



中国科学院大学
University of Chinese Academy of Sciences

CS101

Overview

The field of CS and IT

zxu@ict.ac.cn
zhangjialin@ict.ac.cn

Outline

- CS supports information society
 - Four **facts** of IT, ICT, digital economy, IT professionals
 - Four hypotheses on why CS permeates
- CS shows three **wonders**
 - Of exponentiation, of simulation, of cyberspace
- CS has three **persuasions** (basic problems)
 - Babbage's problem
 - Bush's problem
 - Turing's problem

These slides acknowledge sources for additional data not cited in the textbook

1. CS supports information society

- History has seen three main forms (eras) of human civilizations
 - Agrarian society, Industrial society
 - **Information society**
- Four facts of the CS and IT profession
 - Fact 3: CS supports information society
- Four hypotheses on why CS permeates

- CS is the academic discipline
- IT is the professional field
- Often they are used as synonyms

1.1 Four facts of the CS & IT profession

- **Fact 1: CS directly supports the IT industry**
 - The *information technology (IT)* industry provides computer and network hardware & software products and services. Worldwide IT spending passed US\$2 trillion in 2013.
 - The *information and communication technology (ICT)* industry adds telecommunication sector to IT. Worldwide ICT spending in 2019 was about US\$3.7~5 trillion.
- People sometimes use IT to mean ICT
 - Partly because IT and CT are merging
 - Example: “Gartner Says Worldwide IT Spending to Grow 4% in 2021”

Spending in US\$ billion	2019 Spending	2020 Spending	2021 Spending
Data Center Systems	215	208	219
Enterprise Software	477	459	492
Devices	712	616	641
IT Services	1,040	992	1,033
Communications Services	1,373	1,333	1,370
Overall IT	3,816	3,609	3,755

Data source:

<https://www.gartner.com/en/newsroom/press-releases/2020-10-20-gartner-says-worldwide-it-spending-to-grow-4-percent-in-2021>

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- Fact 2: CS supports **digital economy**
 - which is ICT plus its impact on other economic output
 - Foundational digital economy (ICT, 基础型信息经济),
 - Productivity-enhancing digital economy (效率型信息经济),
 - Convergence digital economy (融合型信息经济),
 - Emergence digital economy (新生型信息经济), and
 - Welfare digital economy (福利型信息经济).
 - By traditional definition, Facebook is not IT but advertisement company
 - Worldwide digital economy was estimated at US\$11.5 trillion in 2017

1.1 Four facts of the CS & IT profession

- **Fact 3:** CS supports the **information society**
- Human civilizations are entering the third era of development
 - Agrarian age, Industrial age, **Information age**
 - By January 2021, the worldwide Internet penetration rate has passed 53%, and an average Internet user spent 6 hours 54 minutes daily to use the Internet
- Information society is not just economic, but a mega trend
 - A new era of human civilizations

Year	Worldwide Internet Users/Population
1996	1%
2001	8%
2006	18%
2011	31%
2016	44%
2021	53%

Country	Daily Time Spent Using Internet 2021
Brazil	10:08 (10 hours 08 minutes)
Indonesia	08:25
Russia	07:52
USA	07:11
Worldwide	06:54
Germany	05:26
China	05:22
Japan	04:25

Data sources: International Telecommunications Union, Datareportal

1.1 Four facts of the CS & IT profession

- **Fact 4:** There are not enough CS or IT **professionals**
 - Definition and observation by David Grier (IEEE Computer Society)
 - IT professionals are people who (1) have earned a bachelor degree and (2) work in **research, education, development, management and services of computing** knowledge, products and services
 - There are only about 3~10 million IT professionals worldwide
 - Roughly one IT professional serving 1000 people worldwide
 - One minute quiz: the CS department at Harvard University did a survey of the work titles of their graduates. The top two titles start with a P. They are:
 - (a) President
 - (b) Production-line worker
 - (c) Professor
 - (d) Programmer

