A Little History of Computers

Lecturer: Alexandru Iosup

A History of Performance

• Improving speed of operation by mechanical means
  
  \[ \text{walking} = 5 \times \text{bicycle} \quad = 200 \times \text{plane} \]
  (1 order of magnitude)

• Multiplication of two \textbf{10} figure numbers, e.g.,
  \[ 5,678,912,343 \times 9,876,543,217 \]
  - by hand: \textbf{10} minutes
  - by computer: \textbf{100} nanosec (10 o.m.)

• \textit{Predicting weather? (accurately)}
Exercise: The Super-Computer Game

• Team work, first 5 minutes
  1. Form team of 2-3 persons
  2. Think about own experience
  3. Convince your team before proposing an answer
  4. Formulate an answer (!)

• Open discussion, next 5 minutes
  - Tell everyone the answer
  - I will nominate the team member who explains

Q: How fast is the fastest computer and why?

Vote on best answer (+50p each in team)
Top500 in November 2014

- Traditional HPC

**Q:** How much is 33,862.7 Tera-FLOPS, in Peta-FLOPS?

<table>
<thead>
<tr>
<th>Rank</th>
<th>Site</th>
<th>System</th>
<th>Cores</th>
<th>Rmax (TFlop/s)</th>
<th>Rpeak (TFlop/s)</th>
<th>Power (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>National University of Defense Technology, China</td>
<td>Tianhe-2 (MilkyWay-2) - TH-IVB-FEP Cluster, Intel Xeon E5-2692 12C 2.200GHz, TH Express-2, Intel Xeon Phi 31S1P</td>
<td>3120000</td>
<td>33862.7</td>
<td>54902.4</td>
<td>17808</td>
</tr>
<tr>
<td>2</td>
<td>DOE/SC/Oak Ridge National Laboratory, United States</td>
<td>Titan - Cray XK7, Opteron 6274 16C 2.200GHz, Cray Gemini interconnect, NVIDIA K20x</td>
<td>560640</td>
<td>17590.0</td>
<td>27112.5</td>
<td>8209</td>
</tr>
<tr>
<td>3</td>
<td>DOE/NNSA/LLNL, United States</td>
<td>Sequoia - BlueGene/Q, Power BQC 16C 1.60 GHz, Custom IBM</td>
<td>1572864</td>
<td>17173.2</td>
<td>20132.7</td>
<td>7890</td>
</tr>
<tr>
<td>4</td>
<td>RIKEN Advanced Institute for Computational Science (AICS), Japan</td>
<td>K computer, SPARC64 Vlllfx 2.0GHz, Tofu interconnect</td>
<td>705024</td>
<td>10510.0</td>
<td>11280.4</td>
<td>12660</td>
</tr>
<tr>
<td>5</td>
<td>DOE/SC/Argonne National Laboratory, United States</td>
<td>Mira - BlueGene/Q, Power BQC 16C 1.60GHz, Custom IBM</td>
<td>786432</td>
<td>8586.6</td>
<td>10066.3</td>
<td>3945</td>
</tr>
</tbody>
</table>
It Depends! Graph500 ≠ Top500!

- **Graph processing**

<table>
<thead>
<tr>
<th>Rank</th>
<th>Machine</th>
<th>Installation Site</th>
<th>Number of nodes</th>
<th>Number of cores</th>
<th>Problem scale</th>
<th>GTEPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>K computer (Fujitsu - Custom supercomputer)</td>
<td>RIKEN, Japan</td>
<td>65536</td>
<td>524288</td>
<td>40</td>
<td>17,977</td>
</tr>
<tr>
<td>2</td>
<td>DOE/NNSA/LLNL Sequoia (IBM - BlueGene/Q, Power BQC 16C 1.60 GHz)</td>
<td>LLNL, USA</td>
<td>65536</td>
<td>1048576</td>
<td>40</td>
<td>16,599</td>
</tr>
<tr>
<td>3</td>
<td>DOE/SC/Argonne National Laboratory Mira (IBM - BlueGene/Q, Power BQC 16C 1.60 GHz)</td>
<td>ANL, USA</td>
<td>49152</td>
<td>786432</td>
<td>40</td>
<td>14,328</td>
</tr>
<tr>
<td>4</td>
<td>JUQUEEN (IBM - BlueGene/Q, Power BQC 16C 1.60 GHz)</td>
<td>FZJ, Germany</td>
<td>16384</td>
<td>262144</td>
<td>38</td>
<td>5,848</td>
</tr>
<tr>
<td>5</td>
<td>Fermi (IBM - BlueGene/Q, Power BQC 16C 1.60 GHz)</td>
<td>CINECA</td>
<td>8192</td>
<td>131072</td>
<td>37</td>
<td>2,567</td>
</tr>
<tr>
<td>6</td>
<td>Tianhe-2 (MilkyWay-2) (National University of Defense Technology - MPP)</td>
<td>Changsha, China</td>
<td>8192</td>
<td>196608</td>
<td>36</td>
<td>2,061</td>
</tr>
<tr>
<td>7</td>
<td>Zanussi (IBM - BlueGene/Q, Power BQC 16C 1.60 GHz)</td>
<td>CNRS/IDRIS-ENCI</td>
<td>4096</td>
<td>65536</td>
<td>36</td>
<td>1,427</td>
</tr>
<tr>
<td>8</td>
<td>DIRAC (IBM - BlueGene/Q, Power BQC 16C 1.60 GHz)</td>
<td>UK-Scaresbury</td>
<td>4096</td>
<td>65536</td>
<td>36</td>
<td>1,427</td>
</tr>
<tr>
<td>9</td>
<td>Zumbrota (IBM - BlueGene/Q, Power BQC 16C 1.60 GHz)</td>
<td>EDF R&amp;D</td>
<td>4096</td>
<td>65536</td>
<td>36</td>
<td>1,427</td>
</tr>
</tbody>
</table>

