Introduction

Fundamentals of Computer and Programming

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What We Will Learn

- What is this course?
- Computer organization
  - Hardware
  - Software
- Algorithms & Programming
  - Algorithm
  - Programming Language
- Solving problems

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This Course

- Introduction to Computer & Programming

How to use computers to solve our problems

- The problems are *computational* problems

This Course (cont'd)

- What we learn
  - Overall overview of computer organization
  - Problem solving steps
    - Algorithm design
    - A programming language: the C

- What we don't learn
  - In depth computer hardware/software details

    CA, OS, …
  - Most advanced algorithms

    Alg, DS, …
  - System programming using C

    OS, …
  - Other programming languages: Java, PHP, …

    AP, IE, …

This Course (cont’d)

- Steps to learn a new language (English, French, … C, Java, Python, …)
  - Present: what is the new language (course slide)
  - Practice: how to use the new language in practice (the example)
  - Produce: use the language to create a new things (Lab, HW)

- Learning Programming Language
  - is not a pure theoretical course (mathematics, …)
    - Reading, reading, reading, ….
  - is a practical course needs the product step
    - Class, Reading, programming, programming, programming,…

This Course (cont'd)

- Course materials
  - Lecture notes (slides) are in (simple) English
  - Available in the course homepage:

    `courses.aut.ac.ir`

    `httpS://ceit.aut.ac.ir/~bakhshiS/c`

  - Textbook
    - C: How to Program
    - How Computers Work

    `courses.aut.ac.ir`

  - Telegram: `https://t.me/CFall99`

Grading & Extra Classes

- Four major parts

Midterm	15%
Final	30%
Homework	30%
Project	10%
Lab	15%

- Lab + TA Classes
  - Lab: A practical class
  - TA: More details, Practical aspects, Solving HW
  - Homework are not accepted after solutions

Any Question?!

- Is CE a good dep. of the university?! Yes ☺
- Is AUT really a top university?! Yes ☺
- Will I wealthy if am a CE?! Yes ☺
- Do I need to learn C?! Yes!!! ☺
- Is CE a simple and easy-going? No ☺
- …

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Computers: The *Computing* Machines

- Computers classification:
  - Supercomputers
    - Weather forecast, Large scale simulation, …
  - Mainframe computers
    - The servers in large companies: Google, …
  - Midsize computers
    - The servers in CE department
  - Micro computers (also called PC)
    - Our laptop
  - Pocket PCs
    - Our mobile phones

Computers

- Computers are anywhere, anytime. Why?
  - They can solve many different problems. How?
- Computers are *programmable machines* capable of performing calculations (computation)
  - Changing program leads to different operation
- *Special-purpose* machines
  - Calculators, game-playing machines, …
- *General-purpose* computers
  - Personal computers, notebooks, …

Data Units

- Computers are digital machines
- Data processed or stored in computer is represented as two-state values
  - either 1 or 0 - BInary digiTs (BIT)
  - 1 Byte = 8 bits
  - 1 kilobyte (KB) = 1024 bytes
  - 1 megabyte (MB) = 1024 kilobyte
  - 1 gigabyte (GB) = 1024 megabyte

Data Representation/Coding

- How to represent our data by 0-1?
- In other word, there are some 0 and 1 in the computer, what is the meaning?

Coding (Representation Standards)

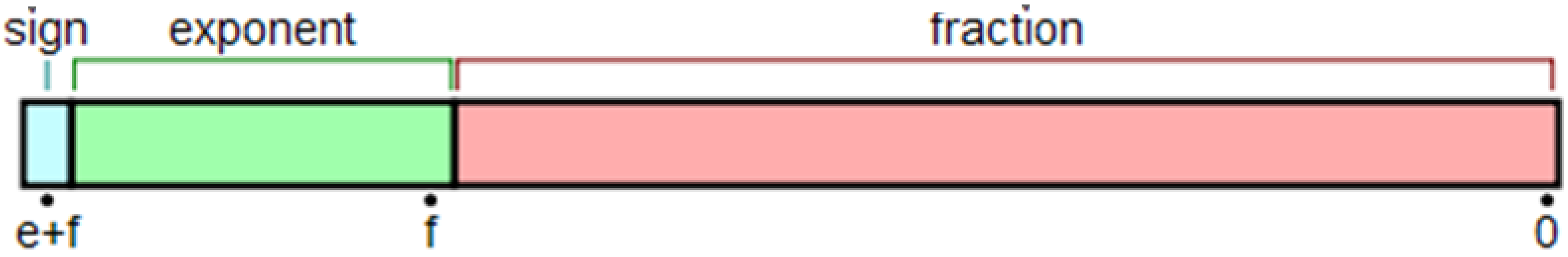
- Major (common) representations (coding)
  - Integer numbers: 1, 1000, -123, 0, …
  - Floating point numbers: 1.1, 11.232, -12.23, …
  - Characters: ‘A’, ‘ب’, ‘@’, …

