Computer Architecture
- Introduction -

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About this course…

Course name : computer architecture (CP26139)

- Study the basics on computer systems
  - Study the basic knowledge about computer systems including CPU, memory system, I/O device, and bus. Study cache, internal & external memory, interconnection mechanism, computer arithmetic and CPU structure
  - Also study RISC based CPU structure and control units of RISC and CISC systems

About this course…

- What you can expect to get from this class
  - to become conversant with computer architecture terms and concepts
  - to understand fundamental concepts in computer architecture and how they impact computer and application performance
  - to be able to read and evaluate architectural descriptions of even today’s most complex processors (i.e., Superscalar Processor, GPU, etc.)
  - to learn experimental techniques used to evaluate advanced architectural ideas
  - to understand current PC architecture
  - to understand current embedded processor architecture and embedded programming technique, etc.

About this course…

- About me…
  - Office : A06-6503
  - Office hours : Monday & Wednesday, 12:00~13:20
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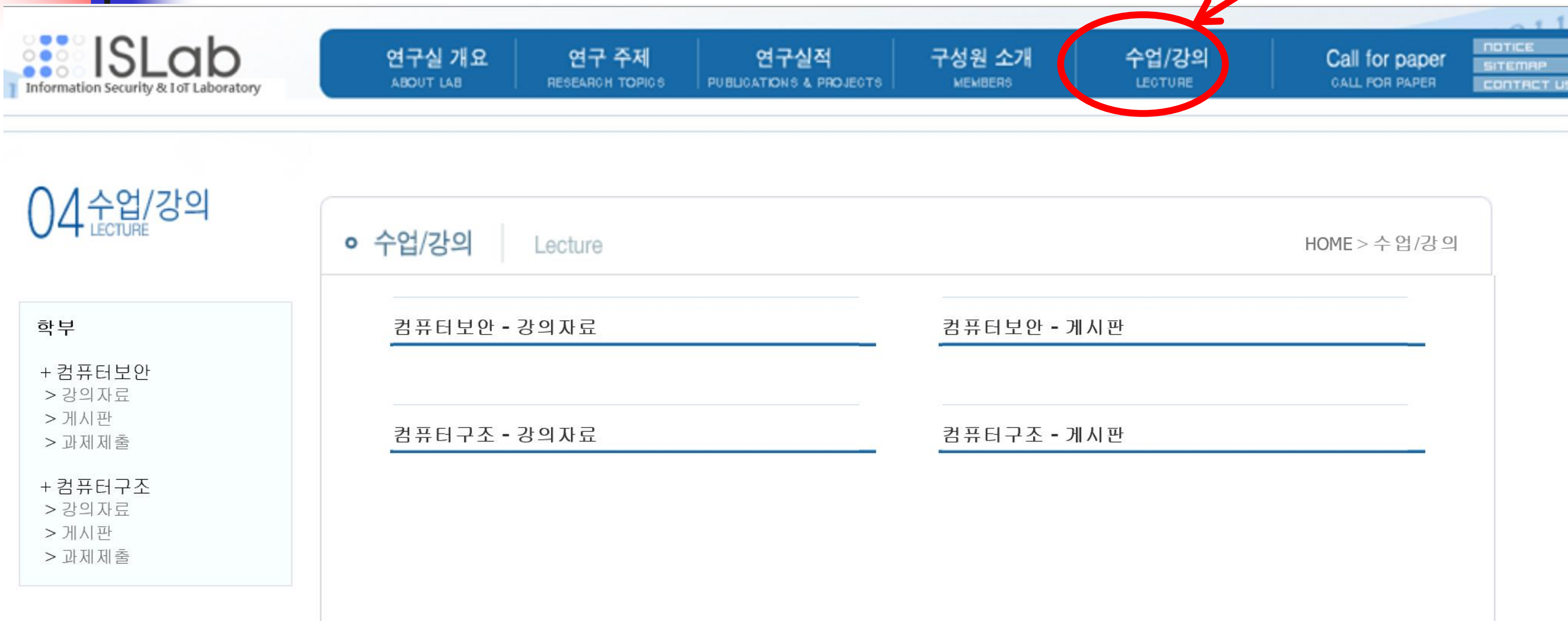
  - http://infosec.pusan.ac.kr
- Current Major Interests
  - 사물인터넷(Internet of Things) 연구
  - 딥러닝, AI 기술 연구
  - 정보보호(Information Security), IoT 보안, 암호 연구
  - 암호 칩, 보안 칩 설계 연구
  - 국가보안기술연구소, ETRI, KISA, IBM과 공동연구
  - 부산대학교 사물인터넷 연구센터 운영 중

