Building Java Programs

Chapter 2: Primitive Data and Definite Loops

Lecture outline

- data concepts
  - **Primitive types**: int, double, char (for now)
  - **Expressions**: operators, precedence…
  - **Variables**: declaration, initialization, assignment
  - **Mixing types**: string concatenation
  - `System.out.print`

The big picture

- Programs need data to be interesting
  - The position of a monster in a game
  - Your current GPA
  - Your e-mail address
  - The GPS coordinates of the space needle
- To manipulate data, computers must know types
  - Can’t compare GPS coordinates to GPAs
  - Division doesn’t work on e-mail addresses
- Programs need to store data
  - Past GPA is needed to calculate current GPA given grades
  - Old position of monster needed to calculate new one

Primitive data and expressions

reading: 2.1

self-check: 1-4

Computer’s vision of data

- Internally, the computer stores everything in terms of 1s and 0s
  - Example:

```
h       → 0110100
"hi"    → 01101000110101
104     → 0110100
```

- How can the computer tell the difference between an h and 104?

Data types

- **type**: A category or set of data values.
  - Constrains the operations that can be performed on data
  - Many languages ask the programmers to specify type
  - Examples: integer, real number, string.

Java's primitive types

- **primitive types**: Java's built-in simple data types for numbers, text characters, and logic.
  - Java has eight primitive types.
  - Also has **object types**, which we'll talk about later
- Four primitive types we will use:

Name	**Description**	**Examples**
`int`	integers (whole numbers)	`42, -3, 0, 926394`
`double`	real numbers	`3.1, -0.25, 9.4e3`
`char`	single text characters	`'a', 'X', '?', '\n'`
`boolean`	logical values	`true, false`

- Isn't every integer a real number? Why bother?

Integer or real number?

- Which type is more appropriate?

integer (`int`)	real number (`double`)

1. Temperature in degrees Celsius
2. The population of lemmings
3. Your grade point average
4. A person's age in years
5. A person's weight in pounds
6. A person's height in meters
7. Number of miles traveled
8. Number of dry days in the past month
9. Your locker number
10. Number of seconds left in a game
11. The sum of a group of integers
12. The average of a group of integers

Manipulating data

- **expression**: A data value, or a set of operations that compute a data value.

  Examples:

  ```
  1 + 4 * 3
  3
  "CSE142"
  (1 + 2) % 3 * 4
  ```

  - The simplest expression is a *literal value*.
  - A complex expression can use *operators* and parentheses.
    - The values to which an operator applies are called *operands*.

Arithmetic operators

- Five arithmetic operators we will use:

+	addition
-	subtraction or negation
*	multiplication
/	division
%	modulus, a.k.a. remainder

Evaluating expressions

- As your Java program executes:
  - When a line with an expression is reached, the expression is *evaluated* (its value is computed).
    - `1 + 1` is evaluated to `2`
  - `System.out.println(3 * 4);` prints `12`
    (How would we print the text `3 * 4` ?)
- When an expression contains more than one operator of the same kind, it is evaluated left-to-right.
  - `1 + 2 + 3` is `(1 + 2) + 3` which is `6`
  - `1 - 2 - 3` is `(1 - 2) - 3` which is `-4`

Integer division with /

- When we divide integers, the quotient is also an integer.
  - 14 / 4 is 3, not 3.5

```
      3                4                     52
   ____             ____                 ______
4 ) 14         10 ) 45             27 ) 1425
    12               40                  135
    --               --                  ---
     2                5                   75
                                          54
                                          --
                                          21
```

  - More examples:
    - 1425 / 27 is 52
    - 84 / 10 is 8
    - 156 / 100 is 1

  - Dividing by 0 causes an error when your program runs.

