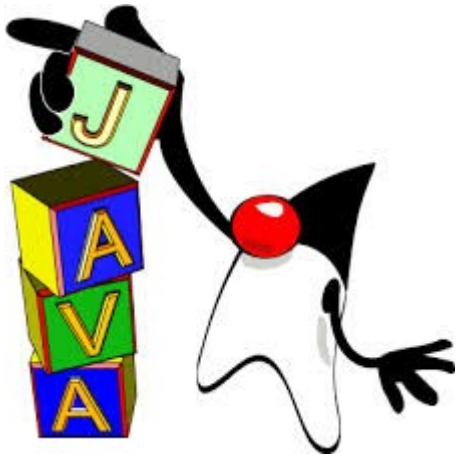
Advanced Programming Introduction

Course Description

https://profs.info.uaic.ro/~acf/java/

- The Goal
- The Motivation
- Lectures and Assignments
- Programming Platform
- Resources
- Evaluation



Lab: *problems, projects, essays* → easy

Exam: *written test* → hard

What exactly is “Java”?

- Programming Language
- Programming **Platform**
- 1995
- Sun Microsystems / **Oracle** (2010)
- James Gosling
- Duke

Why Java?

Java is Everywhere

Java is the world's most popular programming language. Java SE 9, our latest release, is the result of an industry-wide development effort involving open review, weekly builds, and extensive collaboration between Oracle engineers and members of the worldwide Java developer community via the OpenJDK Community and the JCP.

va experts >

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Developers Run Java
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Where Is Java Used?

- **Enterprise** applications (banking, commerce, etc.)
  - Large, complex, distributed, scalable, secure, etc.
  - Web: Gmail, Amazon, LinkedIn, Netflix, EBay, FB, etc.
- **Android** applications: most of them
- **Desktop** applications
  - IDES: Netbeans, Eclipse, IntelliJ, PyCharm, etc.
  - Application servers: GlassFish, Tomcat, etc.
- **IoT** applications
- **Huge** ecosystem of **libraries** and **frameworks**
  - Apache Foundation Projects, Hadoop, Spark, Spring, etc.
- Minecraft :)

Java Programming Language

- **Simplicity**

  "as simple as possible, but not simpler"
- **Robustness**: ~~pointers~~, automatic memory management, garbage collection, strong typing
- Completely **object-oriented**
- **Secure** class loading and verification
- **Architecture Neutrality**
- **Portability**
- **Performance**

WORA
Write once, run anywhere

Java Platforms

- **Java SE (Standard Edition)**

  Desktop applications, applets, Java Web Start, JavaFX

- **Java EE (Enterprise Edition)**

  Complex, distributed, large scale, applications; server-side components, Web Services, etc.

- **Java ME (Micro Edition)**

  Programming embedded systems, mobile devices, TVs, GPSs, etc.

- **Java Card**

Compiled and Interpreted

- **Interpreted languages**
  - simplicity, portability
  - low execution speed
- **Compiled languages**
  - high execution speed
  - no portability
- **Java: compiled *and* interpreted**

  The Java compiler doesn't generate "machine code" (native hardware instructions). Rather, it generates **bytecodes**: a high-level, machine-independent code for a hypothetical machine that is implemented by the Java interpreter and run-time system.

Static vs. Dynamic Types

- **Statically typed** programming languages verify and enforce the constraints of data types at **compile-time**.

