计算机学者发表论文之目的与追求

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Purposes of Scientific Research

- Discoveries
  - New understanding and creating new knowledge
  - Formulating new problems
- Innovations
  - Solutions (algorithms, methodologies, models, et. al)
  - Foundational theory and useful systems
- **Turing's computability describes "D" and "I" as**
  - (1) problem abstractions, (2) algorithms, (3) reasonable complexity.
- Well documented papers for community and society
  - Influential presentations with clear information flow
  - "Science is organized knowledge. Wisdom is organized life". *Immanuel Kant* (1724-1804, 康德, 德国哲学家)

Major Computing Technology Advancements are Driven by Academic Research in Universities

- Brooks Sutherland Report, 1995, for US Academies of Sci/Eng shows
  - ✓Every aspect of computing in our lives can trace back its root of basic research
  - ✓ Basic research is starting point for advancement without any patent protections
    - ✓Claude Shannon, Boolean logic, information theory, MIT, 1937
    - ✓Len Kleinrock , packet communication, UCLA, 1964
    - ✓Alan Kay, small talk (original concept of object oriented programming), Utah, 1969
    - ✓Bob Metcalfe, Ethernet, Harvard, 1973
    - ✓Bill Joy, BSD Unix, Berkeley 1977
    - ✓D. Patterson, RISC, Berkeley, 1981
    - ✓T. Berners-Lee, WWW, CERN, 1989
    - ✓L. Torvalds, Linux, U. of Helsinki, 1991
    - ✓Mark Andreessen, Mosaic browser, UIUC, 1994

- Computer business could make some wrong predictions
  - ➢T. J. Watson, IBM Founder: "There is a market for may five computers", 1943.
  - ➢K. Olsen, DEC Founder: "There is no reason anyone would want a computer in their home", 1977.

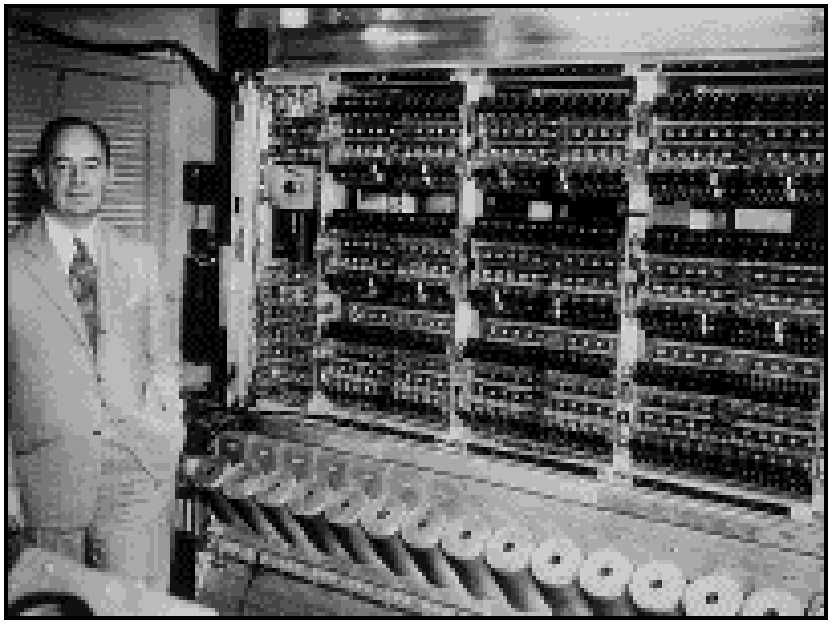
Business Driven R&D are Common in Other Disciplines

- Industrial Revolution (18^{th} to 19^{th} century, 100 years)
  - James Watt's Steam Engine (1763-1775), it was patented.
  - many other patented innovations in coal mining, textile manufacture, metallurgy, chemicals, and gas lightening.