Integer remainder with %

- The % operator computes the remainder from a division of two integers.
  - 14 % 4 is 2
  - 218 % 5 is 3

```
        3                                  43
 4 ) 14                            5 ) 218
     12                                20
     --                                --
      2                                 18
                                        15
                                        --
                                         3
```

- What are the results of the following expressions?
  - 45 % 6
  - 2 % 2
  - 8 % 20
  - 11 % 0

Applications of % operator

- Obtain the last digit (units place) of a number:
  - Example: From 230857, obtain the 7.

- Obtain the last 4 digits of a Social Security Number:
  - Example: From 658236489, obtain 6489.

- Obtain a number's second-to-last digit (tens place):
  - Example: From 7342, obtain the 4.

- Use the % operator to see whether a number is odd:
  - Can it help us determine whether a number is divisible by 3?

Operator precedence

- **precedence**: Order in which operations are computed.
  - `*  /  %` have a higher level of precedence than `+  -`

    `1 + ` **`3 * 4`** is 13

  - Parentheses can be used to force a certain order of evaluation.

    `(1 + 3) * 4` is 16

  - Spacing does not affect order of evaluation.

    `1+3 * 4-2` is 11

Precedence examples

```
1 * 2 + 3 * 5 / 4
 \_/
  |
  2   + 3 * 5 / 4
        \_/
         |
  2   +  15   / 4
          \___/
            |
  2   +     3
   \________/
        |
        5
```

```
1 + 2 / 3 * 5 - 4
    \_/
     |
1 +  0    * 5 - 4
      \_____/
         |
1 +      0    - 4
 \_______/
     |
     1        - 4
      \_________/
           |
          -3
```

Precedence questions

- What values result from the following expressions?
  - 9 / 5
  - 695 % 20
  - 7 + 6 * 5
  - 7 * 6 + 5
  - 248 % 100 / 5
  - 6 * 3 - 9 / 4
  - (5 - 7) * 4
  - 6 + (18 % (17 - 12))

Real numbers (double)

- Java can also manipulate real numbers (type double).
  - Examples: 6.022 -42.0 2.143e17

- The operators + - * / % ( ) all work for real numbers.
  - The / produces an exact answer
    15.0 / 2.0 is 7.5

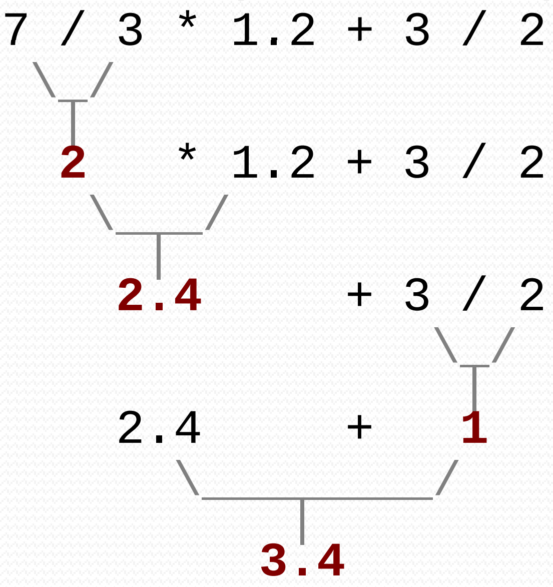
- The same rules of precedence that apply to integers also apply to real numbers.
  - Evaluate ( ) before * / % before + -

Real number example

```
2.0 * 2.4 + 2.25 * 4.0 / 2.0
  \___/
    |
   4.8    + 2.25 * 4.0 / 2.0
              \___/
                |
   4.8    +    9.0   / 2.0
                 \_____/
                    |
   4.8    +        4.5
      \____________/
             |
            9.3
```

Mixing integers and reals

- When a Java operator is used on an integer and a real number, the result is a real number.
  - `4.2 * 3` is `12.6`
- The conversion occurs on a per-operator basis. It affects only its two operands.



```
7 / 3 * 1.2 + 3 / 2

  2   * 1.2 + 3 / 2

    2.4     + 3 / 2

    2.4     +   1

         3.4
```

  - Notice how `3 / 2` is still `1` above, not `1.5`.