Professional Communities

- International Societies
 - **ACM**
 - Association for Computing Machinery
 - about 100,000 members
 - Flagship magazine: *Communications of ACM*
 - IEEE CS
 - **IEEE Computer Society**
 - about 70,000 members
 - Flagship magazine: *Computer*
- **CCF 中国计算机学会**
 - China Computer Federation
 - about 70,000 members
 - Flagship magazine: *Communications of CCF*



1.2 Four hypotheses on why CS permeates

- Why Computer Science Permeates Our Civilizations
 - **Chomsky's digital infinity principle**: A finite set of digital symbols can be combined to produce infinite expressions in many domain languages.
 - **Karp's computational lens thesis**: Many processes in Nature and human Society are also computational processes. Nature computes. Society computes. We can understand Nature and Society better through the computational lens.
 - **Babayan's gold metaphor**: Computing speed is like gold, a hard currency that can be exchanged for anything.
 - **Boutang's bees metaphor**: ICT is like bees, producing two types of outputs. The indirect output (pollination) of bees has economic value that is orders of magnitude larger than the value of the direct output (honey). Similarly, the value of digital economy (indirect output) is much larger than that of the ICT market (direct output).

2. CS shows three wonders

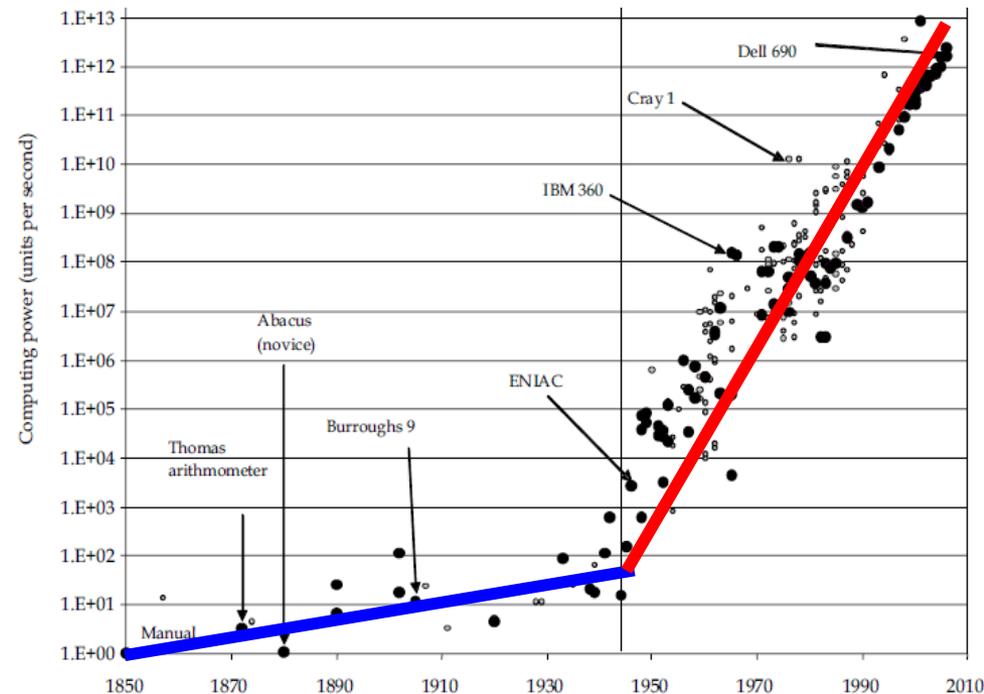
- Wonder of exponentiation
- Wonder of simulation
- Wonder of cyberspace

2.1 Wonder of exponentiation

- For many problems
 - the **number of operations grows exponentially**, 2^n
 - E.g., using a brute-force method, the number of operations in protein folding $\approx 3^{300} \approx 10^{143}$, where the problem size $n = 300$
 - Challenge: reduce it to 1.2^n , or even n^k , where k is a small constant
 - Sources of much interesting research