- Wright Brothers built the first airplane in the world in 1903
  - "Flying Machine" was patented
  - "Wind-tunnel" was patented
  - It took 40 years to enter massive productions (World War II)

- All Edison's inventions have been patented (1,093)
  - Light-bulb (1879), phonograph, motion pictures, film projector, …
  - It took 60 years for US families to widely use light-bulbs

Documented Results and Concepts are Important



Von Neumann model

- a memory containing both data and instructions
- a computing unit for both arithmetic and logical operations
- a control unit to interpret instructions and make actions

- Before Von Neumann's computer project, several operational computers were built:
  - 1936, Zuse's Z1 (1st binary ditital computer) in Germany
  - 1937, Atanasoff and Berry's ABC (1st electronic digital computer) in Iowa State University
  - 1943, ENIAC in UPenn
- The most important milestone Von Neumann left is his paper: "First Draft of a Report to the EDVAC", 1945. (a consulting report to US Army)

Computer Science Research Makes Direct Impact to Society

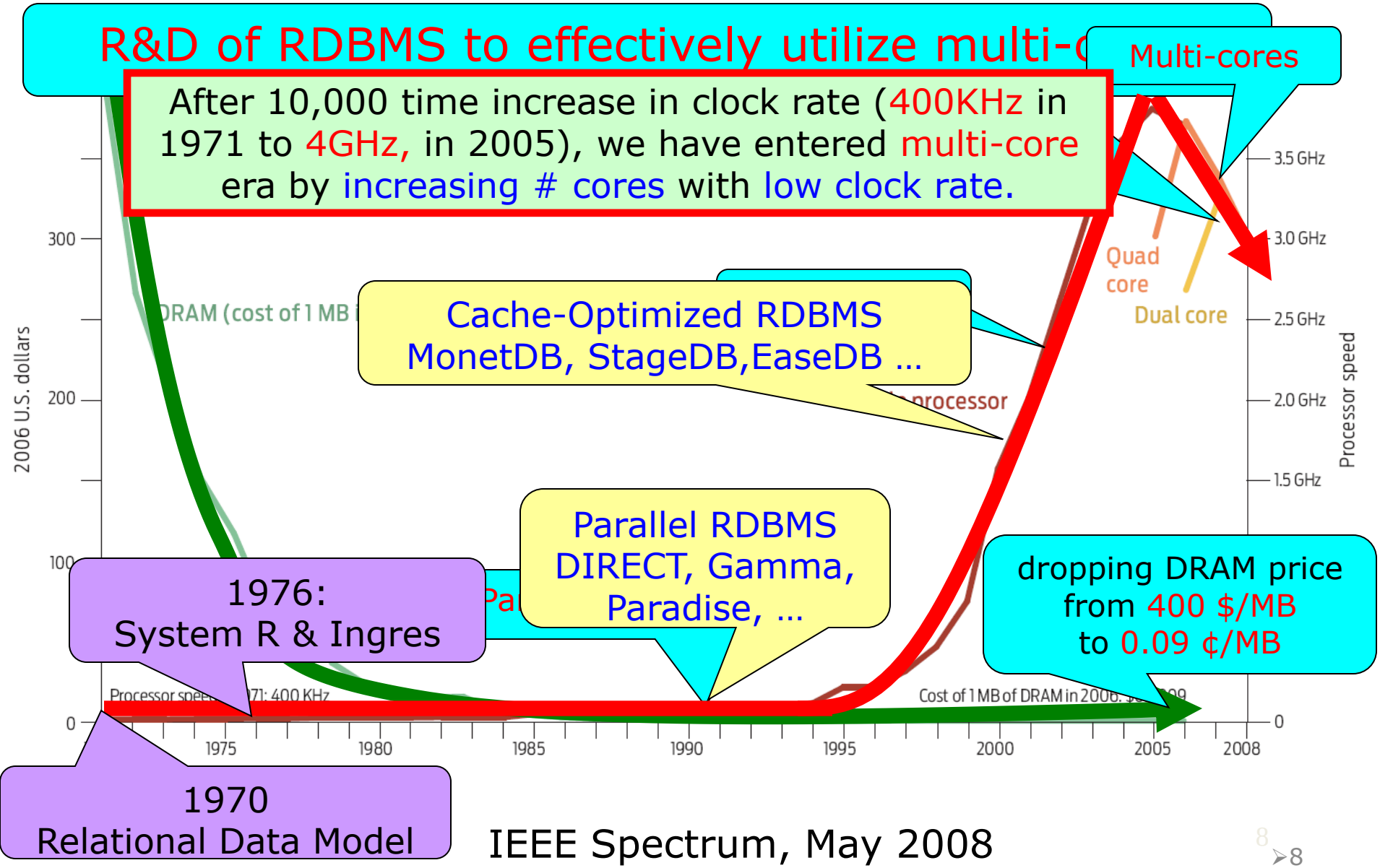
- New York Times' top 20 best innovations in last 30 years (judged by Wharton Business school, Upenn, March 2009)
  - (1) Internet, broadband (2) PC and laptop (3) Mobile phone
  - (4) e-mail (5) DNA sequencing (6) MRI (核磁共振成像)
  - (7) Microprocessors (8) Fiber optics (9) office software
  - (10) Robotic surgery (11) open source software (12)LED(发光二极管)
  - (13) Liquid crystal display (14) GPS (全球定位系統) (15) e-commerce
  - (16) data compression (17) microfinance(小额信贷)
  - (18) Solar energy (19) large wind turbines (20) Social networks

