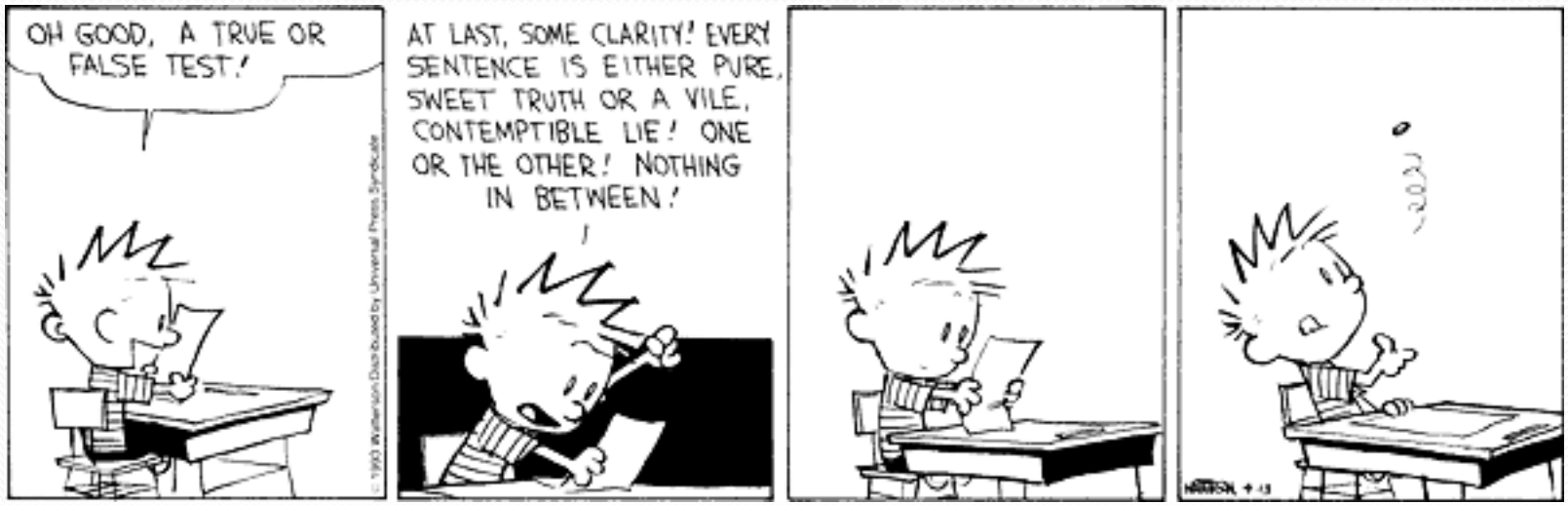
Building Java Programs

Chapter 5
Lecture 12: Random, boolean Logic

reading: 4.4, 5.1, 5.3, 5.6

(Slides adapted from Stuart Reges, Hélène Martin, and Marty Stepp)


OH GOOD, A TRUE OR FALSE TEST!
AT LAST, SOME CLARITY! EVERY SENTENCE IS EITHER PURE, SWEET TRUTH OR A VILE, CONTEMPTIBLE LIE! ONE OR THE OTHER! NOTHING IN BETWEEN!

While loop mystery

- For each call below to the following method, write the output that is produced, as it would appear on the console:

```
public static void mystery(int x, int y) {
    int z = 1;
    while (x > 0) {
        System.out.print(y + ", ");
        y = y - z;
        z = z + y;
        x--;
    }
    System.out.println(y);
}

mystery(2, 3);      // 3, 2, -1

mystery(3, 5);      // 5, 4, -1, -5

mystery(4, 7);      // 7, 6, -1, -7, -6
```

Assertion example 1

```
public static void mystery(int x, int y) {
    int z = 0;

    // Point A

    while (x >= y) {
        // Point B
        x = x - y;
        z++;

        if (x != y) {
            // Point C
            z = z * 2;
        }

        // Point D

    }

    // Point E
    System.out.println(z);
}
```

Which of the following assertions are true at which point(s) in the code? Choose ALWAYS, NEVER, or SOMETIMES.

	x < y	x == y	z == 0
Point A	SOMETIMES	SOMETIMES	ALWAYS
Point B	NEVER	SOMETIMES	SOMETIMES
Point C	SOMETIMES	NEVER	NEVER
Point D	SOMETIMES	SOMETIMES	NEVER
Point E	ALWAYS	NEVER	SOMETIMES

Randomness

- Lack of predictability: don't know what's coming next
- Random process: outcomes do not follow a deterministic pattern (math, statistics, probability)
- Lack of bias or correlation (statistics)
- Relevant in lots of fields
  - Genetic mutations (biology)
  - Quantum processes (physics)
  - Random walk hypothesis (finance)
  - Cryptography (computer science)
  - Game theory (mathematics)
  - Determinism (religion)

Pseudo-Randomness

- Computers generate numbers in a predictable way using a mathematical formula
- Parameters may include current time, mouse position
  - In practice, hard to predict or replicate
- True randomness uses natural processes
  - Atmospheric noise (http://www.random.org/)
  - Lava lamps (patent #5732138)
  - Radioactive decay

The `Random` class

- A `Random` object generates pseudo-random numbers.
  - Class `Random` is found in the `java.util` package.

```
import java.util.*;
```

Method name	Description
`nextInt()`	returns a random integer
`nextInt(`***max***`)`	returns a random integer in the range [0, *max*) in other words, 0 to *max*-1 inclusive
`nextDouble()`	returns a random real number in the range [0.0, 1.0)

  - Example:

```
Random rand = new Random();
int randomNumber = rand.nextInt(10);    // 0-9
```