Compile-time error

```
int test(int a) {
   return (a > 0 ? a + 1 : "a" - 1);
}
//Java
```

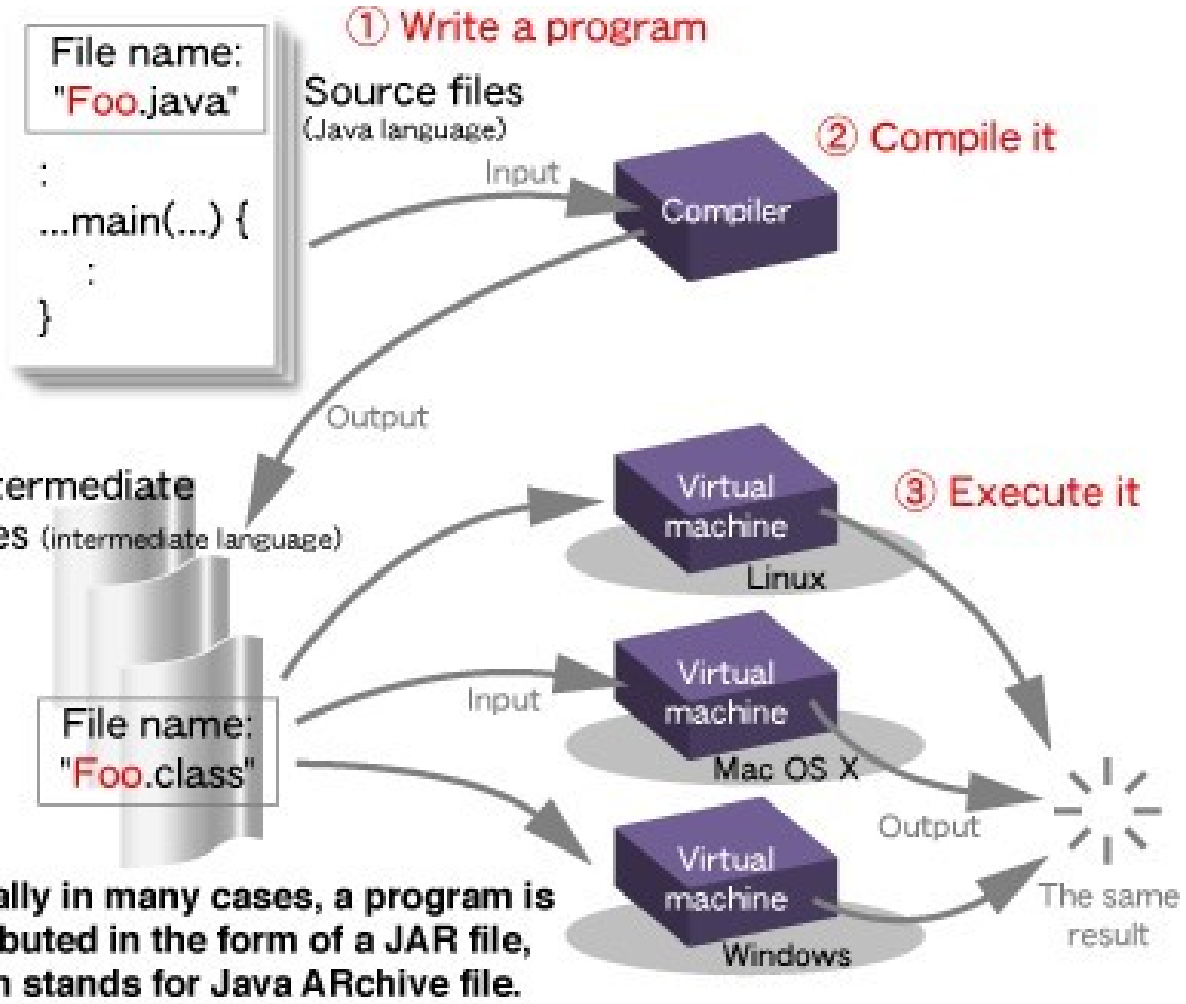
- **Dynamically typed** programming languages do type checking at **run-time**.

```
def test(a):
   return a + 1 if a > 0 else "a" - 1

#Python
```

Run-time error

Java Virtual Machine (JVM)

You are not alone...