Number 1 in Top500
Exercise: The Super-Computer Game

• Team work, first 5 minutes
  1. Form team of 2-3 persons
  2. Think about own experience
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  4. Formulate an answer (!)

• Open discussion, next 5 minutes
  - Tell everyone the answer
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Q: How fast is the fastest computer and why?
Always start with “It depends!”
A History of Computer Invention

• Computer is not a single invention
• Ideas from mathematics, physics, mechanical, and electrical engineering

Q: How different are the 1940s Zuse Z3 and a modern supercomputer?
Outline

A History of Computer Architectures

1. Pre-History (to 1930s)
   • Many approaches, first programmable devices

2. 1st Generation: Electro-Mechanical (1930s-1950s)

3. 2nd Generation: Transistors (1955—1975)

4. 3rd Generation: Microprocessors (1960s—today)

5. 4th Generation: Multi-Computing (1969—today)
Calculators

- Machines of Pascal and Leibnitz were mechanical calculators
  - No memory or program
  - Leibniz used binary system (1705)
  - A single operation at a time
  - Only simple operations (+,-,x,/)
Programmable devices

• Devices that could execute a program existed in different areas:

  • Mechanical Music Instruments
    - Bagdad, 9th Century
    - Carillons
  • Chess / Mechanical Turk (1770)?
  • Punch Cards for weaving machines
    - Jaquard (end 18th Century)
The Jaquard Loom (actually, Head, 1801)
Difference Engine

- Invented by Johann Helfrich von Müller (1786)
- Extended by Charles Babbage (1822)
Charles Babbage

- Designed “Analytical Engine” (1837)
  - Inspired by Jaquard mechanism, von Muller
  - Never completed

- Conceptually
  - Arithmetic unit + Memory + I/O devices + IFs
  - First machine with stored program concept
    (calculations + order sequences)
Ada, Countess of Lovelace

- First computer program (mer), 1840s
- Note G = first computer algorithm (assembly)
Mathematical Influence

• George Boole (1854) showed that logic could be reduced to a simple algebraic system

• Work remained a curiosity until rediscovered by Whitehead and Russell in Principia Mathematica (1910-3)

• Then, formal logic developed resulting in Gödel and the work of Alan Turing
Analog Computers

- Analog computers predated digital computers
  - Slide rule
  - Mechanical integrators (Vannevar Bush, 1931)
- First systems that enabled significant reduction of calculation times
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Spying—A Killer App for Computers Since the 1940s

- COLOSSUS, in the UK (1944)
  - App specific, fully electronic, storage, binary system
  - 5,000 characters processed per second, Lorenz cypher
  - Used during the D-Day, instrumental for VE-Day

- All records destroyed 1970s (natsec), so no IP claims possible
Electro-Mechanical Devices

ASCC

- **1937-1944**, Howard Aiken builds the Automatic Sequence Controlled Calculator (ASCC)
  - First general-purpose digital computer
  - 750,000 components, 5 tons

- **Goal**: 100 times faster than by hand
- **Reality**: 3-5 times faster due to component failures

“Only six electronic digital computers would be required to satisfy the computing needs of the entire United States.”
Electro-Mechanical Devices

ENIAC

  - First all-electronic computer (*)
  - 18,000 tubes (5-10cm each), 150 kilowatt dissipation, 30 tons
  - Large office space
  - 1,000 bits of memory
  - From 20 hours to 20 seconds

- (*) The first computer IP lawsuit: vs John Atanasoff
Electro-Mechanical Devices

Problems with ENIAC

• Each time switched on: 10 tubes failed
• Difficult to program
• Not very flexible
• Technologically too complex
• Memory too small
• Bugs
Electro-Mechanical Devices

EDVAC

- Problems analyzed by Mauchly + Eckert
- Proposed new design: Electronic Discrete Variable Automatic Computer (EDVAC)
- Basis of so-called *Von Neumann Architecture*
von Neumann or Harvard Architecture?

