Java Programming

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Java 407
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Class Information

- Instructor: 盧政良 (Zheng-Liang Lu, Arthur)
- Email: arthurzllu@gmail.com
- The course website is

  https://www.csie.ntu.edu.tw/~d00922011/java.html.
- All lecture slides are organized in English and will be modified if necessary.
- In-class examples may involve with high school math.

Teaching Philosophy

- I try to lower the barriers to entry.
  - Everything in my class is simple, essential, and general.[1]
- I could provide extra studying materials as many as possible.
- I answer your questions.

[1] "Simple is not easy. ... Easy is a minimum amount of effort to produce a result. ... Simple is very hard. Simple is the removal of everything except what matters. ..." by Christopher S. Penn.

Learning Tips

- Start with just one language and master it.
- Ask lots of questions; Google or ChatGPT first.
- Practice makes permanent (and hopefully, perfect).[2]
- It may take 10000 hours, more or less[3]; it is never too late.
- Grasp the fundamentals for long-term benefits; code from the bottom.
- Coding by hand sharpens proficiency.

[2] Try https://leetcode.com/.

[3] Malcolm Gladwell (2008): *Outliers*.

"Knowledge is of no value unless you put it into practice."

– Anton Chekhov (1860-1904)

"Many roads lead to the path, but basically there are only two: reason and practice."

– Bodhidharma

Grading Policy

- To acquire the class certificate, you need to finish all labs listed in the course page.[4]

[4] See the list of programming labs.

Roll Call

```
1 class Lecture1 {
2
3                     "Introduction"
4
5 }
6
7 // Keywords:
8 public, class, static, void
```

