Elementary Programming

EECS1021:
Object Oriented Programming:
from Sensors to Actuators
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Learning Outcomes

- Learn *ingredients* of elementary programming:
  - data types [numbers, characters, strings]
  - literal values
  - constants
  - variables
  - operators [arithmetic, relational]
  - expressions
  - input and output
- Given a problem:
  - First, plan how you would solve it mathematically.
  - Then, *Implement* your solution by writing a Java program.

Entry Point of Execution: the “main” Method

For now, all your programming exercises will be defined within the body of the *main* method.

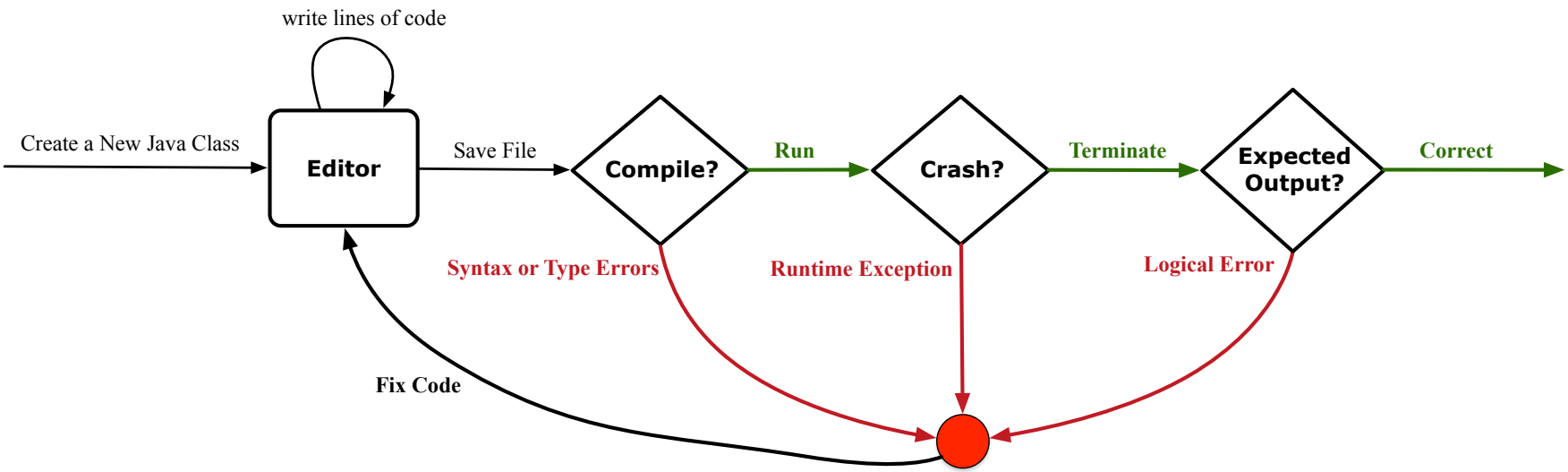
```
public class MyClass {
   public static void main(String[] args) {
      /* Your programming solution is defined here. */
   }
}
```

The *main* method is treated by Java as the *starting point* of executing your program.

Sequential Execution:

The execution starts with the first line in the *main* method, proceed line by line, from top to bottom, until there are no more lines to execute, then it *terminates*.

Development Process



Compile Time vs. Run Time

- These terms refer to two stages of developing your program.
- *Compile time*: when editing programs in Eclipse.
  - There are two kinds of *compile-time errors*:
  - *Syntax errors*: your program does not conform to Java's grammar.
    - e.g., missing the semicolon, curly braces, or round parentheses
    - Java syntax is defined in the Java language specification.
  - *Type errors*: your program manipulates data in an inconsistent way
    e.g., `"York" * 23` [∵ multiplication is only for numbers]
- *Run time* is when executing/running the *main* method.
  - *Exceptions*: your program crashes and terminates *abnormally*
    - e.g., `ArithmeticException` (e.g., `10 / 0`), `ArrayIndexOutOfBoundException`, `NullPointerException`.
  - *Logical errors*: your program terminates *normally* but does not behave as expected
    e.g., calculating area of a circle with radius r using $2 \cdot \pi \cdot r$

Compile Time Errors vs. Run Time Errors

At the end of a computer lab test, if your submitted program:

- Cannot compile

  ⇒ Your program cannot even be run
  ⇒ ***Zero***!