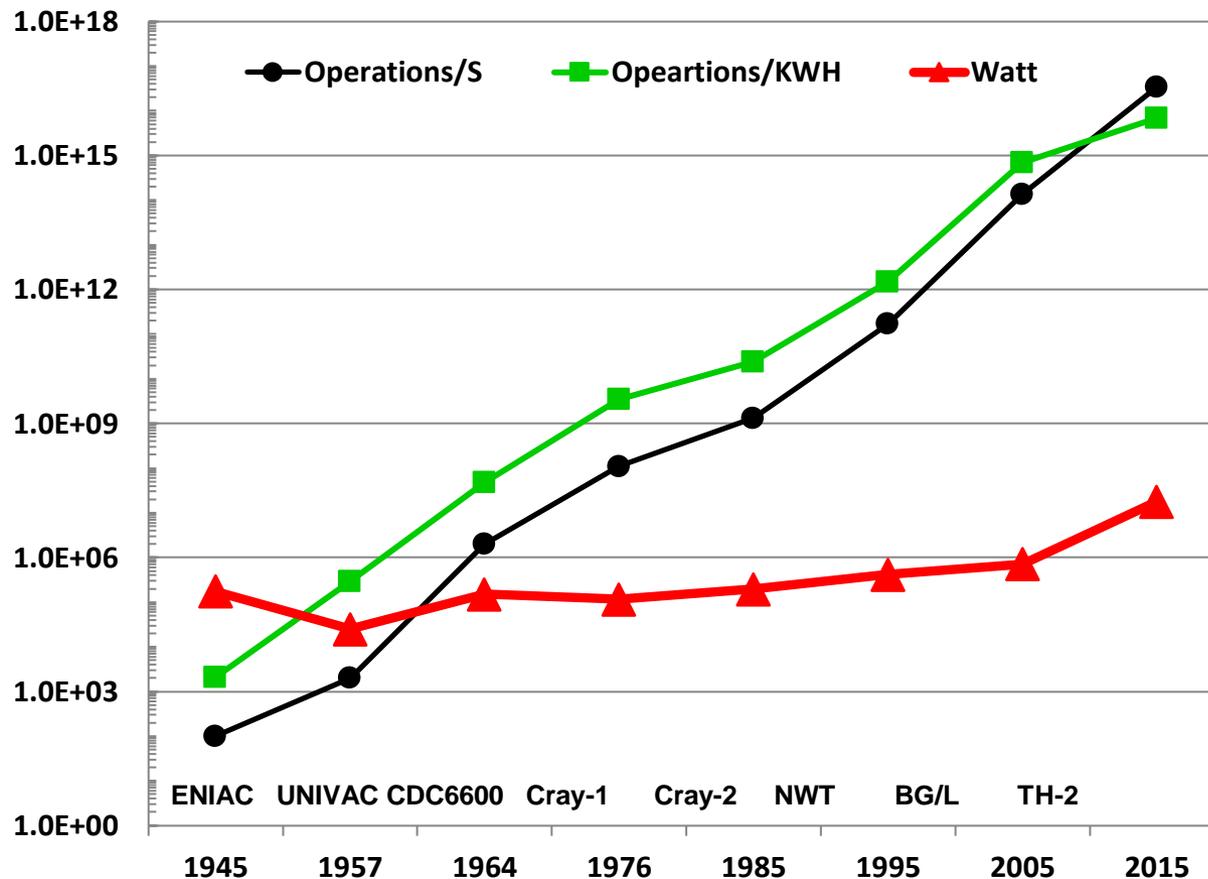
- **Computing speed grows exponentially**

- Nordhaus's law:
During 1945-2006, the speed of a computer increased 50% annually
- Growth before was much smaller
- Why?