PROGRAMMER

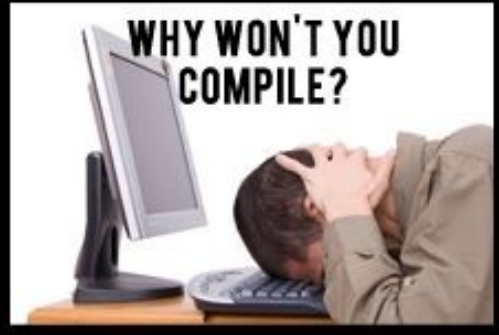
WHAT MY MOM THINKS I DO

WHAT MY FRIENDS THINK I DO

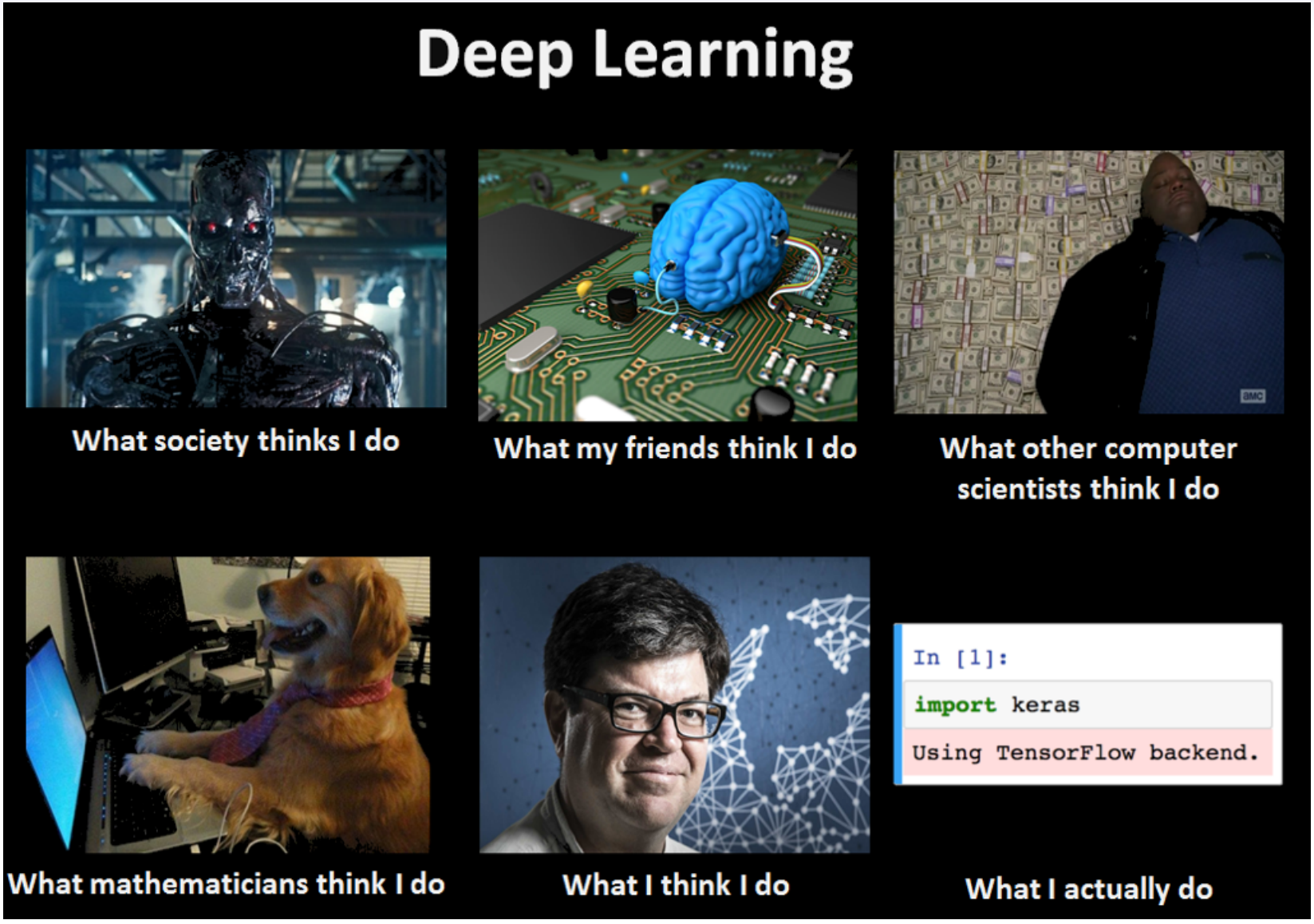
WHAT SOCIETY THINKS I DO

WHAT ARTISTS THINK I DO

WHAT I THINK I DO



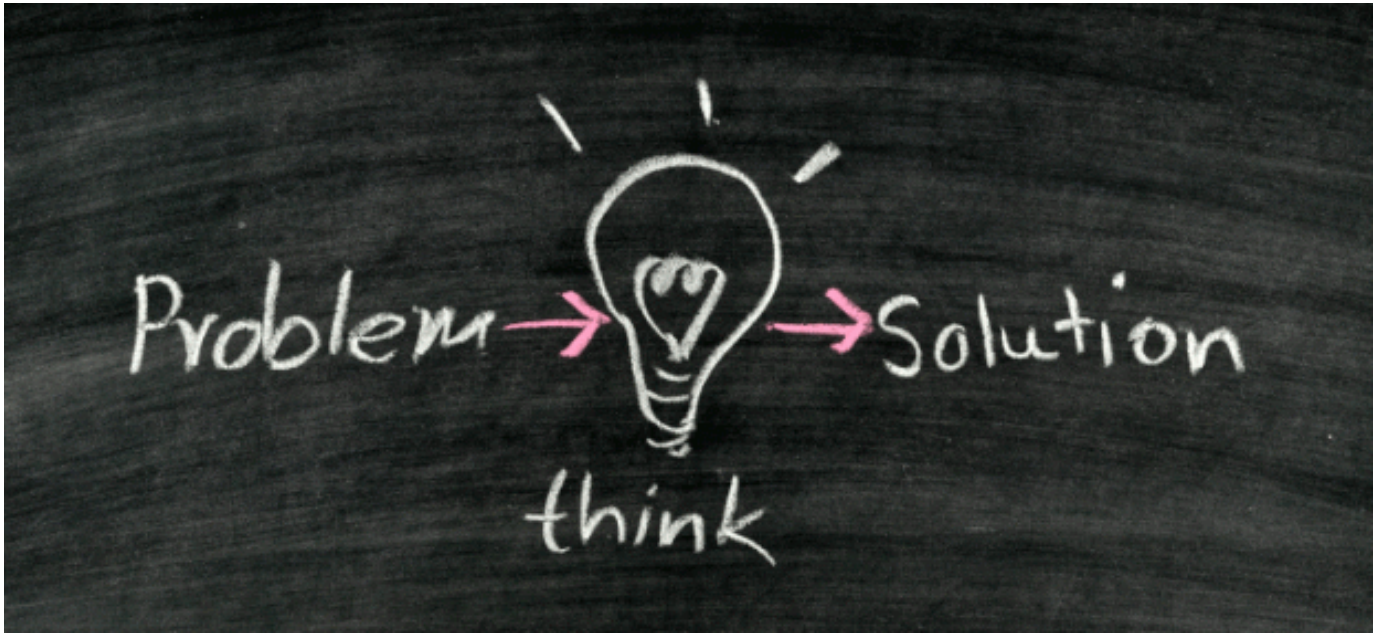
WHAT I ACTUALLY DO



http://p.migdal.pl/2017/04/30/teaching-deep-learning.html

Goal: Problem Solving

- Programming is to provide computational solutions to real-world problems.
- The resulting solution is called a program.



Programs

- A program is a collection of instructions to perform a specified task.
- They are almost everywhere, for example,
  - video games (e.g. Pokémon Go, Travel Frog, ...);
  - operating systems (e.g. Linux, ...);
  - autonomous driving[5] / auto-piloting (e.g. MRT, airplane, ...);
  - search engines (e.g. Google, ...);
  - robotics[6];
  - computer malware[7];
  - and more.[8]

[5] See https://www.tesla.com/autopilot.

[6] See https://www.bostondynamics.com/ and watch videos from its official YouTube channel here.

[7] See malware and computer virus.