  What you should do :
  Practice writing as many programs as possible.

- Compiles, but run with exceptions or unexpected outputs.

  ⇒ Not necessarily zero, but likely ***low marks***!

  What you should do :
  Truly understand the logic/rationale beyond programs.

Always Document Your Code

- Each important design or implementation *decision* should be carefully *documented* at the right place of your code.
- **Single-Lined** Comments: [Eclipse: `Ctrl + /`]

```
// This is Comment 1.
... // Some code
// This is Comment 2.
```

- **Multiple-Lined** Comments: [Eclipse: `Ctrl + /`]

```
/* This is Line 1 of Comment 1.
 */
... // Some code
/* This is Line 1 of Comment 2.
 * This is Line 2 of Comment 2.
 * This is Line 3 of Comment 2.
 */
```

- Comments **do not affect** the runtime behaviour of programs.
- Comments are **only interpreted by** human developers.
  ⇒ Useful for ***revision*** and ***extension***.

Literals (1)

A *literal* is a *constant value* that appears directly in a program.

1. *Character* Literals
   - A single character enclosed within a pair of single quotes
   - e.g., `'a'`, `'1'`, `'*'`, `'('`, `' '`
   - It is invalid to write an empty character: `''`
2. *String* Literals
   - A (possibly empty) sequence of characters enclosed within a pair of double quotes
   - e.g., `"'"`, `"a"`, `"York"`, `"*#@$"`, `" "`
3. *Integer* Literals
   - A non-empty sequence of numerical digits
   - e.g., 0, -123, 123, 23943
4. *Floating-Point* Literals
   - Specified using a combination of an integral part and a fractional part, separated by a decimal point, or using the scientific notation
   - e.g., 0.3334, 12.0, 34.298, 1.23456E+2 (for 1.23456×10^2), 1.23456E-2 (for 1.23456×10^{-2})

Operations

An *operation* refers to the process of applying an *operator* to its *operand*(s).

1. *Numerical* Operations [results are numbers]
   - e.g., `1.1 + 0.34`
   - e.g., `13 / 4` [quotient: `3`]
   - e.g., `13.0 / 4` [precision: `3.25`]
   - e.g., `13 % 4` [remainder: `1`]
   - e.g., `-45`
   - e.g., `-1 * 45`
2. *Relational* Operations [results are true or false]
   - e.g., `3 <= 4` [*true*]
   - e.g., `5 < 3` [*false*]
   - e.g., `56 == 34` [*false*]
3. *String* Concatenations [results are strings]
   - e.g., ``` ``York'' + `` '' + ``University'' ``` is equivalent to ``` ``York University'' ```

Java Data Types

A (data) type denotes a set of related *runtime values*.

1. *Integer* Type

`byte`	8 bits	$-128, \ldots, -1, 0, 1, \ldots, 2^7 - 1]$
`short`	16 bits	$[-2^{15}, 2^{15} - 1]$
`int`	32 bits	$[-2^{31}, 2^{31} - 1]$
`long`	64 bits	$[-2^{63}, 2^{63} - 1]$

2. *Floating-Point Number* Type

`float`	32 bits
`double`	64 bits

3. *Character* Type

   `char`: the set of single characters

4. *String* Type

   `String`: the set of all possible character sequences

*Declaring a variable `v` to be of type `T` constrains `v` to store **only** those values defined in `T`.*

Assignments

An *assignment* designates a value for a variable, or initializes a *named constant*.

That is, an assignment replaces the *old value* stored in a placeholder with a *new value*.

An *assignment* is done using the assignment operator (=).

