Building Java Programs

Chapter 2
Lecture 2-2: The for Loop

reading: 2.3

Repetition with for loops

- So far, repeating a statement is redundant:
  ```java
  System.out.println("Homer says:");
  System.out.println("I am so smart");
  System.out.println("I am so smart");
  System.out.println("I am so smart");
  System.out.println("S-M-R-T... I mean S-M-A-R-T");
  ```

- Java's for loop statement performs a task many times.
  ```java
  System.out.println("Homer says:");
  for (int i = 1; i <= 4; i++) { // repeat 4 times
    System.out.println("I am so smart");
  }
  System.out.println("S-M-R-T... I mean S-M-A-R-T");
  ```
for loop syntax

for (<initialization>; <test>; <update>) {
  <statement>;
  <statement>;
  ...
  <statement>;
}

- Perform <initialization> once.
- Repeat the following:
  - Check if the <test> is true. If not, stop.
  - Execute the <statement>s.
  - Perform the <update>.

Initialization

for (int i = 1; i <= 4; i++) {
  System.out.println("I am so smart");
}

- Tells Java what variable to use in the loop
  - Performed once as the loop begins
  - The variable is called a loop counter
    - can use any name, not just i
    - can start at any value, not just 1
Test

```java
for (int i = 1; i <= 4; i++) {
    System.out.println("I am so smart");
}
```

- Tests the loop counter variable against a limit
- Uses comparison operators:
  - `<` less than
  - `<=` less than or equal to
  - `>` greater than
  - `>=` greater than or equal to

Increment and decrement

*shortcuts to increase or decrease a variable's value by 1*

<table>
<thead>
<tr>
<th>Shorthand</th>
<th>Equivalent longer version</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>&lt;variable&gt;</code>++;</td>
<td><code>&lt;variable&gt;</code> = <code>&lt;variable&gt;</code> + 1;</td>
</tr>
<tr>
<td><code>&lt;variable&gt;</code>--;</td>
<td><code>&lt;variable&gt;</code> = <code>&lt;variable&gt;</code> - 1;</td>
</tr>
</tbody>
</table>

```java
int x = 2;
    x++; // x = x + 1;
    // x now stores 3

double gpa = 2.5;
gpa--; // gpa = gpa - 1;
    // gpa now stores 1.5
```
Modify-and-assign operators

*shortcuts to modify a variable's value*

<table>
<thead>
<tr>
<th>Shorthand</th>
<th>Equivalent longer version</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;variable&gt; += &lt;exp&gt;;</td>
<td>&lt;variable&gt; = &lt;variable&gt; + (&lt;exp&gt;);</td>
</tr>
<tr>
<td>&lt;variable&gt; -= &lt;exp&gt;;</td>
<td>&lt;variable&gt; = &lt;variable&gt; - (&lt;exp&gt;);</td>
</tr>
<tr>
<td>&lt;variable&gt; *= &lt;exp&gt;;</td>
<td>&lt;variable&gt; = &lt;variable&gt; * (&lt;exp&gt;);</td>
</tr>
<tr>
<td>&lt;variable&gt; /= &lt;exp&gt;;</td>
<td>&lt;variable&gt; = &lt;variable&gt; / (&lt;exp&gt;);</td>
</tr>
<tr>
<td>&lt;variable&gt; %= &lt;exp&gt;;</td>
<td>&lt;variable&gt; = &lt;variable&gt; % (&lt;exp&gt;);</td>
</tr>
</tbody>
</table>

```
x += 3;  // x = x + 3;
gpa -= 0.5;  // gpa = gpa - 0.5;
number *= 2 + 1;  // number = number * (2 + 1);
```

**for loop is NOT a method**

- The *for* loop is a *control structure*—a syntactic structure that *controls* the execution of other statements.

- Example:
  - “Shampoo hair. Rinse. **Repeat.**”
Repetition over a range

System.out.println("1 squared = " + 1 * 1);
System.out.println("2 squared = " + 2 * 2);
System.out.println("3 squared = " + 3 * 3);
System.out.println("4 squared = " + 4 * 4);
System.out.println("5 squared = " + 5 * 5);
System.out.println("6 squared = " + 6 * 6);

• Intuition: "I want to print a line for each number from 1 to 6"

• The for loop does exactly that!

    for (int i = 1; i <= 6; i++) {
        System.out.println(i + " squared = " + (i * i));
    }

• "For each integer i from 1 through 6, print ..."

