Building Java Programs

Chapter 16
Linked List Basics

reading: 16.2
Linked node problem 3

- What set of statements turns this picture:

  list1 □ □
  data | next  
  --- | ---
  10 |  

  list2 □ □
  data | next  
  --- | ---
  30 |  

  data | next  
  --- | ---
  10 | □

- Into this?

  list1 □ □
  data | next  
  --- | ---
  10 |  

  list2 □ □
  data | next  
  --- | ---
  40 | □

  data | next  
  --- | ---
  30 | □
Linked node problem 3

• How many ListNode variables?

list1

A

list2

D

10

30

next

next

10

30

• Which variables change?

list1

next

10

next

10

next

next

next

30

20

40

30
References vs. objects

\[
\text{variable} = \text{value};
\]

a \textit{variable} (left side of =) place to put a reference
(where the phone number goes; where the base of the arrow goes)
a \textit{value} (right side of =) is the reference itself
(the phone number; the destination of the arrow)

- For the list at right:
  - \texttt{a.next = value;} \\
    means to adjust where points

  - \texttt{variable = a.next;} \\
    means to make \texttt{variable} point at
Linked node question

- Suppose we have a long chain of list nodes:

  - We don't know exactly how long the chain is.

- How would we print the data values in all the nodes?
Algorithm pseudocode

Start at the **front** of the list.
While (there are more nodes to print):
  Print the current node's **data**.
  Go to the **next** node.

- How do we walk through the nodes of the list?
  
  ```
  list = list.next;
  // is this a good idea?
  ```

```
<table>
<thead>
<tr>
<th></th>
<th>data</th>
<th>next</th>
</tr>
</thead>
<tbody>
<tr>
<td>list</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20</td>
<td></td>
</tr>
<tr>
<td></td>
<td>...</td>
<td></td>
</tr>
<tr>
<td></td>
<td>990</td>
<td></td>
</tr>
</tbody>
</table>
```
Traversing a list?

- One (bad) way to print every value in the list:

```java
while (list != null) {
    System.out.println(list.data);
    list = list.next;        // move to next node
}
```

- What's wrong with this approach?
  - (It loses the linked list as it prints it!)
A current reference

- Don't change `list`. Make another variable, and change it.
  - A `ListNode` variable is NOT a `ListNode` object

```
ListNode current = list;
```

- What happens to the picture above when we write:
  ```
current = current.next;
```
Traversing a list correctly

- The correct way to print every value in the list:

```java
ListNode current = list;
while (current != null) {
    System.out.println(current.data);
    current = current.next; // move to next node
}
```

- Changing `current` does not damage the list.
**Linked List vs. Array**

- **Print list values:**

  ```java
  ListNode list = ...;
  ListNode current = list;
  while (current != null) {
      System.out.println(current.data);
      current = current.next;
  }
  ```

- **Similar to array code:**

  ```java
  int[] a = ...;
  int i = 0;
  while (i < a.length) {
      System.out.println(a[i]);
      i = i + 1;
  }
  ```

<table>
<thead>
<tr>
<th>Description</th>
<th>Array Code</th>
<th>Linked List Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Go to front of list</td>
<td><code>int i = 0;</code></td>
<td><code>ListNode current = list;</code></td>
</tr>
<tr>
<td>Test for more elements</td>
<td><code>i &lt; size</code></td>
<td><code>current != null</code></td>
</tr>
<tr>
<td>Current value</td>
<td><code>elementData[i]</code></td>
<td><code>current.data</code></td>
</tr>
<tr>
<td>Go to next element</td>
<td><code>i=i+1;</code></td>
<td><code>current = current.next;</code></td>
</tr>
</tbody>
</table>
Abstract data types (ADTs)

- **abstract data type (ADT):** A specification of a collection of data and the operations that can be performed on it.
  - Describes *what* a collection does, not *how* it does it

- Java's collection framework describes several ADTs:
  - Queue, List, Collection, Deque, List, Map, Set

- An ADT can be implemented in multiple ways:
  - `ArrayList` and `LinkedList` implement `List`
  - `HashSet` and `TreeSet` implement `Set`
  - `LinkedList`, `ArrayDeque`, etc. implement `Queue`

- The **same** external behavior can be implemented in many different ways, each with pros and cons.
A LinkedIntList class

- Let's write a collection class named LinkedIntList.
  - Has the same methods as ArrayIntList:
    - add, add, get, indexOf, remove, size, toString

