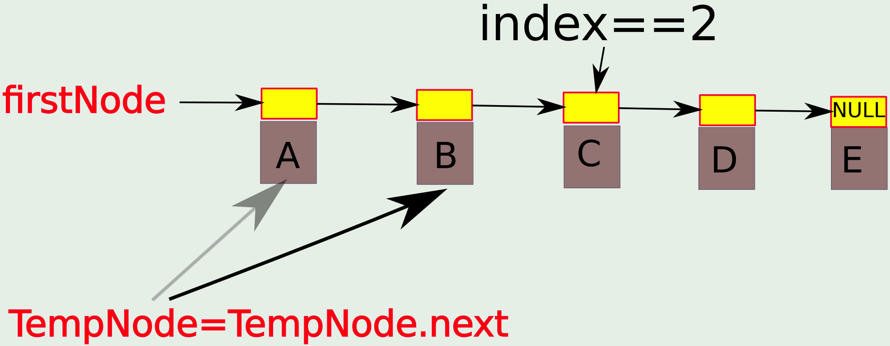

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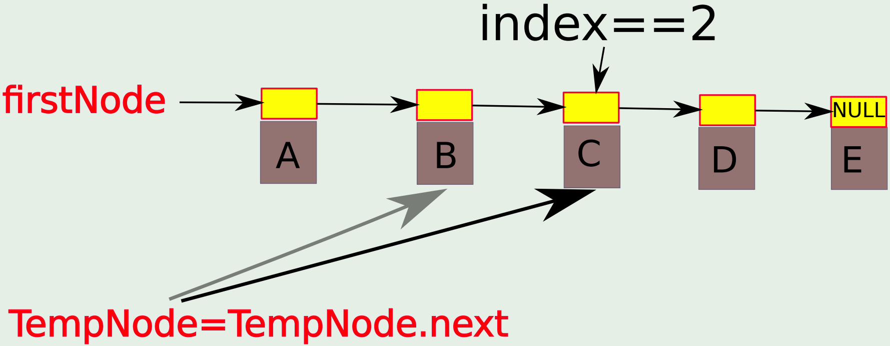

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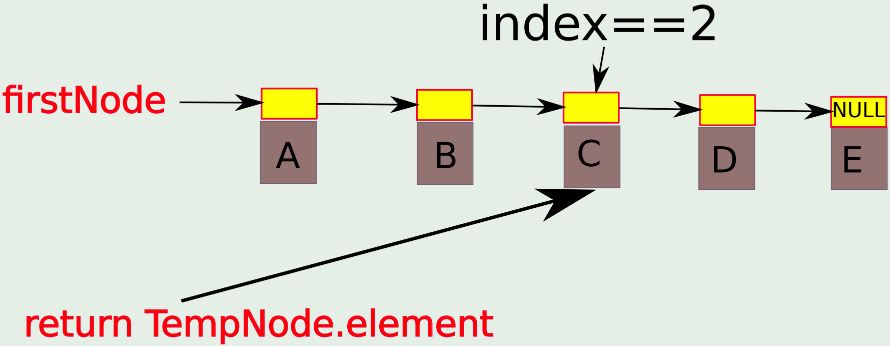

Code

Here is the method

```
public <Item> get(int index){
     ChainNode<Item> TempNode;
     //Check always
     if (this.size == 0) return null;
     if (index<0 || index>this.size -1){
          System.out.println("Index␣out␣of␣bound");
          System.exit(0);
     }
     //Move to the correct position
     TempNode = this.firstNode;
     for(int i=0 ; i<index ; i++){
          TempNode = TempNode.next;
     }
     return TempNode.element;
}
```

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   - Where are all these things?

Now, Remove

We have two cases

Any ideas?

Case I

Removing from the beginning.

Case II

Remove from the middle.

Now, Remove

We have two cases

Any ideas?

Case I

Removing from the beginning.

Case II

Remove from the middle.

Now, Remove

We have two cases

Any ideas?

Case I

Removing from the beginning.

Case II

Remove from the middle.