Integer Number Coding

- There are different representations
  - You will learn them (in details) in other courses (e.g. Computer Architecture)
- One of the (simple) coding is sing-magnitude coding
  - If we have n bit for coding integers
    - The left bit (the MSB): sign
    - n-1 bits: magnitude
  - E.g., 8 bit for coding
    - 4 → 00000100 -4 → 10000100
    - 0 → 00000000 -0 → 10000000 :-P :-D

Floating Point Number Coding

- Usually, this coding pattern



- You will see all details in other courses
- Two precisions
  - Single precision
    - exponent: 8 bit, fraction: 23 bit
  - Double precision:
    - exponent: 11 bit, fraction: 52 bit

Character Coding

- Common character encoding: ASCII

Character	ASCII Code	Binary (8 bit)
‘0’	48	00110000
‘A’	65	01000001

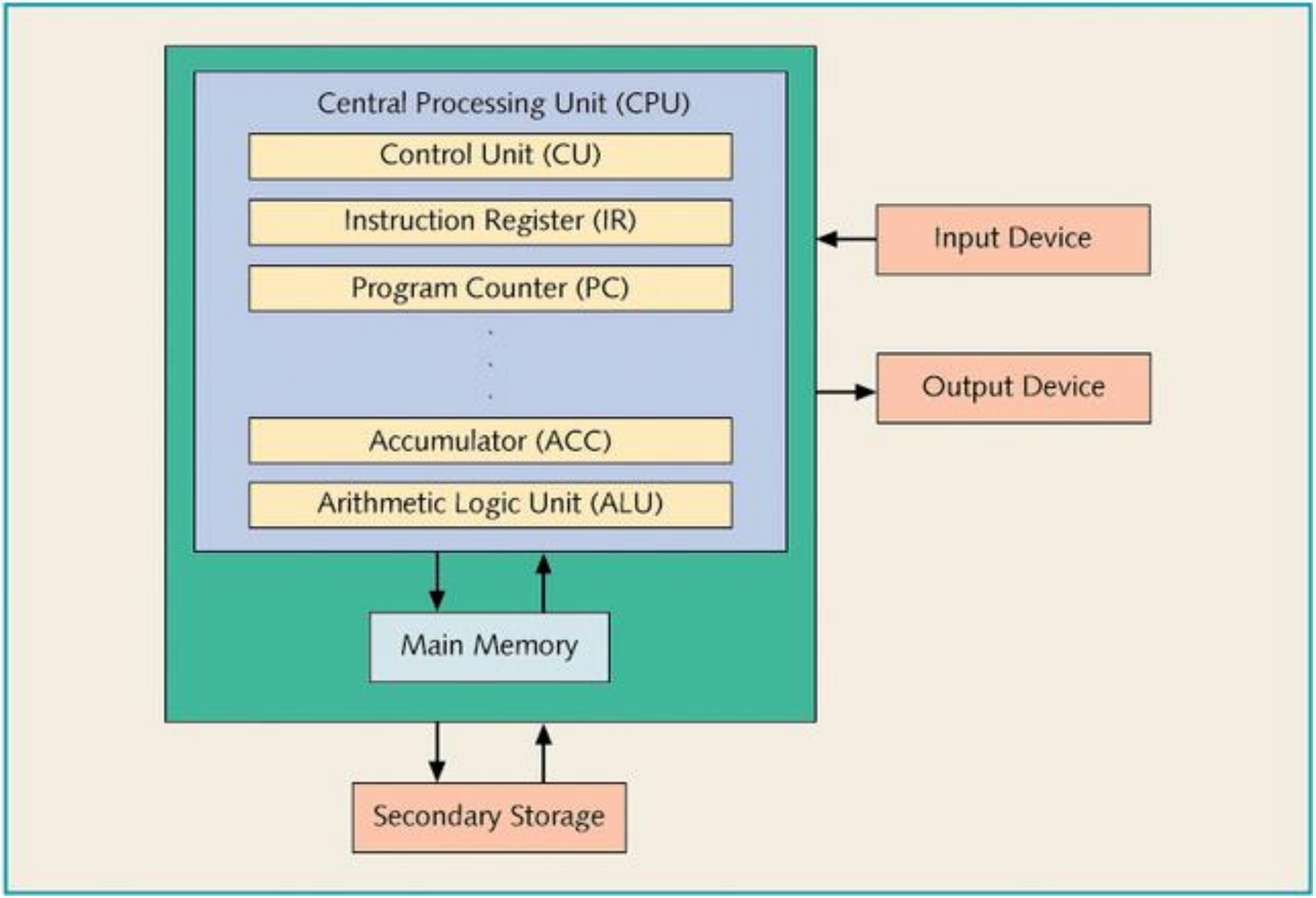
- 8 bits can represent 256 characters; but,
  - There are so many characters (Farsi, Arabic, …)
  - Solution: UTF (Variable length coding)
    - 0xxxxxxx: 1 byte code
    - 110xxxxx 10xxxxxx: 2 byte code
    - …

