Recreation

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

CS61B Lecture #3: Values and Containers

- Labs are normally due at midnight Friday. Last week’s lab, however, is due this coming Friday at midnight.

- **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.** (So, for example, the assignment `3 = 2` would be invalid.)

  \[ 3 \quad \text{'}a\text{'} \quad \text{true} \]

- **Simple containers** contain values:

  \[ x: 3 \quad L: \quad p: \]

Examples: variables, fields, individual array elements, parameters. The **contents** of containers can change.
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>Alternative Notation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>h</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

```
h: 3
t: 
```

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>42</td>
<td>17</td>
<td>9</td>
</tr>
</tbody>
</table>

```
[ ]
```

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>42</td>
<td>17</td>
<td>9</td>
</tr>
</tbody>
</table>

Last modified: Mon Jan 24 00:22:33 2022
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).

```
p: 3 7
```

- In Java, assignment copies values into simple containers.
- Exactly like Scheme and Python!
- (Python also has slice assignment, as in `x[3:7]=...`, 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;
}
```
```

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
```

Last modified: Mon Jan 24 00:22:33 2022
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:

![Diagram showing a pointer pointing to an object with a label on it.]

• Alternative view:

![Diagram showing a variable containing a pointer with a label on it.]

Last modified: Mon Jan 24 00:22:33 2022
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

  last: □

  result: □ 5 □ 45

- Alternative view:

  last: □ #3

  result: □ #7 □ 5 □ 3 #3 □ 45

  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.
Destructive vs. Non-destructive

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 `incrList` is non-destructive, because it leaves the input objects unchanged, as shown on the left. A destructive method may modify the input objects, so that the original data is no longer available, as shown on the right:

After \( Q = incrList(L, 2) \):

\[
\begin{array}{c}
L: \quad 3 \quad 43 \\
Q: \quad 5 \quad 45
\end{array}
\]

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

\[
\begin{array}{c}
L: \quad 5 \quad 45 \\
Q: \quad -
\end{array}
\]
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));
    }
}

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

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

• Answer: The last one.
Nondestructive IncrList: Why Return the Value?

- If I want to update Q to an incremented list, why must I write
  \[ Q = \text{incrList}(Q, 4); \]

- Couldn't I instead just write
  \[ \text{incrList2}(Q, 4); \]

and define

```java
/** List of all items in P incremented by n. */
static IntList incrList2(IntList P, int n) {
    if (P == null) {
        P = null;
    } else {
        P = new IntList(P.head+n, incrList2(P.tail, n));
    }
    return P;
}
```
Nondestructive IncrList: Why Return the Value?

- If I want to update Q to an incremented list, why must I write
  
  \[ Q = \text{incrList}(Q, 4); \]

- Couldn't I instead just write
  
  \[ \text{incrList2}(Q, 4); \]

  and define

  ```java
  /** List of all items in P incremented by n. */
  static IntList incrList2(IntList P, int n) {
    if (P == null) {
      P = null;
    } else {
      P = new IntList(P.head+n, incrList2(P.tail, n));
    }
    return P;
  }
  ```

- No. Assigning to the formal parameter does not affect the actual. Java uses call by value, just like Python.
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;

    return result;
}
```

![Diagram](image-url)
An Iterative Version

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

\begin{verbatim}
static IntList incrList(IntList P, int n) {
    if (P == null)
        return null;
    IntList result, last;

    return result;
}
\end{verbatim}
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;
    return result;
}
```

![Diagram of list operations]
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;

    return result;
}
```

```
P: 3 → 43 → 56

last:

result: 5 → 45
```
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;

    return result;
}
```

![Diagram of list operations](image-url)
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;

    return result;
}
```

![Diagram showing the incremental list operation](image-url)
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;

    return result;
}
```

![Diagram showing the iterative version of incrList]
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;

    return result;
}
```

![Diagram showing an example of incrList function](attachment:image.png)
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;
}
```

![Diagram of list addition](image)

Last modified: Mon Jan 24 00:22:33 2022
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;
}
```

Last modified: Mon Jan 24 00:22:33 2022
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;
}
```

P: 3 43 56

last: 5

result:
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;
}
```

![Diagram of list operations]
An iterative \texttt{incrList} is tricky, because it is \textit{not} tail recursive. Easier to build things first-to-last, unlike recursive version:

\begin{verbatim}
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;
}
\end{verbatim}
An Iterative Version

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

```
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;
}
```
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;
}
```

```
P: 3 → 43 → 56
last: result: 5 → 45 → 58
```
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;
}
```

#### Diagram

- **P:**
  - 3 → 43 → 56
- **last:**
  - 
- **result:**
  - 5 → 45 → 58