Computation Structures 2014 — Yue Zhang

S7
- ☐ Turing machines & computability
- ☐ The von Neumann architecture
- ☐ A rough sketch of CPU
- ☐ Three types of beta instructions

• Turing machines & computability

- mathematical functions

  + - * / log cos factorial ...

  Map $X \mapsto Y$

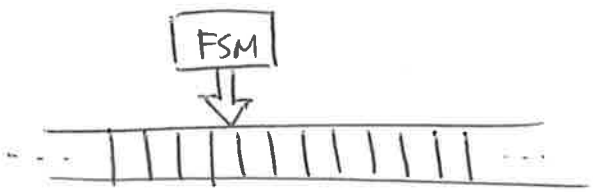
- integer functions $X, Y = \mathbb{Z}$

- can all integer functions be computed? no.

Theory

- Combinational logic
  - ^
- finite state machines (take steps)
  - ^
- Turing machines.
  - ^
- All integer functions.

- Turing machines.



infinite tape

i: data on tape

o: write; move.

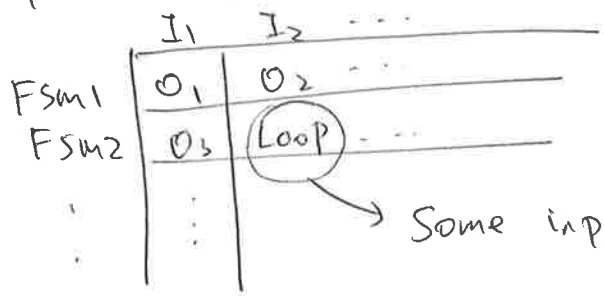
Turing machines are more powerful because of infinite tape.

- It has been shown that Turing Machines have the same computation power as recursion and lambda calculus, another two famous comptation tools 50s.

- It has been hypothesized that anything computable by a machine is computable by Turing machine.
  (Church-Turing thesis)

- It has been proved that there are integer functions that Turing machines cannot compute.

  (optional proof)



Some inputs make Turing machines loop infinitely

There are an infinite number of rows / columns

$T_k(j) \rightarrow FSM_k$ on I_j ; halt(k, j) is computable.

Can build a Turing machine $T_N(x)$ that loops if $T_x(x)$ halts
halts if $T_x(x)$ loops

T_N cannot exist, because $T_N(N)$ is dilema.

Practice —— no infinite tapes
therefore,
Turing machines with finite ~~can~~ must be FSM

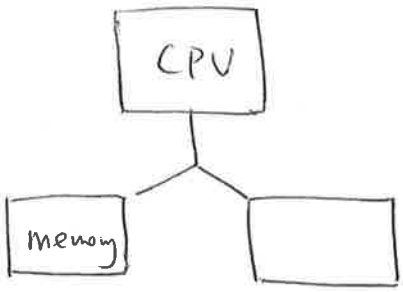
All computers are FSMs.

- So is it only useful theoretically to study Turing machines?
  not really. because of the concept being extended

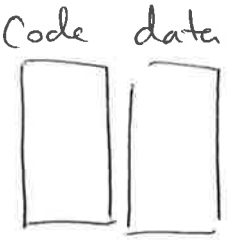
- Universal Turing machines.
  $\forall k, j \quad U(k, j) = T_k(j)$ is computable.
  Useful!
  One machine, simulates all machines.
  k — algorithm (code)
  j — data
  Prototype of computers.

- von Neumann machine

- The current computers are based on von Neumann machines.
- It models computers in a more engineering way.
- machine



- memory



- CPU repeatedly load code and execute, reading and writing data
- Devices interact with CPU via memory for data interaction, and via OS for command interaction.

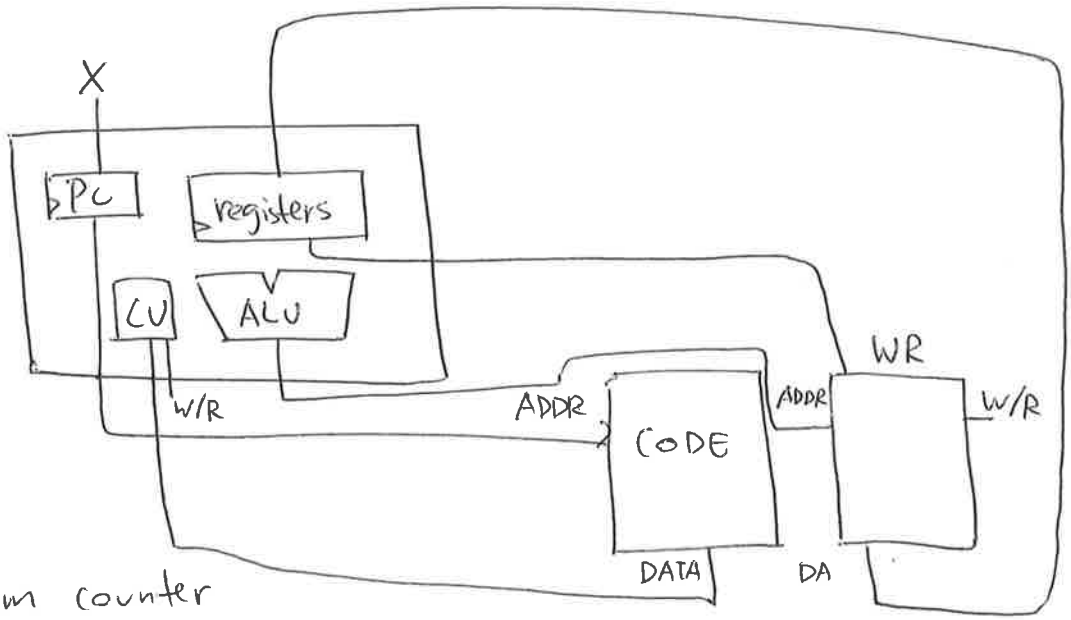
- Is that all?

  Yes

  { Showing to monitor is writty to monitor
  { Controly robots is writty to robots.
  { ready from te Internet is from URL

  all is data/IO.

- CPU



  - program counter

    points to te code section of te memory
    loading te current instruction
    automatically increment by 1

  - control unit

    interprets instructions and decides output signals

  - what instructions are?

    B a computer word just like other data
    encodes commands for te CU
    We study te MIT beta system, word = four bytes

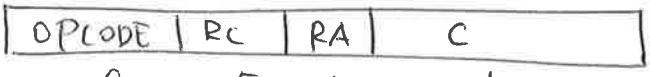
  - memory. byte ad.

- Three types of beta instructions

ALU instructions

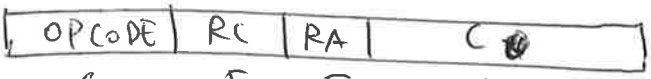
→ how many registers ?

ADD (RA, RB → RC) . SUB. MUL ...



ADDC (RA, C → RC) ...

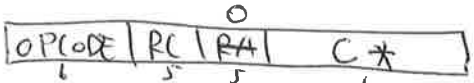
Memory loading / storing



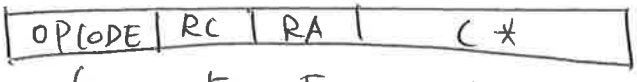
REG[RC] ↔ MEM[REG[RA] + SXT(C)]

LD. ST

PC changes



LDR REG[RC] ↔ MEM[PC+4+4SXT(C)]



PC → PC+4+4SXT(C) , if REG[RA] =/= 0

RC → PC+4

BEQ . BNE

JMP PC → PC + REG[RA]

RC → PC+4.