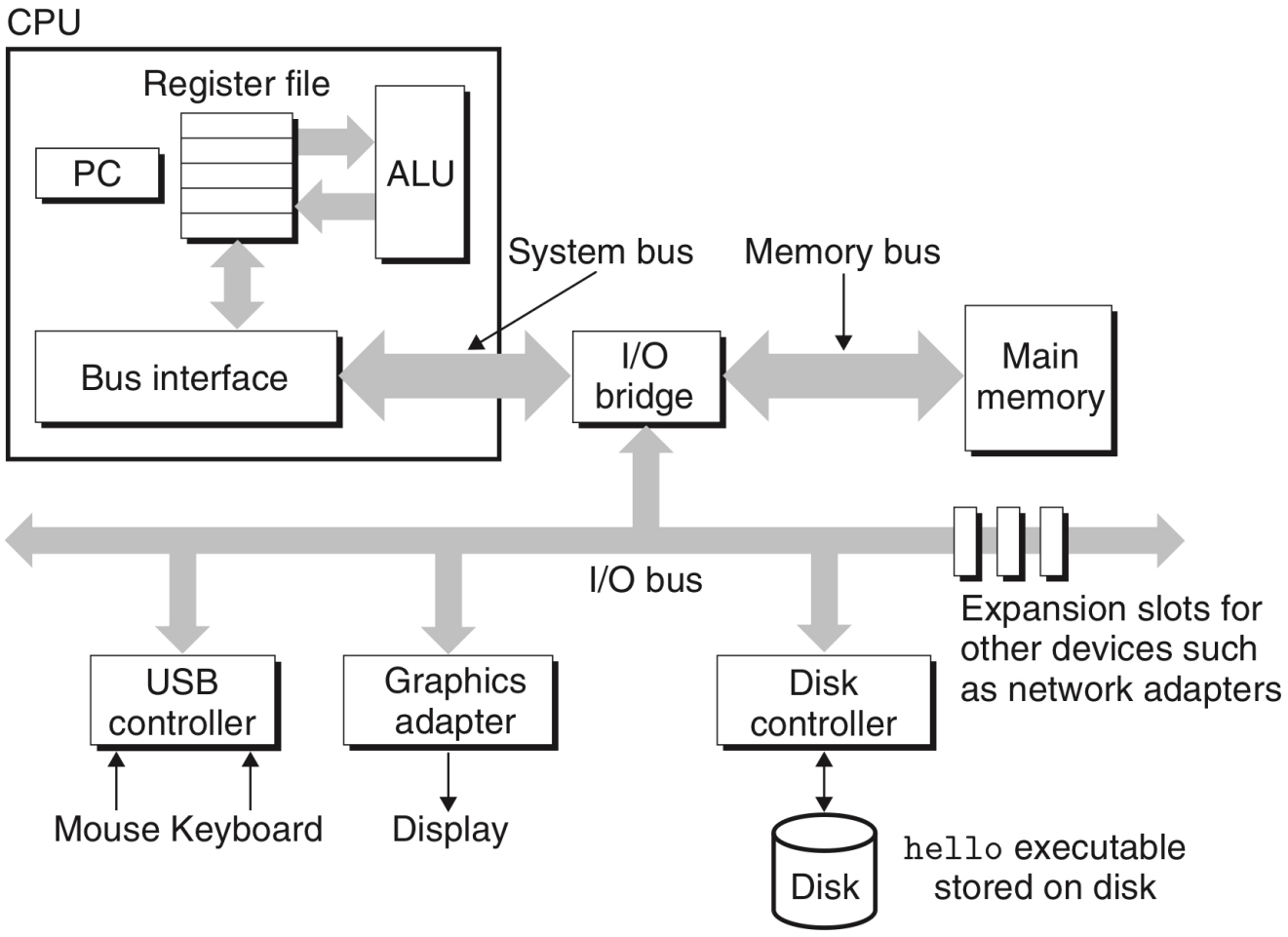
[8] See Internet of Things (IoT).

How to Execute Programs[12]

- Once the program is activated, both data and instructions are loaded from the disk into the main memory.
- We now call it a process, which is the smallest unit of resource allocation.[9]
- Then the instructions in the program are scheduled to be executed by the CPU.[10]
  - A CPU consists of 6 main components: arithmetic & logic units (ALUs), registers, control units, cache, buses, and clock.[11]
- The immediate result is stored back to the main memory and further written into the disk if necessary.

[9] See https://en.wikipedia.org/wiki/Process_(computing).
[10] See https://en.wikipedia.org/wiki/Scheduling_(computing).
[11] See https://en.wikipedia.org/wiki/Central_processing_unit.
[12] See Inside Your Computer by Bettina Bair and Systems Architecture by BBC.

Hardware Organization: Illustration[13]



[13] See Figure 1-4 in Bryant, p. 44.

Memory Hierarchy[14]