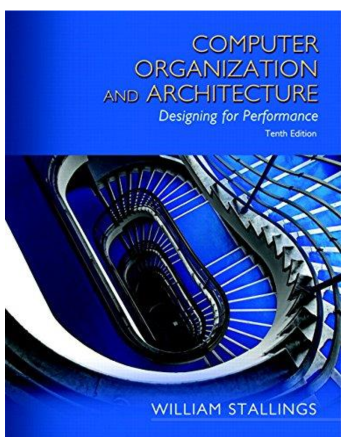
About this course…

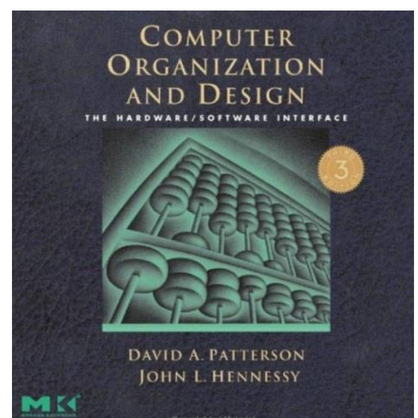
- Course Materials
  - http://infosec.pusan.ac.kr



About this course…

- Textbook
  - Computer Organization and Architecture : Designing for Performance, 10th Edition, W. Stallings, Prentice Hall, 2015
  - http://williamstallings.com/ComputerOrganization/
- References
  - Computer Organization and Design: The Hardware/Software Interface, Morgan Kaufmann3rd edition, 2007
- Class time & Classroom
  - Monday, Wednesday : 15:00~16:15





About this course…

Detailed schedule on this class

주	학습내용	범위 등
1	Introduction	CH1 & 2, H/W #1
2	Computer Function and Interconnection	CH3
3	Computer Function and Interconnection	CH3
4	Cache Memory	CH4, H/W #2
5	Internal Memory	CH5
6	External Memory	CH6, H/W #3
7	Computer Arithmetic	CH9
8	Midterm Exam	
9	Processor Structure and Function	CH12,H/W #4
10	Reduced Instruction Set Computers	CH13
11	Reduced Instruction Set Computers	CH13
12	Control Unit Operation	CH16, H/W #5
13	Micro-programmed Control	CH17
14	Micro-programmed Control	CH17, H/W #6
15	Final Exam	

About this course…

- Assessment

항 목	점 수
출 석	5
중간고사	40
기말고사	40
과제물	15 (1 week delay: -20% penalty)
합 계	100

The History of Computer

- Read the following material !
  - Timeline of Computer history
    - http://www.computerhistory.org/timeline/computers/
  - The history of computer:
    - https://en.wikipedia.org/wiki/Computer
  - The quantum computer:
    - https://en.wikipedia.org/wiki/Quantum_computing

What is Computer Architecture ?

- Hardware designer
  - thinks about circuits, components, timing, functionality, ease of debugging
- Computer architect
  - thinks about high-level components, how they fit together, how they work together to deliver performance

Why do I care ?

- You may actually do computer architecture someday
- You may actually care about software performance someday
  - The ability of application programs, compilers, operating systems, etc. to deliver performance depends critically on an understanding of the underlying computer organization
    - What does the option in GCC compiler mean ?
    - For example, the -mthumb option for ARM-gcc. What does it mean?
  - That becomes more true every year
  - Computer architectures become more difficult to understand every year

Architecture & Organization

- Architecture is those attributes visible to the programmer
  - Instruction set, number of bits used for data representation, I/O mechanisms, addressing techniques.
  - e.g. Is there a multiply instruction?
- Organization is how features are implemented
  - Control signals, interfaces, memory technology.
  - e.g. Is there a hardware multiply unit or is it done by repeated addition?
- All Intel x86 family share the same basic architecture
  - This gives code compatibility (at least backwards)
  - Organization differs between different versions

Architecture & Organization

Computer Architecture

- Attributes of a system visible to the programmer
- Have a direct impact on the logical execution of a program

Architectural attributes include:

- Instruction set, number of bits used to represent various data types, I/O mechanisms, techniques for addressing memory

Computer Organization

- The operational units and their interconnections that realize the architectural specifications

Organizational attributes include:

- Hardware details transparent to the programmer, control signals, interfaces between the computer and peripherals, memory technology used

Architecture & Organization

- For example,
  - It is an architectural issue whether a computer will have a multiply instruction
  - It is an organizational issue whether that instruction will be implemented by a special multiply unit or by a mechanism that makes repeated use of the add unit of the system

How to Speak Computer ?

High Level Language Program

Compiler

Assembly Language Program

Assembler

Machine Language Program

Machine Interpretation

Control Signal Spec.

```
Temp = V[k];
V[k] = V[k+1];
V[k+1] = temp;
```

```
lw $15, 0($2)
lw $16, 4($2)
sw $16, 0($2)
sw $15, 4($2)
```

```
1000110001100010000000000...
1000110011110010000000000...
```

```
ALUOP[0:3] <= InstReg[9:11] & MASK;
```