- **Actually in many cases, a program is distributed in the form of a JAR file, which stands for Java ARchive file.**

JVM Specifications

https://docs.oracle.com/javase/specs/jvms/se8/html/index.html

“The Java Virtual Machine is the cornerstone of the Java platform. It is the component of the technology responsible for its hardware- and operating system-independence, the small size of its compiled code, and its ability to protect users from malicious programs.

The JVM is an abstract computing machine. Like a real computing machine, it has an instruction set and manipulates various memory areas at run time.

JVM does not assume any particular implementation technology, host hardware, or host operating system. It is not inherently interpreted, but can just as well be implemented by compiling its instruction set to that of a silicon CPU.

The JVM knows nothing of the Java programming language, only of a particular binary format, the class file format. A class file contains JVM instructions (or bytecodes).

For the sake of security, the JVM imposes strong syntactic and structural constraints on the code in a class file. However, any language with functionality that can be expressed in terms of a valid class file can be hosted by the Java Virtual Machine. “

JVM Languages

- Java
- Groovy :dynamic, scripting
- Scala :functional
- Kotlin :static, less verbose, Android
- Clojure :functional, Lisp dialect
- JRuby :port for Ruby
- Jython :port for Python
- etc.

The First Program

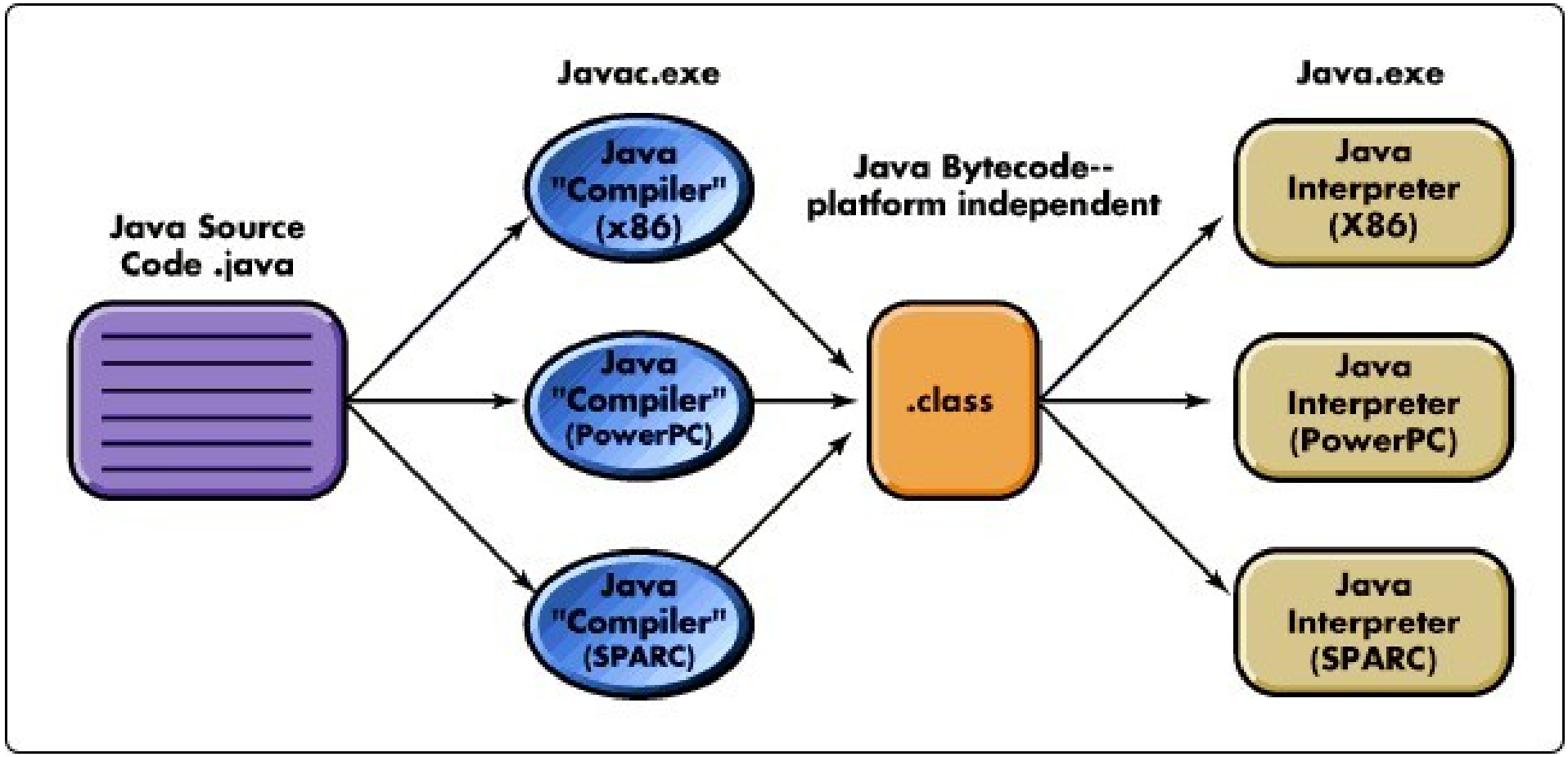
```
public class HelloWorld {

 public static void main(String args[]) {
   System.out.println("Hello world!");
 }
}
```