Computer Organization

- Major Components
  - Hardware
    - *Physical devices* that are *wired* and performs *basic* operations
  - Software
    - Set of *programs* that run on the hardware

- Hardware
  - CPU (Central Processing Unit)
  - Main Memory
  - Secondary Storage
  - Input/output

Computer Organization



Computer Organization: CPU

- ALU (Arithmetic Logic Unit)
  - Performs mathematic calculations
  - Makes decision based on conditions

- Special Floating Point processors
- Set of working area: Registers
- Control Unit
  - Controls system operation
- Operation and operands are required
  - Which are provided by instructions in the main memory

Computer Organization: Main Memory

- Ordered sequence of cells (memory cells)
- Directly connected to CPU
- All programs must be in main memory before execution
- When power is turned off,
  Main memory is cleared

Computer Organization: Secondary Storage

- Provides permanent storage for information
- Examples of secondary storages:
  - Hard Disks
  - Floppy Disks
  - Flash/Cool/USB Disks
  - CD/DVD
  - Tapes

Computer Organization: Input Devices

- Devices that feed data and programs into computers
- Examples:
  - Keyboard
  - Mouse
  - Network Interface Card
  - Joystick
  - Microphone

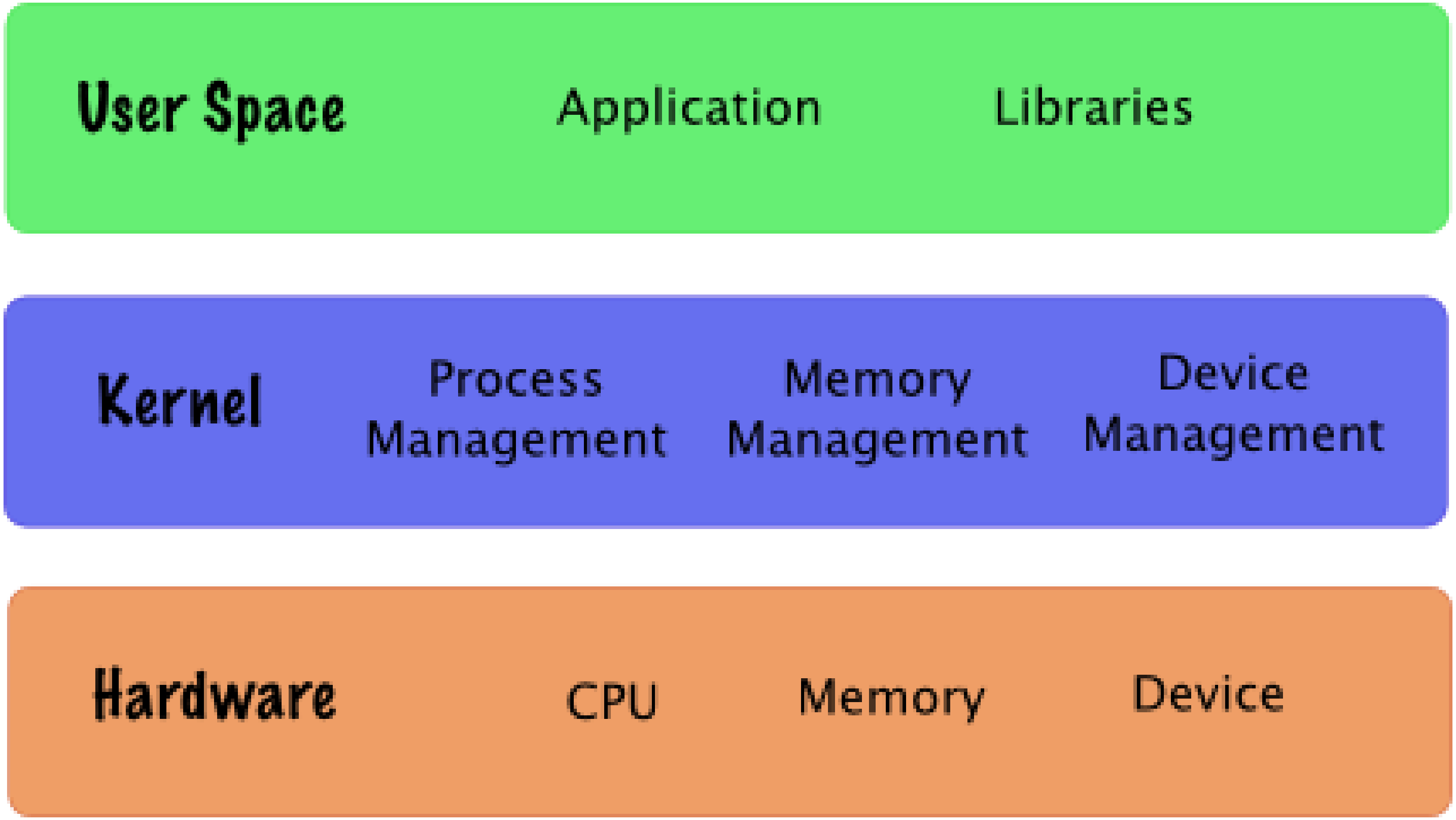
Computer Organization: Output Devices

- Devices that computer uses to generate results/outputs
- Examples:
  - Printer
  - Monitor
  - Speaker
  - Network Interface Card

Computer Organization: Software

- What can do the Hardware?
  - No useful operation, if there isn’t any software
  - We should *tell/plan/program* it to do something
- Software
  - Programs which are designed for a specific task
- Major Software types
  - Operating System
  - Libraries
  - Applications (this course)

Computer HW & SW Organization



User Space
Application
Libraries

Kernel
Process Management
Memory Management
Device Management

Hardware
CPU
Memory
Device

Computer Organization: OS

- OS
  - *Manages* the hardware
    - HW is a shared resources
  - Application programmers can easily use HW
    - *Without knowing the HW details*
- Common operating systems
  - Windows XP/Vista/8/10, Linux, Unix, …

Computer Organization: Libraries

- The libraries provide the most common functionalities

- In mathematic programs
  - sin(x), cos(x), matrix multiplication/inversion

- In graphical programs
  - Draw a line/cycle, set color, new window