Complex Computer System

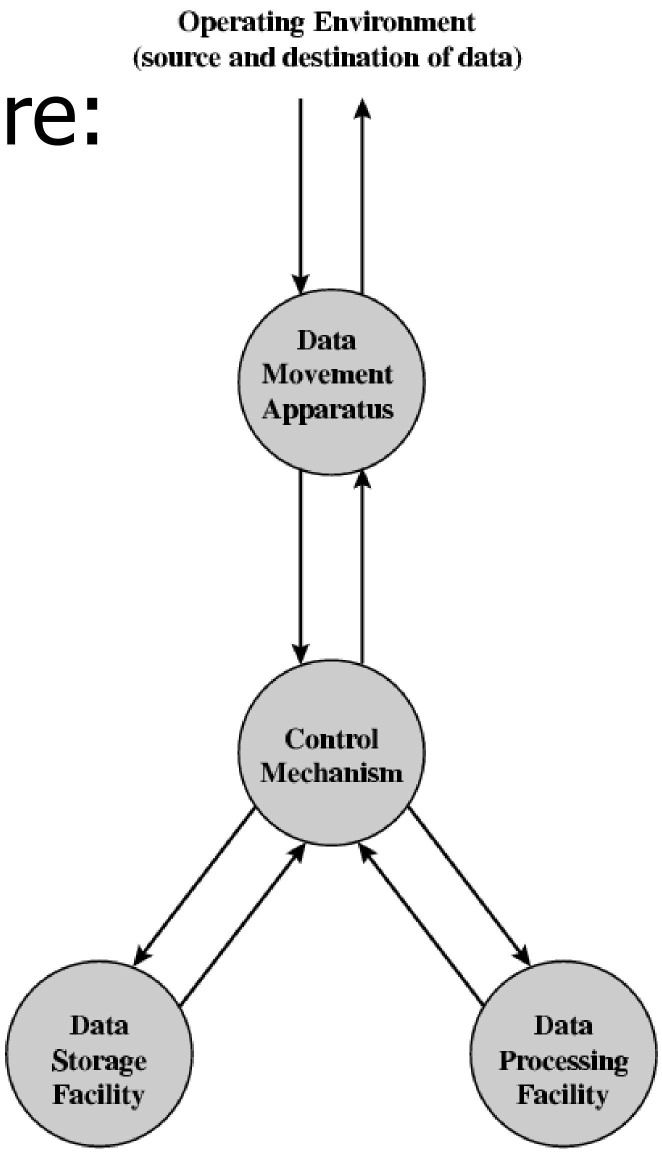
- A computer is a complex system
  - Contemporary computers contain millions of Elementary electronic components
  - How can one clearly describe them?
    - The key is to recognize the hierarchical nature of most complex systems
- The hierarchical nature of complex systems is essential to both their design and their description
  - The designer needs to only deal **with a particular level of the system at a time.**
  - At each level, the designer is concerned with **structure and function**

Structure & Function

- Structure is the way in which components relate to each other
- Function is the operation of individual components as part of the structure

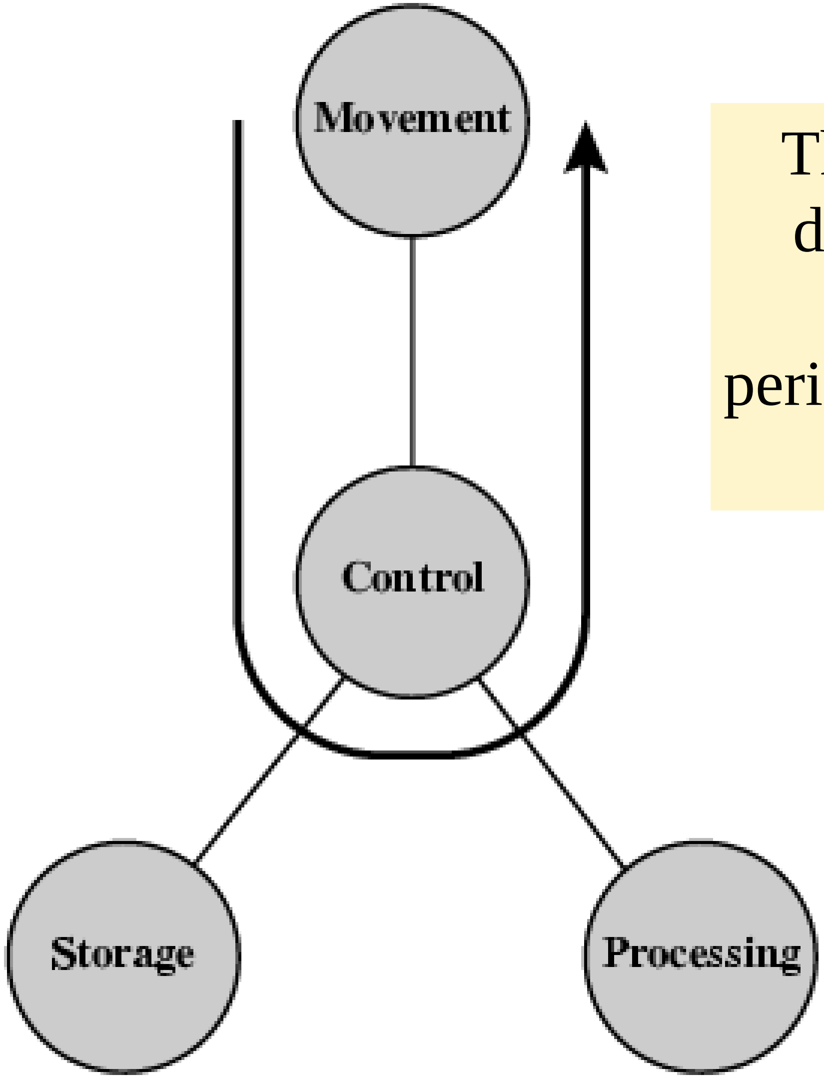
Function

- All computer functions are:
  - Data processing
  - Data storage
  - Data movement
  - Control