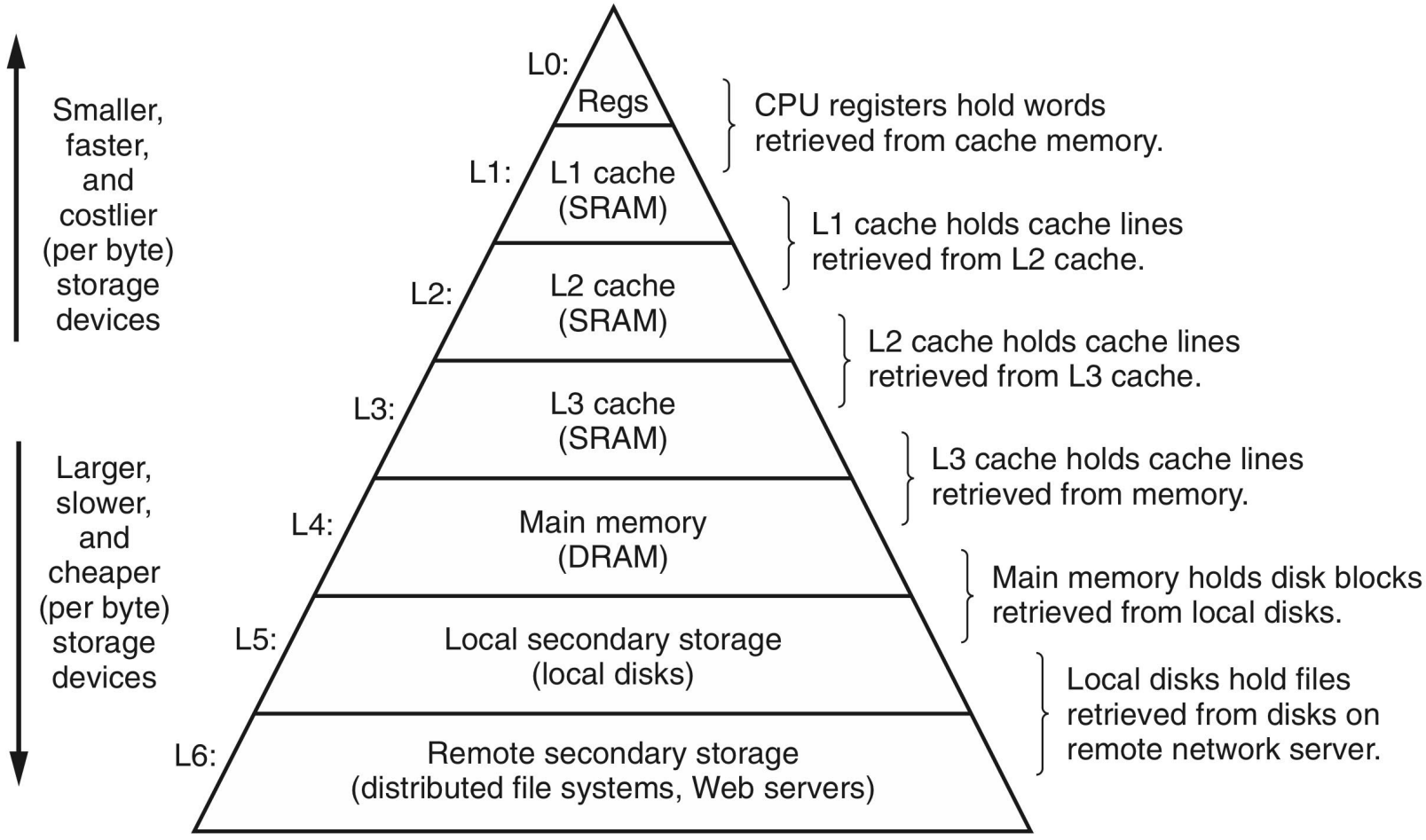


Figure 1.9 **An example of a memory hierarchy.**

[14] See Figure 1-9 in Bryant, p. 50.

Programming Languages

- A programming language is an artificial language to communicate with machines.[15]
- The elements of programming languages are syntax and semantics, used to control the behavior of machines.
- Top 20 programming languages can be found in TIOBE.
- Every language originates from some reasons.

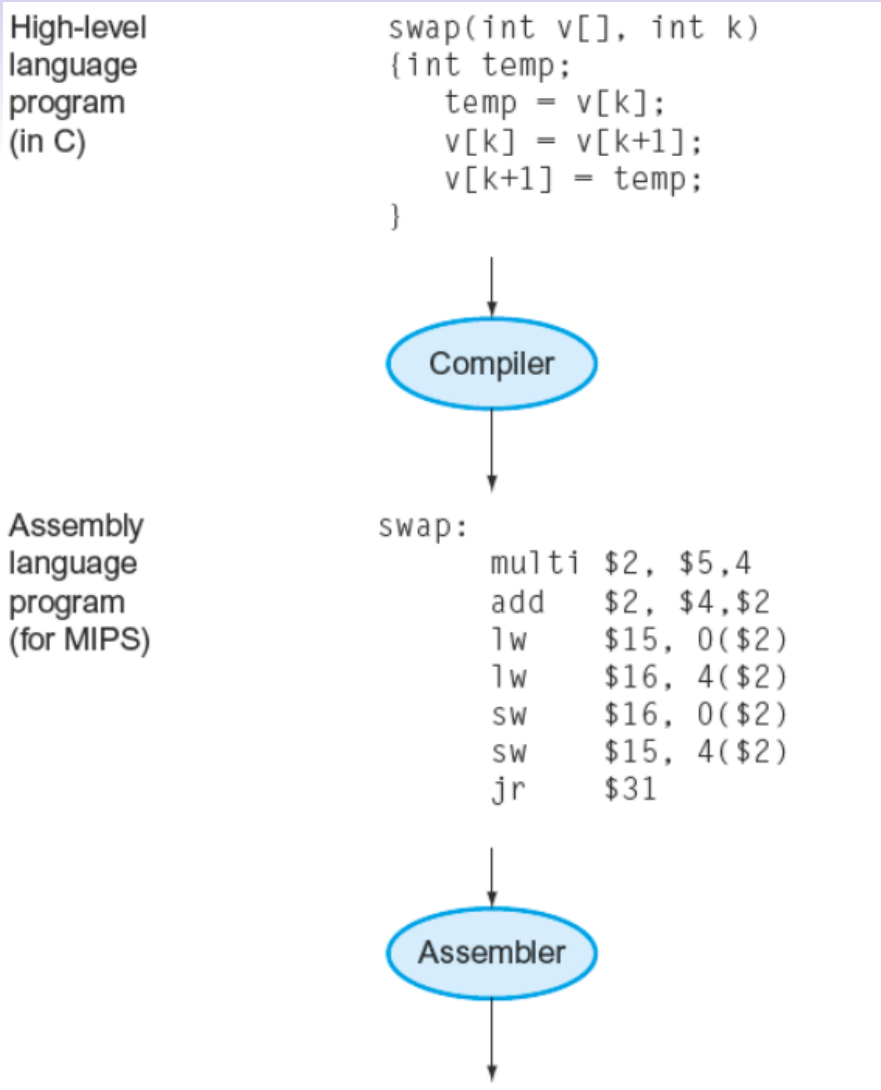
[15] See https://en.wikipedia.org/wiki/Programming_language.

