

Programming Assignment Lecture I

Introduction

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Basic Info

- ▶ Course Content
 - ▶ PA1
- ▶ Time
 - ▶ Friday each odd weak
- ▶ Assessment methods
 - ▶ Submit project and report before **deadline**.
 - ▶ An act of plagiarism is absolutely forbidden.
 - ▶ For more details, see SUBMIT REQUIREMENT WEBPAGE.
- ▶ Instruction
 - ▶ <https://nju-ics.gitbooks.io/ics2017-programming-assignment/>
 - ▶ Please check the "news" module of website at least once each day.

Teacher and T.A.s

Teacher Liang Wang(wl@nju.edu.cn)

T.A. Ruize Tang(151220100@smail.nju.edu.cn)
Minhui Xie(xiemhemail@gmail.com)

Q&A Time 125,7pm-9pm,Saturday

Task load index

Here are 3 questionnaires to assess your perceived workload. **We sincerely hope you finish them** in each stage for our teaching research. But it isn't mandatory, **all by voluntary!**

Q1.doc Please fill it up before the start of PA **and** fill it up when submitting **each** large stage.

Q2.doc id.

Q3.doc Please fill it up when submitting **each** large stage.

Submission format

Compress them with your report and PA. Submission of the first time of Q1 and Q2 (*i.e. Before the start of PA*) can be postponed to the submission of whole PA1. But make sure you have distinguish them in file name such like Q1_1st.doc, Q1_2nd.doc.

Resources

Platform and tools IA-32 + GNU/Linux + gcc + C

Guidebook <https://nju-ics.gitbooks.io/ics2017-programming-assignment/>

Skeleton <https://github.com/NJU-ProjectN/ics-pa>

Tip

You can download the PDF or epub version of guide in github.

Programming Assignment Lecture I

- 1 From Computer System, to ICS, to PA
- 2 How we emulate a computer? → The story of computer
- 3 Help you do it! → Brand new PA based on AM

Why we need learn ICS?

Motivation

Question

```
int main()
{
    printf("Hello World");
    return 0;
}
```

What the computer are doing when you execute the program above?

Tip

This may appear in exams.

System Stack

Application
Algorithm
Programming Language
Operating System/Virtual Machines
Instruction Set Architecture
Micro-architecture
Register-Transfer Level
Gates
Circuits
Devices
Physics

What you'll get after finishing PA

- You'll
- ▶ **Get Systems thinking**
 - ▶ Understand how program run on a computer
 - ▶ Enhance **coding** ability
 - ▶ Prepare for later courses (OS, Compiling)

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- Way Complete a tiny but entire computer system and run program on it.

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Way Complete a tiny but entire computer system and run program on it.

PA **NEMU** (*i.e. NJU Emulator*)

Question

What is an *emulator*?

What is an *emulator*?

Emulator –Wikipedia

In computing, an **emulator** is hardware or software that enables one computer system (called the *host*) to behave like another computer system (called the *guest*).

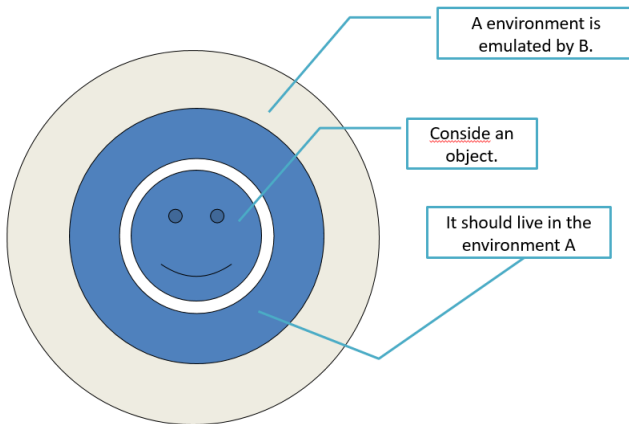
An emulator typically enables the host system to run software or use peripheral devices designed for the guest system.

What is an *emulator*?



What is an *emulator*?





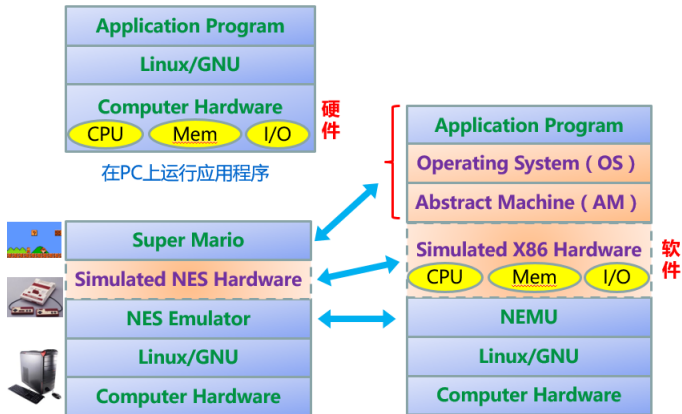
Question

Does the object know he is living in a virtualized environment?