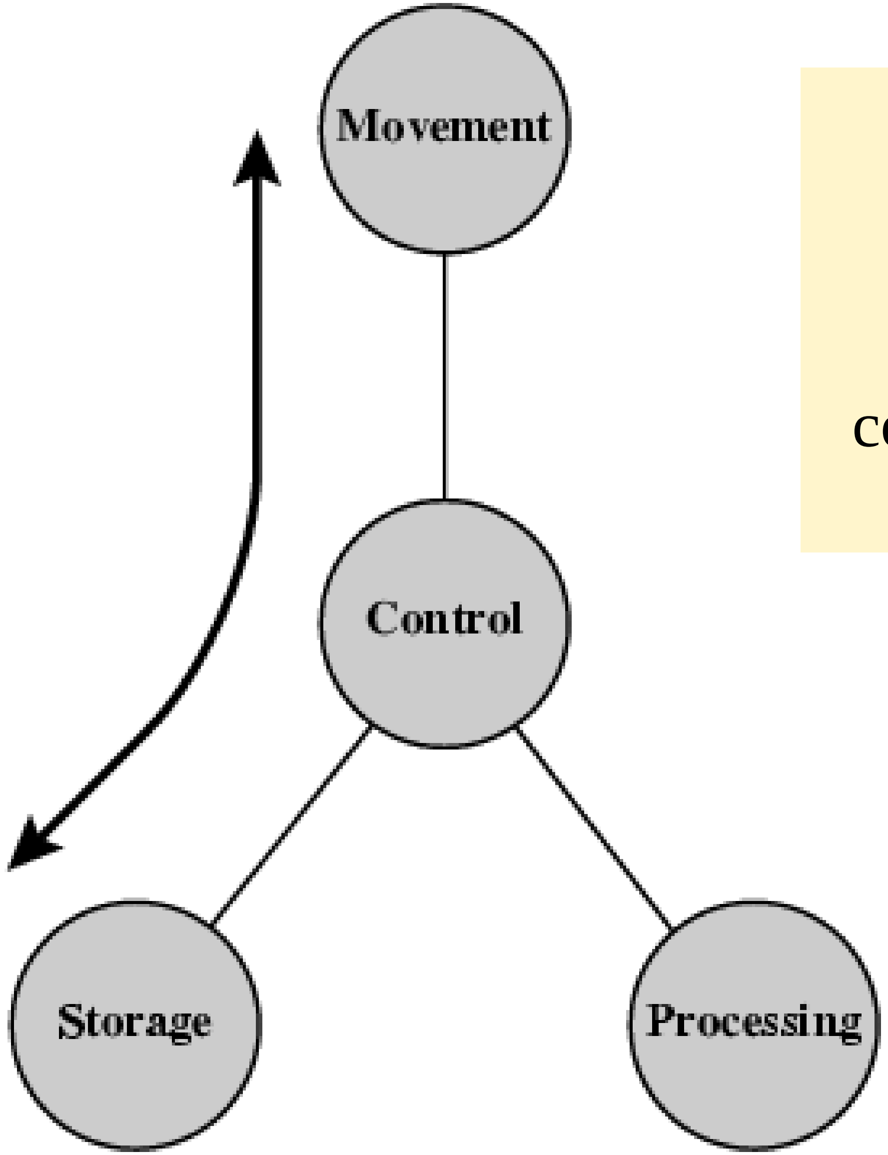
The number of possible operations that can be performed is few. This figure depicts the four possible types of operations.