- A unique and high expectation to Computer Science Research: it must be relevant to the advancement of the technology to improve our society

追求与目的之一: 把握技术发展方向和应用需求, 做重要的问题

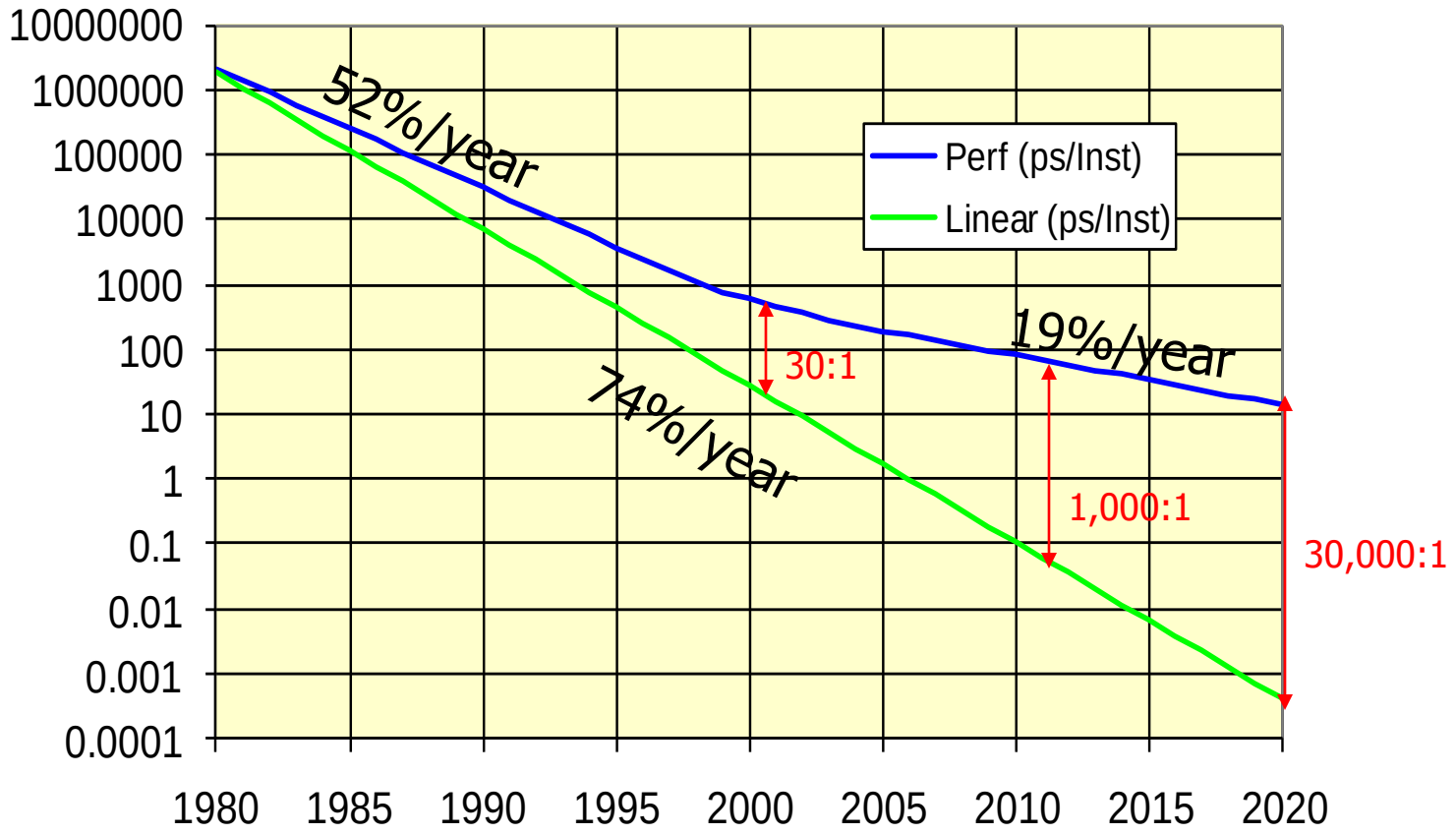
- CS research is technology driven and fast changing
  - New problems are caused by rapid technology updates, such as Moore's Law, application demands, and infrastructure cost change
  - Many research problems come and go, and some are persistent, such as performance, security, reliability
  - There are a limited number of classical problems in our field. Knuth says, we have less than 100 general-purpose algorithms
- CS research is easy to lag behind, "bubble", or irrelevant
  - Many algorithms design are architecture dependent, e.g. O(n) measures CPU cycles, but performance determines by data
  - Many real-world issues can be abstracted into math problems with unrealistic assumptions to publish papers
  - Many important development are engineering oriented, needs only a few papers.

