Building Java Programs

Chapter 2
Nested Loops, Figures and Constants

reading: 2.3 - 2.5
#include <stdio.h>
int main(void)
{
    int count;
    for (count = 1; count <= 500; count++)
        printf("I will not throw paper airplanes in class.");
    return 0;
}
Nested loops

reading: 2.3
YO DAWG, I HEARD YOU LIKE LOOPS

SO I PUT A LOOP INSIDE A LOOP SO YOU CAN REPEAT WHILE YOU REPEAT
Nested loops

- **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
22
333
4444
55555
```
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();
}
```

```java
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
```

*inner loop (repeated characters on each line)*

```
1
2
3
4
5
```

*outer loop (loops 5 times because there are 5 lines)*

- 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(3 * count + 1 + " ");
}
```

- What statement in the body would cause the loop to print:
  4 7 10 13 16
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, \(y = 2\).

\[
y = m \times x + b
\]

\[
2 = 5 \times 1 + b
\]

Then \(b = -3\)

- So the equation is

\[
y = m \times x + b
\]

\[
y = 5 \times x - 3
\]

\[
y = 5 \times \text{count} - 3
\]

<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>
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<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

- 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.

```
   1   2   3   4   5

<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.println(line);
    for (int j = 1; j <= (line - 1); j++) {
      System.out.print(".");
    }
  }
  ```
Drawing complex figures

- Use nested `for` loops to produce the following output.

- Why draw ASCII art?
  - Real graphics require a lot of finesse
  - ASCII art has complex patterns
  - Can focus on the algorithms

```
#================#
|      <><>      |
|    <>....<>    |
|  <>........<>  |
|<>............<>|
|<>............<>|
|  <>........<>  |
|    <>....<>    |
|      <><>      |
#================#
```
Development strategy

Recommendations for managing complexity:

1. Design the program (think about steps or methods needed).
   - write an English description of steps required
   - use this description to decide the methods

2. Create a table of patterns of characters
   - use table to write your for loops

```
#================#
|     <><>      |
|    <>....<>    |
|  <>........<>  |
|<>............<>|
|<>............<>|
|  <>........<>  |
|    <>....<>    |
|     <><>      |
#================#
```
1. Pseudo-code

- **pseudo-code**: An English description of an algorithm.

- Example: Drawing a 12 wide by 7 tall box of stars

```
print 12 stars.
for (each of 5 lines) {
    print a star.
    print 10 spaces.
    print a star.
}
print 12 stars.
```

```
************
*          *
*          *
*          *
*          *
*          *
************
```
Pseudo-code algorithm

1. Line
   • #, 16 =, #

2. Top half
   • |
   • spaces (decreasing)
   • <<>
   • dots (increasing)
   • <>
   • <>
   • spaces (same as above)
   • |

3. Bottom half (top half upside-down)

4. Line
   • #, 16 =, #
public class Mirror {
    public static void main(String[] args) {
        line();
        topHalf();
        bottomHalf();
        line();
    }

    public static void topHalf() {
        for (int line = 1; line <= 4; line++) {
            // contents of each line
        }
    }

    public static void bottomHalf() {
        for (int line = 1; line <= 4; line++) {
            // contents of each line
        }
    }

    public static void line() {
        // ...
    }
}
2. Tables

- A table for the top half:
  - Compute spaces and dots expressions from line number

<table>
<thead>
<tr>
<th>line</th>
<th>spaces</th>
<th>(-2 \times \text{line} + 8)</th>
<th>dots</th>
<th>(4 \times \text{line} - 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>6</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>2</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>0</td>
<td>12</td>
<td>12</td>
</tr>
</tbody>
</table>

```markdown
#==============#
|      <><>      |
|    <>....<>    |
|  <>........<>  |
|<>............<>|
|<>............<>|
|  <>........<>  |
|    <>....<>    |
|      <><>      |
#==============#
```
3. Writing the code

- Useful questions about the top half:
  - What methods? (think structure and redundancy)
  - Number of (nested) loops per line?
Partial solution

// Prints the expanding pattern of <> for the top half of the figure.
public static void topHalf() {
    for (int line = 1; line <= 4; line++) {
        System.out.print('|');
        for (int space = 1; space <= (line * -2 + 8); space++) {
            System.out.print(' ');  // Yellow Box
        }
        System.out.print('<>');
        for (int dot = 1; dot <= (line * 4 - 4); dot++) {
            System.out.print('.');   // Yellow Box
        }
        System.out.print('<>');
        for (int space = 1; space <= (line * -2 + 8); space++) {
            System.out.print(' '); // Yellow Box
        }
        System.out.println('|');
    }
}
Class constants and scope

reading: 2.4
**Scope**

- **scope**: The part of a program where a variable exists.
  - From its declaration to the end of the `{ }` braces
    - A variable declared in a `for` loop exists only in that loop.
    - A variable declared in a method exists only in that method.

```java
public static void example() {
    int x = 3;
    for (int i = 1; i <= 10; i++) {
        System.out.println(x);
    }
    // i no longer exists here
    // x ceases to exist here
}
```
Scaling the mirror

- Let's modify our Mirror program so that it can scale.
  - The current mirror (left) is at size 4; the right is at size 3.
- We'd like to structure the code so we can scale the figure by changing the code in just one place.
Limitations of variables

- Idea: Make a variable to represent the size.
  - Use the variable's value in the methods.

- Problem: A variable in one method can't be seen in others.

