



Instructor Introduction

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My Technical Background

- Wonsun Ahn
 - First name is pronounced one-sun (if you can manage)
 - Or you can just call me Dr. Ahn (rhymes with naan)
- PhD in CPU Design and Compilers
 - University of Illinois at Urbana Champaign
- Industry Experience
 - Software engineer, field engineer, technical lead, manager
 - Bluebird Corporation (70-person startup company)
 - ☐ Manufactures industrial hand-held devices from top to bottom
 - □ Me: Built software stack based on Windows Embedded
 - IBM Research (thousands of people)
 - □ Does next-gen stuff like carbon nanotubes, quantum computers
 - □ Me: Designed supercomputers for ease of parallel programming

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My World View

- Everything is connected
 - Pandemic: If my neighbors catch the virus, so will I
 - Environment: If my neighbors pollute, I will feel the effects
 - Economy: Think of how the subprime mortgage crisis spread
- Zero-sum thinking (old way of thinking)
 - "If you get a larger slice of the pie, I get a smaller slice."
 - Therefore, if you lose, I win (and vice versa)
- Zero-sum thinking no longer works
 - If you catch the virus, do I become safer from the virus?
- Collaboration is replacing competition

Collaboration is Replacing Competition

- Is happening in all spheres of life
- Collaboration is also happening in the IT industry
 - The open source movement
 - Increasing importance of the software/hardware ecosystem
 - Increasing importance of the developer community
- Collaboration is also important for learning
 - During my undergrad years, what do I remember best?
 - Stuff that I explained to my classmates
 - Stuff that my classmates taught me



Supporting Collaborative Learning

- I never grade on a curve
 - You will not be competing against your classmates
 - You are graded on your own work on an absolute scale
- You will be a member of a Team
 - You are already a member of the class on Microsoft Teams
 - I encourage you to be on Teams at most times (I will too)
 - ☐ You can install app on both laptop and cell phone
 - If you have a question, you can ask in the Team "Posts" tab
 - ☐ Either your classmate or your instructor will answer
 - You can chat with any individual on the Team
 - ☐ "Manage Team" item in the "..." Team context menu



Supporting Collaborative Learning

- You will be a member of a Group
 - On Teams, you are part of a chat group of 7~8 members
 - Members are a good mix of in-person and online students
 - Your instructor is also a member of each Group
 - It is a smaller support group where you can talk more freely
- You are allowed to discuss TopHat lecture questions
 - The goal is no-student-left-behind (pun intended)
 - Discuss answers on Teams even before submitting them
 - Form a basis of knowledge for doing homeworks and exams



Course Introduction

Structure of the Course

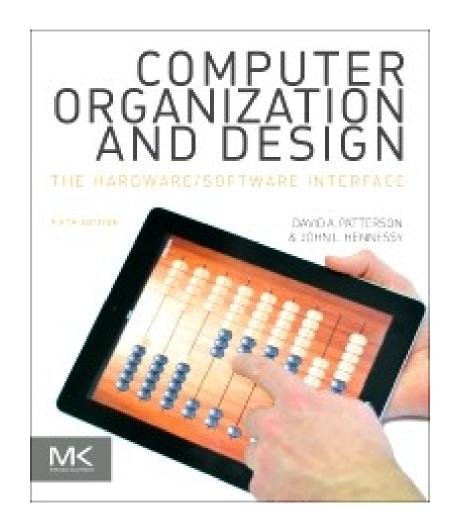


- (45% of grade) Three midterms
- (20% of grade) Two projects
 - Implementing a CPU simulator using C programming language
- (20% of grade) Four homeworks
- (15% of grade) Participation
 - TopHat lecture questions, Teams participation
- Class resources:
 - Canvas: announcements, Zoom meetings, recorded lectures
 - GitHub: syllabus, lectures, homeworks, projects
 - Tophat: online lecture questions
 - GradeScope: homework / projects submission, grading and feedback
 - Microsoft Teams: Online / off-line communication



Textbook (You Probably Have it)

"Computer Organization and Design - The Hardware/Software Interface" by David Patterson and John Hennessy Fifth Edition - Morgan & Kaufmann.



For More Details



- Please refer to the course info page: https://github.com/wonsunahn/CS1541_Fall2020/bl ob/master/course-info.md
- Please follow the course schedule syllabus: https://github.com/wonsunahn/CS1541_Fall2020/blob/master/syllabus.md

TODO



Submit the TopHat survey questions (due 8/21)

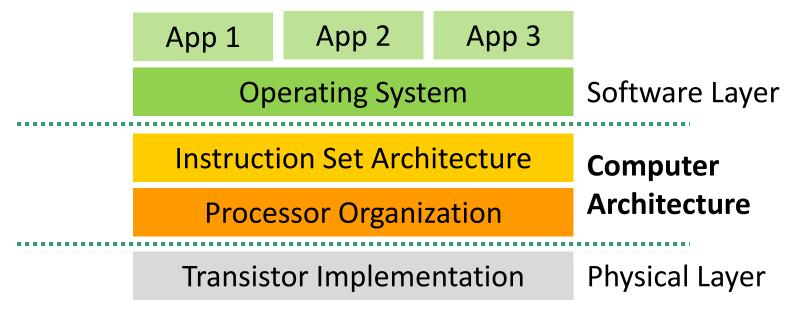
What is Computer Architecture?