Mixed types example

```
2.0 + 10 / 3 * 2.5 - 6 / 4
       \___/
         |
2.0 +    3   * 2.5 - 6 / 4
         \_____/
            |
2.0 +      7.5     - 6 / 4
                      \_/
                       |
2.0 +      7.5     -   1
 \_________/
      |
     9.5           -   1
       \______________/
               |
              8.5
```

Variables

reading: 2.2

self-check: 1-15

exercises: 1-4

Receipt program

```
public class Receipt {
    public static void main(String[] args) {
        // Calculate and display the total owed
        // assuming 9% tax and 15% tip
        System.out.println("Subtotal:");
        System.out.println(38 + 40 + 30);
        System.out.println("Tax:");
        System.out.println((38 + 40 + 30) * .09);
        System.out.println("Tip:");
        System.out.println((38 + 40 + 30) * .15);
        System.out.println("Total:");
        System.out.println(38 + 40 + 30 +
                          (38 + 40 + 30) * .15 +
                          (38 + 40 + 30) * .09);
    }
}
```

Receipt: what's wrong?

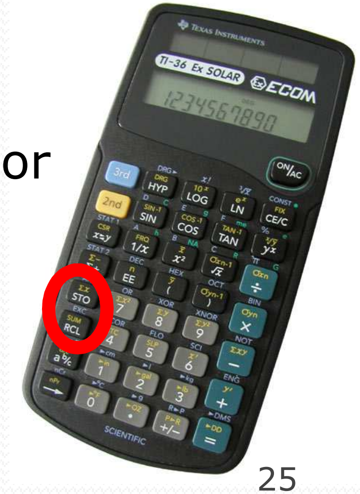
- The subtotal expression `(38 + 40 + 30)` is repeated
  - Meaning of expression can be lost
  - Potential for transcription errors
  - Program is hard to read

- So many `println` statements
  - Not clear how many pieces of information are printed

Variables

- **variable**: A piece of your computer's memory that is given a name and type and can store a value.
  - Variables are a bit like preset stations on a car stereo.

  - Or like the memory buttons on a calculator
    - Expressions are like using the computer as a calculator



Declaring variables

- **variable declaration statement**: A Java statement that creates a new variable of a given type.
  - A variable is declared in a statement with its type and name.
  - Variables must be declared before they can be used.

- Declaration syntax:

  <type> <name> ;

  - int x;
  - double myGPA;
  - The name can be any identifier.

More on declaring variables

- Declaring a variable sets aside a piece of memory in which you can store a value.
  - `int x;`
  - `int y;`

  - Part of the computer's memory:

x

y

(The memory has no values in it yet.)

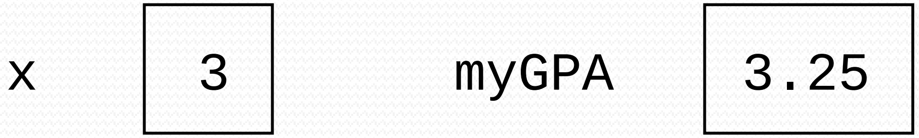
Assignment statements

- **assignment statement**: A statement that stores a value into a variable's memory.
  - Variables must be declared before they can be assigned a value.

- Assignment statement syntax:

  <name> = <value> ;

  - `x = 3;`
  - `myGPA = 3.25;`



```
x     3          myGPA    3.25
```

More about assignment

- The ***<value>*** assigned can be a complex expression.
  - The expression is evaluated; the variable stores the result.
  - `x = (2 + 8) / 3 * 5;`

```
x        15
```

- A variable can be assigned a value more than once.
  - Example:

```
int x;
x = 3;
System.out.println(x);   // 3

x = 4 + 7;
System.out.println(x);   // 11
```

Using variables' values

- Once a variable has been assigned a value, it can be used in an expression, just like a literal value.

```
int x;
x = 3;
System.out.println(x * 5 - 1);
```

  - The above has output equivalent to:

```
System.out.println(3 * 5 - 1);
```

Assignment and algebra

- Though the assignment statement uses the = character, it is not an algebraic equation.
  - = means, "store the value on right in the variable on left"
  - Some people read `x = 3;` as, "x becomes 3" or, "x gets 3"
  - We would not say `3 = 1 + 2;` because 3 is not a variable.
- What happens when a variable is used on both sides of an assignment statement?

```
int x;
x = 3;
x = x + 2;   // what happens?
```

  - The above wouldn't make any sense in algebra...

