Computers & Computer Science

• Computer:
  ‣ is an electronic device for storing and processing data, according to instructions given to it in the form of a program

• Computer Science:
  ‣ is concerned with the representation, storage, manipulation and presentation of information including communication between man and computer
• How to best design the computer and its programs forms the field of computer science
  ‣ Computer scientists

• How to best express tasks or applications in a form or language understandable to computers falls under computer programming
  ‣ Computer programmers
Computing Devices Now
Computing Devices Then…
Computing: The art of abstraction

- Application
- Algorithm
- Programming Language
- Operating System/Virtual Machine
- Instruction Set Architecture (ISA)
- Microarchitecture
- Register-Transfer Level (RTL)
- Circuits
- Devices
- Physics
• New technologies not only provide greater speed, size and reliability at lower cost, but more importantly these dictate the kinds of structures that can be considered and thus come to shape our whole view of what a computer is.

Bell & Newell
Technology is the dominant factor in computer design.

- Transistors
- Integrated circuits
- VLSI (initially)

- Core memories
- Magnetic tapes
- Disks

- ROMs, RAMs
- VLSI
- Packaging
- Low Power

Computers

Computer Architecture and Embedded Systems Laboratory (CAES Lab)
• As people write programs and use computers, our understanding of *programming* and *program behavior* improves.

  ‣ *This has profound though slower impact on computer architecture*

• Modern architects cannot avoid paying attention to software and compilation issues.
A Journey Through Space

• What is Computer architecture and what do computer architects actually do?

• Illustrate via historical examples
  ‣ Prehistory: Babbage and Analytic Engine
  ‣ Early days: Eniac, Edvac and Edsac
  ‣ Arrival of IBM 650 and then IBM 360
  ‣ Seymour Cray – CDC 6600, Cray 1
  ‣ Microprocessors, Multicores, SoCs

• Focus on ideas and mechanisms that have withstood the test of time
Who invented the Computer?

• Lot of people and it is still being invented

Punch Cards
Jacquard Card
1801
Who invented the Computer?

• Lot of people and it is still being invented

Charles Babbage

The forerunner of modern digital computer: Difference Engine - 1823
Charles Babbage 1791-1871

• *Difference Engine* 1823
• *Analytic Engine* 1833
  ‣ The forerunner of modern digital computer!

• Application
  ‣ Mathematical Tables – Astronomy
  ‣ Nautical Tables – Navy

• Background
  ‣ Any continuous function can be approximated by a polynomial
  ‣ Any Polynomial can be computed from difference tables
The first programmer

• Ada Byron *aka* “Lady Lovelace” 1815-52

• Ada’s tutor was Babbage himself!
Harvard Mark I

• Built in 1944 in IBM Endicott laboratories
  ‣ Howard Aiken – Professor of Physics at Harvard
  ‣ Essentially mechanical but had some electromagnetically controlled relays and gears
    ‣ Weighed 5 tons and had 750,000 components
    ‣ A synchronizing clock that beat every 0.015 seconds

• Performance:
  ‣ 0.3 seconds for addition
  ‣ 6 seconds for multiplication
  ‣ 1 minute for a sine calculation

Broke down once a week!
Linear Equation Solver

• 1930’s:
  ‣ Atanasoff built the Linear Equation Solver.
  ‣ It had 300 tubes!

• Application:
  ‣ Linear and Integral differential equations

• Background:
  ‣ Vannevar Bush’s Differential Analyzer - an analog computer

• Technology:
  ‣ Tubes and Electromechanical relays
Electronic Numerical Integrator

- Designed and built by Eckert and Mauchly at the University of Pennsylvania during 1943-45
- The first, completely electronic, operational, general-purpose analytical calculator!
  - 30 tons, 72 square meters, 200KW
- Performance
  - Read in 120 cards per minute
  - Addition took 200 ms, Division 6 ms
  - 1000 times faster than Mark I
- Not very reliable!
Automatic Computer

• Electronic Discrete Variable Automatic Computer

• ENIAC’s programming system was external
  ‣ Sequences of instructions were executed independently of the results of the calculation
  ‣ Human intervention required to take instructions “out of order”

• EDVAC was designed by Eckert, Mauchly and von Neumann in 1944 to solve this problem
  ‣ Solution was the stored program computer
  ‣ “program can be manipulated as data”
• First Draft of a report on EDVAC was published in 1945, but just had von Neumann’s signature!

• Without a doubt the most influential paper in computer architecture
Program = A sequence of instructions

- How to control instruction sequencing?
  - Manual control
    - Calculators
  - Automatic control external (paper tape)
    - Harvard Mark I, 1944
    - Zuse’s Z1, WW2
  - Internal
    - plug board ENIAC 1946
Program = A sequence of instructions

• How to control instruction sequencing?
  ‣ Internal
    • read-only memory    ENIAC    1948
    • read-write memory   EDVAC    1947 (concept )
    • EDSAC    1950          Maurice Wilkes
      ‣ considered the first complete and fully operational regular electronic digital stored-program computer
The Spread of Ideas

• ENIAC & EDVAC had immediate impact
  ‣ brilliant engineering: Eckert & Mauchley
  ‣ lucid paper: Burks, Goldstein & von Neumann
    • IAS Princeton 46-52 Bigelow
    • EDSAC Cambridge 46-50 Wilkes
    • MANIAC Los Alamos 49-52 Metropolis
    • JOHNIAC Rand 50-53
    • ILLIAC Illinois 49-52
    • Argonne 49-53

• UNIVAC - the first commercial computer, 1951
Software Developments

• Up to 1955 Libraries of numerical routines
  ‣ Floating point operations
  ‣ Transcendental functions
  ‣ Matrix manipulation, equation solvers, . . .

• 1955-60 High level Languages
  ‣ Fortran 1956
  ‣ Operating Systems
  ‣ Assemblers, Loaders, Linkers, Compilers
  ‣ Accounting programs to keep track of usage and charges
First Program Bug

• The first computer bug is a moth!
• Grace Murray Hopper found the bug while working on the Harvard Mark II computer
Architecture Features

- HD Boost.
  - significant gains on the latest SSE4 instruction set

- Hyper-Threading Technology.
  - each core processes two application “threads” simultaneously

- Turbo Boost Technology.
  - increases the processor’s frequency when needed

- True quad-core
  - enables cores to communicate at die level
Architecture Features

• Wide Dynamic Execution
  ‣ enables the delivery of more instructions per clock cycle

• Intelligent Power Capability
  ‣ turning off portions of the processor when they aren't being used

• Smart Memory Access
  ‣ increasing available data bandwidth

• 8 MB Shared Smart Cache.
  ‣ enabling multiple cores to dynamically share this space
Kid, why all this excitement!!!

- But Albert, just look, look for yourself, how far we have come in just few decades!!!
- Is not this marvelous!!!
Transistor

- Uses Silicon
- Developed in 1947 in Bell Laboratories by William Shockley, John Bardeen and Walter Brattain Won a Nobel prize
- On-off switch
First Integrated Circuit

- Invented at Texas Instruments by Jack Kilby in 1958
First Microprocessor

• By Intel Corporation
• 4-bit Microprocessor 4004 in 1971
• 8-bit microprocessor 8008 in 1972
IBM PC - 1981

- IBM-Intel-Microsoft joint venture
  - First wide-selling personal computer used in business
  - 8088 Microchip - 29,000 transistors
  - 4.77 Mhz processing speed
  - 256 K RAM (Random Access Memory) standard
The Amiga 1000 1985
Windows 3 1989
PowerPC 1991
Windows 95
Next class

• Information representation: Bit, Byte, ...