- In multimedia programs
  - Open/close files, jump, …

Computer Organization: Applications

- An application program
  - Users use them to do some specific things
  - *Without knowing the details of the computer*
- Common application programs
  - *Word*, *Internet Explorer*, *FireFox, Messengers*
- Common applications in mathematic:
  - *Matlab, Mathematica, Maple, GAMS, AIMMS*

Programming Execution Phases

- Program is loaded from secondary storage to main memory by OS
- OS gives the control to the program
- Instructions run
- Required inputs are got from input device & saved in main memory & used by CPU
- Result is saved in main/secondary memory or sent to output devices

Instruction Execution Steps

- Basic steps in running instructions
- Read instruction from main memory: fetch
  - `“000110…011”`
- Decode the instruction
  - `add 1 to memory location XYZ save result in ABC`
- Get required operands from main memory
  - `Read value of location XYZ to temp1`
- Run the instruction
  - `temp2 = temp1 + 1`
- Save the result
  - `Write temp2 in memory location ABC`

How to be general purpose machine?

- Hardware is simple & general purpose
  - Only a small set of basic instructions (+ - * …) are implemented by hardware
- Complex tasks (e.g. average, sort, …) are programmed by software
  - Basic instruction and high-level complex instructions
- Software is translated to the basic instructions
  - Hardware can run it
- This is the way that we “*program*” computers

Reference

- Reading Assignment: Chapter 1 and Appendix C of “C How to Program”
- Learn more about computer hardware
  - “How Computers Work”

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Algorithm??!!!

- Hardware do the basic operations
- We want to solve a real problem by computers
  - Take average, Sort, Painting, Web, Multimedia, …
- We need a solution that
  - Specifies how the real (complex) problem should be solved *step-by-step* using the basic operations
- The solution is the “Algorithm” of the problem

Algorithms (cont'd)

- Common Sense (in computer science):
  1) The way to do some things
  2) An abstract way to solve a problem
- Formal Definition:

"*An algorithm is a finite list of well-defined instructions for accomplishing some task that, given an initial state, will proceed through a well-defined series of successive states, possibly eventually terminating in an end-state*"