Operations - Data movement



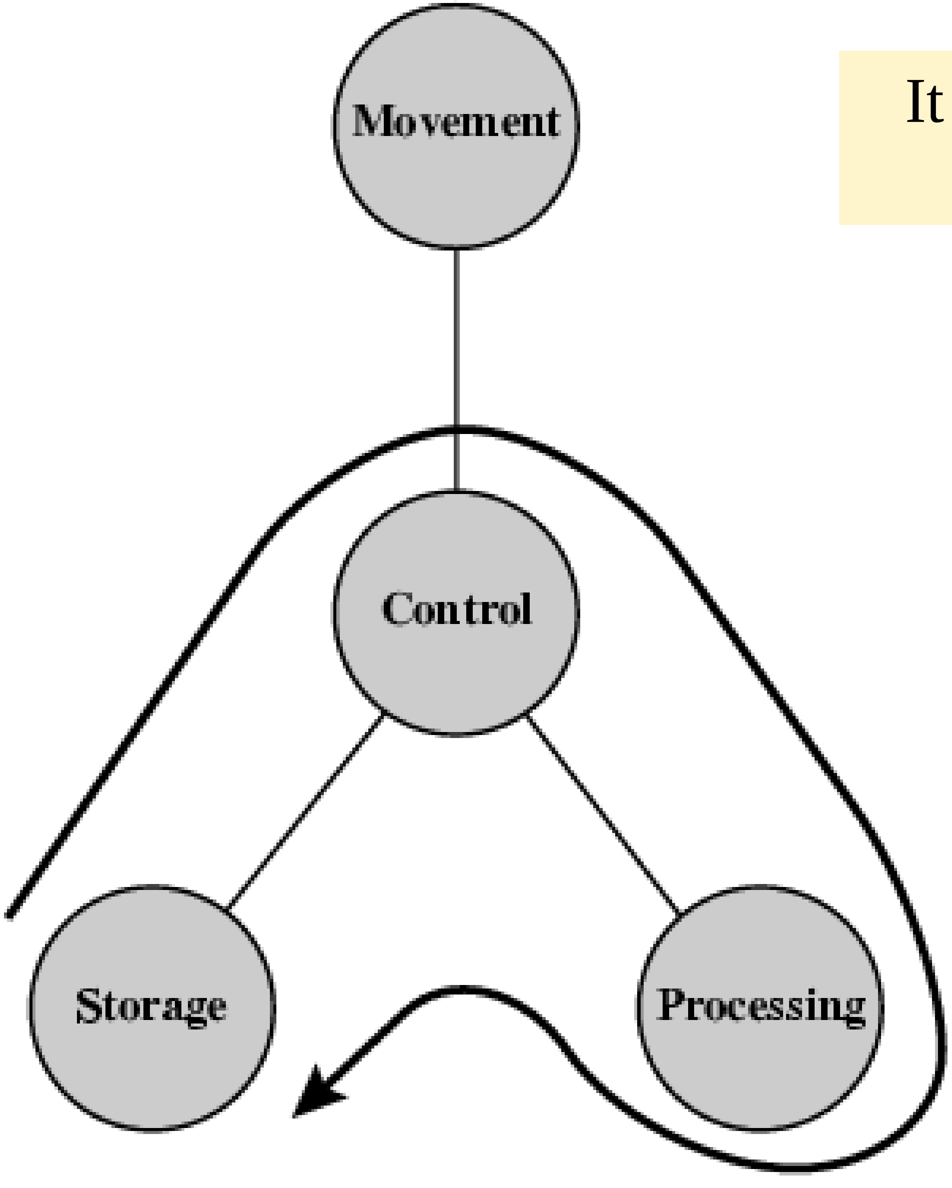
The computer can function as a data movement device, simply transferring data from one peripheral or communication line to another.

Operations - Storage



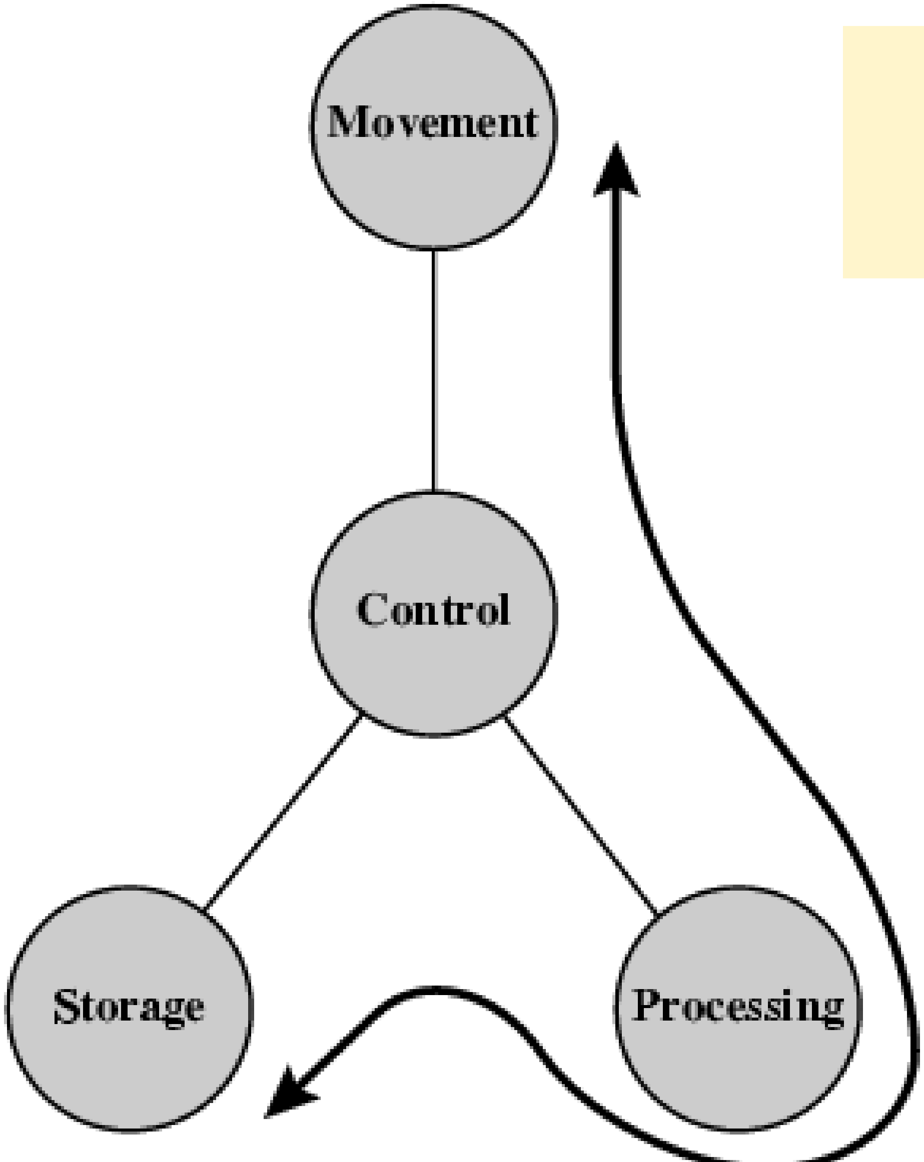
It can also function as a data storage device, with data transferred from
the external environment to computer storage (read) and vice versa (write).