Task of PA

Task of PA

To realize **NEMU**, a simplified x86 system-wide **emulator**.



在虚拟机上运行应用程序

Transition

So how we emulate a computer?

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DLC

- ▶ Most of you have completed the Digital Logic Circuit Course.(Taught by zzs whj)
 - ▶ Adder
 - ▶ Register
 - ▶ Multiplexer
 - ▶ *etc.*

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 - ▶ *etc.*
- ▶ Logic Gate → digital logic device → Computer

The simplest computer- Turing machine

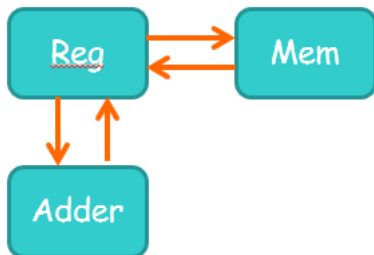
Ultimate goal of computer

Run programs on it.

To place programs Memory

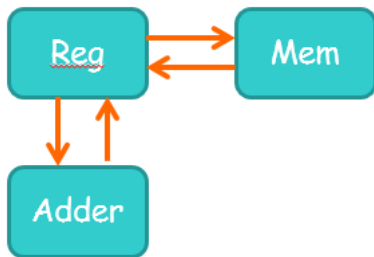
To process data Adder

To store temporary results efficiently Reg



The simplest computer- Turing machine

- ▶ $\text{TRM} = \text{Reg} + \text{Adder} + \text{Mem}$
 - ▶ These are all what we learned in DLC!
- ▶ Computers read data from Mem, store them to Reg, do some calculate and write the result to Mem.



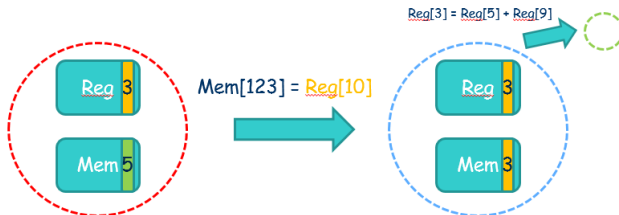
State of TRM

- ▶ Reg and Mem are all Sequential Logic Device. They can store value (i.e. state).
- ▶ The process of computer working = These sequential logical devices transfer one state to another state



Instructions of TRM

- ▶ This large state machine does have abundant states.
- ▶ But how one state transfer to another is not at liberty.
- ▶ **Instructions = Commands that guide the state transition of computer**
 - ▶ R/W Mem ,Computing
- ▶ **Program = A lot of instructions**



Instruction Set

- ▶ Instruction Set = All things computer can do
 - ▶ e.g. inc,dec,jne

Question

What can TRM do with just these 3 instructions?

Instruction Set

- ▶ Instruction Set = All things computer can do
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Question

What can TRM do with just these 3 instructions?

- ▶ Computability theory shows that TRM can do anything!

loop jne

add inc,inc,inc,inc,inc...

multiply add,add,add,add...

NEMU Wow!

Instruction Set

- ▶ However, the speed of only 3 instructions-version TRM is so slow.
- ▶ Why do we add more powerful instructions to the computer?
- ▶ **Modern computer Instruction Set** (x86, mips)
 - ▶ mul, div, cmp, bit operation, string manipulation
 - ▶ Adder → ALU

inc
inc
 ...
inc



add

add
 add
 ...
 add



mul

Input & Output

Question

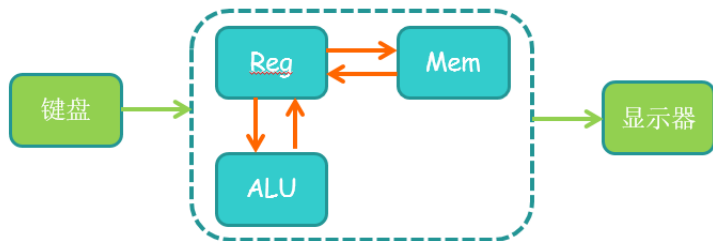
Now, it seems that we have a powerful computer. Are there any unsatisfactory drawbacks?