An *assignment operator* has two operands:

- The *left* operand is called the *assignment target*
  which must be a variable name
- The *right* operand is called the *assignment source*
  which must be an expression whose type is *compatible* with the declared type of *assignment target*

e.g., This is a *valid* assignment:

```
String name1 = ``Heeyeon'';
```

e.g., This is an *invalid* assignment:

```
String name1 = (1 + 2) * (23 % 5);
```

Named Constants vs. Variables

A *named constant* or a *variable*:

- Is an identifier that refers to a *placeholder*
- Must be declared with its *type* (of stored value) before use:

```
final double PI = 3.14159; /* a named constant */
double radius; /* an uninitialized variable */
```

- Can only store a value that is *compatible with its declared type*

However, a *named constant* and a *variable* are different in that:

- A named constant must be *initialized*, and cannot change its stored value.
- A variable may change its stored value as needed.

Expressions (1)

An *expression* is a composition of *operations*.
An expression may be:

- *Type Correct*: for each constituent operation, types of the *operands* are compatible with the corresponding *operator*.

  e.g., `(1 + 2) * (23 % 5)`

  e.g., ``` ``Hello '' + ``world'' ```
- *Not Type Correct*

  e.g., ``` ``46'' % ``4'' ```

  e.g., ``` (``YORK '' + ``University'') * (46 % 4) ```
  - ``` ``YORK'' ``` and ``` ``University'' ``` are both strings
    ∴ LHS of `*` is *type correct* and is of type `String`
  - `46` and `4` are both integers
    ∴ RHS of `%` is *type correct* and is of type `int`
  - Types of LHS and RHS of `*` are not compatible
    ∴ Overall the expression (i.e., a multiplication) is *not type correct*

Multiple Executions of Same Print Statement

Executing *the same print statement* multiple times *may or may not* output different messages to the console.

e.g., Print statements involving literals or named constants only:

```
final double PI = 3.14; /* a named double constant */
System.out.println("Pi is " + PI); /* str. lit. and num. const. */
System.out.println("Pi is " + PI);
```

e.g., Print statements involving variables:

```
String msg = "Counter value is "; /* a string variable */
int counter = 1; /* an integer variable */
System.out.println(msg + counter);
System.out.println(msg + counter);
counter = 2; /* re-assignment changes variable's stored value */
System.out.println(msg + counter);
```

Case Study 1: Compute the Area of a Circle

Problem: declare two variables `radius` and `area`, initialize `radius` as 20, compute the value of `area` accordingly, and print out the value of `area`.

```
public class ComputeArea {
  public static void main(String[] args) {
    double radius; /* Declare radius */
    double area; /* Declare area */
    /* Assign a radius */
    radius = 20; /* assign value to radius */
    /* Compute area */
    area = radius * radius * 3.14159;
    /* Display results */
    System.out.print("The area of circle with radius ");
    System.out.println(radius + " is " + area);
  }
}
```

It would be more flexible if we can let the user specify the inputs via keyboard!

Input and Output

Reading input from the console enables *user interaction*.

```
import java.util.Scanner;
public class ComputeAreaWithConsoleInput {
  public static void main(String[] args) {
    /* Create a Scanner object */
    Scanner input = new Scanner(System.in);
    /* Prompt the user to enter a radius */
    System.out.print("Enter a number for radius: ");
    double radius = input.nextDouble();
    /* Compute area */
    final double PI = 3.14169; /* a named constant for π */
    double area = PI * radius * radius; /* area = πr^2 */
    /* Display result */
    System.out.println(
      "Area for circle of radius " + radius + " is " + area);
  }
}
```

Useful Methods for Scanner

- *nextInt()* which reads an integer value from the keyboard
- *nextDouble()* which reads a double value from the keyboard
- *nextLine()* which reads a string value from the keyboard

Variables: Common Mistakes (1)

Mistake: The same variable is declared more than once.

```
int counter = 1;
int counter = 2;
```

Fix 1: Assign the new value to the same variable.

```
int counter = 1;
counter = 2;
```

Fix 2: Declare a new variable (with a different name).

```
int counter = 1;
int counter2 = 2;
```

Which fix to adopt depends on what you need!

Variables: Common Mistakes (2)

Mistake: A variable is used before it is declared.

