CS 271
Computer Architecture & Assembly Language

Lecture 1

Introduction and Course Syllabus

1/4/22, Tuesday

Oregon State University

Lecture Topics:

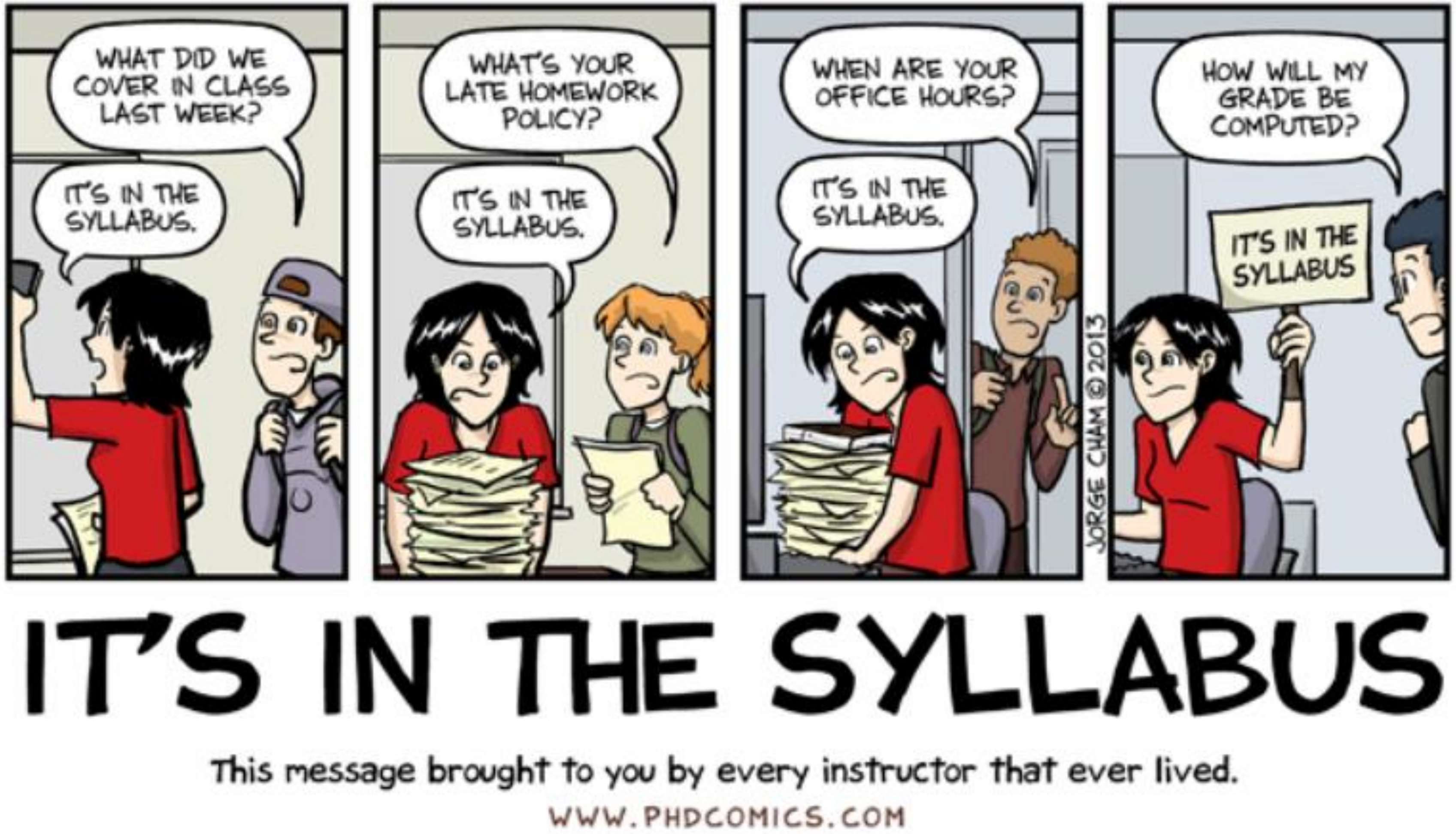
- Syllabus
- Introduction to Hardware, Software, and Languages
- Setup Instructions

About Me

- 8th year at OSU, got my Bachelor degree in Spring 2018, and Master Degree in Fall 2020
- Became a full-time instructor since Winter 2021☺
- Involved in First year CS program since 2017
  - TA 2017-2018
  - GTA 2018-2020