A Short History[17]

- Gen 1: machine code.
- Gen 2: assembly code.
- Gen 3: high-level programming languages.
  - For example, C, C++, Java, C#, Python, JavaScript, etc.
- Gen 4.
  - For example, SQL[16].

[16] Edgar Frank Codd (1974).

[17] See generations of language and computer programming history.


High-level language program (in C)
swap(int v[], int k)
{int temp;
temp = v[k];
v[k] = v[k+1];
v[k+1] = temp;
}
Compiler
Assembly language program (for MIPS)
swap:
multi $2, $5,4
add $2, $4,$2
lw $15, 0($2)
lw $16, 4($2)
sw $16, 0($2)
sw $15, 4($2)
jr $31
Assembler
Binary machine language program (for MIPS)
00000000101000100000000100011000
00000000100000100001000000100001
10001101111000100000000000000000
10001110000100100000000000000100
10101110000100100000000000000000
10101101111000100000000000000100
00000011111000000000000000001000

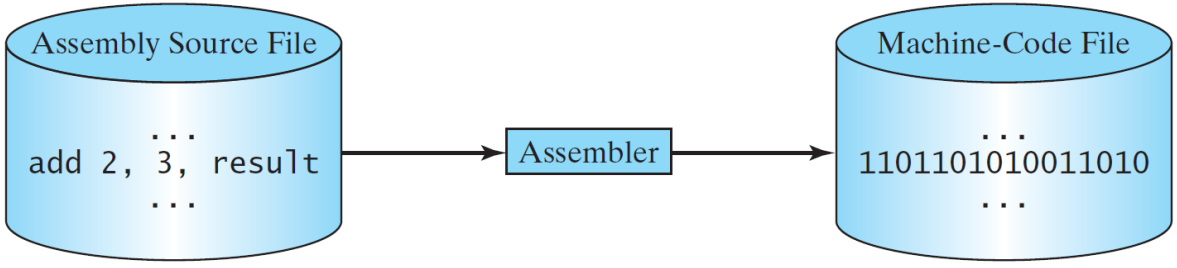
1st-Generation Languages

- The 1st-generation language is pure machine code, which represents instructions in just ones and zeros. (Why?)
- Each machine has its own instruction set.[18]
- So machine code is platform-dependent!
- More worse, the machine language is not human-readable.

[18] For example, the instruction set of the x86 family and the ARM family are incompatible.

2nd-Generation Languages

- An assembly language uses mnemonics to represent instructions as opposed to the machine codes.
- Hence, assembly code is easier for human to read and write.
- When the assembly code is executed, it is then converted to the resulting machine code.

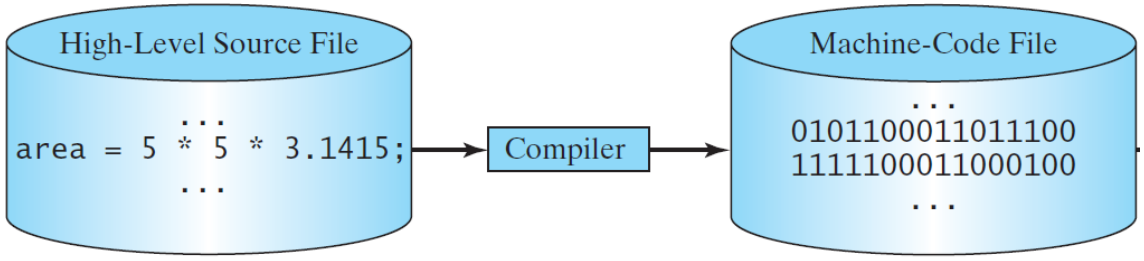


- It is worth to mention that the program flow of assembly code is almost close to the execution steps in the machine.[19]

[19] To be a hacker, you should learn assembly languages.

3rd-Generation Languages

- High-level languages are much closer to human languages by using English-like words, mathematical notations, and punctuation to write programs.