More recent trends on speed growth

- Energy efficiency becomes a big challenge
 - 将能效曲线扳回上方！可能吗？

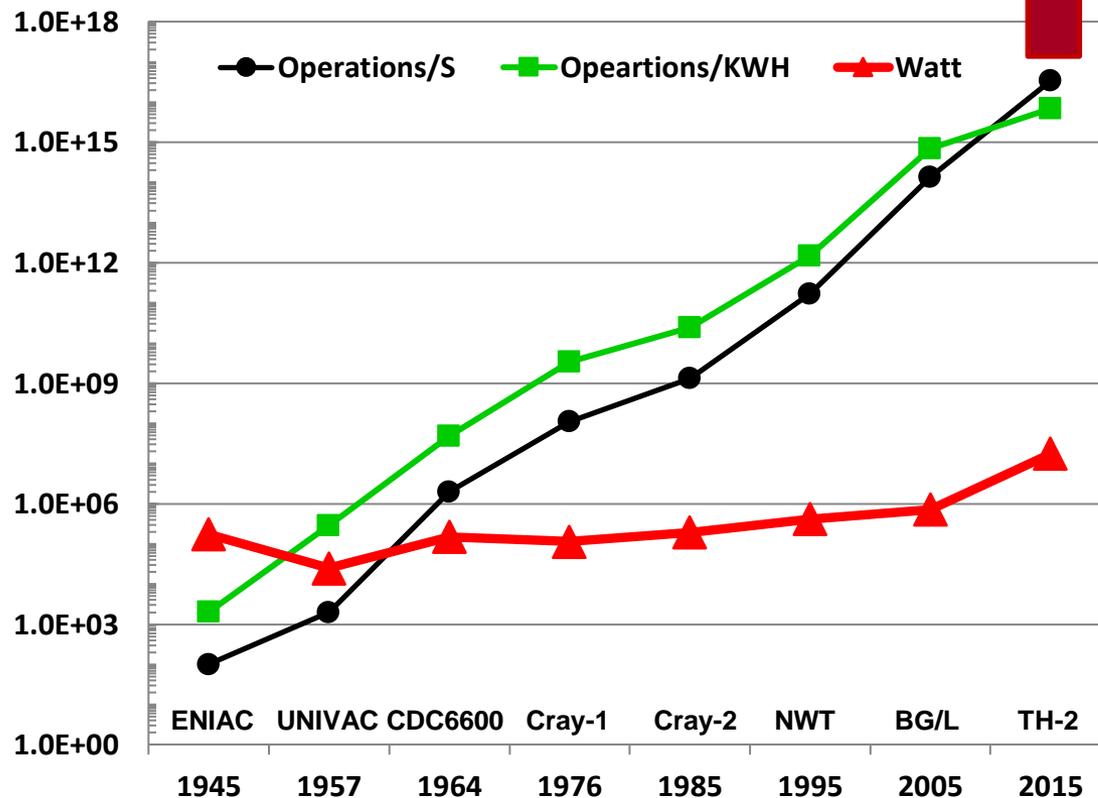


Growth trends of computing speed, energy efficiency, and power consumption of the world's fastest computers (supercomputers) from 1945 to 2015. Special thanks to Drs. Gordon Bell, Jonathan Koomey, Dag Spicer and Ed Thelen for providing data for the first three computers.

More recent trends on speed growth

- Energy efficiency becomes a big challenge

Moving up the energy efficiency curve



Chen, Y., Chen, T., Xu, Z., Sun, N., & Temam, O. (2016). DianNao family: energy-efficient hardware accelerators for machine learning. *Communications of the ACM*, 59(11), 105-112.

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2.1 Wonder of exponentiation

- Not just computing speed
- William Nordhaus (2007)
 - Nordhaus's law: **computer speed** grew exponentially with time, increasing 50% per year from 1945 to 2006.
- Gordon Moore (1975)
 - Moore's law: the **number of transistors in a semiconductor chip** grows exponentially with time, doubling every two years or so.
- Donald Keck (2015)
 - Keck's law: the **data transmission rate of a single optical fiber** grows exponentially with time, increasing about 100 times in 10 years.