Operation - Processing from/to storage



It processes the data, which is in storage

Operation - Processing from storage to I/O



It functions as a route between storage and the external environment

Computer – External/Internal View

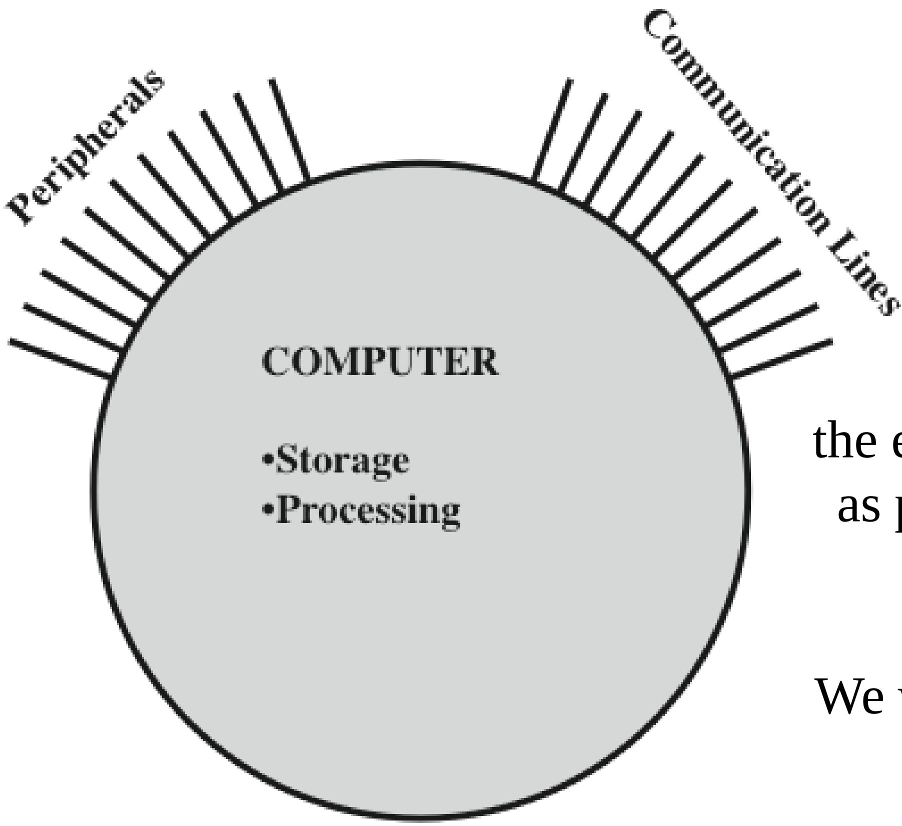


Figure 1.3 The Computer

This is the simplest possible depiction of a computer.

