Recreation

Prove that \[ \lfloor (2 + \sqrt{3})^n \rfloor \] is odd for all integer \( n \geq 0 \).

CS61B Lecture #4: Values and Containers

• I will post classroom announcements from outside groups to Piazza in the future in the 'outside_postings' folder.

• Labs are normally due at midnight Friday.

• Project 0 now released.

• **Today.** Simple classes. Scheme-like lists. Destructive vs. non-destructive operations. Models of memory.
Values and Containers

- **Values** are numbers, booleans, and pointers. Values never change.

  3  'a'  true  \_

- **Simple containers** contain values:

  Examples: variables, fields, individual array elements, parameters.
Structured Containers

Structured containers contain (0 or more) other containers:

<table>
<thead>
<tr>
<th>Class Object</th>
<th>Array Object</th>
<th>Empty Object</th>
</tr>
</thead>
<tbody>
<tr>
<td>h: 3 h: 3</td>
<td>0: 42 1: 17 2: 9</td>
<td></td>
</tr>
<tr>
<td>t: 0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Alternative Notation
Pointers

- **Pointers** (or references) are values that reference (point to) containers.

- One particular pointer, called **null**, points to nothing.

- In Java, structured containers contain only simple containers, but pointers allow us to build arbitrarily big or complex structures anyway.
Containers in Java

- Containers may be named or anonymous.
- In Java, all simple containers are named, all structured containers are anonymous, and pointers point only to structured containers. (Therefore, structured containers contain only simple containers).

![Diagram showing simple and structured containers]

- In Java, assignment copies values into simple containers.
- Exactly like Scheme and Python!
- (Python also has slice assignment, as in \(x[3:7]=\ldots\), which is shorthand for something else entirely.)
Defining New Types of Object

- Class declarations introduce new types of objects.
- Example: list of integers:

```java
public class IntList {
    // Constructor function (used to initialize new object)
    /** List cell containing (HEAD, TAIL). */
    public IntList(int head, IntList tail) {
        this.head = head; this.tail = tail;
    }

    // Names of simple containers (fields)
    // WARNING: public instance variables usually bad style!
    public int head;
    public IntList tail;
}
```
Primitive Operations

IntList Q, L;

L = new IntList(3, null);
Q = L;

Q = new IntList(42, null);
L.tail = Q;

L.tail.head += 1;
// Now Q.head == 43
// and L.tail.head == 43
Side Excursion: Another Way to View Pointers

• Some folks find the idea of “copying an arrow” somewhat odd.
• Alternative view: think of a pointer as a label, like a street address.
• Each object has a permanent label on it, like the address plaque on a house.
• Then a variable containing a pointer is like a scrap of paper with a street address written on it.

• One view:

```
last:  
result:  
```

```
  5  
  45  
```

• Alternative view:

```
last: #7  
result: #7  
```

```
  5  #3  
  45  
```

```
  7  
  3  
```
Another Way to View Pointers (II)

- Assigning a pointer to a variable looks just like assigning an integer to a variable.

- So, after executing “last = last.tail;” we have

- Alternative view:

- Under alternative view, you might be less inclined to think that assignment would change object #7 itself, rather than just “last”.

- BEWARE! Internally, pointers really are just numbers, but Java treats them as more than that: they have types, and you can’t just change integers into pointers.
Problem: Given a (pointer to a) list of integers, \( L \), and an integer increment \( n \), return a list created by incrementing all elements of the list by \( n \).

```c
/** List of all items in P incremented by n. Does not modify * existing IntLists. */
static IntList incrList(IntList P, int n) {
    return /*( P, with each element incremented by n )*/
}
```

We say \texttt{incrList} is \textit{non-destructive}, because it leaves the input objects unchanged, as shown on the left. A \textit{destructive} method may modify the input objects, so that the original data is no longer available, as shown on the right:

After \( Q = \text{incrList}(L, 2) \):

\begin{align*}
L: & \quad 3 \quad \rightarrow \quad 43 \quad \rightarrow \quad 45 \\
Q: & \quad 5 \quad \rightarrow \quad 45
\end{align*}

After \( Q = \text{dincrList}(L, 2) \) (destructive):

\begin{align*}
L: & \quad 5 \quad \rightarrow \quad 45 \\
Q: & \quad 45
\end{align*}
Nondestructive IncrList: Recursive

/** List of all items in P incremented by n. */
static IntList incrList(IntList P, int n) {
    if (P == null)
        return null;
    else return new IntList(P.head+n, incrList(P.tail, n));
}

• Why does incrList have to return its result, rather than just setting P?

• In the call incrList(P, 2), where P contains 3 and 43, which IntList object gets created first?
An Iterative Version

An iterative incrList is tricky, because it is not tail recursive. Easier to build things first-to-last, unlike recursive version:

```java
static IntList incrList(IntList P, int n) {
    if (P == null) <<<
        return null;
    IntList result, last;
    result = last
        = new IntList(P.head+n, null);
    while (P.tail != null) {
        P = P.tail;
        last.tail
            = new IntList(P.head+n, null);
        last = last.tail;
    }
    return result;
}
```

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        return null;
    IntList result, last;
    result = last <<<
        = new IntList(P.head+n, null);
    while (P.tail != null) {
        P = P.tail;
        last.tail
            = new IntList(P.head+n, null);
        last = last.tail;
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    while (P.tail != null) {
        P = P.tail;  <<<
        last.tail
            = new IntList(P.head+n, null);
        last = last.tail;
    }
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        last = last.tail;
    }
    return result;
}
```
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    if (P == null)
        return null;
    IntList result, last;
    result = last =
        new IntList(P.head+n, null);
    while (P.tail != null) {
        P = P.tail;
        last.tail =
            new IntList(P.head+n, null);
        last = last.tail; //<<<
    }
    return result;
}
```

![Diagram of list operations]
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    while (P.tail != null) {
        P = P.tail;
        last.tail =
            = new IntList(P.head+n, null);
        last = last.tail;
    }
    return result;
}
```

```
P: 3 43 56

last:

result: 5 45 58
```
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    while (P.tail != null) {
        P = P.tail;
        last.tail
            = new IntList(P.head+n, null);
        last = last.tail; <<<
    }
    return result;
}
```