Loop walkthrough

    for (int i = 1; i <= 4; i++) {
        System.out.println(i + " squared = " + (i * i));
    }
    System.out.println("Whoo!");

Output:
1 squared = 1
2 squared = 4
3 squared = 9
4 squared = 16
Whoo!
Multi-line loop body

System.out.println("+----+");
for (int i = 1; i <= 3; i++) {
    System.out.println("\    "/");
    System.out.println="/    ");
}
System.out.println("+----+");

• Output:
  +----+
  \    /
  /    \
  \    /
  /    \
  \    /
  /    \
  +----+

Expressions for counter

int highTemp = 5;
for (int i = -3; i <= highTemp / 2; i++) {
    System.out.println(i * 1.8 + 32);
}

• This computes the Fahrenheit equivalents for -3 degrees Celsius to 2 degrees Celsius.

• Output:
  26.6
  28.4
  30.2
  32.0
  33.8
  35.6
System.out.print

- Prints without moving to a new line
- allows you to print partial messages on the same line

```java
int highestTemp = 5;
for (int i = -3; i <= highestTemp / 2; i++) {
    System.out.print((i * 1.8 + 32) + " ");
}
```

- Output:
  26.6  28.4  30.2  32.0  33.8  35.6
  - Concatenate " " to separate the numbers

Counting down

- The `<update>` can use -- to make the loop count down.
- The `<test>` must say > instead of <

```java
System.out.print("T-minus ");
for (int i = 10; i >= 1; i--) {
    System.out.print(i + ", ");
}
System.out.println("blastoff!");
System.out.println("The end.");
```

- Output:
  T-minus 10, 9, 8, 7, 6, 5, 4, 3, 2, 1, blastoff!
The end.
Nested loops

reading: 2.3

- nested loop: A loop placed inside another loop.

```java
for (int i = 1; i <= 5; i++) {
    for (int j = 1; j <= 10; j++) {
        System.out.print("*");
    }
    System.out.println(); // to end the line
}
```

- Output:

```
**********
**********
**********
**********
**********
```

- The outer loop repeats 5 times; the inner one 10 times.
  - "sets and reps" exercise analogy
Nested for loop exercise

• What is the output of the following nested for loops?

```java
for (int i = 1; i <= 5; i++) {
    for (int j = 1; j <= i; j++) {
        System.out.print("*");
    }
    System.out.println();
}
```

• Output:
  *
  **
  ***
  ****
  *****

Nested for loop exercise

• What is the output of the following nested for loops?

```java
for (int i = 1; i <= 5; i++) {
    for (int j = 1; j <= i; j++) {
        System.out.print(i);
    }
    System.out.println();
}
```

• Output:
  1
  2
  3
  4
  5
  6
  7
  8
  9
  10
  11
  12
  13
  14
  15
  16
  17
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  99
  100
Common errors

- Both of the following sets of code produce infinite loops:

```java
for (int i = 1; i <= 5; i++) {
    for (int j = 1; i <= 10; j++) {
        System.out.print("*");
    }
    System.out.println();
}

for (int i = 1; i <= 5; i++) {
    for (int j = 1; j <= 10; i++) {
        System.out.print("*");
    }
    System.out.println();
}
```

Complex lines

- What nested for loops produce the following output?

```
....1
....2
..3
 .4
 5
```

- We must build multiple complex lines of output using:
  - an outer "vertical" loop for each of the lines
  - inner "horizontal" loop(s) for the patterns within each line
Outer and inner loop

- First write the outer loop, from 1 to the number of lines.
  
  ```java
  for (int line = 1; line <= 5; line++) {
      ...
  }
  ```

- Now look at the line contents. Each line has a pattern:
  - some dots (0 dots on the last line), then a number
    
    ```
    ....1
    ...2
    ..3
    .4
    5
    ```

- Observation: the number of dots is related to the line number.

Mapping loops to numbers

```java
for (int count = 1; count <= 5; count++) {
    System.out.print( ... );
}
```

- What statement in the body would cause the loop to print:
  
  4 7 10 13 16

```java
for (int count = 1; count <= 5; count++) {
    System.out.print(3 * count + 1 + " ");
}
```
Loop tables

- What statement in the body would cause the loop to print:
  2 7 12 17 22

- To see patterns, make a table of count and the numbers.
  - Each time count goes up by 1, the number should go up by 5.
  - But count * 5 is too great by 3, so we subtract 3.

