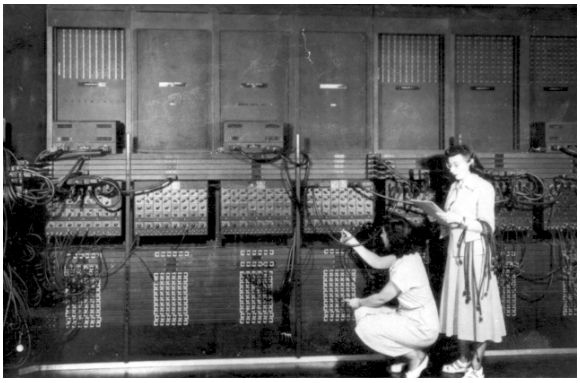
how computers work (3)

systems software - the bridge between application software and computer hardware

motivation

- imagine a computer without systems software – only applications software and hardware
- the earliest computers were this way

programming without an operating system :-)

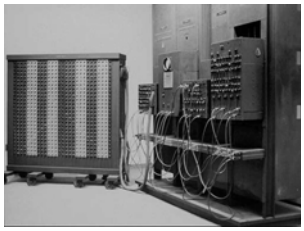


http://www.berkeleyprep.org/webhouse/bh/html/histpic.htm

ENIAC (Electronic Numerical Integrator and Computer) 1946

"The procedure for instructing the ENIAC in its routine, then, consists of setting program switches on the units so that, when stimulated by a program input pulse, the program controls will cause the units to carry out a set of specific operations."

- Adele Goldstine, 1946



http://www.seas.upenn.edu/~museum/

what is systems software?

- *application software* refers to Word, Firefox, Ultimate Paint, e-mail clients, programs you write yourself, etc.
- *systems software* provides a high-level environment in which we can run applications on the computer
- **note:** boundary between application and systems software is not always clear

what systems services can you think of?

some services of modern systems software

- organizing files (folders etc.)
- downloading software
- scheduling programs on the processor
- interfacing with the internet
- managing communication with peripherals
- providing security

…

- and lots more (GUI, windows, ...)

early operating systems

- advances following the ENIAC allowed programs to be stored in computer memory, paving the way for *batch* operating systems
- users submitted programs (one instruction per punch card) and retrieve the results later
- a stack of jobs could be scheduled on the computer, hence the name "batch"
- the computer processed one job at a time
- often all cards needed to be read before a program could be started – slow!

early operating systems

as technology advanced, several ideas improved on the batch operating systems:

- *multiprogramming* allowed one program to run while another paused, e.g., while waiting for a printer to finish
- *time-sharing* allowed several users to run programs on a machine, providing the opportunity for interactivity

the unix operating system

- developed in early 1970s at Bell Labs
- innovations include:
  - hierarchical file system
  - ability to run several programs simultaneously (*time-sharing*)
  - ability to simultaneously support several users on one computer
  - ability for user base to add and share tools that run as part of the system
- command line interface meant high learning curve initially, but provides lots of flexibility to a knowledgeable user

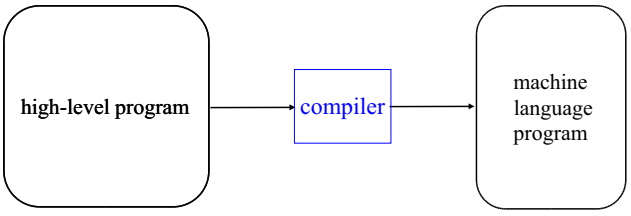
windows operating system

- inspired by early GUIs developed at Xerox PARC (Palo Alto Research Center) in early 1980s
- The Apple Macintosh operating system offered the first commercial window-based GUI
- Microsoft's earliest windows system was released in 1985, built on top of a command line operating system (MS DOS); Windows became popular in 1990 with introduction of Windows 3.0
- Modern Unix operating systems also have window-based GUIs (XWindows)

more system software: translating between programming languages

compilers translate programs written in a high-level programming language (e.g., Java) into the low-level machine language understood by a computer processor

a compiler is a program whose input and output data are programs!



implications of compilation

- high level programming language must be automatically translatable to low-level code
- this constrains the expressiveness of programming languages (since computers are not very good at language processing)
- in particular, programming languages have to be very precise

summary

- **operating system:** software that coordinates and manages resources on the computer
- **compiler:** software that translates programs written in a high level language into a low-level language

putting it all together

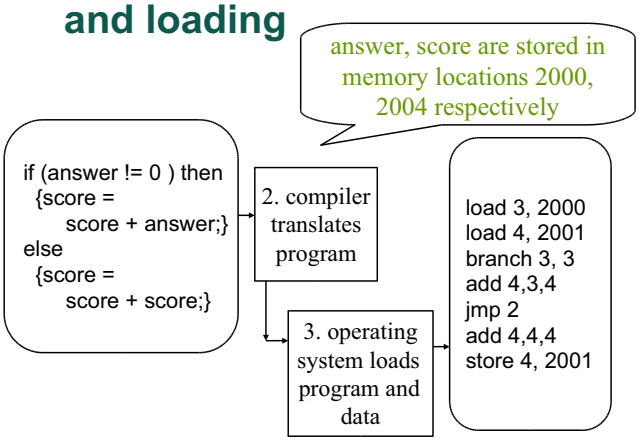
1. an application is written in a high-level programming language (e.g., Java)
2. the code is translated to machine language (e.g., by a compiler)
3. when you want to run the application, the operating system loads the code into RAM (random access memory)
4. the fetch/execute cycle is performed

let's look at an example

1. application code

```
if (answer != 0 )
   {score = score + answer;}
else
   {score = score + score;}
```

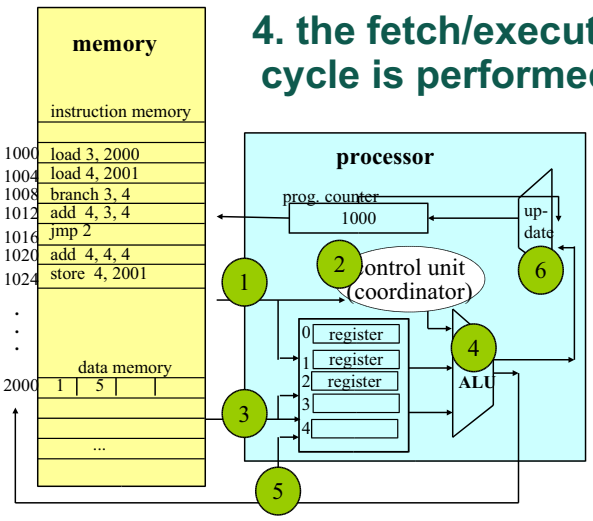
2, 3: translating and loading



(recall our low-level instructions)

- **add** 3, 4, 3
  add the contents of registers 3 and 4, and store the answer in register 3
- **load** 3, 7000
  load into register 3 the contents of memory location 7000
- **store** 2, 2040
  store into register 2 the contents of memory location 2040
- **jmp** 7
  move ahead by 7 (low level) instructions
- **branch** 2, 5
  if content of register 2 is 0, then move ahead by 5 instructions, otherwise continue to the next instruction

4. the fetch/execute cycle is performed



recall the fetch/execute cycle:

1. fetch instruction specified by program counter
2. decode instruction
3. fetch data from memory and store in registers
4. perform operation and send result to data memory, a register, or program counter
5. update data memory
6. update program counter

resources

- overview of operating systems: http://en.wikipedia.org/wiki/Operating_system
- the original operations manual for the ENIAC, by Adele Goldstine: http://ftp.arl.mil/~mike/comphist/46eniac-report/