Algorithms: Examples

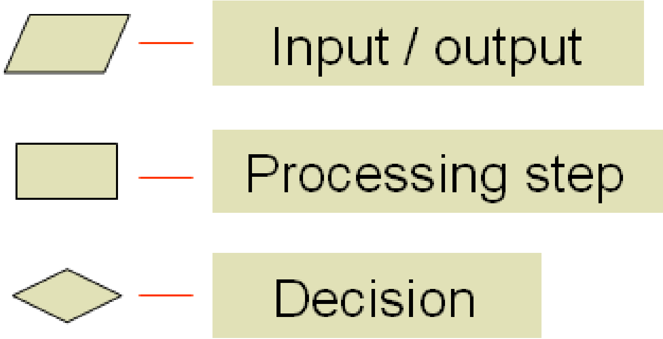
- Finding Common Divisor
- Finding 2 largest element in a set
- Finding shortest path in a graph
- Searching in a sorted array
- Sorting a set
- Combining 2 sorted set in a sorted set
- Solving an equation
- Compression algorithms
- Cryptography algorithms
- ….

Algorithms: Description

- Algorithms are the problem solving steps in our mind!!!
- How can we document it (don’t forget it)?
- How can we explain/teach it to others peoples?
- How can we explain it to computers?
- We need some methods to describe algorithms!
  - Flow chart
  - Pseudo-codes
  - Codes/Programs

Algorithms: Description (cont’d)

- Flowcharts:
  - Schematic representation

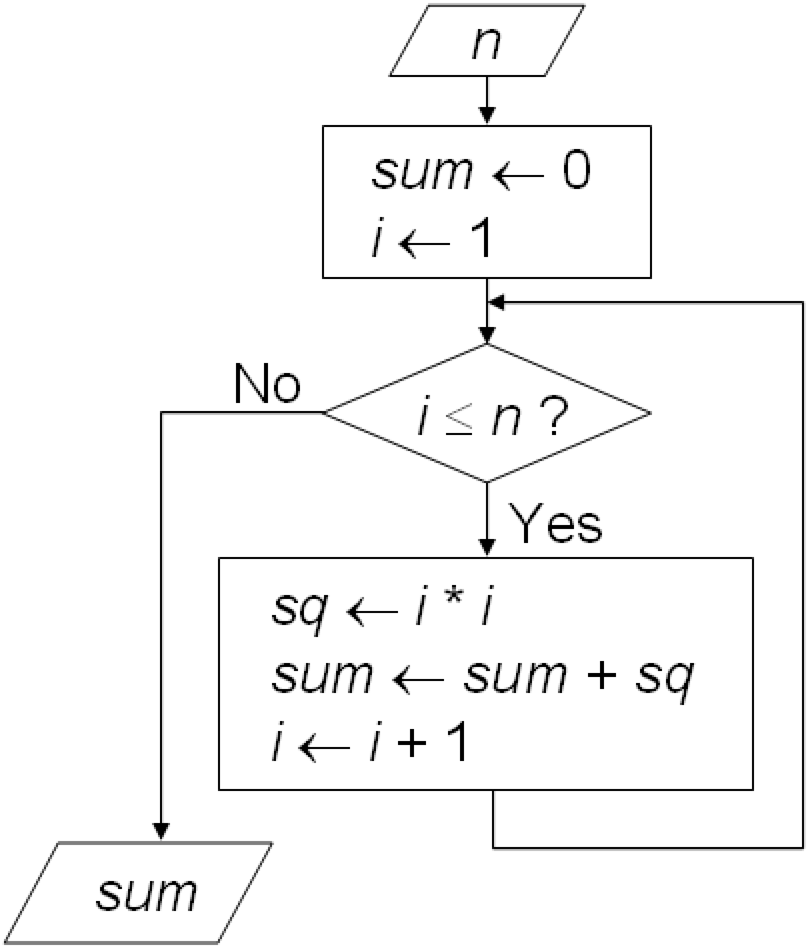

Input / output

Processing step

Decision

- Example:

calculate $1^2 + 2^2 + \ldots + n^2$



Algorithms: Description (cont’d)

- Pseudo-code
  - A sequence of English and mathematical statements

Algorithm: calculate $1^2 + 2^2 + ... + n^2$

Input: n

Output: sum

```
sum ← 0
i ← 1
Repeat the following three steps while i ≤ n:
    sq ← i * i
    sum ← sum + sq
    i ← i + 1
```

Algorithms: Description (cont’d)

- Flowcharts and Pseudo-code are for humans not for computer
  - Computer cannot run them
- What can computer run?
  - Instructions in main memory
  - The instructions are in “011100001…” format
  - To use computers
    - We should describe your algorithm in “01” format
  - ????? ☹ ☹