- *Source*: `HelloWorld.java`
- *Compile*

  `javac HelloWorld.java → HelloWorld.class`
- *Run*

  `java HelloWorld`

java, javac


Javac.exe
Java.exe
Java Source Code .java
Java "Compiler" (x86)
Java "Compiler" (PowerPC)
Java "Compiler" (SPARC)
Java Bytecode-- platform independent
.class
Java Interpreter (X86)
Java Interpreter (PowerPC)
Java Interpreter (SPARC)

javap

javap -c HelloWorld

```
Compiled from "HelloWorld.java"
public class HelloWorld extends java.lang.Object{
HelloWorld();
  Code:
   0: aload_0
   1: invokespecial #1;
      //Method java/lang/Object."<init>":()V
   4: return

public static void main(java.lang.String[]);
  Code:
   0: getstatic  #2;
      //Field java/lang/System.out:Ljava/io/PrintStream;
   3: ldc #3;
      //String Hello world!
   5: invokevirtual  #4;
      //Method java/io/PrintStream.println:(Ljava/lang/String;)V
   8: return
}
```

aload = load a reference onto the stack from a local variable #index
invokespecial = invoke instance method on object objectref and puts the result on the stack
getstatic = get a static field value of a class, where the field is identified by field reference in the constant pool index
ldc = push a constant #index from a constant pool
...

Obfuscation

JDK, JRE

- **JDK** = Java Development Kit
  - All the tools you need for Java **development**
  - Includes a JRE
  - Does not include an IDE
- **JRE** = Java Runtime Environment
  - All that is required to **run** a Java program
- Both include the **JVM**
- Current version: **17** (sept. 2021)
- Oracle JDK vs Open JDK

JVM Performance

- Early versions → bytecode was only interpreted
- **Just-in-time (JIT) compilation** (dynamic translation or run-time compilations)
  - Bytecode → Machine code
  - 10x faster
- **HotSpot**: code executed frequently
- **Warm-up** (lazy class loading and JIT compilation)
  - The first request made to a Java application is often substantially slower than the average response time during the lifetime of the process

Case Study (Informal)

- A $O(n^2)$ “intensive” bubble sort

```
int n = 100_000;
int a[] = new int[n];
for (int i = 0; i < n; i++) { a[i] = n - i; }
long t1 = System.currentTimeMillis();
for (int i = 0; i < n - 1; i++) {
    for (int j = 0; j < n - i - 1; j++) {
        if (a[j] > a[j + 1]) {
            int aux = a[j];
            a[j] = a[j + 1];
            a[j + 1] = aux;
        }
    }
}
long t2 = System.currentTimeMillis();
System.out.println(t2 - t1);
```

- Java: **5** s
- C++ Release: **4** s; C++ Debug: **20** s

Arrays.sort(a): **4** ms

Integrated Development Environment (IDE)

Code Assistance: Smart code completion, managing imports, refactoring, generating code, templates, hints, navigation, documentation, debugging, profiling, etc.