Case I: Remove(0)

Process

```
1 if index == 0 do
    1 TempNode = firstNode
    2 firstNode=firstNode.next
    3 TempNode.next=NULL
    4 return TempNode.element
```

Case I: Remove(0)

Process

```
1. if index == 0 do
    1. TempNode = firstNode
    2. firstNode=firstNode.next
    3. TempNode.next=NULL
    4. return TempNode.element
```

Case I: Remove(0)

Process

```
1 if index == 0 do
    1 TempNode = firstNode
    2 firstNode=firstNode.next
    3 TempNode.next=NULL
    4 return TempNode.element
```

Case I: Remove(0)

Process

```
1 if index == 0 do
    1 TempNode = firstNode
    2 firstNode=firstNode.next
    3 TempNode.next=NULL
    4 return TempNode.element
```

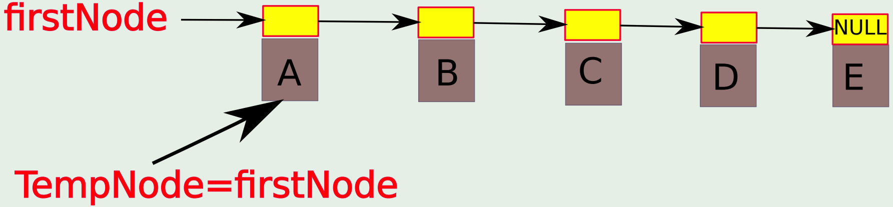
Case I: Remove(0)

Process

```
1 if index == 0 do
    1 TempNode = firstNode
    2 firstNode=firstNode.next
    3 TempNode.next=NULL
    4 return TempNode.element
```

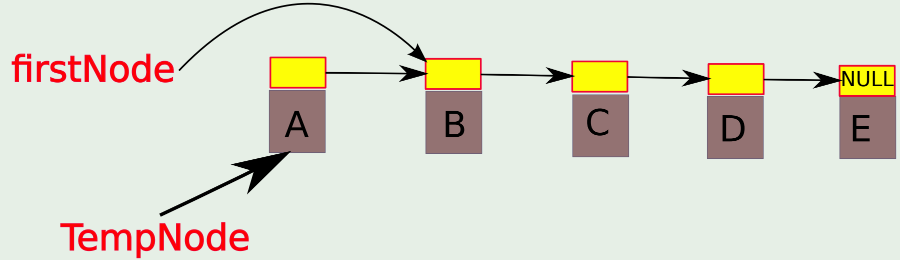
Process

TempNode=firstNode



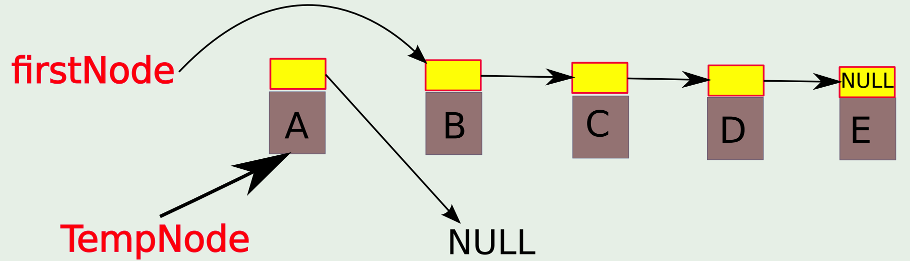
Process

firstNode=firstNode.next



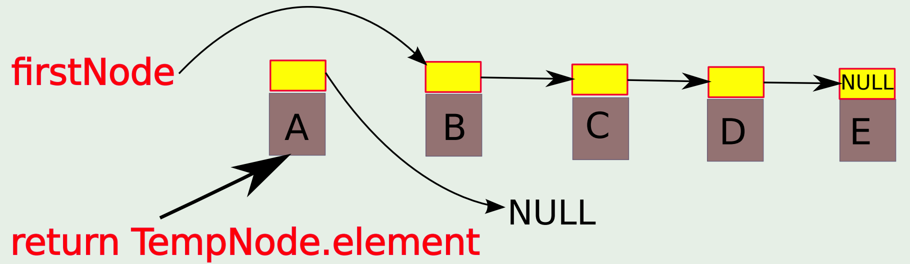
Process

TempNode.next=NULL



Process

return TempNode.element



Case II: Remove(2)

Process

1. Check Index
2. Starting at the first node
3. TempNode=firstNode;
4. Loop doing
    1. beforeNode=TempNode;
    2. TempNode=TempNode.next;
5. before.next = TempNode.next
6. TempNode.next = NULL
7. return TempNode.element

Case II: Remove(2)