Input & Output

Question

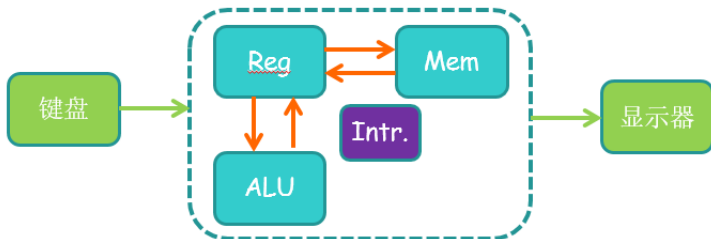
Now, it seems that we have a powerful computer. Are there any unsatisfactory drawbacks?

- ▶ It can only do computing!
- ▶ To interact with the outside world, we need to add I/O devices
- ▶ plus with some relative instructions.



Interrupt & Exception

- ▶ Besides running regular program, computer should deal with emergencies whenever possible.
- ▶ Such as,
 - ▶ Inner exception: division by 0, access violation, trap etc.
 - ▶ Outer interrupt: Keyboard, device ready, etc.
- ▶ We need add asynchronous processing unit to deal with emergencies.



Multitask

Question again

Now, it seems that we have a powerful computer. Are there any unsatisfactory drawbacks?

Multitask

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Now, it seems that we have a powerful computer. Are there any unsatisfactory drawbacks?

- ▶ Monotask → Mutitask
- ▶ **Time-division multiplexing**: Improve the efficiency of resources usages.
 - ▶ CPU, I/O Device: Take turns!

Question

Can tasks use memory exclusively by turns? What else should we do in practice?

Multitask

Question again

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Answer

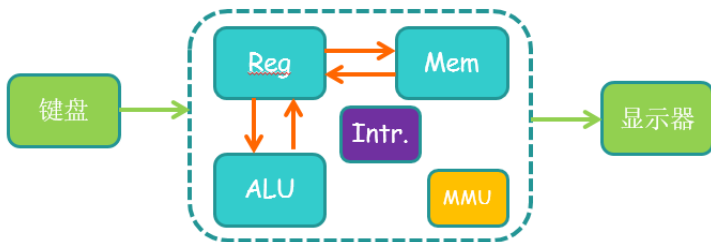
Certainly not. Exclusive memory using will cause inefficiency.

We should add MMU for memory protection.

AM(Abstract Machine)

$$AM = TRM + IOE + ASYE + PTE + MPE$$

- ▶ TRM(Turing Machine)
- ▶ IOE(I/O Extension)
- ▶ ASYE(Asynchronous Extension)
- ▶ PTE(Protection Extension)
- ▶ MPE(Multi-Processor Extension) (not included in PA)



How to realize NEMU?

By now, we have known what a modern computer should look like, then how we emulate it? Or what is the constituent of NEMU?

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What tools we already have?

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What tools we already have?

- ▶ Variables, data structure
- ▶ Algorithm

Devices C variables, arrays, link list, etc.

Logic functions Algorithmic functions

Runtime support Loop

E.g. cpu

```
struct CPU_State
{
    rtlreg_t eax, ecx, edx, ebx, esp, ebp, esi, edi;
    vaddr_t eip;
    EFLAGS;
    CRs;
    .....
}
```



E.g. memory

```
uint8_t pmem[PMEM_SIZE];
```



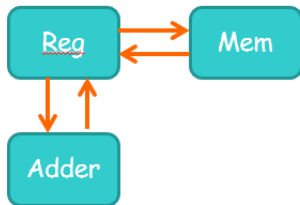
The simplest computer- Turing machine

Architecture of the simplest computer

To place programs Memory

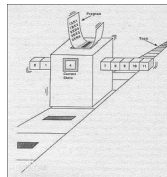
To process data Adder

To store temporary results efficiently
Reg



Working mode of the simplest computer

- ▶ Fetch instruction from Mem using PC.
- ▶ Execute instruction.
- ▶ Update PC.



TRM in NEMU

Architecture of the simplest computer

Memory **pmem array**(128MB nemu/src/memory/memory.c)

Adder(ALU) **functions**

Reg **CPU_state struct** (nemu/include/cpu/reg.h)

Working mode of the simplest computer

Function cpu_exec() (nemu/src/monitor/cpu-exec.c)

- ▶ Fetch instruction from Mem using PC.
- ▶ Execute instruction.
- ▶ Update PC.