- **NetBeans IDE**
  - Apache Software, Oracle
- **Eclipse IDE**
  - Eclipse Foundation, IBM
- **IntelliJ IDEA**
  - JetBrains
- JDeveloper
- Oracle Developer Studio, etc.

<u>Examples (Netbeans)</u>

Write:

```
sout
```

*Press **TAB** and you get:*

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

Easy to write the code.
Easy to **read** its meaning.

*Suggestions: **Ctrl+Space***
*Rename: **Ctrl+R***
...

UNICODE

"Without Unicode, Java wouldn't be Java, and the Internet would have a harder time connecting the people of the world."
James Gosling, Inventor of Java

- Character encoding system.
- It supports most of the written languages.
- Each character is represented using **2 bytes**
- **65536** symbols, **\uxxxx** (\u03B1 → α)
- ASCII compatible
- Structured in **blocks**: Basic Latin, Greek, Arabic, Gothic, Currency, Mathematical, Arrows, Musical, etc.
- public class приветмир { }
- System.out.println(" 好世界 ");

Java Basic Syntax

- Similar to C++
- Keywords (50) (C++:93, C#: 79, Python: 33, Go:25, SmallTalk:6)
- Literals: “Hello World”, 'J', 'a', 'v', 'a', 10, 010, 0xA, 0b11, 12.3, 12.3d, 12.3f, 12e3, 123L, true, false, null, 0722_123_456
- Separators: `( ) { } [ ] ; , .`
- Operators

  (char)65 + “nna” + “has” + (8 >> 2) + “ apples”

  http://docs.oracle.com/javase/tutorial/java/nutsandbolts/index.html

Comments

```
/* To change this template file, choose Tools | Templates
   and open the template in the editor. */
/**
 * Main class of the application
 * @author Duke
 */
public class HelloWorld {
    /**
     The execution of the application starts here.
     @param args the command line arguments
     */
    public static void main(String args[]) {
        // TODO code application logic here
        System.out.println("Hello World!"); // Done!
    }
}
```

javadoc – a tool for generating API documentation in HTML format from doc comments in source code

Data Types

Primitive types

- arithmetic: `byte (1), short (2), int (4), long (8)`
- floating point: `float (4), double (8)`
- character: `char (2)`
- logical: `boolean (?)`

Reference types

classes, interfaces, annotations, enumerations

~~pointer, struct, union~~

Variables

A variable's name can be any legal identifier — an unlimited-length sequence of Unicode letters and digits, beginning with a letter, the dollar sign "$", or the underscore character "_". Subsequent characters may be letters, digits, dollar signs, or underscore characters

Declaration [+ Initialization]

```
byte a;
int value = 100;
final double PI = 3.14;
boolean isFebruary = true;
long numberOfElements = 12345678L;
String myFavouriteDrink = "water";
```

Java naming conventions

in that case...

(underscores)

SCREAMING_SNAKE_CASE

(UPPER_SNAKE)

(words-on-a-skewer)

(lower_snake)

see also: UpperCamel

aka PascalCase

@allison_horst

Variables (cont.)

```
class Example {
  int a; //class member

  public void someMethod(int b) { //method argument
    a = b;
    int c = 10;//local to a method
    for(int d=0; d < 10; d++) {
      //local to a block of code
      c --;
    }
    try {
      a = b/c;
    } catch(ArithmeticException e){
      //exception handler argument
      System.err.println(e.getMessage());
    }
  }
}
```