- Taught CS 161 in Fall 2019 and 2020, Winter 2021, and Spring 2021
- Taught CS 162 in Spring and Summer 2020, and Fall 2021
- Taught CS 271 in Winter 2021
- Taught CS 372 in Summer and Fall 2021
- Taught CS 444/544 in Spring 2021

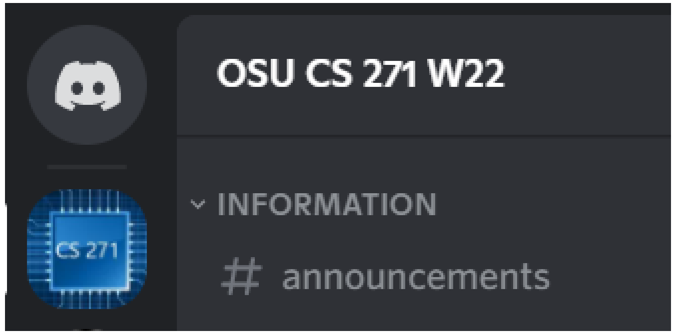
Syllabus



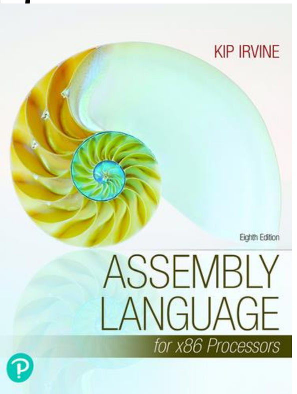
WHAT DID WE COVER IN CLASS LAST WEEK?
IT'S IN THE SYLLABUS.
WHAT'S YOUR LATE HOMEWORK POLICY?
IT'S IN THE SYLLABUS.
WHEN ARE YOUR OFFICE HOURS?
IT'S IN THE SYLLABUS.
JORGE CHAM © 2013
HOW WILL MY GRADE BE COMPUTED?
IT'S IN THE SYLLABUS
IT'S IN THE SYLLABUS
This message brought to you by every instructor that ever lived.
WWW.PHDCOMICS.COM

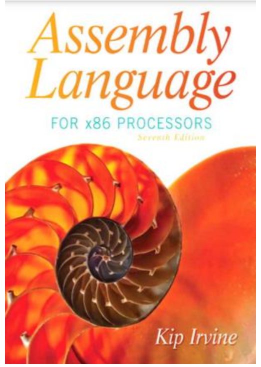
Course Information

- Canvas site:
  - All course materials
  - Code submission (as .asm)
  - Must score 100% on syllabus quiz to unlock the rest
- Discord:
  - Online discussion forum



- Textbook:
  - Irvine, Kip R., **Assembly Language for x86 Processors** (8th ed.)
  - You may access the 7th edition here





Basics

- Instructor: Yipeng (Roger) Song
  - I go by Roger ☺
- Email
  - Instructor: songyip@oregonstate.edu
  - TAs: cs271-ta@engr.orst.edu (TAs and me)
- Office Hours: TBD
- Requirements: Laptop
- Programming Language: Assembly (MASM)

```
INCLUDE Irvine32.inc

DOG_FACTOR = 7

.data
userName    BYTE    33 DUP(0)    ;string to be entered by user
userAge     DWORD   ?            ;integer to be entered by user
intro_1     BYTE    "Hi, my name is Lassie, and I'm here to tell you your age in dog years !", 0
prompt_1    BYTE    "What's your name? ", 0
intro_2     BYTE    "Nice to meet you, ",0
prompt_2    BYTE    "How old are you? ", 0
dogAge      DWORD   ?
result_1    BYTE    "Wow ... that's ", 0
result_2    BYTE    " in dog years !", 0
goodBye     BYTE    "Good-bye, ", 0
x           DWORD   153461
y           BYTE    37
z           BYTE    90
.code
main PROC

;Introduce programmer
    mov     AH, y
    mov     AL, z



    mov     edx, OFFSET intro_1
    call    WriteString
    call    CrLf

;Get user name
    mov     edx, OFFSET prompt_1
    call    WriteString
    mov     edx, OFFSET userName
    mov     ecx, 32
    call    ReadString

;Get user age
    mov     edx, OFFSET prompt_2
    call    WriteString
    call    ReadInt
    mov     userAge, eax
```