R&D of Applications Have Been Driven by Moore's Law

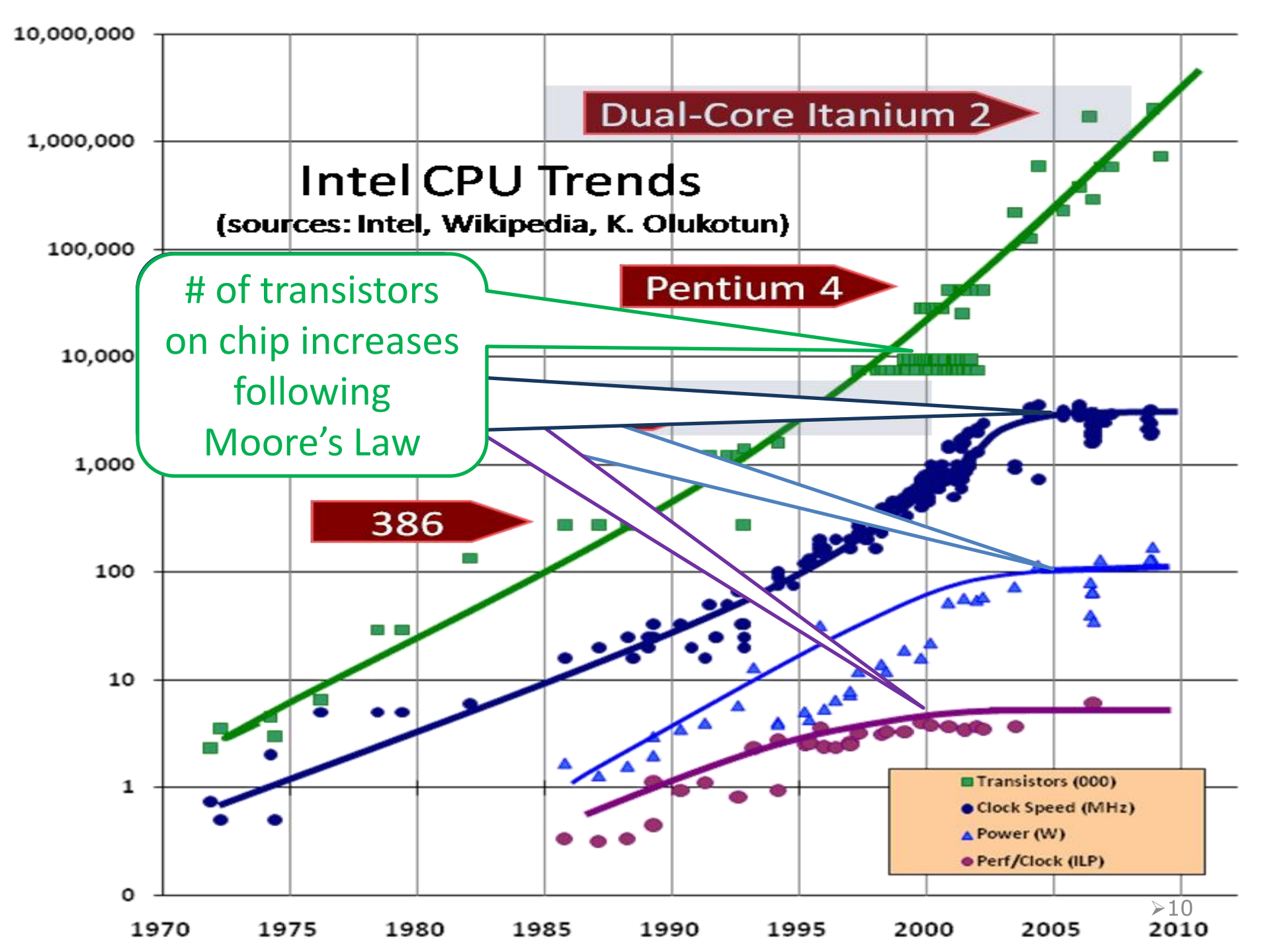


IEEE Spectrum, May 2008

Single-core Architecture has been Inefficient for 10 years



Dally, et. al. The Last Classical Computer, Information Science and Technology Group (ISAT) Report, DARPA, 2001


