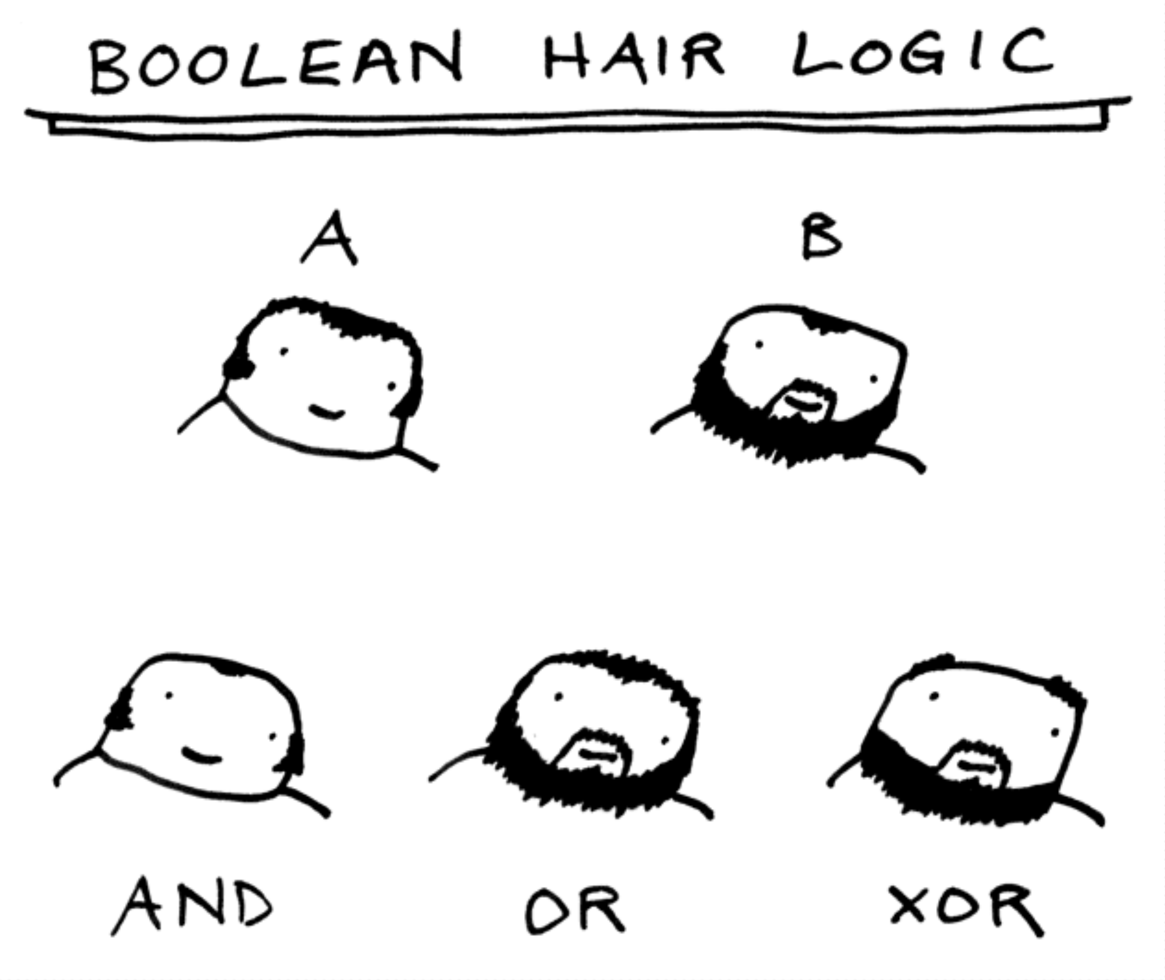
Building Java Programs

Chapter 5
Lecture 5-3: Boolean Logic and Assertions

reading: 5.3 – 5.5


BOOLEAN HAIR LOGIC
A
B
AND
OR
XOR

Type `boolean`

- **`boolean`**: A logical type whose values are `true` and `false`.
  - A logical ***test*** is actually a `boolean` expression.
  - Like other types, it is legal to:
    - create a `boolean` variable
    - pass a `boolean` value as a parameter
    - return a `boolean` value from methods
    - call a method that returns a `boolean` and use it as a test

```
boolean minor     = age < 21;
boolean isProf    = name.contains("Prof");
boolean lovesCSE = true;

// allow only CSE-loving students over 21
if (minor || isProf || !lovesCSE) {
    System.out.println("Can't enter the club!");
}
```