More Basics…

- Be respectful (Establishing a Positive Community)
- Have a growth mindset
  - Most abilities could be developed through dedication and hard work
- Academic Misconduct (0 tolerance!!) (See section 17 of the syllabus)
  - https://engineering.oregonstate.edu/academic-misconduct
- Be Proactive
  - Take control and cause something to happen, rather than just adapt to a situation or wait for something to happen

Technology

- Laptops (Windows)
  - Phones needed for DUO
  - bypass DUO: Follow instructions here

Attendance

- **Lecture**: Strongly Encouraged
  - I will post lecture slides and demoed code on Canvas

Grade Breakdown

- 20% - Weekly Summaries
- 10% - Quizzes
- 15% - Midterm Exam
- 35% - Assignments
- 20% - Final Project

Weekly Summaries – 20%

- 10 in total (2% each)
  - Open book, open note, open internet, open lecture, open classmates/friends.
- Available from: Thur 12 pm (after lecture) to Sun 11:59 pm
  - Canvas is very unforgiving about due times -- don't push it.
- T/F, and multiple choices, short answers, covering assigned reading material and lectures from the week
- A time limit of 6 hours
- Two attempts, the higher score will be recorded
- Cannot be taken after the due

Quizzes – 10%

- 5 in total, including the syllabus quiz (2% each)
  - Open book, open note, open internet, but NOT open classmates/friends
- Available from: Thur 12 pm (after lecture) to Sun 11:59 pm
  - Canvas is very unforgiving about due times -- don't push it.
- T/F, and multiple choices, short answers, covering material taught from the previous quiz to that point
- 1 attempt, 60-minute time limit

- Refer to the Course Calendar for quiz due dates (weeks)

Midterm Exam – 15%

- One Mid Term (in Week 6)
  - During lecture time
  - In person, same classroom
    - T/F, and multiple choices, short answers
  - Close-everything
  - Allowed to use a calculator, and scratch paper

Programming Assignments – 35%

- 5 in the term
- Some are one-week, and some are two-week assignments
- **All programming assignments must be submitted in order to pass the course – otherwise F**
- **Always due Sunday by midnight**
- **All code (.asm) must run on Visual Studio – otherwise 0**
- Late assignments
    - 2 grace days throughout the term
    - Late work is penalized 15% per day
    - At max, 2 days late.
    - More than 2 days after due → 0

- Refer to section 13 on the syllabus

Final Project – 20%

- No final exam, but a project
- Due during final’s week (exact time: TBD)
- Fail to submit the final project → F
- Not allowed to use grace days

Grading Philosophy*

- A [93 or greater) mastery
- A- [90 – 93)
- B+ [87 – 90)
- B [83 – 87) stable/proficient
- B- [80 – 83)
- C+ [77 – 80)
- C [73 – 77) passable
- C- [70 – 73)

*Note: I do round ☺ (i.e. 89.45 → 89.5 → 90 ☺)

How to Be Successful

- Read and listen carefully
- Start assignments early
- Be proactive with absences and issues that arise in the term
- Get help when you need it
  - Make use of Discord and Office Hours

- Refer to section 14 on the syllabus

TAs

- Go see your TAs!!!
- Where: Varies
- When: Varies – check the Office Hours page on Canvas

Help Hierarchy

- Reread assignment, lecture slides, syllabus, textbook
- Google online
- Ask a friend
- Check Discord for relevant posts or create a new question
- Ask a TA
  - You can attend office hours
  - TAs will also be monitoring Discord
- Ask Roger

Lecture Topics:

- Syllabus
- Introduction to Hardware, Software, and Languages
- Setup Instructions

Intro to Problem-Solving Languages

- Viewed by "levels"
  - Natural languages:
    - E.g.: English, Spanish, Chinese…
    - Used by humans
    - Many interpretations
    - Translated to programming languages by computer programmers

Intro to Problem-Solving Languages

- Viewed by "levels"
  - High-level computer programming languages
    - E.g.: Java, C/C++, Python…
    - English like, portable to various architectures
    - Strict rules of syntax and semantics
    - Translated to lower levels by compilers/translators
  - Low-level computer programming languages
    - E.g.: Intel assembly, MacOS assembly…
    - Mnemonic instructions for specific computer architectures
    - Translated to machine languages by assemblers

```
    section   .data
message: db     "Hello, World!", 0Ah, 00h
    global  _main
    section   .text
_main:
    mov     rax, 0x02000004    ; system call for write
    mov     rdi, 1             ; file descriptor 1 is stdout
    mov     rsi, qword message ; get string address
    mov     rdx, 13            ; number of bytes
    syscall                    ; execute syscall (write)
    mov     rax, 0x02000001    ; system call for exit
    mov     rdi, 0             ; exit code 0
    syscall                    ; execute syscall (exit)
```