Intel CPU Trends
(sources: Intel, Wikipedia, K. Olukotun)
Dual-Core Itanium 2
Pentium 4
386
# of transistors on chip increases following Moore's Law
Transistors (000)
Clock Speed (MHz)
Power (W)
Perf/Clock (ILP)
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
0
1970
1975
1980
1985
1990
1995
2000
2005
2010

What Matter most in Single-cores and Multi-core?

- Single-core performance mainly depends on hardware advancement
  - ✓Clock speed: stop increase in 2005 due to power consumption limit
  - ✓Execution optimization: pipelining, out-of-order, et. al. (little gain after 2000)
  - ✓Cache: large and high associativity, major source for performance gain

  single cores are inefficient (1,000+ times less from its ideal model now, and reach to 30,000 times in 2020)

- Multi-core performance mainly depends on software advancement
  - ➢Number of cores: continue to increase (inevitable hardware advancement)
  - ➢Concurrency: parallel/concurrent execution is scheduled by OS/software
  - ➢Shared cache: data sharing and conflict avoidance is managed by OS/software
  - ➢ Throughput = concurrency / latency

  Major efforts: high concurrency (scheduling) and low misses (exploiting locality)

Architecture Teaching Lags behind Research

- ILP is still a dominant portion in architecture classroom (H&P Book)
  - ✓Instruction Set Principles and Examples: Chapter 2, 72 pages
  - ✓Instruction-Level Parallelism and its Dynamic Exploiting: Chapter 3, 117 pages
  - ✓Exploiting Instruction-Level Parallelism by Software: Chapter 4, 175 pages

  A total of 361 pages

- Only one chapter for memory performance
  - Memory Hierarchy Design: Chapter 5, 124 pages.

- Other Chapters are non-microprocessor topics
  - ➢ Multiprocessor and Thread-Level Parallelism: Chapter 4, 138 pages (SMP)
  - ➢Storage Systems: Chapter 7, 101 pages (I/O is an independent topic)
  - ➢Interconnection Networks and Clusters: Chapter 8, 90 pages (a part of parallel computing class along with Chapter 4, SMP).

追求与目的之二: 争取让更多的同行读我们发表的论文

- Why publish in top venues?
  - Each field has its own flagship and leading conferences and journals, the recognitions come from reputation and influence
  - Most researchers only read papers from these venues
  - Number of citations is an indicator of the amount of readerships
- Conferences versus Journals
  - In certain technology based fields, such as systems, architecture, networking, and databases, top conference papers are prestigious, highly visible, with 4-5 more reviews in depth, and low acceptance rate.
- SCI and EI driven publications are not desirable
  - An SCI/EI entry may not ensure the quality of the journal/conference
  - The quality should be judged by the peers in the field
  - The impact factor sometimes is field size dependent

追求与目的之三:发表有影响力的论文

- Seeking useful theory to layout foundations
  - As basic theories are missing or lagging behind, technology developers can only have ad-hoc and sub-optimal solutions
  - A true theory guides us to develop best solutions
- Understanding intrinsic nature of complex problems
  - A complex problem is a problem that we do not understand
  - "The search for simplicity is the search for a structure within which the complex become transparent" (R. Gallager, a pioneer of computer networks)
- Examples of influential papers
  - Shortest path algorithm, (Dijkstra's notes, 1959)
  - Relational data model, (CACM'70)
  - Co-scheduling in distributed systems (ICDCS'82)
  - HITS algorithm lays out a foundation for search engine (SODA'98)