Using boolean

- Why is type boolean useful?
  - Can capture a complex logical test result and use it later
  - Can write a method that does a complex test and returns it
  - Makes code more readable
  - Can pass around the result of a logical test (as param/return)

```
boolean goodAge    = age >= 12 && age < 29;
boolean goodHeight = height >= 78 && height < 84;
boolean rich       = salary >= 100000.0;

if ((goodAge && goodHeight) || rich) {
    System.out.println("Okay, let's go out!");
} else {
    System.out.println("It's not you, it's me...");
}
```

Logical operators

- Tests can be combined using *logical operators*:

<table>
<tr><th>Operator</th><th>Description</th><th>Example</th><th>Result</th></tr>
<tr><td>&&</td><td>and</td><td>(2 == 3) && (-1 < 5)</td><td>false</td></tr>
<tr><td>||</td><td>or</td><td>(2 == 3) || (-1 < 5)</td><td>true</td></tr>
<tr><td>!</td><td>not</td><td>!(2 == 3)</td><td>true</td></tr>
</table>

- "Truth tables" for each, used with logical values *p* and *q*:

<table>
<tr><th>p</th><th>q</th><th>p && q</th><th>p || q</th></tr>
<tr><td>true</td><td>true</td><td>true</td><td>true</td></tr>
<tr><td>true</td><td>false</td><td>false</td><td>true</td></tr>
<tr><td>false</td><td>true</td><td>false</td><td>true</td></tr>
<tr><td>false</td><td>false</td><td>false</td><td>false</td></tr>
</table>

p	!p
true	false
false	true

Evaluating logical expressions

- Relational operators have lower precedence than math; logical operators have lower precedence than relational operators

```
5 * 7 >= 3 + 5 * (7 - 1) && 7 <= 11
5 * 7 >= 3 + 5 * 6 && 7 <= 11
35    >= 3 + 30 && 7 <= 11
35    >= 33 && 7 <= 11
true && true
true
```

- Relational operators cannot be "chained" as in algebra

```
2 <= x <= 10
true   <= 10
Error!
```

(assume that `x` is `15`)

  - Instead, combine multiple tests with `&&` or `||`

```
2 <= x && x <= 10
true   && false
false
```

Returning boolean

```
public static boolean isPrime(int n) {
    int factors = 0;
    for (int i = 1; i <= n; i++) {
        if (n % i == 0) {
            factors++;
        }
    }

    if (factors == 2) {
        return true;
    } else {
        return false;
    }
}
```

- Calls to methods returning `boolean` can be used as tests:

```
if (isPrime(57)) {
    ...
}
```

"Boolean Zen", part 1

- Students new to `boolean` often test if a result is `true`:

```
if (isPrime(57) == true) {     // bad
    ...
}
```

- But this is unnecessary and redundant. Preferred:

```
if (isPrime(57)) {             // good
    ...
}
```

- A similar pattern can be used for a `false` test:

```
if (isPrime(57) == false) {    // bad
if (!isPrime(57)) {            // good
```

"Boolean Zen", part 2

- Methods that return `boolean` often have an `if/else` that returns `true` or `false`:

```
public static boolean bothOdd(int n1, int n2) {
    if (n1 % 2 != 0 && n2 % 2 != 0) {
        return true;
    } else {
        return false;
    }
}
```

  - But the code above is unnecessarily verbose.

Solution w/ boolean variable

- We could store the result of the logical test.

```
public static boolean bothOdd(int n1, int n2) {
    boolean test = (n1 % 2 != 0 && n2 % 2 != 0);
    if (test) {    // test == true
        return true;
    } else {       // test == false
        return false;
    }
}
```

- Notice: Whatever test is, we want to return that.
  - If test is true , we want to return true.
  - If test is false, we want to return false.

Solution w/ "Boolean Zen"

- Observation: The `if/else` is unnecessary.
  - The variable `test` stores a `boolean` value; its value is exactly what you want to return. So return that!

```
public static boolean bothOdd(int n1, int n2) {
    boolean test = (n1 % 2 != 0 && n2 % 2 != 0);
    return test;
}
```

- An even shorter version:
  - We don't even need the variable `test`. We can just perform the test and return its result in one step.

```
public static boolean bothOdd(int n1, int n2) {
    return (n1 % 2 != 0 && n2 % 2 != 0);
}
```

"Boolean Zen" template

- Replace

```
public static boolean name(parameters) {
    if (test) {
        return true;
    } else {
        return false;
    }
}
```

- with

```
public static boolean name(parameters) {
    return test;
}
```

Improved `isPrime` method

- The following version utilizes Boolean Zen:

```
public static boolean isPrime(int n) {
    int factors = 0;
    for (int i = 1; i <= n; i++) {
        if (n % i == 0) {
            factors++;
        }
    }
    return factors == 2;   // if n has 2 factors -> true
}
```