Control Flow Statements

- <u>Decision-making</u>

  if-else, switch-case
- <u>Looping</u>

  for, while, do-while
- <u>Exception handling</u>

  try-catch-finally, throw
- <u>Branching</u>

  break, continue, return, ~~goto~~, *label:*

Arrays

- <u>Declaration</u>

```
int[] a; byte b[];
```

- <u>Instantiation</u>

100 elements of type char

```
a = new int[10]; char c[] = new char[100];
```

- <u>Initialization</u>

```
String colors[] = {"Red", "Yellow"};
someMethod( new String[] {"Red", "Yellow"} );
```

- <u>The size of an array</u>

`a.length` **and not** ~~`a.length()`~~

Multi-dimensional Arrays

- Arrays of arrays

```
int[][] m2d = new int[10][20];
int[][][] m3d = new int[10][20][30];
```

- Copying arrays

```
System.arrayCopy
int a[]; int b[]; …  What about a = b?;
```

- Utility methods for arrays

```
java.util.Arrays
   - binarySearch, equals, fill, ...
```

Strings

- char[]

```
char data[] = {'a', 'b', 'c'};
```

- String Immutable Object

```
String s = "abc";  String s = "a" + "b" + "c";
String s = new String("abc");
String s = new String(data);
```

- StringBuilder, StringBuffer

```
StringBuilder sb = new StringBuilder("a");
sb.append("b").append("c");
```

Equality Testing

- <u>Arrays</u>

```
int a[] = {1, 2};
int b[] = {1, 2};
```

~~a == b~~ / ~~a.equals(b)~~ / `Arrays.equals(a,b)`

- <u>Strings</u>

```
String s1 = new String("abc");
String s2 = new String("abc");
```

~~s1 == s2~~ / `s1.equals(s2)` / `s1.compareTo(s2)`

`"abc" == "abc"` ?

Example of array of Strings

```
    String words[] = {"AA", "AB", "BB", "BC", "DD"};
    String[][] neighbors = {
        {"AB"},
        {"AA", "BB", "BC"},
        {"AB", "BC"},
        {"AB", "BB"},
        {}
    };
```

or

```
    int nWords = words.length;
    String[][] neighbors = new String[nWords][];
    neigbors[0] = new String[]{"AB"};              //AA
    neigbors[1] = new String[]{"AA", "BB", "BC"}; //AB
    neigbors[2] = new String[]{"AB", "BC"};        //BB
```

or

```
    neigbors[3] = new String[2]; //BC
    neighbors[3][0] = "AB";
    neighbors[3][1] = "BB";
    neigbors[4] = new String[0]; //DD
```

Example of Using Chars and Strings

```
/** Generates random words, using a given set of characters. */
public class Example {

  public static void main(String args[]) {
      Example app = new Example();
      int nbWords = 10; //how many words to generate
      final int alphabetSize = 26; //how many characters has the alphabet
      char[] latin = new char[alphabetSize]; //create the alphabet array
      for (int i = 0; i < latin.length; i++) {
          latin[i] = (char) ('a' + i); //a b c d ...
      }
      String words[] = app.generate(nbWords, latin);
    }

    public String[] generate(int n, char[] alphabet) {
      String[] words = new String[n];
      for (int i = 0; i < n; i++) {
          StringBuilder sb = new StringBuilder();
          while (true) {
              int pos = (int) (Math.random() * (alphabet.length + 1)) - 1;
              if (pos < 0) break;
              sb.append(alphabet[pos]);
          }
          words[i] = sb.toString();
      }
      return words;
  }
}
```

Command Line Arguments

```
public class Main {
  public static void main (String args[]) {
    if (args.length < 3) {
      System.out.println("Not enough arguments!");
      System.exit(-1);
    }
    String str = args[0];
    int a = Integer.parseInt(args[1]);
    double x = Double.parseDouble(args[2]);
  }
}
```

```
java Main "Hello World" 2021 15.00
```

Bibliography

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