```
System.out.println("Counter value is " + counter);
int counter = 1;
counter = 2;
System.out.println("Counter value is " + counter);
```

Fix: Move a variable's declaration before its very first usage.

```
int counter = 1;
System.out.println("Counter value is " + counter);
counter = 2;
System.out.println("Counter value is " + counter);
```

Remember, Java programs are always executed, line by line, *from top to bottom*.

Case Study 2: Display Time

Problem: prompt the user for an integer value of seconds, divide that value into minutes and remaining seconds, and print the results. For example, given an input 200, output “200 seconds is 3 minutes and 20 seconds”.

```
import java.util.Scanner;
public class DisplayTime {
  public static void main(String[] args) {
    Scanner input = new Scanner(System.in);
    /* Prompt the user for input */
    System.out.print("Enter an integer for seconds: ");
    int seconds = input.nextInt();
    int minutes = seconds / 60; /* minutes */
    int remainingSeconds = seconds % 60; /* seconds */
    System.out.print(seconds + " seconds is ");
    System.out.print(" minutes and ");
    System.out.println(remainingSeconds + " seconds");
  }
}
```

Where May Assignment Sources Come From?

In `tar = src`, the *assignment source* `src` may come from:

- A literal

```
int i = 23;
```

- A variable

```
int i = 23;
int j = i;
```

- An expression involving literals and variables

```
int i = 23;
int j = i * 2;
```

- An input from the user

```
Scanner input = new Scanner(System.in);
int i = input.nextInt();
int j = i * 2;
```

Numerical Type Conversion: Coercion

- *Implicit* and *automatic* type conversion
- Java *automatically* converts an integer value to a real number when necessary (which adds a fractional part).

```
double value1 = 3 * 4.5;  /* 3 coerced to 3.0 */
double value2 = 7 + 2;  /* result of + coerced to 9.0 */
```

- However, does the following work?

```
int value1 = 3 * 4.5;
```

  - RHS evaluates to `13.5` due to coercion.
  - LHS declares a variable for storing integers (with no fractional parts).

$\therefore$ Not compatible [***compile-time error***]

$\Rightarrow$ Need a way to "truncate" the fractional part!

Numerical Type Conversion: Casting

- *Explicit* and *manual* type conversion
- **Usage 1**: To assign a real number to an integer variable, you need to use explicit *casting* (which throws off the fractional part).

```
int value3 = (int) 3.1415926;
```

- **Usage 2:** You may also use explicit *casting* to force precision.
  - ```
    System.out.println(1 / 2);  /* 0 */
    ```
    ∵ When both operands are integers, division evaluates to quotient.
  - ```
    System.out.println( ((double) 1) / 2 ); /* 0.5 */
    System.out.println( 1 / ((double) 2) ); /* 0.5 */
    System.out.println( ((double) 1) / ((double) 2) ); /* 0.5 */
    ```
    ∵ Either or both of the integers operands are cast to `double` type
  - ```
    System.out.println((double) 1 / 2);  /* 0.5 */
    ```
    ∵ Casting has *higher precedence* than arithmetic operation.
  - ```
    System.out.println((double) (1 / 2));  /* 0.0 */
    ```
    ∵ Order of evaluating division is forced, via parentheses, to occur first.

Numerical Type Conversion: Exercise

Consider the following Java code:

```
1  double d1 = 3.1415926;
2  System.out.println("d1 is " + d1);
3  double d2 = d1;
4  System.out.println("d2 is " + d2);
5  int i1 = (int) d1;
6  System.out.println("i1 is " + i1);
7  d2 = i1 * 5;
8  System.out.println("d2 is " + d2);
```

Write the **exact** output to the console.

```
d1 is 3.1415926
d2 is 3.1415926
i1 is 3
d2 is 15.0
```

Expressions (2.1)

Consider the following Java code, is each line type-correct? Why and Why Not?