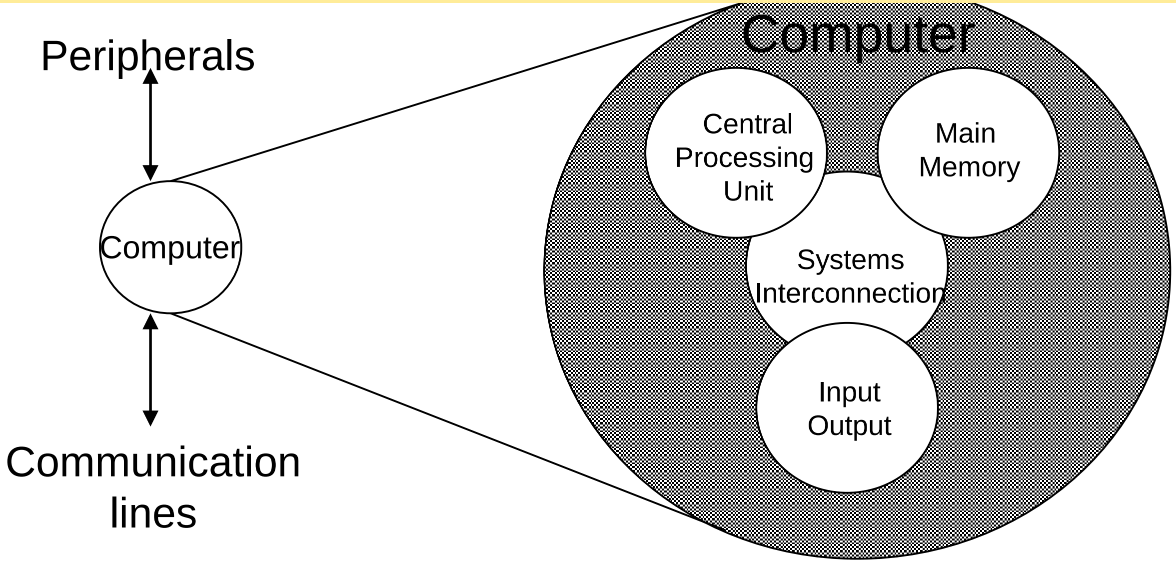
The computer interacts in some fashion with its external environment.

In general, all of its linkages to the external environment can be classified as peripheral devices or communication lines.

We will have something to say about both types of linkages.

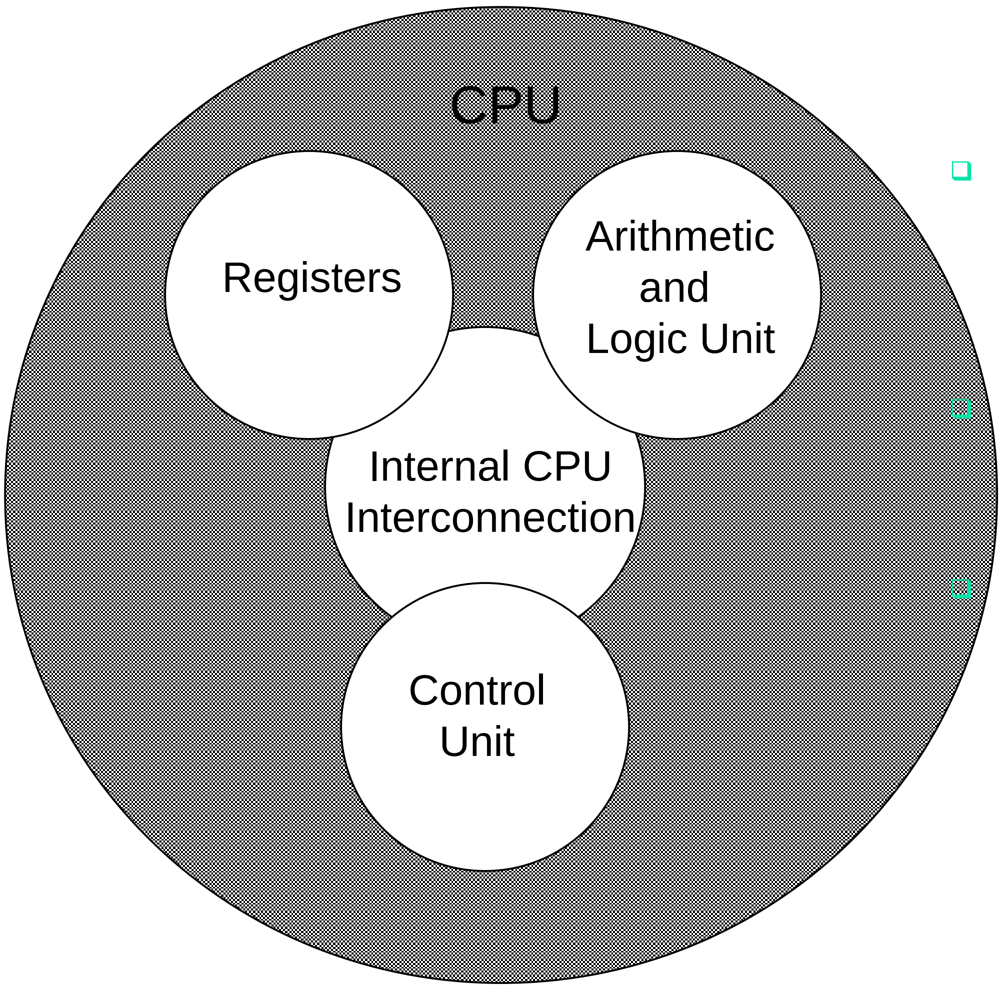
Structure - Top Level

But of greater concern in this course **is the internal structure of the computer itself**, which is shown in Figure. There are four main structural components: **Central Processing Unit (CPU), Main Memory, I/O System Interconnection**