<table>
<thead>
<tr>
<th>count</th>
<th>number to print</th>
<th>5 * count</th>
<th>5 * count - 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>4</td>
<td>17</td>
<td>20</td>
<td>17</td>
</tr>
<tr>
<td>5</td>
<td>22</td>
<td>25</td>
<td>22</td>
</tr>
</tbody>
</table>

Loop tables question

- What statement in the body would cause the loop to print:
  17 13 9 5 1

- Let's create the loop table together.
  - Each time count goes up 1, the number printed should ...
  - But this multiple is off by a margin of ...

<table>
<thead>
<tr>
<th>count</th>
<th>number to print</th>
<th>-4 * count</th>
<th>-4 * count + 21</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>17</td>
<td>-4</td>
<td>17</td>
</tr>
<tr>
<td>2</td>
<td>13</td>
<td>-8</td>
<td>13</td>
</tr>
<tr>
<td>3</td>
<td>9</td>
<td>-12</td>
<td>9</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>-16</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>-20</td>
<td>1</td>
</tr>
</tbody>
</table>
Another view: Slope-intercept

- The next three slides present the mathematical basis for the loop tables. Feel free to skip it.

<table>
<thead>
<tr>
<th>count (x)</th>
<th>number to print (y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>4</td>
<td>17</td>
</tr>
<tr>
<td>5</td>
<td>22</td>
</tr>
</tbody>
</table>

Another view: Slope-intercept

- **Caution**: This is algebra, not assignment!
- Recall: slope-intercept form \((y = mx + b)\)
- Slope is defined as “rise over run” (i.e. rise / run). Since the “run” is always 1 (we increment along \(x\) by 1), we just need to look at the “rise”. The rise is the difference between the \(y\) values. Thus, the slope \((m)\) is the difference between \(y\) values; in this case, it is +5.
- To compute the \(y\)-intercept \((b)\), plug in the value of \(y\) at \(x = 1\) and solve for \(b\). In this case, \(y = 2\).

\[
\begin{align*}
  y &= m \times x + b \\
  2 &= 5 \times 1 + b \\
  \text{Then } b &= -3
\end{align*}
\]
- So the equation is

\[
\begin{align*}
  y &= m \times x + b \\
  y &= 5 \times x - 3 \\
  y &= 5 \times \text{count} - 3
\end{align*}
\]
Another view: Slope-intercept

- Algebraically, if we always take the value of \( y \) at \( x = 1 \), then we can solve for \( b \) as follows:
  \[
  y = m \times x + b \\
  y_1 = m \times 1 + b \\
  y_1 = m + b \\
  b = y_1 - m
  \]
- In other words, to get the \( y \)-intercept, just subtract the slope from the first \( y \) value (\( b = 2 - 5 = -3 \))
- This gets us the equation
  \[
  y = m \times x + b \\
  y = 5 \times x - 3 \\
  y = 5 \times \text{count} - 3
  \]
  (which is exactly the equation from the previous slides)

Nested for loop exercise

- Make a table to represent any patterns on each line.

<table>
<thead>
<tr>
<th>line</th>
<th># of dots</th>
<th>-1 * line</th>
<th>-1 * line + 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>-1</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>-2</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>-3</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>-4</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>-5</td>
<td>0</td>
</tr>
</tbody>
</table>

- To print a character multiple times, use a for loop.

```java
for (int j = 1; j <= 4; j++) {
    System.out.print("."); // 4 dots
}
```
Nested for loop solution

- **Answer:**

```java
for (int line = 1; line <= 5; line++) {
    for (int j = 1; j <= (-1 * line + 5); j++) {
        System.out.print(".");
    }
    System.out.println(line);
}
```

- **Output:**

```
....1
...2
..3
.4
5
```

Nested for loop exercise

- **What is the output of the following nested for loops?**

```java
for (int line = 1; line <= 5; line++) {
    for (int j = 1; j <= (-1 * line + 5); j++) {
        System.out.print(".");
    }
    for (int k = 1; k <= line; k++) {
        System.out.print(line);
    }
    System.out.println();
}
```

- **Answer:**

```
....1
...22
..333
.4444
55555
```
Nested for loop exercise

- Modify the previous code to produce this output:
  
  ....1
  ...2.
  ..3..
  .4...
  5....

- Answer:
  
  ```java
  for (int line = 1; line <= 5; line++) {
    for (int j = 1; j <= (-1 * line + 5); j++) {
      System.out.print(".");
    }
    System.out.print(line);
    for (int j = 1; j <= (line - 1); j++) {
      System.out.print(".");
    }
    System.out.println();
  }
  ```