- The list is internally implemented as a chain of linked nodes
  - The LinkedIntList keeps a reference to its front as a field
  - null is the end of the list; a null front signifies an empty list
public class LinkedIntList {
    private ListNode front;

    public LinkedIntList() {
        front = null;
    }

    methods go here
}

new LinkedIntList()
Poll Everywhere Workflow

1. Think (1 minute)
   1. Take 45 seconds to think on your own about the problem
   2. Take 15 seconds to poll in by yourself

2. Pair (2 minutes) [TAs will walk around]
   1. Take 1.5 minutes to talk with your neighbors about the problem and compare how you answered
      • If you and your neighbors agree, try to figure out why the other answers might be wrong
      • If you and your neighbors disagree, talk about the material to figure out who is right!
   2. Take 30 seconds to finish discussion and poll in with your new final answer

3. Share (2 minutes)
   1. Talk as a class about what people were answering in and why
Suppose our list had the contents

```
front

<table>
<thead>
<tr>
<th>data</th>
<th>next</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>30</td>
</tr>
</tbody>
</table>
```

Practice simulating the code we wrote and tell us what the result will look like when we call `list.add(40);`

```
public void add(int value) {
    ListNode curr = front;
    while (curr != null) {
        curr = curr.next;
    }
    curr = new ListNode(value);
}
```

Options

- `[10, 20, 30]`
- `[10, 20, 40]`
- `[10, 20, 40, 30]`
- `[10, 20, 30, 40]`
- Error
Before/After

• Before

front

<table>
<thead>
<tr>
<th>data</th>
<th>next</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>data</th>
<th>next</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>data</th>
<th>next</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td></td>
</tr>
</tbody>
</table>

• After

front

<table>
<thead>
<tr>
<th>data</th>
<th>next</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>data</th>
<th>next</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>data</th>
<th>next</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>data</th>
<th>next</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td></td>
</tr>
</tbody>
</table>
Implementing `add`

// Adds the given value to the end of the list.
public void add(int value) {
    ...
}

- How do we add a new node to the end of a list?
- Does it matter what the list's contents are before the add?
Adding to an empty list

- Before adding 20:

  \[
  \text{front} = \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad
\]

- After:

\[
\begin{array}{|c|c|}
\hline
\text{data} & \text{next} \\
\hline
20 & \text{element 0} \\
\hline
\end{array}
\]

- We must create a new node and attach it to the list.
The `add` method, 1st try

```java
// Adds the given value to the end of the list.
public void add(int value) {
    if (front == null) {
        // adding to an empty list
        front = new ListNode(value);
    } else {
        // adding to the end of an existing list
        ...
    }
}
```
Adding to non-empty list

- Before adding value 20 to end of list:

- After:
Don't fall off the edge!

- To add/remove from a list, you must modify the `next` reference of the node *before* the place you want to change.

  - Where should `current` be pointing, to add 20 at the end?
  - What loop test will stop us at this place in the list?
The **add** method

// Adds the given value to the end of the list.
public void add(int value) {
    if (front == null) {
        // adding to an empty list
        front = new ListNode(value);
    } else {
        // adding to the end of an existing list
        ListNode current = front;
        while (current.next != null) {
            current = current.next;
        }
        current.next = new ListNode(value);
    }
}
changing a list

- There are only two ways to change a linked list:
  - Change the value of \texttt{front} (modify the front of the list)
  - Change the value of \texttt{<node>.next} (modify middle or end of list to point somewhere else)

- Implications:
  - To add in the middle, need a reference to the \textit{previous} node
  - Front is often a special case
Implementing `get`

// Returns value in list at given index.
public int get(int index) {
    ...
}

- Exercise: Implement the `get` method.
The `get` method

// Returns value in list at given index.
// Precondition: 0 <= index < size()
public int get(int index) {
    ListNode current = front;
    for (int i = 0; i < index; i++) {
        current = current.next;
    }
    return current.data;
}
// Inserts the given value at the given index.
public void add(int index, int value) {
    ...
}

- Exercise: Implement the two-parameter `add` method.
The `add` method (2)

// Inserts the given value at the given index.
// Precondition: 0 <= index <= size()
public void add(int index, int value) {
    if (index == 0) {
        // adding to an empty list
        front = new ListNode(value, front);
    } else {
        // inserting into an existing list
        ListNode current = front;
        for (int i = 0; i < index - 1; i++) {
            current = current.next;
        }
        current.next = new ListNode(value, current.next);
    }
}