Some errors

- A compiler error will result if you declare a variable twice, or declare two variables with the same name.

  -
    ```
    int x;
    int x;                          // ERROR: x already exists
    ```

- A variable that has not been assigned a value cannot be used in an expression or `println` statement.

  -
    ```
    int x;
    System.out.println(x);   // ERROR: x has no value
    ```

    “variable x might not have been initialized”

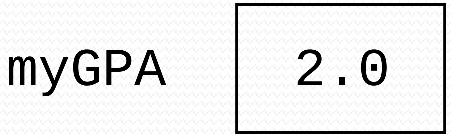
Assignment and types

- A variable can only store a value of its own type.

  -
    ```
    int x;
    x = 2.5;    // ERROR: x can only store int
    ```

- An `int` value can be stored in a `double` variable.
  - The value is converted into the equivalent real number.

  -
    ```
    double myGPA;
    myGPA = 2;
    ```



Assignment examples

- What is the output of the following Java code?

```
int number;
number = 2 + 3 * 4;
System.out.println(number - 1);

number = 16 % 6;
System.out.println(2 * number);
```

- What is the output of the following Java code?

```
double average;
average = (11 + 8) / 2;
System.out.println(average);

average = (5 + average * 2) / 2;
System.out.println(average);
```

Declaration/initialization

- A variable can be declared and assigned an initial value in the same statement.

- Declaration/initialization statement syntax:

  <type> <name> = <value> ;

```
double myGPA = 3.95;
int x = (11 % 3) + 12;
```

same effect as:

```
double myGPA;
myGPA = 3.95;

int x;
x = (11 % 3) + 12;
```

Multiple declaration error

- The compiler will fail if you try to declare-and-initialize a variable twice.

  -
    ```
    int x = 3;
    System.out.println(x);

    int x = 5;       // ERROR: variable x already exists
    System.out.println(x);
    ```
  - This is the same as trying to declare x twice.

- How can the code be fixed?

String concatenation

- **string concatenation**: Using the + operator between a String and another value to make a longer String.
  - Examples:
    - Recall: Precedence of + operator is below * / %

```
"hello" + 42      is "hello42"
1 + "abc" + 2     is "1abc2"
"abc" + 1 + 2     is "abc12"
1 + 2 + "abc"     is "3abc"
"abc" + 9 * 3     is "abc27"
"1" + 1           is "11"
4 - 1 + "abc"     is "3abc"

"abc" + 4 - 1     causes a compiler error... why?
```

Printing String expressions

- Print complicated messages with computed values

  -
    ```
    double grade = (95.1 + 71.9 + 82.6) / 3.0;
    System.out.println("Your grade was " + grade);

    int students = 11 + 17 + 4 + 19 + 14;
    System.out.println("There are " + students +
                       " students in the course.");
    ```

Output:

```
Your grade was 83.2
There are 65 students in the course.
```

Example variable exercise

- Rewrite the Receipt program using what we just learned

```
public class Receipt2 {
    public static void main(String[] args) {
        //Calculate and display the total owed
        // assuming 9% tax and 15%      tip
        double subtotal = 38 + 40 + 30;
        double tax = subtotal * .09;
        double tip = subtotal * .15;
        double total = subtotal + tax + tip;

        System.out.println("Subtotal: " + subtotal);
        System.out.println("Tax: " + tax);
        System.out.println("Tip: " + tip);
        System.out.println("Total: " + total);
    }
}
```