```java
public static void main(String[] args) {
    int size = 4;
    topHalf();
    printBottom();
}

public static void topHalf() {
    for (int i = 1; i <= size; i++) {
        // ERROR: size not found
        ...
    }
}

public static void bottomHalf() {
    for (int i = size; i >= 1; i--) {
        // ERROR: size not found
        ...
    }
}
```
Scope implications

- Variables without overlapping scope can have same name.

```java
for (int i = 1; i <= 100; i++) {
    System.out.print("/");
}
for (int i = 1; i <= 100; i++) {  // OK
    System.out.print("\\");
}
int i = 5;                      // OK: outside of loop's scope
```

- A variable can't be declared twice or used out of its scope.

```java
for (int i = 1; i <= 100 * line; i++) {
    int i = 2;                    // ERROR: overlapping scope
    System.out.print("/");
}
i = 4;                          // ERROR: outside scope
```
Class constants

• **class constant**: A fixed value visible to the whole program.
  • value can be set only at declaration; cannot be reassigned, hence the name: *constant*

• Syntax:
  ```java
  public static final type name = expression;
  ```
  • name is usually in ALL_UPPER_CASE

• Examples:
  ```java
  public static final int HOURS_IN_WEEK = 7 * 24;
  public static final double INTEREST_RATE = 3.5;
  public static final int SSN = 658234569;
  ```
Constants and figures

- Consider the task of drawing the following scalable figure:

```
+\/_/_/_/_/_/_/_/_/+
|                   |
|                   |
|                   |
|                   |
+\/_/_/_/_/_/_/_/_/+
```

Multiples of 5 occur many times

```
+\/_/_/_/_+_+
|       |   |
|       |   |
|       |   |
+\/_/_/_/_+_+
```

The same figure at size 2
public class Sign {

    public static void main(String[] args) {
        drawLine();
        drawBody();
        drawLine();
    }

    public static void drawLine() {
        System.out.print("+");
        for (int i = 1; i <= 10; i++) {
            System.out.print("/\")
        }
        System.out.println("+");
    }

    public static void drawBody() {
        for (int line = 1; line <= 5; line++) {
            System.out.print("|");
            for (int spaces = 1; spaces <= 20; spaces++) {
                System.out.print(" ");
            }
            System.out.println("|");
        }
    }
}
Adding a constant

```java
public class Sign {
    public static final int HEIGHT = 5;

    public static void main(String[] args) {
        drawLine();
        drawBody();
        drawLine();
    }

    public static void drawLine() {
        System.out.print("+");
        for (int i = 1; i <= HEIGHT * 2; i++) {
            System.out.print("/\" ");
        }
        System.out.println("+");
    }

    public static void drawBody() {
        for (int line = 1; line <= HEIGHT; line++) {
            System.out.print("|");
            for (int spaces = 1; spaces <= HEIGHT * 4; spaces++) {
                System.out.print(" ");
            }
            System.out.println("|");
        }
    }
}
```
Modify the Mirror code to be resizable using a constant.

A mirror of size 4:
```
#================#
|      <><>      |
|    <>....<>    |
|  <>........<>  |
|<>............<>|
|<>............<>|
|  <>........<>  |
|    <>....<>    |
|      <><>      |
#================#
```

A mirror of size 3:
```
#============#
|    <><>    |
|  <>....<>  |
|<>........<>|
|<>........<>|
|  <>....<>  |
|    <><>    |
#============#
```
Using a constant

- Constant allows many methods to refer to same value:

```java
public static final int SIZE = 4;

public static void main(String[] args) {
    topHalf();
    bottomHalf();
}

public static void topHalf() {
    for (int i = 1; i <= SIZE; i++) {
        // OK
        ...
    }
}

public static void bottomHalf() {
    for (int i = SIZE; i >= 1; i--) {
        // OK
        ...
    }
}
```
## Loop tables and constant

- Let's modify our loop table to use `SIZE`
- This can change the amount added in the loop expression

<table>
<thead>
<tr>
<th>SIZE</th>
<th>line</th>
<th>spaces</th>
<th>(-2*\text{line} + (2*\text{SIZE}))</th>
<th>dots</th>
<th>(4*\text{line} - 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>1,2,3,</td>
<td>6,4,2,</td>
<td>(-2*\text{line} + 8)</td>
<td>0,4,8,1</td>
<td>4*\text{line} - 4</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>0</td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1,2,3</td>
<td>4,2,0</td>
<td>(-2*\text{line} + 6)</td>
<td>0,4,8</td>
<td>4*\text{line} - 4</td>
</tr>
</tbody>
</table>

\#=================================#
|   |   |   |   |   |
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Partial solution

```java
public static final int SIZE = 4;

// Prints the expanding pattern of <> for the top half of the figure.
public static void topHalf() {
    for (int line = 1; line <= SIZE; line++) {
        System.out.print("|");

        for (int space = 1; space <= (line * -2 + (2*SIZE)); space++)
        {
            System.out.print(" ");
        }
        System.out.print("<>");

        for (int dot = 1; dot <= (line * 4 - 4); dot++) {
            System.out.print(".");
        }
        System.out.print("<>");

        for (int space = 1; space <= (line * -2 + (2*SIZE)); space++)
        {
            System.out.print(" ");
        }
        System.out.println("|");
    }
}
```
Observations about constant

- The constant can change the "intercept" in an expression.
  - Usually the "slope" is unchanged.

```java
public static final int SIZE = 4;

for (int space = 1; space <= (line * -2 + (2 * SIZE)); space++) {
    System.out.print(" ");
}
```

- It doesn't replace every occurrence of the original value.

```java
for (int dot = 1; dot <= (line * 4 - 4); dot++) {
    System.out.print(".");
}
```
Assignment 2: ASCII Art