Generating random numbers

- Common usage: to get a random number from 1 to *N*

```
int n = rand.nextInt(20) + 1;   // 1-20 inclusive
```

- To get a number in arbitrary range [*min*, *max*] inclusive:

name*.nextInt(*size of range*) + *min

  - Where ***size of range*** is (***max*** - ***min*** + 1)

  - Example: A random integer between 4 and 10 inclusive:

```
int n = rand.nextInt(7) + 4;
```

`Random` questions

- Given the following declaration, how would you get:

```
Random rand = new Random();
```

  - A random number between 1 and 47 inclusive?

```
int random1 = rand.nextInt(47) + 1;
```

  - A random number between 23 and 30 inclusive?

```
int random2 = rand.nextInt(8) + 23;
```

  - A random even number between 4 and 12 inclusive?

```
int random3 = rand.nextInt(5) * 2 + 4;
```

`Random` and other types

- `nextDouble` method returns a `double` between 0.0 - 1.0
  - Example: Get a random GPA value between 1.5 and 4.0:

```
double randomGpa = rand.nextDouble() * 2.5 + 1.5;
```

- Any set of possible values can be mapped to integers
  - code to randomly play Rock-Paper-Scissors:

```
int r = rand.nextInt(3);
if (r == 0) {
    System.out.println("Rock");
} else if (r == 1) {
    System.out.println("Paper");
} else {  // r == 2
    System.out.println("Scissors");
}
```

Random question

- Write a program that simulates rolling of two 6-sided dice until their combined result comes up as 7.

```
2 + 4 = 6
3 + 5 = 8
5 + 6 = 11
1 + 1 = 2
4 + 3 = 7
You won after 5 tries!
```

Random answer

```
// Rolls two dice until a sum of 7 is reached.
import java.util.*;

public class Dice {
    public static void main(String[] args) {
        Random rand = new Random();
        int tries = 0;

        int sum = 0;
        while (sum != 7) {
            // roll the dice once
            int roll1 = rand.nextInt(6) + 1;
            int roll2 = rand.nextInt(6) + 1;
            sum = roll1 + roll2;
            System.out.println(roll1 + " + " + roll2 + " = " + sum);
            tries++;
        }

        System.out.println("You won after " + tries + " tries!");
    }
}
```

Random question

- Write a program that plays an adding game.
  - Ask user to solve random adding problems with 2-5 numbers.
  - The user gets 1 point for a correct answer, 0 for incorrect.
  - The program stops after 3 incorrect answers.

```
4 + 10 + 3 + 10 = 27
9 + 2 = 11
8 + 6 + 7 + 9 = 25
Wrong! The answer was 30
5 + 9 = 13
Wrong! The answer was 14
4 + 9 + 9 = 22
3 + 1 + 7 + 2 = 13
4 + 2 + 10 + 9 + 7 = 42
Wrong! The answer was 32
You earned 4 total points.
```

Random answer

```
// Asks the user to do adding problems and scores them.
import java.util.*;

public class AddingGame {
    public static void main(String[] args) {
        Scanner console = new Scanner(System.in);
        Random rand = new Random();

        // play until user gets 3 wrong
        int points = 0;
        int wrong = 0;
        while (wrong < 3) {
            int result = play(console, rand);    // play one game
            if (result == 0) {
                wrong++;
            }
            points += result;
        }

        System.out.println("You earned " + points + " total points.");
    }
```

Random answer 2

```
...
    // Builds one addition problem and presents it to the user.
    // Returns 1 point if you get it right, 0 if wrong.
    public static int play(Scanner console, Random rand) {
        // print the operands being added, and sum them
        int operands = rand.nextInt(4) + 2;
        int sum = rand.nextInt(10) + 1;
        System.out.print(sum);

        for (int i = 2; i <= operands; i++) {
            int n = rand.nextInt(10) + 1;
            sum += n;
            System.out.print(" + " + n);
        }
        System.out.print(" = ");

        // read user's guess and report whether it was correct
        int guess = console.nextInt();
        if (guess == sum) {
            return 1;
        } else {
            System.out.println("Wrong! The answer was " + sum);
            return 0;
        }
    }
}
```

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 >= 19 && 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...");
}
```

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
}
```

De Morgan's Law

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

Original Expression	Negated Expression	Alternative
`a && b`	`!a || !b`	`!(a && b)`
`a || b`	`!a && !b`	`!(a || b)`

  - Example:

Original Code	Negated Code

`if (x == 7 && y > 3) {`
`  ...`
`}`
	`if (x != 7 || y <= 3) {`
	`  ...`
	`}`

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);
}
```

When to return?

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

- Write a method `hasVowel` that accepts a `String` parameter and that returns true if the `String` contains at least one vowel. Return false otherwise.

Flawed solution

```
// Returns true if s contains at least 1 vowel.
public static boolean hasVowel(String s) {
    for (int i = 0; i < s.length(); i++) {
        if (isVowel(s.substring(i, i + 1))) {
            return true;
        } else {
            return false;
        }
    }
}
```

- The method always returns immediately after the first letter!
- If the first letter is not a vowel but the rest of the word contains a vowel, the result is wrong.

Returning at the right time

```
// Returns true if s contains at least 1 vowel.
public static boolean hasVowel(String s) {
    for (int i = 0; i < s.length(); i++) {
        // found vowel - exit
        if (isVowel(s.substring(i, i + 1))) {
            return true;
        }
    }
    return false;   // if we get here, there was no vowel
}
```

- Returns `true` immediately if vowel is found.
- If vowel isn't found, the loop continues walking the string.
- If no character is a vowel, the loop ends and we return `false`.