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Programming Language

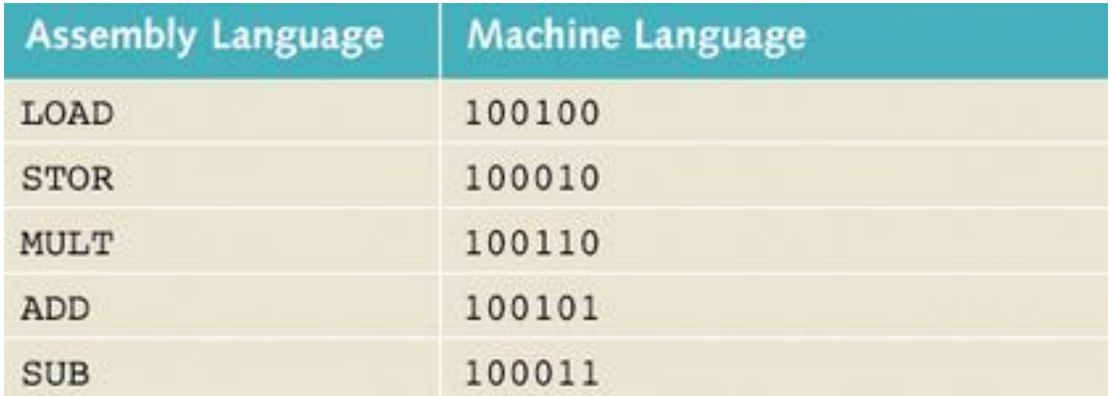
- Programming languages are the tools to describe your algorithms for computers
  - Software is developed by programming languages
- New languages which is understandable by computers
- Human languages are not used. Why?
- When algorithm is described with a programming language
  - It cannot be run on computer directly if the languages is not 011001001 ☹
  - There are some other programs that translate the programming language to “010…”
  - The output “0101…” can run on computers ☺☺

Programming Language: Machine Level

- Computer’s native language
- What is saved in the main memory
- The processor architecture specifies the format of 01s, machine depended
- Example
  - Add two numbers: `00100111 1010 0101`
- Completely incomprehensible to (most) people

Programming Language: Assembly

- Programming based on mnemonics
- There are one-to-one mapping between machine language and assembly mnemonics



Assembly Language	Machine Language
LOAD	100100
STOR	100010
MULT	100110
ADD	100101
SUB	100011

- Example

```
load   r1, [4000]  ; read content of address 4000
add    r1, 1       ; add 1 to CPU register r1
store  [5000], r1  ; save the result in location 5000
```

Programming Language: High Level

- Easy for programming, English-like keywords
  - More similar to natural languages
- There isn’t one-to-one relation between high level statements and machine level statements
- Example: C, C++, Pascal, Java, PHP, Python,…
- Example:

```
int xyz;
int abc;
abc = xyz + 1;
```