2.2 Wonder of simulation

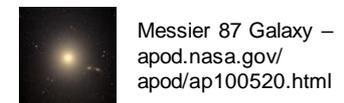
- **Simulation** is to mimic physical or social processes
 - by executing computer programs (computational processes)
 - Aka computer simulation, computer experiment, numerical experiment
- The first computer simulation was conducted in 1953
 - By physicists Enrico Fermi, John Pasta, and Stanislaw Ulam
 - to solve a physics problem later known as “the Fermi-Pasta-Ulam paradox”.
- Computer simulation provides a third paradigm for scientific enquiry besides theory and observation/experiment
 - “a third way of doing science...helped scientists to **see the invisible and imagine the in-conceivable**”, as commented by Steven Strogatz
- Example: Atoms in the Surf

2.3 Wonder of cyberspace

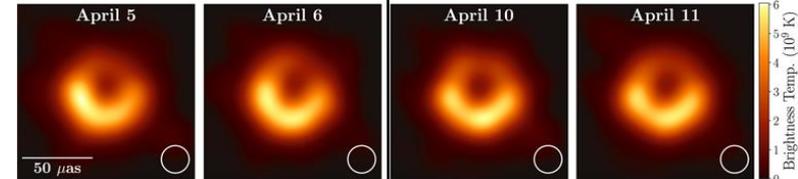
- There are three worlds (spaces)
 - Human society
 - Physical world (Nature and human-built things)
 - Cyberspace
- The cyberspace is created by humans
 - Human is the designer, and in control (usually)
 - Enable virtual things or virtual worlds that may not be possible in the physical world
 - A shopping mall hosting a million vendors
 - A bookstore holding a billion books
 - A thousand-floor library
 - Computer games which follow their own laws
 - Counterfactuals

Human-Cyber-Physical ternary computing system

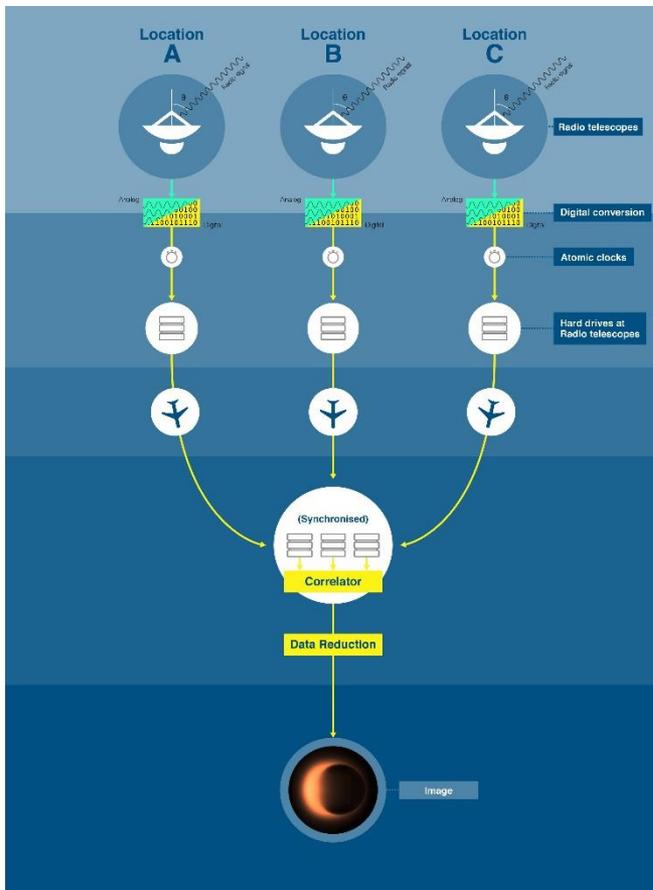
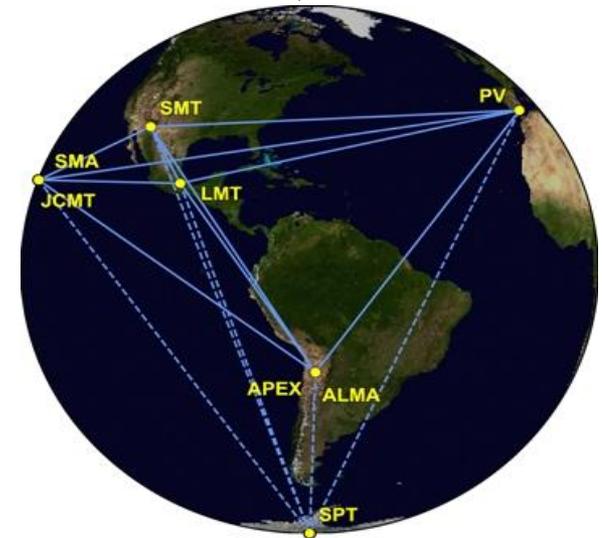
- First photographs of a blackhole by Earth-diameter virtual telescope EHT