追求与目的之四: 更新和创造核心技术, 推动社会进步

- Systems research has a high potential to directly advance technology
  - Solving real problems in core components of system infrastructure
  - Creating new system frameworks for low costs and high returns
  - Building new systems that responds rapid demands in society
- One more step after research prototypes can make a big difference
  - Open source software, Linux, BSD, MySQL, Hadoop, BitTorrent, …
  - Commercial products, RISC CPU, GPU, Yahoo!, VMWare, ...
- Examples of influential papers changing the world
  - Ingres/PostgreSQL (TODS,76, most advanced open source database)
  - 汉字激光照排技术, (计算机学报, 81, 90+%的国内外华文报业市场)
  - RAID, (SIGMOD'88, $10 billion storage market)
  - WWW, (A proposal of Information management, CERN, 1989)
  - Google, (WWW'98, the World dependent search engine)
  - Computer architecture advancement, (by influential papers)
  - OS advancement, such as Linux and BSD, (by influential papers)

A List of Research Contributions by UC Berkeley (1957-2007)

- Theoretical Foundations and Influential Algorithms
  - Fuzzy logic (Zadeh)
  - Theory of NP-Completeness (Cook and Karp)
  - Karmarkar's Algorithm for Linear Programming (Karmarka /Karp)
  - Complexity of Cryptography (Blum, Micali and Goldwasser)
- Advancing Technology and Improving Society Productivity
  - Design automation: SPICE and others (Pederson, Rohrer, Sangiovanni, and Newton; -> Cadence and Synopsys)
  - INGRES (Stonebraker and Wong; -> Oracle and PostgreSQL)
  - Berkeley Unix (Fabry/Joy; -> Sun, FreeBSD, and NetBSD)
  - IEEE 754 Standard for Floating-point Arithmetic (Kahan)
  - RISC (Paterson/Sequin; -> chip designs in Sun, Fujitsu and others)
  - RAID (Paterson/Katz/Gibson; -> more than 15 vendors)

Requirements to Computer Science Ph.D. Students

- Rigorous training with a strong foundation
  - Both systems and analytical skills
  - merge one into a focused area

- Identify significant problems
  - Literature search and reading, attending seminars
  - Interns in industries and research labs

- Completing a Ph.D. dissertation
  - Working hard (100 hours per week)
  - Articulating ideas and results well in papers and presentations
  - Achieving goals #1 and #2
  - Aiming at goals #3 and 4

Results of Computer Science Ph.D. Research

- 读博士， 就是挑选一个狭窄并重要的领域作研究, 毕业的时候交出一篇世界一流的毕业论文，成为这个领域里世界首屈一指的专家。任何人提到这个领域的时候，都会想起你的名字。

- 你从学校带走的、最有价值的、不是这份论文，而是你分析和独立思考的能力、研究和发现真理的经验，还有科学家的胸怀。当你某一天不再研究这个领域的时候，你依然能在任何一个新的领域做到最好。

Nico Habermann (CMU computer science chair/dean, 1979-1988)

王选定义的一流研究

我认为在国内，达到以下四个目标之一的项目均属第一流成果。

1. 文章发表在权威杂志上，有国内外学者的引用。
2. 在原理性样机或系统中，提出了新思想、新技术或新方法，被后来的研究者采纳，并最终影响了工业界。
3. 把新技术首次应用于某一领域，并在应用中效果显著，从而得到了一定的推广，随之而来的是该领域的商品热潮。
4. 风靡市场的商品

王选, “科研选题和制定目标时要注意的几个问题”, 《计算机世界》1994年

- Aiming high to technology transfer (goal #4), and he himself is a role model
- Influential scholarships also include theoretical foundations and leading new directions

Summary

- CS Research advances technology and impacts the society
  - Computing technology in the society deeply roots to research
  - Patent-free, open source, and conference driven research make our field fast moving and highly competitive
- How to measure achievements of Goals #1 and #2
  - Citations
    - High citations reflect high readerships and follow-ups
    - High citations means the area is active
    - However, high citations can also mean the area is "bubbled"
  - Persistency and classics of the problems
  - Potentials to achieving goals #3 or/and #4
- Measuring Goals #3 and #4 needs hard evidences and time
  - Quality citations: laying out foundations (5-10 years)
  - Updating technologies: new standard, new model, new products
  - Systems are widely used: supporting many applications

Last Words: Contribution-driven Research

- Einstein said:
  - "Try not to become a man of **success** rather try to become a man of **value**"

- Success can be measured by
  - A large number of publications, visibility, and more grants
  - Awards, promotions, and high salary
  - Upgrading official levels and respects

- Value is measured by impact and contributions
  - New findings and foundations for advancing knowledge
  - Research results directly updating technology
  - How many people use it, and how large scope it affects
  - Service by widely used software, textbooks, and inspiring lectures.

Thank You !