Process

1. Check Index
2. Starting at the first node
3. TempNode=firstNode;
4. Loop doing
    1. beforeNode=TempNode;
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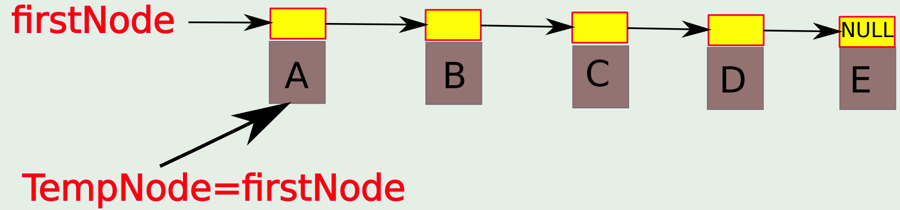
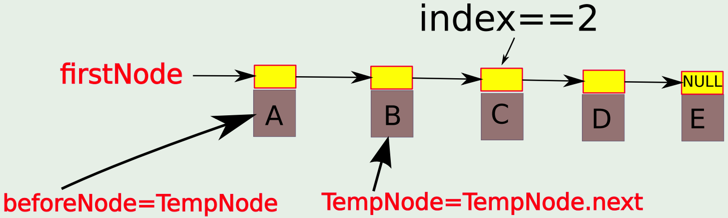
Process

TempNode=firstNode



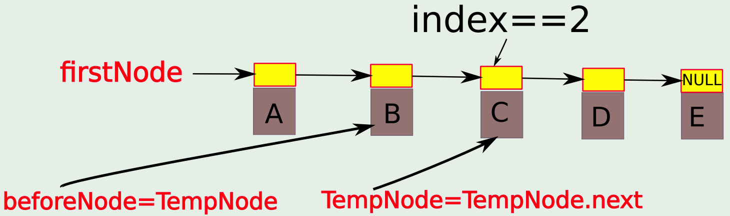
Process: index == 2

```
beforeNode=TempNode;
TempNode=TempNode.next;
```



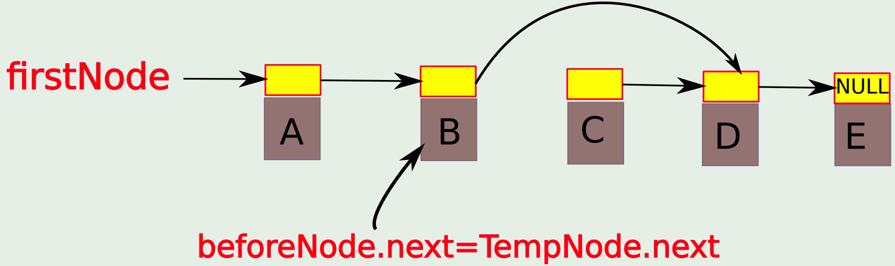
Process: index == 2

beforeNode=TempNode;
TempNode=TempNode.next;



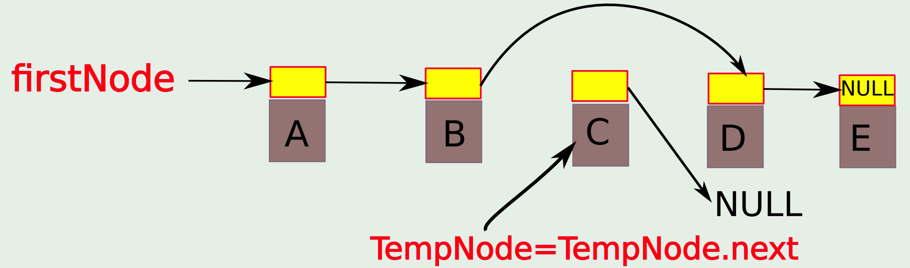
Process: index == 2

before.next = TempNode.next



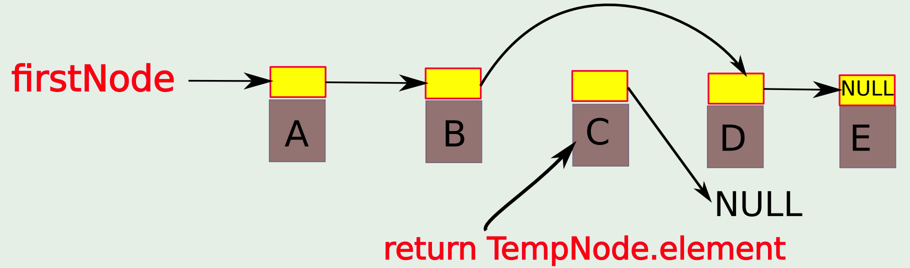
Process: index == 2

TempNode.next = NULL



Process: index == 2

TempNode.next = NULL



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Now, Add

We have four cases

Any ideas?

Case I

The Chain is Empty

Case II

Add at the beginning.

Now, Add

We have four cases

Any ideas?

Case I

The Chain is Empty

Case II

Add at the beginning.

Now, Add

We have four cases

Any ideas?

Case I

The Chain is Empty

Case II

Add at the beginning.