- **Central processing unit (CPU):** Controls the operation of the computer and performs its data processing functions; often simply referred to as **processor.**
- **Main memory:** Stores data.
- **I/O:** Moves data between the computer and its external environment.
- **System interconnection:** Some mechanism that provides for communication among CPU, main memory, and I/O. A common example of system interconnection is by means of a **system bus,** consisting of a number of conducting wires to which all the other components attach

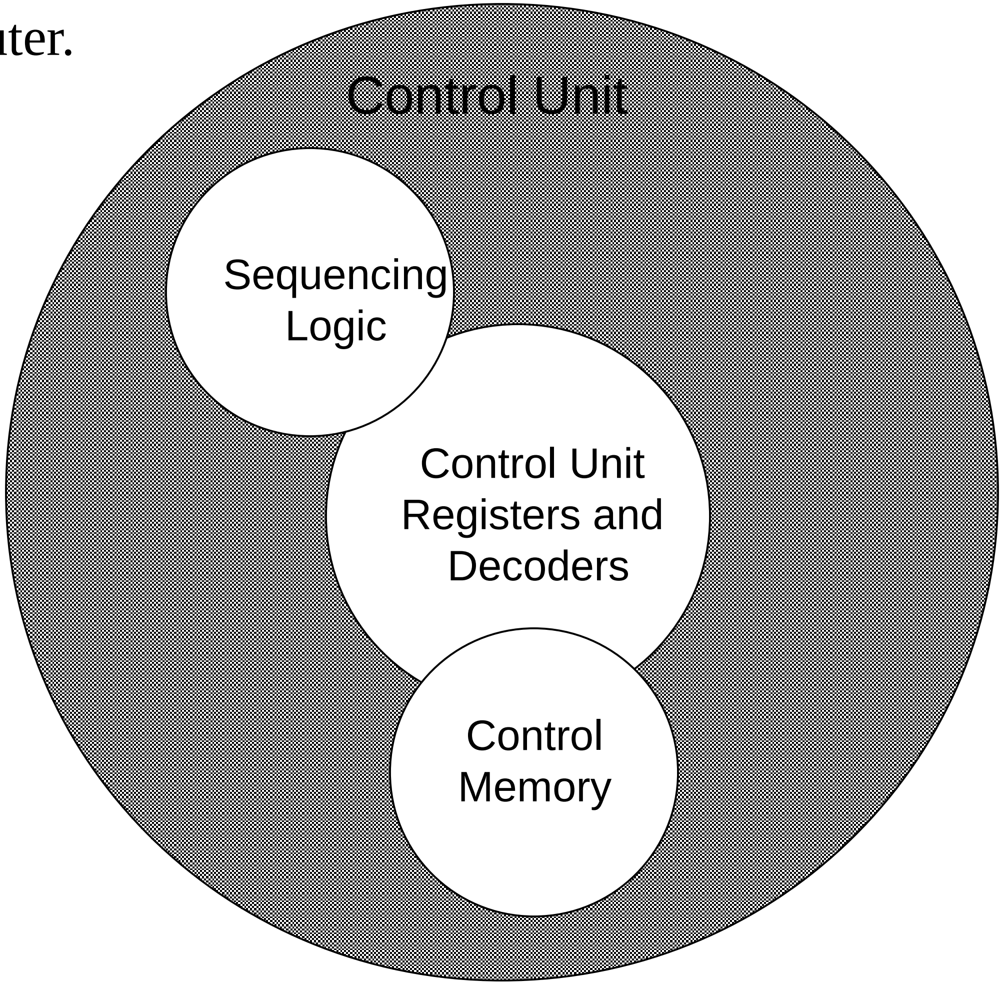
Structure - The CPU



- **Control Unit**
  - Controls the operation of the CPU and hence the computer
- **Arithmetic and Logic Unit (ALU)**
  - Performs the computer's data processing function
- **Registers**
  - Provide storage internal to the CPU
- **CPU Interconnection**
  - Some mechanism that provides for communication among the control unit, ALU, and registers

Structure - The Control Unit

- **Control unit:** Controls the operation of the CPU and hence the computer.



Outline of the Main textbook (1)

- Computer Evolution and Performance
- Computer Interconnection Structures
- Internal Memory
- External Memory
- Input/Output
- Operating Systems Support
- Computer Arithmetic
- Instruction Sets

Outline of the Main textbook (2)

- CPU Structure and Function
- Reduced Instruction Set Computers
- Superscalar Processors
- Control Unit Operation
- Microprogrammed Control
- Multiprocessors and Vector Processing
- Digital Logic (Appendix)

Internet Resources - Web site for textbook

- **http://williamstallings.com/ComputerOrganization/styled-6/**
  - Links to sites of interest
  - Links to sites for courses that use the book
  - Errata list for book
  - Information on other books by W. Stallings

Next…

- Study on the computer evolution & performance …
  - ENIAC
  - Von Neumann
  - IBM
  - Moore’s Law
  - Performance
  - etc.

Next…

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  - Von Neumann
  - IBM
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  - etc.

Q&A

Reference

[1] Introduction to Computer Architecture by Allan Snaverly