- C

```
#include <stdio.h>

int main(int argc, char ** argv)
{
   printf("Hello, World!\n");
}
```

- Java

```
public class Hello
{
   public static void main(String argv[])
   {
      System.out.println("Hello, World!");
   }
}
```

- now in Python

```
print "Hello, World!"
```

```

.intel_syntax noprefix

.section .text

# Program entry point
.globl _start

_start:

    # Put the code number for system call
    mov eax, 1

    # Return value
    mov ebx, 0

    # Kernel call
    int 0x80

```

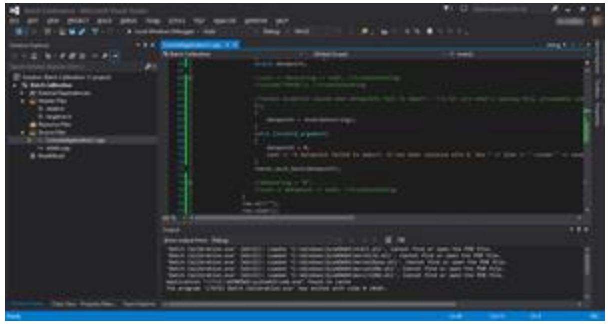
Intro to Problem-Solving Languages

- Viewed by "levels"
  - Machine-level computer languages
    - E.g.: Intel machine instructions, MacOS machine instructions
    - Actual binary code instructions for specific architecture

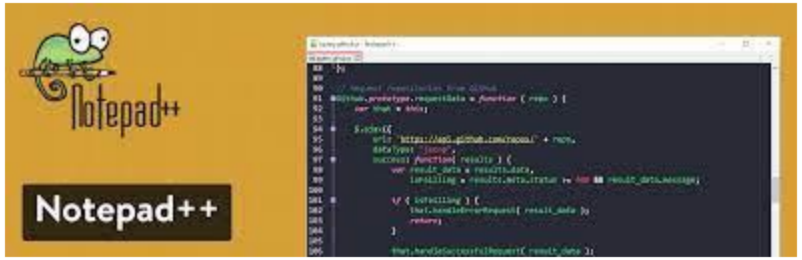
```
00000000: 01001101 01011010 10010000 00000000 00000011 00000000  MZ....
00000006: 00000000 00000000 00000100 00000000 00000000 00000000  ......
0000000c: 11111111 11111111 00000000 00000000 10111000 00000000  ......
00000012: 00000000 00000000 00000000 00000000 00000000 00000000  ......
00000018: 01000000 00000000 00000000 00000000 00000000 00000000  @.....
0000001e: 00000000 00000000 00000000 00000000 00000000 00000000  ......
00000024: 00000000 00000000 00000000 00000000 00000000 00000000  ......
0000002a: 00000000 00000000 00000000 00000000 00000000 00000000  ......
00000030: 00000000 00000000 00000000 00000000 00000000 00000000  ......
00000036: 00000000 00000000 00000000 00000000 00000000 00000000  ......
0000003c: 10000000 00000000 00000000 00000000 00001110 00011111  ......
00000042: 10111010 00001110 00000000 10110100 00001001 11001101  ......
00000048: 00100001 10111000 00000001 01001100 11001101 00100001  !..L.!
0000004e: 01010100 01101000 01101001 01110011 00100000 01110000  This p
00000054: 01110010 01101111 01100111 01110010 01100001 01101101  rogram
0000005a: 00100000 01100011 01100001 01101110 01101110 01101111   canno
00000060: 01110100 00100000 01100010 01100101 00100000 01110010  t be r
00000066: 01110101 01101110 00100000 01101001 01101110 00100000  un in
0000006c: 01000100 01001111 01010011 00100000 01101101 01101111  DOS mo
00000072: 01100100 01100101 00101110 00001101 00001101 00001010  de....
00000078: 00100100 00000000 00000000 00000000 00000000 00000000  $.....
0000007e: 00000000 00000000 01010000 01000101 00000000 00000000  ..PE..
```