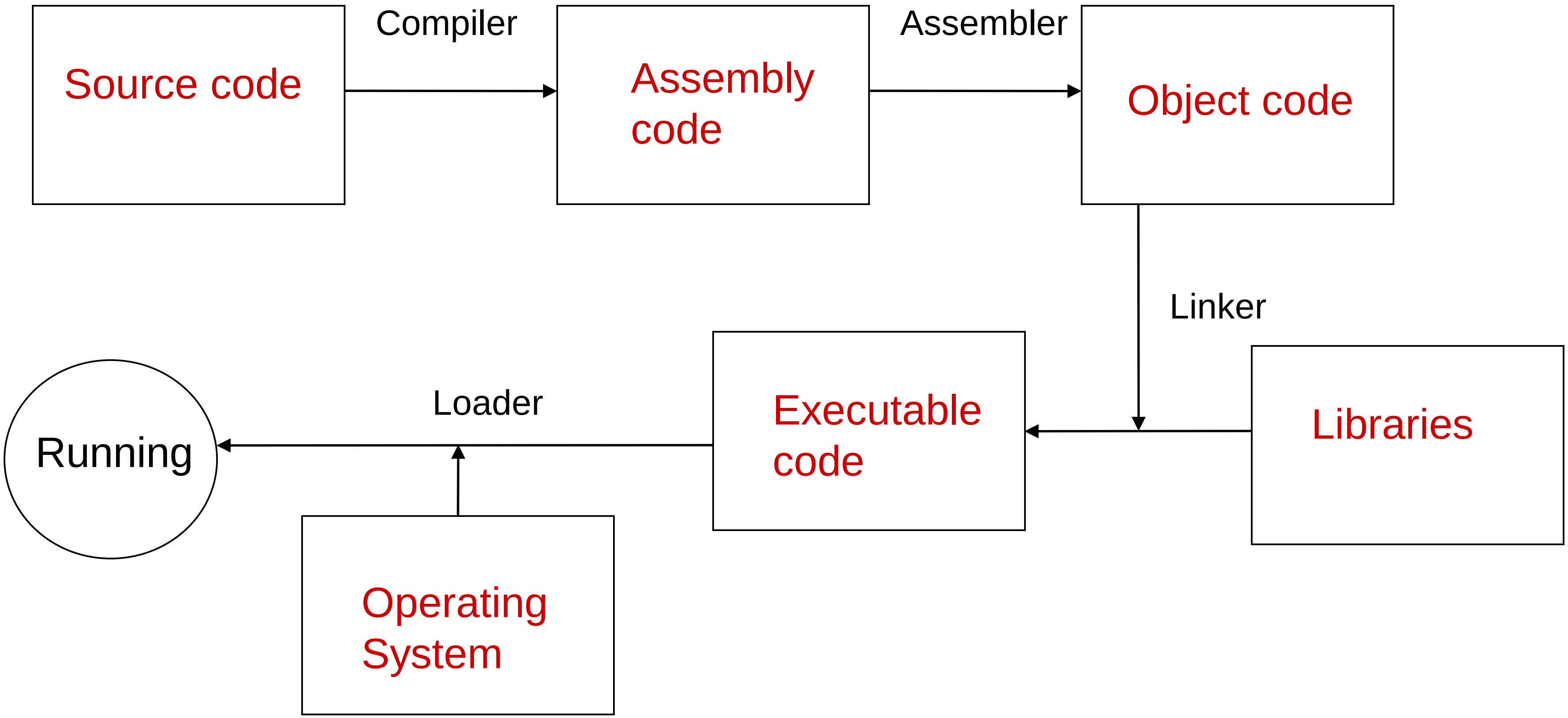
Translation of High Level Languages

- Two types of translators
  - Interpreter (مفسر)
  - Compiler (مترجم)
- Interpreter
  - Checks and runs program lines one-by-one
  - Easy, slow, and we need the interpreter
- Compiler
  - Check all lines, creates executable output file
  - Fast and Stand alone program

Compiler

- Compiler
  - A set of computer programs do the Compilation
  - Preprocessor: Prepare file for compiler
  - Compiler: Create assembly code
  - Assembler: Convert assembly code to binary code
  - Linker: Collect all required binary files (from libraries) into a single loadable file
  - Each language has its own compiler
- Usually compiler do all above steps, you just compile the file and get a executable file

Building & Running Program



Source code

Compiler

Assembly code

Assembler

Object code

Linker

Libraries

Executable code

Loader

Running

Operating System

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Solving Problems

- How to solve problems using computers
  - Develop a program for it
- Steps
  - Analysis: Input, output
  - Algorithm Design
  - Coding
  - Compile → program
  - Execution → test
  - Documentation

Solving Problems: Analysis

- Problem solving process consists of

  Input → Algorithm → Output

- Determine what information is available as the input to your algorithm
- Determine what information is desired as the output from your algorithm
- What needs to be done on the input to produce the output? Algorithm

Solving Problems: Algorithm

- Determine a series of steps that transforms the input data into the output results
    - Find a solution
    - Break down the steps
- Find all the special cases that the must be handled
- If necessary modify or redesign your series of steps so that all special cases are handled
- Verify your algorithm

Solving Problems: Coding

- Describe your algorithm by a programming language
- You must code exactly in the programming language syntax
- Compiler itself is a program it isn’t a human
  - It is not intelligent
  - It just does the steps of the compiling algorithm
  - It does not understand what do you mean!!!

Solving Program: Execution

- Compiler generated the executable file
- Run the executable code
  - First try to use simple
    - Give the input
    - Get results
  - Then try larger and complex inputs