Now, Add

We have four cases

Any ideas?

Case III

Add at the middle.

Case IV

Add at the end.

Now, Add

We have four cases

Any ideas?

Case III

Add at the middle.

Case IV

Add at the end.

Now, Add

We have four cases

Any ideas?

Case III

Add at the middle.

Case IV

Add at the end.

Why?

Think About it!!!

Remember you have a sequential access.

Add at an empty list

Steps

1. Create a node to store the element, NewNode
2. Then assign firstNode = NewNode

Add at an empty list

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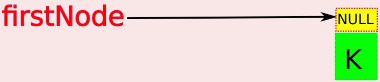

Add At the Beginning

Steps

1. Create a node to store the element, NewNode
2. Do NewNode.next = firstNode
3. Then reassign firstNode = NewNode
4. Then, size = size +1

Add At the Beginning

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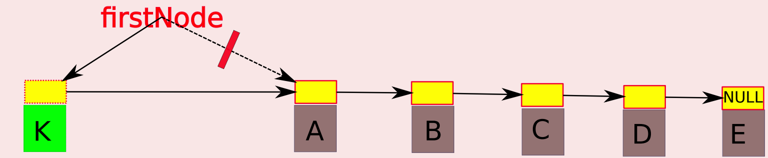

What about the other case?

Do you have an idea?

- Add at the Middle.
- Add at the end.

What about the other methods?

Linear List

```
AbstractDataType LinearList
{
   instances
      ordered finite collections of zero or more elements
   operations
      isEmpty(): return true iff the list is empty, false otherwise
      size(): return the list size (i.e., number of elements in the list)
      get(index): return the element with the “index” index
      indexOf(x): return the index of the first occurrence of x in the list, return -1
                  if x is not in the list
      remove(index): remove and return the indexth element, elements with higher
                     index have their index reduced by 1
      add(theIndex, x): insert x as the index of th element, elements with
                        theIndex ≥ index have their index increased by 1
      output(): output the list elements from left to right
}
```

Complexity of Linked List

We have

	Dynamic Array Amortized Analysis	Linked List
Indexing	$O(1)$	$O(n)$
Search	$O(n)$	$O(n)$
Add/Remove at the beginning	$O(n)$	$O(1)$
Add/Remove at the middle	$O(n)$	Search Time $+O(1)$
Space Complexity	$O(n)$	$O(n)$

Average Performance with Each Implementation on a Slow Machine!!!

40,000 Operations each type on a 350Mhz PC

Operation	FastArrayLinearList	Chain
average get	5.6 ms	157 sec
average adds	5.8 sec	115 sec
average removes	5.8 sec	157 sec

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Can we simplify the code?

How?

We would like to simplify the code.... How?

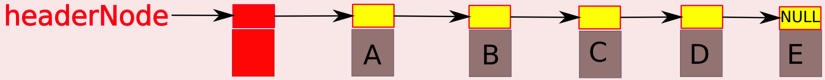
What about

Can we simplify the code?

How?

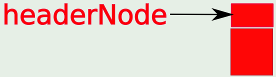
We would like to simplify the code.... How?

What about



Can we simplify the code?

Then, the empty list looks like

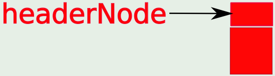


Thus

This simplify a lot the code because everything is a middle node

Can we simplify the code?

Then, the empty list looks like



Thus

This simplify a lot the code because everything is a middle node

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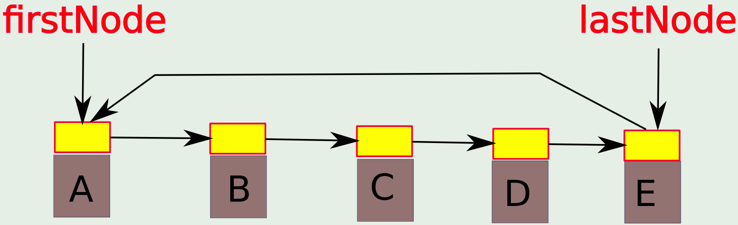
Circular List

Circular List



Here, we need to have the following changes

We need to add the following to the class

```
/** linked implementation of LinearList */
package infrastructures;
import java.util.*;  // has Iterator
public class Chain<Item> implements LinearList<Item>
{
// data members
protected ChainNode<Item> firstNode;
protected ChainNode<Item> lastNode;
protected int size;

// methods of Chain come here
}
```

Example of add(index) at the end

Process

- Check if (index==size-1)

Next

Make the lastNode.next = TempNode

Then

TempNode.next = firstNode

Example of add(index) at the end

Process

- Check if (index==size-1)