- Von Neumann Architecture
  - Single Instruction and Data memory
  - Single memory-CPU pathway = simple + bottleneck

**Q:** Which is used **today** and **why**?

- Harvard Architecture
  - Separate Instruction and Data memories (word size)
  - Separate memory-CPU pathways = complex + perf.
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Transistors (1955—1975) and Microprocessors (1960s—today)

- Transistors
  - Reliable
  - Less power
  - Smaller
- U. Manchester (1953)/Bell Labs (1948)
- DEC PDP-1 (1959)
  - Hacker culture, first game (Spacewar), text-ed, dbg
- First supercomputer: Cray’s CDC 6600, 10MFLOPS

- Integrated Circuits
  - Enabled small, low-cost microprocessors
- MOS Tech (ATARI)
- Apple & Apple ][
- Current technology
  - 1971 Intel 4004 @108KHz: 1st uproc.
Devices in the Transistor and Microprocessor eras

- The first monitor (1951) —US Army’s display system, part of WHIRLWIND
- The first mouse (1968) —Doug Engelbart’s "X-Y Position Indicator for a Display System"
The IBM Personal Computer

- Released in the 1980s
  - The blueprint for today’s PCs
  - Changed the market
- Open standards and friendliness to third-party hardware and software developers

Q: How much is third-party hardware allowed today? (e.g., by Apple)

Q: How much is third-party software allowed today? (e.g., in App Stores of Apple, Google, Microsoft)
Research

Moore and Rock’s Laws

Also read: http://spectrum.ieee.org/semiconductors/materials/5-commandments/

- **Moore’s Law (number of transistors/chip):**
  density of silicon chip $2^x$ every 1.5 (2) years

- **Rock’s Law (cost to produce chips):**
  cost of equipment to produce chips $2^x$ every 4 years
  ($12k$ in 1968, $14M$ in 2012
  193-nm wavelength stepper)

Source: http://www.accelerating.org/acc2003/moores_law.htm

Is Moore’s Law Eternal?

Microprocessor Transistor Counts 1971-2011 & Moore’s Law

- Single-core processors
- Multi-core processors

curve shows transistor count doubling every two years

Date of introduction

Transistor count

Koomey’s Law (Computation/Energy)
Electrical efficiency $2x$ every 1.5 years

Exercise: The Exascale Computer Game

• Team work, first 5 minutes
  1. Form team of 2-3 persons
  2. Think about own experience
  3. Convince your team before proposing an answer
  4. Formulate an answer (!)

• Open discussion, next 5 minutes
  - Tell everyone the answer
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Q: Can we reach Exascale by 2020? Hint: predict speed (now 33 PFLOPS), cost (100 M$).

Vote on best answer (+50p each in team)
Outline

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The Internet: Early History

- 1965-1969 ARPANET
  - Leonard Kleinrock develops the Queueing Theory (theoretical properties of the Internet)
  - 4 computers at
    UC Santa Barbara
    UC Los Angeles
    Stanford Research Inst.
    U of Utah

- 1972 ARPANET public + Email
- 1974 TCP/IP at Stanford
- 1982 ARPANET + TCP/IP = the (early) Internet
The Internet Today

Source: http://www.opte.org/maps/
Internet-Based Applications

• Metcalfe’s Law: usefulness of a network \( \sim n^2 \)
Peer-to-Peer File-Sharing

Tribler.org, developed at TU Delft
Flashcrowds

Research

**ABIENE: Backbone Research Network**

- Test: Land Speed Record
- ~ 7 Gb/s in single TCP stream from Geneva to Caltech

Source: MonALISA monitoring framework, 2005
Research

Grid Computing

Just plug in the computing grid and get your results

• The Grid = integration of computers as day-to-day computing utility, similar to phone, water, and electricity
  - Economy of scale: better service at lower cost
  - Large-scale reality: operational overhead, functionality (robustness + manageability), real heterogeneity

• Primary users
  - E-Science: high-energy physics, earth sciences, bioinformatics
  - Big Companies: financial services, search engines (Google)
  - Governments: planning, taxes, etc.
Research

Grids: Vision vs. Reality

• Many grids deployed, but not The Grid
• Cloud computing?
A Computer In Your Pocket (or Hand)

- Not tech, apps + mobility
- Internet everywhere (?)
- PC killers (?)

- iPhone and relatives (2007—)
  - Initially music device++

- iPad and relatives (2010—)
  - Small format (7-11”)
  - High resolution (now ~240ppi)

Take-Home Message

• Digital Computers are not a single invention
• The von Neumann and/or Harvard architectures?
• Are Moore’s and Rock’s Laws still valid?
• Single and/or distributed computers?
• PC and/or Mobile computing?
The Pre-History: Pascal and Leibniz

• Development of calculation machines started in 17-th century:
  - Pascal: two-operation (+, -) machine in 1642
  - Leibnitz: four-operation machine (+, -, x,/) in 1671

• Conceptually, led to electronic calculators in 1975
Herman Hollerith

- Punch Cards for processing census data of the 1890 census in US
- Great success
- Founded Tabulating Machine Company (1889). Later became IBM.