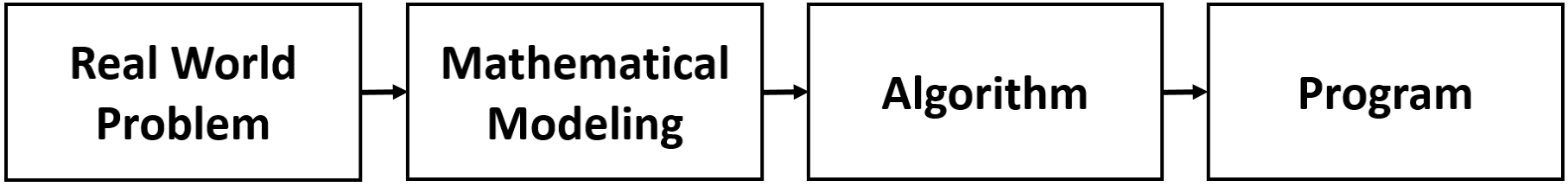


- For example, C[20], C++[21], Python[22], and Java[23].

[20] Dennis Ritchie (1972).
[21] Bjarne Stroustrup (1983).
[22] Guido van Rossum (1991).
[23] James Gosling (1995).

What Can A Program Do?

- A program is an implementation of an algorithm expressed in a specific programming language.



First Glance at Algorithms[24]

- Simply put, an algorithm is a well-defined procedure that solves a specific category of problems, like a recipe or a cookbook.
- In general, an algorithm may take adequate information as its input and produce the correct result as its output.

[24] See also What's an Algorithm? by David J. Malan.

Example: Largest Number

- Let A be a nonempty list of any real numbers.
- Now try to propose an algorithm to find the largest number for any list of numbers.

Input: A.
Algorithm: your work here...
Output: the largest number in A.

- For example, assume that $A = \{1, 7, 9, -2, 4\}$.
- It is clear that the answer is 9.
- Can you teach the computer to repeat your idea?

Optimal Algorithm (Pseudo Code)

- For convenience, $A(i)$ denotes the i-th number of A and the symbol $\leftarrow$ denotes a copy operator from right to left.
- Then the optimal algorithm could be as follows:

```
1 max <- A(1) // Initial guess, without loss of generality!
2 for i <- 2 ~ n
3     if A(i) > max
4         max <- A(i)
5     end
6 end
7 return max
```

Discussions

- In Line 1, why not $\boxed{\max \leftarrow 0}$?
- You may extend this algorithm for following questions:
  - smallest number;
  - location of the largest (also smallest) number;
  - ... (more and more)
- We are eager for efficient algorithms.[25]
  - Will "sorting the list and then the largest number could be the last number" be more efficient than the previous one?

[25] We will show you the complexity analysis in the end of the chapter of loops.

"Computers are good at following instructions, but not at reading your mind."

– Donald Knuth (1938-)

"There are two ways of constructing a software design: One way is to make it so simple that there are obviously no deficiencies, and the other way is to make it so complicated that there are no obvious deficiencies. The first method is far more difficult."

– Tony Hoare (1934-)

Alan Turing

- Provided a formalization of the concepts of algorithm and computation with the Turing machine[26], which can be considered a model of a general-purpose computer.
- Proposed the famous question: "*Can machines think?*"[27]
  - Well-known as the Turing test.
- Turing Award is recognized as the highest distinction in computer science and the"Nobel Prize of computing".[28]

[26] Turing (1936). Try this google doodle.
[27] Turing (1950). You could find the paper here. See also Turing Test.
[28] See https://en.wikipedia.org/wiki/Turing_Award#Recipients.

- You may watch The Imitation Game (2014).
- Britain's £50 note will honor computing pioneer Alan Turing.[29]

[29] See Alan Turing to be the Face of New £50 Note by Bank of England.

About Java[30]

- Java is one of general-purpose programming languages, supporting the object-oriented programming (OOP) paradigm.
- Java was first released by Sun Microsystems back in 1995 and is now maintained by Oracle (ORCL) after the year of 2010.
- Java was intended to let application developers write once, run anywhere (WORA).
- Nowadays, Java is widely used in web apps (especially the back-end services), mobile apps (for example, Android apps) and embedded systems.

[30] See Java Version History.

Java Virtual Machine (JVM)[33]

- JVM is a software program, not a physical machine.
- JVM translates Java bytecodes into machine codes which can be executed by the host platform.[31]
- JVM verifies all bytecodes before the program is executed, so that no user program can crash the host machine.[32]
- You can find further details about JVM from its specification.

[31] For example, Windows, Linux, and MacOS for desktop/laptop computers; Android and iOS for mobile devices.

[32] See Security Vulnerabilities of Java.

[33] See http://en.wikipedia.org/wiki/Java_virtual_machine.