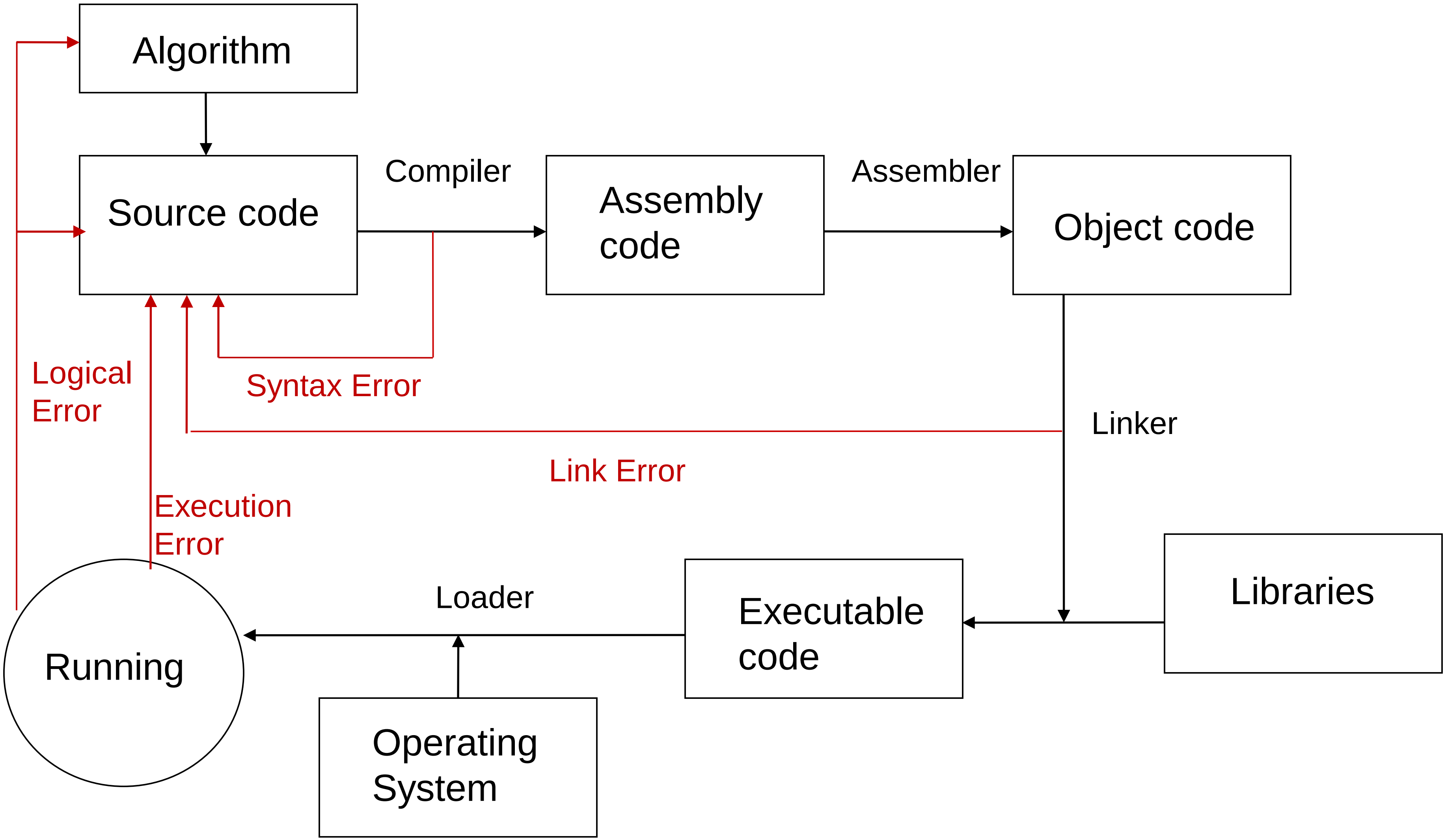
Errors in Solving Problems

- Compile / Syntax error: Compiler does not recognize your code
- Link error: Linker cannot find the required libraries
- Runtime error: Program does not run correctly
  - Example: Division by zero
- Logical Error: Program does not produce the expected result
  - It is called bug
  - No one (compiler, assembler) except debugger can help you ☹
- Why error?
  - You do not understand and analysis the problem correctly
  - You do not develop a right algorithm for the problem
  - You have mistakes in your coding

Debugging

- The process of resolving the errors
  - Example: A program to divide two numbers
- Compile/Syntax error
  - Compiler tells where it is → check syntax
- Link error
  - Compiler tells what it is → check syntax & libraries
- Run time error
  - Try to find it → use debugger to run step-by-step, print debug messages
  - Check syntax & semantic of the line
- Logical error
  - Try to find it → use debugger to run step-by-step, print debug messages
  - Check syntax & semantic of program
  - Revise the algorithm

Building & Running Program



Desired Features of Programs

- Integrity (درستی)
  - Correctly solve the problem
- Clarity (وضوح)
  - Easy to read
- Simplicity (سادگی)
  - Easy to understand
- Efficiency (کارایی)
  - Speed and memory
- Modularity (پیمانه‌ای)
  - Break down of a large task
- Generality (عمومیت)
  - Tunable by input as much as possible

Summary

- Computer organization
  - Hardware and Software
- Algorithm & Program
  - What is the difference between them
- How to solve a problem using computer
  - Steps
- Errors in problem solving
- What is the next: Design algorithm → Program

Reference

- Reading Assignment: Chapter 1 of “C How to Program”