```
1  double d1 = 23;
2  int i1 = 23.6;
3  String s1 = ' ';
4  char c1 = " ";
```

- **L1**: YES [coercion]
- **L2**: NO [cast assignment source, i.e., `(int) 23.6`]
- **L3**: NO [cannot assign char to string]
- **L4**: NO [cannot assign string to char]

Expressions (2.2)

Consider the following Java code, is each line type-correct? Why and Why Not?

```
1  int i1 = (int) 23.6;
2  double d1 = i1 * 3;
3  String s1 = "La ";
4  String s2 = s1 + "La Land";
5  i1 = (s2 * d1) + (i1 + d1);
```

- **L1**: YES [proper cast]
- **L2**: YES [coercion]
- **L3**: YES [string literal assigned to string var.]
- **L4**: YES [type-correct string concat. assigned to string var.]
- **L5**: NO [string × number is undefined]

Augmented Assignments

- You very often want to increment or decrement the value of a variable by some amount.

```
balance = balance + deposit;
balance = balance - withdraw;
```

- Java supports special operators for these:

```
balance += deposit;
balance -= withdraw;
```

- Java supports operators for incrementing or decrementing by 1:

```
i ++; j --;
```

- *Confusingly*, these increment/decrement assignment operators can be used in assignments:

```
int i = 0; int j = 0; int k = 0;
k = i ++; /* k is assigned to i's old value */
k = ++ j; /* k is assigned to j's new value */
```

Literals (2)

Q. Outputs of `System.out.println('a')` versus `System.out.println(''a'')`? [SAME]

Q. Result of comparison `''a'' == 'a'`? [TYPE ERROR]

- Literal `''a''` is a string (i.e., *character sequence*) that consists of a single character.
- Literal `'a'` is a single *character*.

∴ You cannot compare a character sequence with a character.

Escape Sequences

An *escape sequence* denotes a single character.

- Specified as a *backslash* (\) followed by a *single character*
  - e.g., `\t`, `\n`, `\'`, `\"`, `\\`
- *Does not mean literally*, but means specially to Java compiler
  - `\t` means a tab
  - `\n` means a new line
  - `\\` means a back slash
  - `\'` means a single quote
  - `\"` means a double quote
- May use an *escape sequence* in a character or string literal:
  - `''' ` [INVALID; need to escape ']
  - `'\''` [VALID]
  - `'"'` [VALID; no need to escape "]
  - `""" ` [INVALID; need to escape "]
  - `"\""` [VALID]
  - `"' "` [VALID; no need to escape ']
  - `"\n\t\""` [VALID]

print vs. println

Executing `System.out.println(someString)` is the same as executing `System.out.print(someString + "\n")`.

- e.g.,

```
System.out.print("Hello");
System.out.print("World");
```

```
HelloWorld
```

- e.g.,

```
System.out.println("Hello");
System.out.println("World");
```

```
Hello
World
```

Identifiers & Naming Conventions

- Identifiers are *names* for identifying Java elements: *classes*, *methods*, *constants*, and *variables*.
- An identifier:
  - Is an arbitrarily long sequence of characters: letters, digits, underscores (`_`), and dollar signs (`$`).
  - Must start with a letter, an underscore, or a dollar sign.
  - Must not start with a digit.
  - Cannot clash with reserved words (e.g., `class`, `if`, `for`, `int`).
- *Valid* ids: `$2`, `Welcome`, `name`, `_name`, `YORK_University`
- *Invalid* ids: `2name`, `+YORK`, `Toronto@Canada`
- More conventions:
  - Class names are compound words, all capitalized: e.g., `Tester`, `HelloWorld`, `TicTacToe`, `MagicCardGame`
  - Variable and method names are like class names, except 1st word is all lower cases: e.g, `main`, `firstName`, `averageOfClass`
  - Constant names are underscore-separated upper cases: e.g., `PI`, `USD_IN_WON`

Beyond this lecture. . .

- Create a *tester* in Eclipse.
- Try out the examples give in the slides.
- See `https://docs.oracle.com/javase/tutorial/java/nutsandbolts/datatypes.html` for more information about data types in Java.

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