Programming Tools/Environments for Various Language Levels

- Natural Language
  - Word processors



- High-level programming languages
  - Text editor, libraries, compiler, linker, loader, debugger
  - E.g.: Eclipse, Visual Studio, …



- Low-level programming languages
  - Text editor, libraries, assembler, linker, loader, debugger
  - E.g.: any text editor together with MASM, Visual Studio, …
- Machine-level computer languages
  - Some way to assign machine instructions directly into computer memory
  - E.g.: set individual bits (switches), loader

Computer Languages / Computer Hardware Viewed by "Levels" (simplified)

- Level 4: Problem solution in natural language
  - Description of algorithm, solution design
  - Programmer translates to …
- Level 3: Computer program in high-level computer programming language
  - Source code (machine independent)
  - Compiler translates to …
- Level 2: Program in assembly language
  - Machine specific commands to control hardware components
  - Assembler translates to …
- Level 1: Program in machine code
  - Object code (binary)
  - Linker / loader sets up …
- Level 0: Actual computer hardware
  - Program in electronic form

Assembly Language

- In this course…
  - Skip the “high-level language” level
  - Write programs in assembly language
  - Expand levels 2, 1, and 0
    - understand what happens inside the computer

  - Use an assembly language to understand a specific architecture
  - Concepts transfer to other architectures

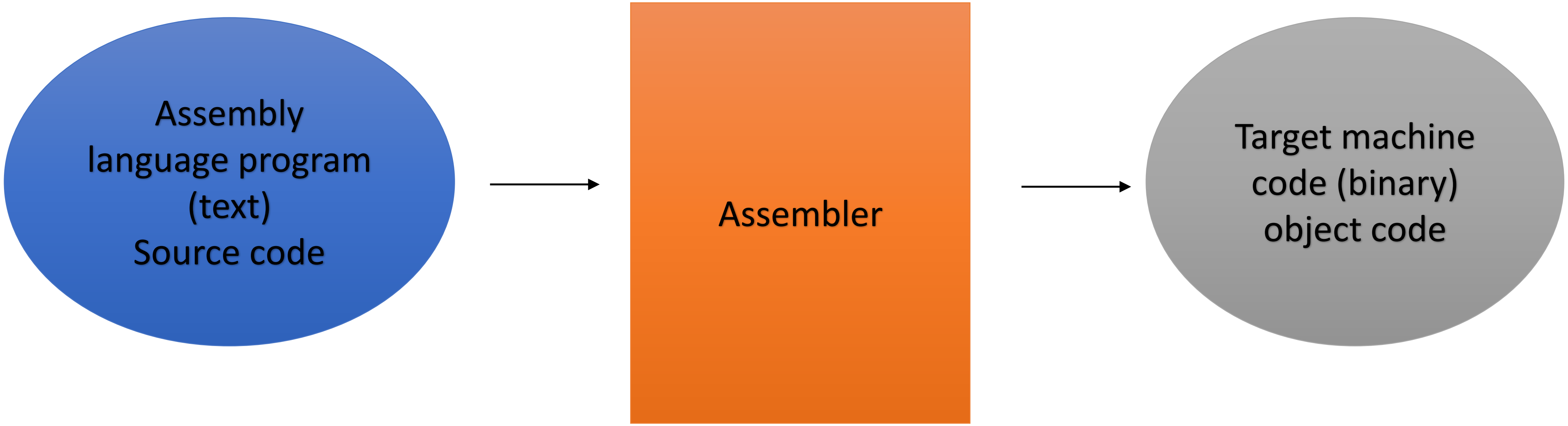
Assembly Language

Mnemonic	Description
`ADD A, byte`	add A to byte, put result in A
`ADDC A, byte`	add with carry
`SUBB A, byte`	subtract with borrow
`INC A`	increment A