Boolean practice questions

- Write a method named `isVowel` that returns whether a `String` is a vowel (a, e, i, o, or u), case-insensitively.
  - `isVowel("q")` returns `false`
  - `isVowel("A")` returns `true`
  - `isVowel("e")` returns `true`

- Change the above method into an `isNonVowel` that returns whether a `String` is any character except a vowel.
  - `isNonVowel("q")` returns `true`
  - `isNonVowel("A")` returns `false`
  - `isNonVowel("e")` returns `false`

Boolean practice answers

```
// Enlightened version.  I have seen the true way (and false way)
public static boolean isVowel(String s) {
    return s.equalsIgnoreCase("a") || s.equalsIgnoreCase("e") ||
           s.equalsIgnoreCase("i") || s.equalsIgnoreCase("o") ||
           s.equalsIgnoreCase("u");
}


// Enlightened "Boolean Zen" version
public static boolean isNonVowel(String s) {
    return !s.equalsIgnoreCase("a") && !s.equalsIgnoreCase("e") &&
           !s.equalsIgnoreCase("i") && !s.equalsIgnoreCase("o") &&
           !s.equalsIgnoreCase("u");

    // or, return !isVowel(s);
}
```

De Morgan's Law

- **De Morgan's Law**: Rules used to negate boolean tests.
  - Useful when you want the opposite of an existing test.

<table>
<tr><th>Original Expression</th><th>Negated Expression</th><th>Alternative</th></tr>
<tr><td><code>a && b</code></td><td><code>!a || !b</code></td><td><code>!(a && b)</code></td></tr>
<tr><td><code>a || b</code></td><td><code>!a && !b</code></td><td><code>!(a || b)</code></td></tr>
</table>

  - Example:

<table>
<tr><th>Original Code</th><th>Negated Code</th></tr>
<tr><td><code>if (x == 7 && y > 3) {</code>
<code>   ...</code>
<code>}</code></td><td><code>if (x <b>!=</b> 7 <b>||</b> y <b><=</b> 3) {</code>
<code>   ...</code>
<code>}</code></td></tr>
</table>

When to return?

- Methods with loops and return values can be tricky.
  - When and where should the method return its result?

- Write a method `seven` that accepts a `Random` parameter and uses it to draw up to ten lotto numbers from 1-30.
  - If any of the numbers is a lucky 7, the method should stop and return `true`. If none of the ten are 7 it should return `false`.
  - The method should print each number as it is drawn.

```
15 29 18 29 11 3 30 17 19 22          (first call)
29 5 29 4 7                           (second call)
```

Flawed solution

```
// Draws 10 lotto numbers; returns true if one is 7.
public static boolean seven(Random rand) {
    for (int i = 1; i <= 10; i++) {
        int num = rand.nextInt(30) + 1;
        System.out.print(num + " ");
        if (num == 7) {
            return true;
        } else {
            return false;
        }
    }
}
```

- The method always returns immediately after the first draw.
- This is wrong if that draw isn't a 7; we need to keep drawing.

Returning at the right time

```
// Draws 10 lotto numbers; returns true if one is 7.
public static boolean seven(Random rand) {
    for (int i = 1; i <= 10; i++) {
        int num = rand.nextInt(30) + 1;
        System.out.print(num + " ");
        if (num == 7) {    // found lucky 7; can exit now
            return true;
        }
    }
    return false;   // if we get here, there was no 7
}
```

- Returns `true` immediately if 7 is found.
- If 7 isn't found, the loop continues drawing lotto numbers.
- If all ten aren't 7, the loop ends and we return `false`.

Boolean return questions

- `hasAnOddDigit` : returns `true` if any digit of an integer is odd.
  - `hasAnOddDigit(4822116)` returns `true`
  - `hasAnOddDigit(2448)` returns `false`

- `allDigitsOdd` : returns `true` if every digit of an integer is odd.
  - `allDigitsOdd(135319)` returns `true`
  - `allDigitsOdd(9174529)` returns `false`

- `isAllVowels` : returns `true` if every char in a `String` is a vowel.
  - `isAllVowels("eIeIo")` returns `true`
  - `isAllVowels("oink")` returns `false`
    - These problems are available in our Practice-It! system under **5.x**.

Boolean return answers

```
public static boolean hasAnOddDigit(int n) {
    while (n != 0) {
        if (n % 2 != 0) {   // check whether last digit is odd
            return true;
        }
        n = n / 10;
    }
    return false;
}

public static boolean allDigitsOdd(int n) {
    while (n != 0) {
        if (n % 2 == 0) {   // check whether last digit is even
            return false;
        }
        n = n / 10;
    }
    return true;
}

public static boolean isAllVowels(String s) {
    for (int i = 0; i < s.length(); i++) {
        String letter = s.substring(i, i + 1);
        if (!isVowel(letter)) {
            return false;
        }
    }
    return true;
}
```