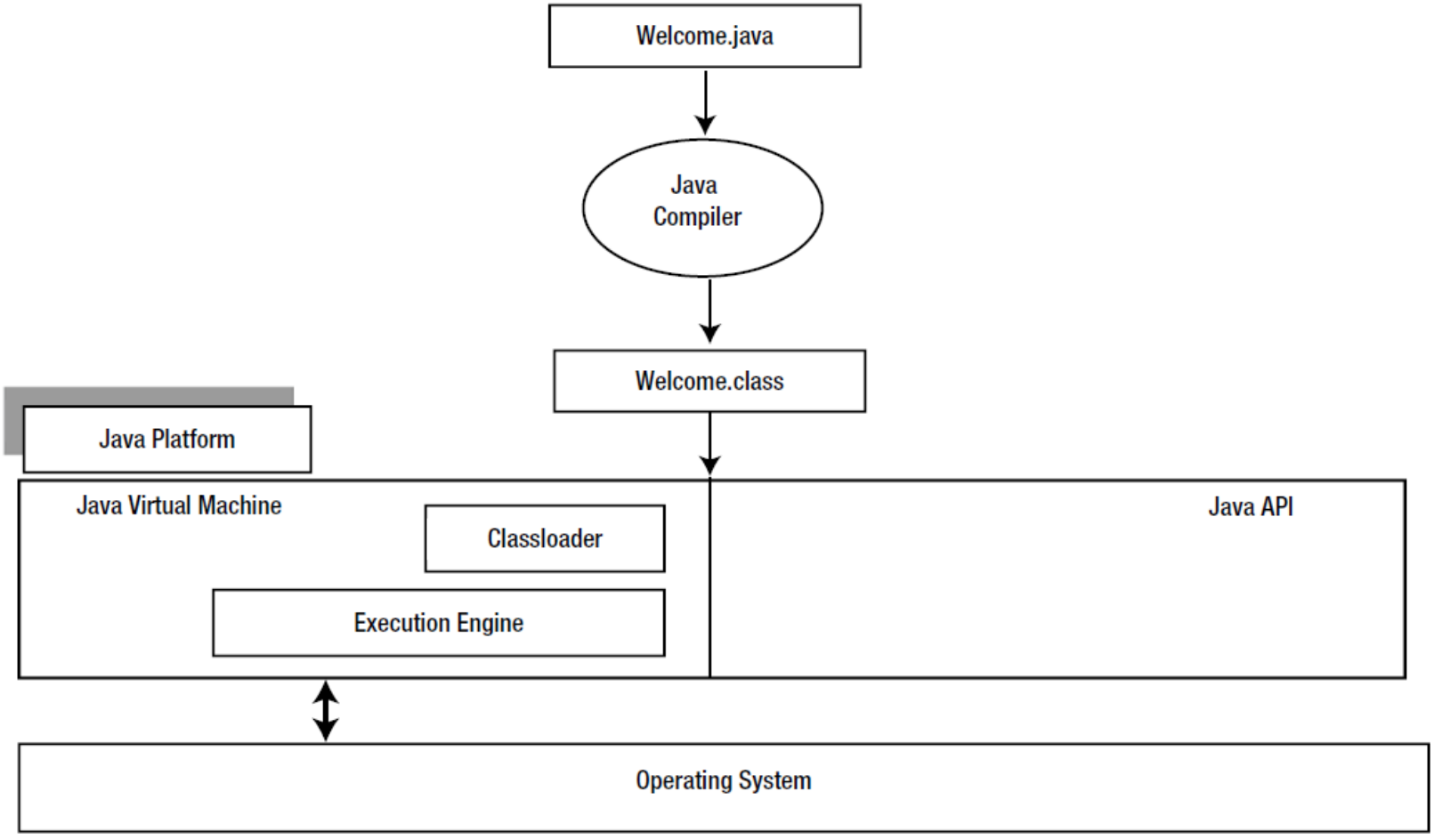
Software Installation

- First download and install the Java Development Kit (JDK).[34]
- Then choose an integrated development environment (IDE) which may provide comprehensive facilities, say debugger, code completion, and build automation tools.
- In this course, I will use Eclipse which is a free and powerful IDE.[35]
- Uncheck Create module-info.java file for every new project; simply remove it when the "module-info.java" file is already present in the project.

[34] See https://www.oracle.com/java/technologies/downloads/.

[35] You may try the following alternatives: NetBeans, IntelliJ IDEA and Visual Studio Code with proper packages.

Workflow[36]



[36] See Figure 2-19 in Sharan, p. 59.

First Program: Hello, World[37]

```
1  public class HelloWorldDemo {
2
3      public static void main(String[] args) {
4
5          // Print "Hello, Java." on the screen.
6          System.out.println("Hello, Java.");
7
8      }
9
10 }
```

- class: define a new class.
- public: accessible to anyone.
- static: can be called without having any object.
- void: no return value.

[37] See https://en.wikipedia.org/wiki/"Hello,_World!"_program.

Discussions (1/3)

- A class is an entity of Java programs.
- A Java program can consist of many classes.[38]
- To be executable, a program needs one special method[39] called the main method as the entry point of the program.
- **System**.out refers to the standard output device, say the monitor screen.
- The println method is used to output the string you offer.
- Every statement should end with a semicolon (;).

[38] We will discuss more later in the OOP chapter.

[39] Also called functions and subroutines in other programming languages.