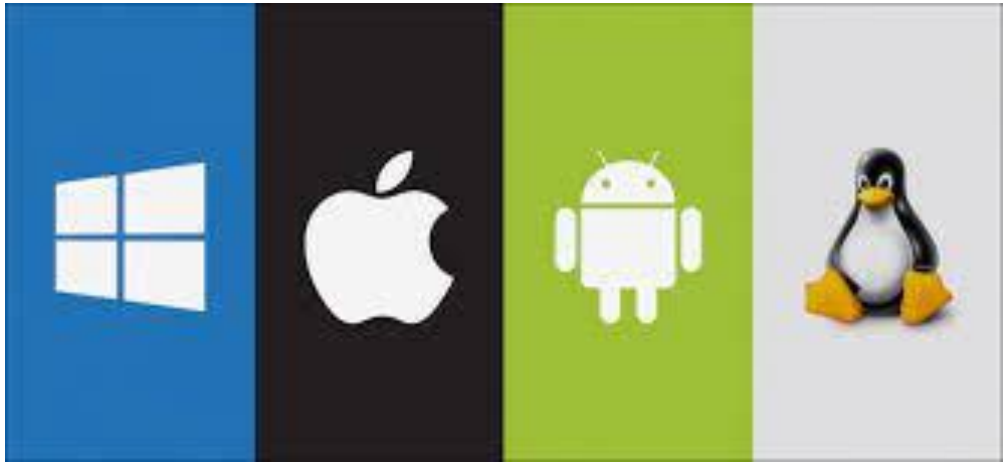
- Assembly language provides:
  1. Set of mnemonics for machines instructions
     - Opcodes and addressing modes
  2. Mechanism for naming memory addresses and other constants
     - Note: a named memory address is usually called a "variable"
  3. Other "conveniences" for developing source code for a particular machine architecture

Assembler and assembly

- An assembler is a software system that takes assembly language as input and produces machine language as output



Operating Systems (OS)



- Operating systems provide interfaces among users, programs, and devices (including the host computer itself).

- Implemented for specific architecture (in the host computer's machine language).

Low-level programming

- Level 2: Program in assembly language
  - Assembler translates to …
- Level 1: Program in machine code
  - Operating system does partial translation
  - The hardware's instruction set architecture (ISA) provides a micro-program for each machine instruction (CISC*) or direct execution (RISC*)
- Level 0: Actual computer hardware
  - Digital logic (circuits)
  - Micro-architecture circuits control computer components

*More later on CISC (Complex Instruction Set Computer) and RISC (Reduced Instruction Set Computer)

Relationship: Instruction Set ←→ Architecture

- A computer's instruction set is defined by the computer's architecture.
  - i.e.: each computer's architecture has its own machine language.
    - E.g.: Sun machine instructions will not work on an Intel architecture

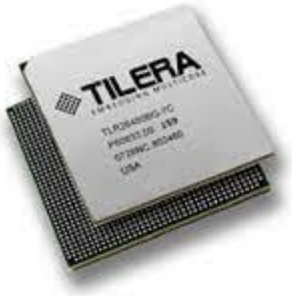
- Cross-assemblers (software) can be used to convert a machine language to another machine languages.
- Virtual machines (software) can be used to simulate another computer's architecture

Relationship:
Architecture ←→ Software

- Hardware: Physical devices
  - E.g.: circuits, chips, disk drives, printers…
- Software: Instructions that control hardware
  - E.g.: games, word processors, compilers, operating systems…
- Sometimes the line between hardware and software is not clear
  - E.g.: Parts of an operating system might be implemented in hardware