55 Mly



2017



Data captured April 5-11 2017

Hard disks shipped to supercomputers

Data correlation and reduction took two years

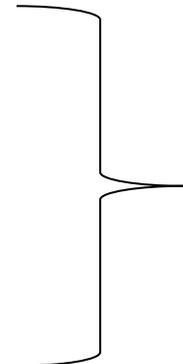
Images published April 2019

3. CS has three persuasions

- Recurring problems to be solved again and again
- Babbage's problem
 - How to design computers
- Bush's problem
 - How to use computers
- Turing's problem
 - How to make computers intelligent

3.1 Babbage's problem

- How to build efficient, programmable computers?
- Milestones
 - 2000 BCE
 - Abacus
 - 1703-1936
 - Leibniz invented binary arithmetic
 - Babbage proposed Difference Machine
 - 1936-Present
 - 1936, Turing machines
first universal abstract computer
 - 1946, ENIAC
first real general-purpose digital
electronic computer
 - 1960, first CS department at Purdue University



Birth year of
modern CS

3.1 Babbage's problem

- Three types of computers
 - **Client**-side computers
 - Users see and use them directly
 - **Server**-side computers
 - Users use them indirectly (remotely)
 - **Embedded** computers
 - Computers embedded (hidden) in other systems



A server example

3.1 Babbage's problem

- **Bell's law:** Computers develop by following three design styles, to generate a new computer class roughly every 10 years.
 - Develop the most capable computers
 - Improve performance but maintain a constant price
 - Minimal-priced computer
- 10 classes from 1950-2007
 - Supercomputers
 - Mainframes, such as IBM S360
 - Minicomputers, such as DEC PDP-11
 - Clusters (systems of interconnected computers), such as IBM SP2
 - Workstation, with graphics processing and display capability
 - Personal computers (desktop PC), such as Apple 2
 - Portable computers, such as laptop computers
 - Dedicated personal devices, such as a game device, a digital camera
 - Smartphone, such as Apple iPhones
 - Wearable devices, such as a smart watch

3.2 Bush's problem

- How to use computers effectively?
 - Relationship between *thinking man and the sum of human knowledge*
 - How to best connect people, computers, and information
- Usage mode
 - The intended user community
 - The organization style of information
 - The style of human-computer interaction
- Memex
 - scientists
 - hyperlinked records
 - interactive read, write & select
- Styles of human-computer interaction
 - Batch
 - Interactive
 - Personal computing
 - GUI
 - Multimedia
 - Portable computing
 - Network computing
 - Mobile Internet

3.3 Turing's problem

- How to make computing *application* systems intelligent?
- Three Types of computer applications
 - Scientific computing
 - for scientists and engineers
 - solve equations, do simulations, process scientific data
 - Enterprise computing (business computing)
 - for organizations
 - companies, government agencies, and not-for-profit institutions
 - business workflows, transaction processing, data analytics, decision support
 - Consumer computing
 - for individual consumer users (the masses)

One minute quiz

- Connect items on the left to the items on the right by placing the correct letter between parentheses for each line
- “to B” refers to ()
- “to C” refers to ()
- B2B refers to ()
- B2C refers to ()
- C2C refers to ()
- C2B refers to ()
- U. products or services for business
- V. products or services for consumers
- W. company serving other companies
- X. company serving consumers
- Y. consumers serving one another
- Z. company providing personalized service
- Which class does Taobao belong to?
- Which class does Tmall belong to
- Which class does a web search engine belong to?

Examples of intelligent applications

- Turing's Test
 - Imitation Game
- Examples
 - Beat human players in games
 - Chess, Go, Poker, and DOTA
 - Image recognition
 - ImageNet
 - Natural language translation
 - Autonomous vehicles
 - Robotics
- A subfield called artificial intelligence (AI)

