Topic 17
assertions and program logic

"As soon as we started programming, we found out to our surprise that it wasn't as easy to get programs right as we had thought. Debugging had to be discovered. I can remember the exact instant when I realized that a large part of my life from then on was going to be spent in finding mistakes in my own programs."

Maurice V Wilkes

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Based on slides by Marty Stepp and Stuart Reges
from http://www.buildingjavaprograms.com/

Clicker question

What is output by the following method?

```java
public static void mysteryB(boolean b) {
    System.out.print(b + " ");
    b = (b == false);
    System.out.print(b);
}
```

A. no output due to syntax error
B. no output due to runtime error
C. not possible to predict output
D. always outputs true false OR false true
E. always outputs true true OR false false

Assertions

- **Assertion**: A declarative sentence that is either true or false
- Examples:
  - 2 + 2 equals 4
  - The St. Louis Cardinals played in the 2011 world series
  - x > 45
  - It is raining.
  - UT beat OU last year.
  - UT qualified for the NCAA tourney last year.
- Not assertions
  - How old are you?
  - Take me to H.E.B.

Assertions

- Some assertions are true or false depending on context. Which of these depend on the context?
  - 2 + 2 equals 4
  - The St. Louis Cardinals played in the world series this year
  - x > 45
  - It is raining.
  - UT beat OU last year.
  - UT qualified for the NCAA tourney last year.
Assertions

- Assertions that depend on context can be evaluated if the context is provided.
  - when \( x \) is 13, \( x > 45 \)
  - It was raining in Round Rock, at 8 am on, October 10, 2006.
- Many skills required to be a programmer or computer scientist
  - ability to generalize
  - create structured solutions
  - trace code
  - manage lots of details

Another important skill in programming and computer science is the ability "to make assertions about your programs and to understand the contexts in which those assertions will be true."

```
Scanner console = new Scanner(System.in);
System.out.print("Enter Y or N: ");
String result = console.nextLine();
// is result equal to "Y" or "N" here?
```

Checking Input

```
Scanner console = new Scanner(System.in);
System.out.print("Enter Y or N: ");
String result = console.nextLine();
while(!result.equals("Y") && !result.equals("N")){
    System.out.print("That wasn't a Y or N. ");
    System.out.print("Enter Y or N: ");
    result = console.nextLine();
}
// is result equal to "Y" or "N" here?
```

Assertions

- Provable Assertion: An assertion that can be proven to be true at a particular point in program execution.
- Program Verification: A field of computer science that involves reasoning about the formal properties of programs to prove the correctness of a program.
  - Instead of testing.
  - A number of UTCS faculty are involved in verification research: Emerson, Hunt, Lam, Moore, Young
Reasoning about assertions

Suppose you have the following code:

```java
if (x > 3) {
    // Point A
    x--; // Point B
} else {
    // Point B
    x++; // Point C
}
// Point D
```

What do you know about x's value at the three points?
- Is $x > 3$? Always? Sometimes? Never?

Reasoning about programs

Right after a variable is initialized, its value is known:
```java
int x = 3;
// is x > 0? ALWAYS
```

In general you know nothing about parameters' values:
```java
public static void mystery(int a, int b) {
    // is a == 10? SOMETIMES
}
```

Assertions in code

We can make assertions about our code and ask whether they are true at various points in the code.
- Valid answers are ALWAYS, NEVER, or SOMETIMES.

```java
System.out.print("Type a nonnegative number: ");
double number = console.nextDouble(); // Point A: is number < 0.0 here? (SOMETIMES)
while (number < 0.0) {
    // Point B: is number < 0.0 here? (ALWAYS)
    System.out.print("Negative; try again: ");
    number = console.nextDouble(); // Point C: is number < 0.0 here? (SOMETIMES)
}
// Point D: is number < 0.0 here? (NEVER)
```

Reasoning about programs

But inside an if, while, etc., you may know something:
```java
public static void mystery(int a, int b) {
    if (a < 0) {
        // is a == 10? NEVER
    }
    ...
}
```
Assertions and loops

- At the start of a loop's body, the loop's test must be true:
  ```java
  while (y < 10) {
      // is y < 10? ALWAYS ...
  }
  ```

- After a loop, the loop's test must be false:
  ```java
  while (y < 10) {
      ...
  // is y < 10? NEVER
  ```

- Inside a loop's body, the loop's test may become false:
  ```java
  while (y < 10) {
      y++;
      // is y < 10? SOMETIMES
  }
  ```

"Sometimes"

- Things that cause a variable's value to be unknown (often leads to "sometimes" answers):
  - reading from a Scanner
  - reading a number from a Random object
  - initial value of a parameter in a method

- If you can reach a part of the program both with the answer being "yes" and the answer being "no", then the correct answer is "sometimes".

Assertion example 1

```java
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);
}
```

Assertion example 2

```java
public static int mystery(Scanner console) {
    int prev = 0;
    int count = 0;
    int next = console.nextInt();
    // Point A
    while (next != 0) {
        // Point B
        if (next == prev) {
            // Point C
            count++;
        }
        prev = next;
        next = console.nextInt();
        // Point D
    }
    // Point E
    return count;
}
```

For each assertion state if it is ALWAYS, NEVER, or SOMETIMES true at the specified points in the code.

<table>
<thead>
<tr>
<th></th>
<th>x &lt; y</th>
<th>x = y</th>
<th>z = 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point A</td>
<td>SOMETIMES</td>
<td>SOMETIMES</td>
<td>ALWAYS</td>
</tr>
<tr>
<td>Point B</td>
<td>NEVER</td>
<td>SOMETIMES</td>
<td>SOMETIMES</td>
</tr>
<tr>
<td>Point C</td>
<td>SOMETIMES</td>
<td>NEVER</td>
<td>NEVER</td>
</tr>
<tr>
<td>Point D</td>
<td>SOMETIMES</td>
<td>SOMETIMES</td>
<td>NEVER</td>
</tr>
<tr>
<td>Point E</td>
<td>ALWAYS</td>
<td>NEVER</td>
<td>SOMETIMES</td>
</tr>
</tbody>
</table>
Assertion example 3

```java
// Assumes y >= 0, and returns x^y
public static int pow(int x, int y) {
    int prod = 1;

    // Point A
    while (y > 0) {
        // Point B
        if (y & 2 == 0) {
            // Point C
            x = x * x;
            y = y / 2;
            // Point D
        } else { // Point E
            prod = prod * x;
            y--; // Point F
        }
    }
    // Point G
    return prod;
```

For each assertion state if it is ALWAYS, NEVER, or SOMETIMES true at the specified points in the code:

<table>
<thead>
<tr>
<th>Point</th>
<th>y &gt; 0</th>
<th>y &amp; 2 == 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point A</td>
<td>SOMETIMES</td>
<td>SOMETIMES</td>
</tr>
<tr>
<td>Point B</td>
<td>ALWAYS</td>
<td>SOMETIMES</td>
</tr>
<tr>
<td>Point C</td>
<td>ALWAYS</td>
<td>ALWAYS</td>
</tr>
<tr>
<td>Point D</td>
<td>ALWAYS</td>
<td>SOMETIMES</td>
</tr>
<tr>
<td>Point E</td>
<td>ALWAYS</td>
<td>NEVER</td>
</tr>
<tr>
<td>Point F</td>
<td>SOMETIMES</td>
<td>ALWAYS</td>
</tr>
<tr>
<td>Point G</td>
<td>NEVER</td>
<td>ALWAYS (SOMETIMES if expectation ignored)</td>
</tr>
</tbody>
</table>