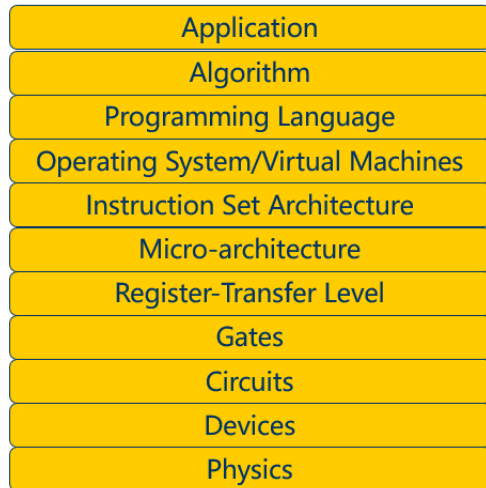
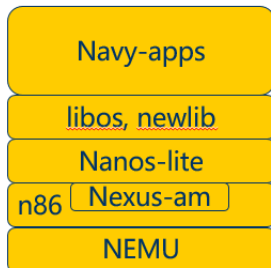
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Structure of PA

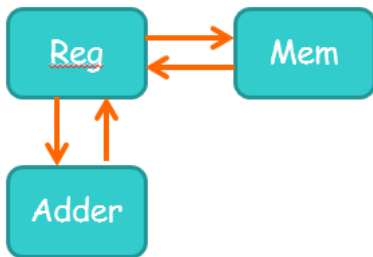
```
ics2017
|---nanos-lite    # mini operating system kernel
|---navy-apps     # apps
|---nemu          # NEMU
|---nexus-am      # abstract machine
```

Structure of PA



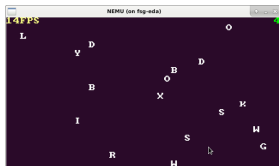
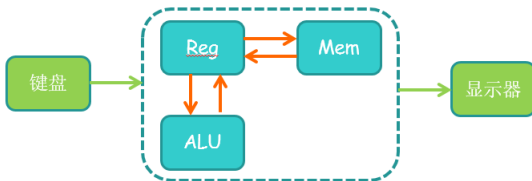
PA0 and PA1

- ▶ PA0 - Environment configuration
- ▶ PA1 - Simple monitor



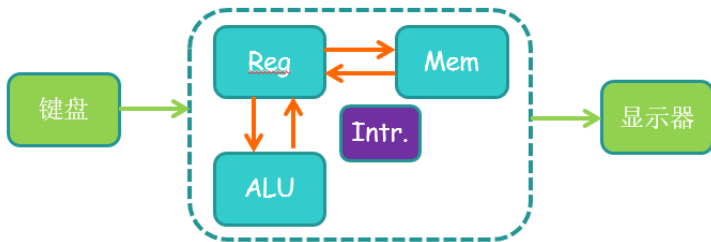
PA2-Von Neumann Computer System (TRM+IOE)

- ▶ Instructions system + I/O
- ▶ Run interesting apps on NEMU



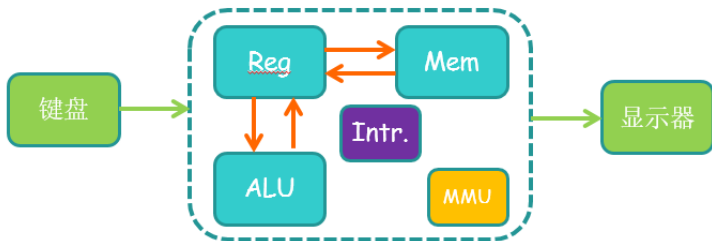
PA3- Asynchronous Extension

- ▶ Run tiny operating system Nanos-lite on NEMU.
 - ▶ ramdisk, fs, raw img loader
- ▶ Implement some library functions which packing the system call .
- ▶ App calls library functions and run PAL.



PA4- Multitask(Protection Extension)

- ▶ Virtual storage.
- ▶ Interruption.
- ▶ Run pal,typing game,clock at the same time on Nanos-lite.



PA5- Performance

- ▶ Elf32 loader
- ▶ cache
- ▶ TLB
- ▶ profiler, performance optimization
- ▶ JIT (*i.e just-in-time*) compilation

实验内容(括号中为新方案)	持续时间/周	预计耗时/小时	代码量/行
PA0 - 开发环境配置(不变)	1	10	无
PA1 - 简易调试器(不变)	3	30	400
PA2 - 指令系统 (PA2 - 冯诺依曼计算机系统)	6 (4)	60 (30)	800 (300)
课时不足可选择完成到PA2 [小计]	(8)	(70)	(700)
PA3 - 存储管理 (PA3 - 异常控制流)	4 (3)	50 (30)	500 (200)
PA4 - 中断与I/O (PA4 - 分时多任务)	3 (3)	30 (30)	300 (200)
无 (PA5 - 程序性能)[可设置为选做]	无 -	无 -	无 -
总计	17 (14)	180 (130)	2000 (1100)

The End