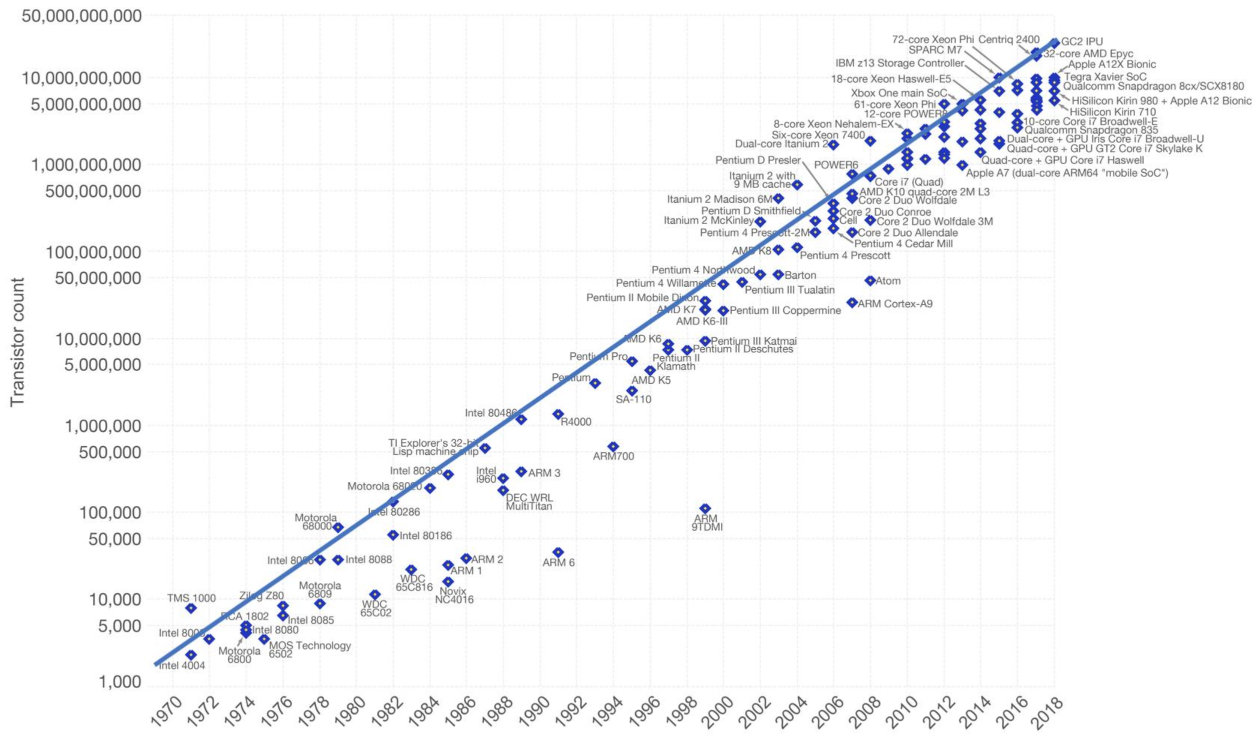
System Architectures

- Super-computer
- Mainframe
- Multiprocessor/Parallel (multi-core)
- Server
- Distributed (collection of Workstations)
  - Network
- Personal computer
  - Desktop, laptop, netbook …
- Micro-controller (Real-time/Embedded system)
  - Phone, car, watch, appliance …
- Etc.



Two architecture development tracks

- Build more powerful machines
  - Multi-core, etc.
- Build some machine smaller/cheaper
  - Nanotech



- *Moore's Law
  - the number of transistors in a dense integrated circuit (IC) doubles about every two years

Why use assembly language?

- Easier than machine code
- Access to all features of target machine
- Performance (maybe)
- Using mixed languages

- Note that assembly language tends to solve toward a high-level language
  - Advanced features (“auto” loop control, etc.)
  - Libraries

```c
void SimdMul( float *a, float *b,   float *c,   int len )
{
    int limit = ( len/SSE_WIDTH ) * SSE_WIDTH;
    __asm
    (
        ".att_syntax\n\t"
        "movq    -24(%rbp), %r8\n\t"        // a
        "movq    -32(%rbp), %rcx\n\t"       // b
        "movq    -40(%rbp), %rdx\n\t"       // c
    );

    for( int i = 0; i < limit; i += SSE_WIDTH )
    {
        __asm
        (
            ".att_syntax\n\t"
            "movups (%r8), %xmm0\n\t"   // load the first sse register
            "movups (%rcx), %xmm1\n\t"  // load the second sse register
            "mulps  %xmm1, %xmm0\n\t"   // do the multiply
            "movups %xmm0, (%rdx)\n\t"  // store the result
            "addq $16, %r8\n\t"
            "addq $16, %rcx\n\t"
            "addq $16, %rdx\n\t"
        );
    }

    for( int i = limit; i < len; i++ )
    {
        c[i] = a[i] * b[i];
    }
}
```

Common uses of assembly language

- Embedded systems
  - Efficiency is critical
- Real-time applications
  - Timing is critical
- Interactive games
  - Speed is critical
- Low-level tasks, Device drivers
  - Direct control is critical

Main concepts:

- Hardware/software
- Languages (high-level, assembly, machine)
- How statements are translated from higher to lower levels
- Variety of architectures
  - Each has its own instruction set
- Applications of assembly language

Lecture Topics:

- Syllabus
- Introduction to Hardware, Software, and Languages
- Setup Instructions

Things to do before next lecture

- Complete the syllabus quiz (and make sure you get 100%)
- Complete the Visual Studio Setup

- Do the self-check exercise

- Continue on the assigned readings