Discussions (2/3)

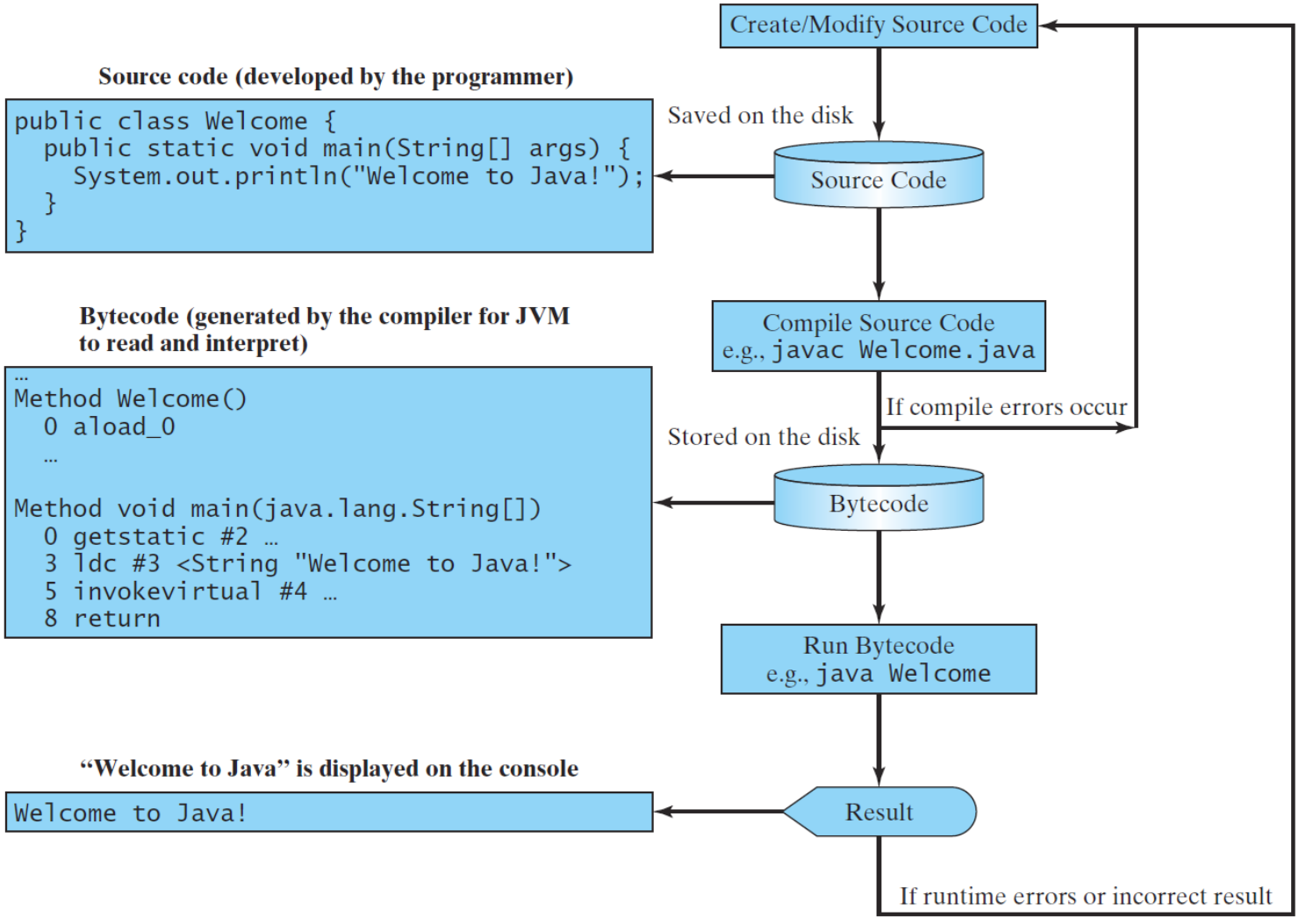
- For now, one program has only one public class.
- The only public class should have the same name as the filename.
  - For example, the public **HelloWorldDemo** class should be in the source file whose filename must be *HelloWorldDemo.java*.
- Note that you cannot have more than one public class in single java file.
- The keyword public is one of access modifiers, allowing you to control the visibility of classes and also its members.[40]

[40] We will visit more access controls later.

Discussions (3/3): Table of Special Characters

Symbol	Description
{ }	Denote a scope to enclose statements; enumerate a set of objects.
( )	Mostly used with expressions and methods.
[ ]	Mostly used with arrays.
" "	Enclose a string.
;	Mark the end of a statement.
//	Precede a comment line.
/* ... */	Used as block comments.

Recall How To Run A Java Program[41]



[41] See Figure 1.14 in YDL, p.20.

Digression: Bugs[42]

- A bug is an error, flaw, failure, or fault in a computer program or system, producing an incorrect or unexpected result, or misbehaving in unintended ways.
  - Compile-time error: most of them are syntax errors.
  - Runtime error: occurs when Java program runs, e.g. $1/0$.
  - Logic error: introduced by implementing the functional requirement incorrectly.
- Note that logic (semantic) errors are the obscurest because they are hard to be found.

[42] See Computer Bugs.

"If debugging is the process of removing software bugs, then programming must be the process of putting them in."

– Edsger W. Dijkstra (1930–2002)

"Why do we fall sir? So that we can learn to pick ourselves up."

– Alfred Pennyworth, *Batman Begins* (2005)

Programming Style

- A good programming style makes programs easy to read and helps programmers prevent from errors.
  - For example, Google Java Style Guide and Code Style of Java from IntelliJ IDEA.
- In particular, we use indentation to enhance the structural relationships by visual.
  - For Eclipse users, select the code snippet and press ctrl + I to make correct indentation.
- Be consistent through the whole program, even in the project!