Next

Make the lastNode.next = TempNode

Then

TempNode.next = firstNode

Example of add(index) at the end

Process

- Check if (index==size-1)

Next

Make the lastNode.next = TempNode

Then

TempNode.next = firstNode

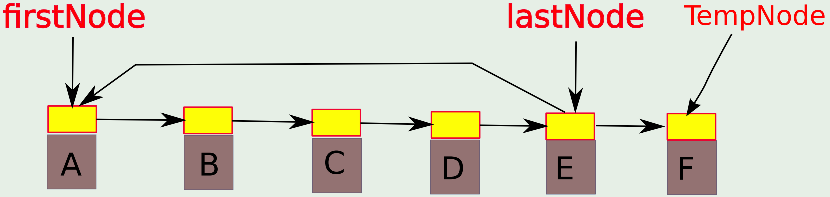
Example of add(index) at the end

Finally

lastNode = TempNode

Circular List

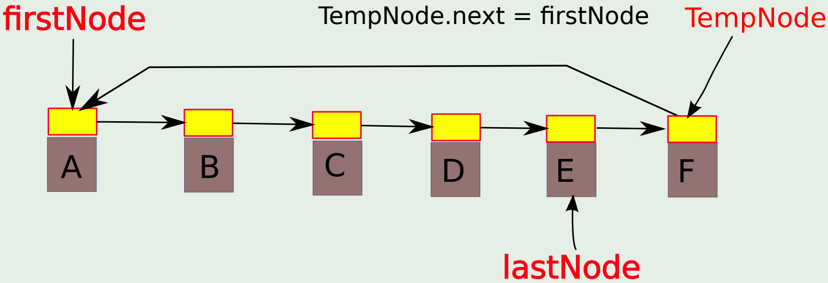
Add at the end



lastNode.next = TempNode

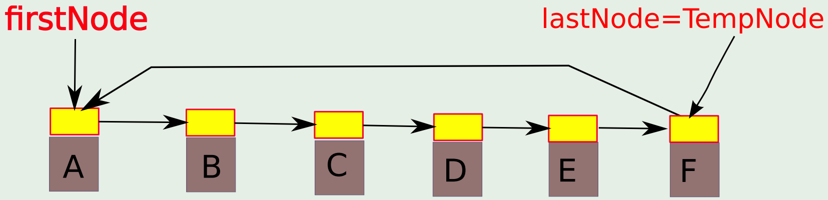
Circular List

Add at the end



Circular List

Add at the end



We have other representations for the lists

Doubly Linked List

- You have two chain list going through the nodes.
- It has a firstNode
- It has a lastNode

Doubly Linked Circular List

- You have two chain list going through the nodes.
- It has a firstNode

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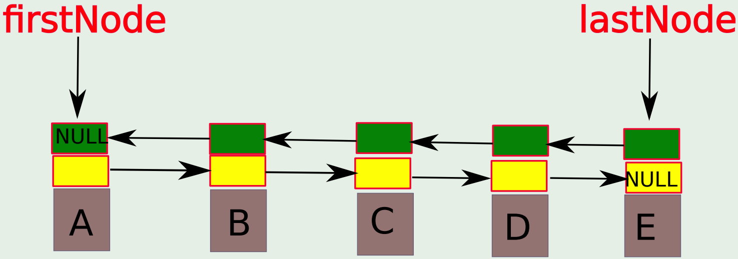
Doubly Linked List

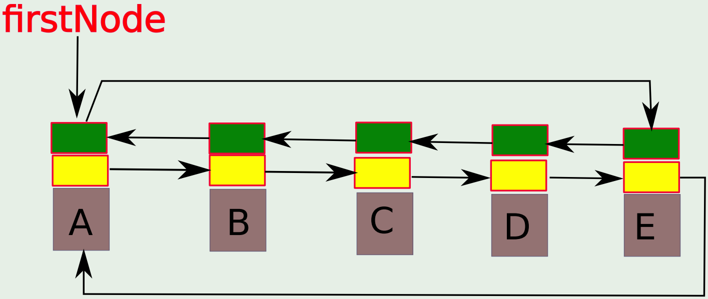
Doubly Linked List



What about the changes here

Doubly Linked Circular List

Doubly Linked Circular List



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Where does Java has all these things?

Package

java.util.LinkedList

There you have

- It has the Linked implementation of a linear list.

Where does Java has all these things?

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java.util.LinkedList

There you have

- It has the Linked implementation of a linear list.
- It has the doubly linked circular list with header node.
- It Has all methods of LinearList plus many more.

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