- At a high-level: how a computer is built
 - Computer here meaning the processor (CPU)
- You probably heard of a similar term before: ISA
 - ISA (Instruction Set Architecture)
- Review: what is defined by an ISA?
 - Set of instructions usable by the computer
 - Set of registers available in the computer
 - Functional attributes are clearly defined (it's the interface)
- What is not defined by an ISA?
 - Speed of computer
 - Energy efficiency of computer
 - Reliability of computer
 - Performance attributes are undefined (intentionally so)



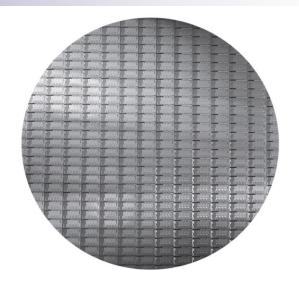
Computer Architecture Defined



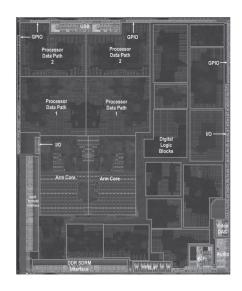
- Computer Architecture = ISA + Processor Organization
 - Processor organization is also called Microarchitecture
- Performance is decided by:
 - Processor organization (internal design of the processor)
 - Transistor implementation (semiconductor technology)

Scope of Class

Physical layer is beyond the scope of the class



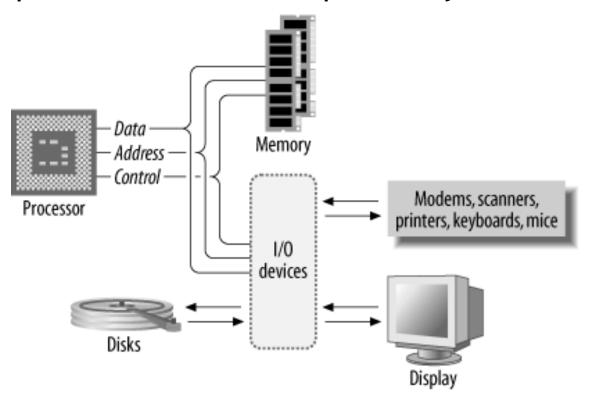
- We will focus mostly on processor organization
 - And how performance goals are achieved



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Scope of Class

Computer architecture is part of system architecture

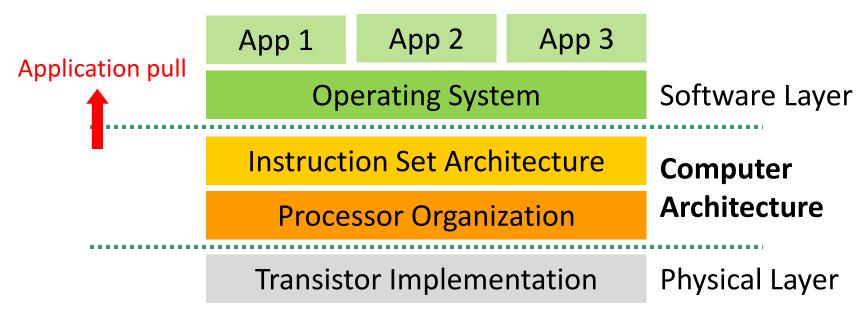


Other components beside processor is beyond the scope

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Application Pull

Different applications pull in different directions



- Real-time app (e.g. Game): Short latency
- Server app: High throughput
- Mobile app: High energy-efficiency (battery life)
- Mission critical app: High reliability
- An app typically has multiple goals that are important

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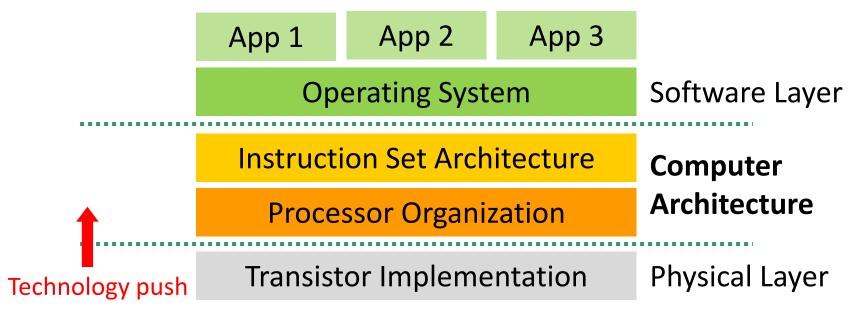
Application Pull

- Some goals can be incompatible
 - E.g. Speed and energy-efficiency are incompatible
 - ☐ Running is faster than walking but uses more energy
 - ☐ A Ferrari is faster than a Prius but has worse fuel efficiency
 - E.g. Reliability is incompatible with many other goals
 - ☐ If you use redundancy, you use twice the amount of energy
- Even when sharing a goal, apps have unique needs
 - Scientific apps need lots of floating point units to go fast
 - Database apps need lots of memory cache to go fast
- An architecture is a compromise among all the apps
 - When app achieves market critical mass, designs diverge (Mobile chips / Server chips / GPUs / TPUs diverged)
 - Sometimes even ISAs diverge (GPUs and TPUs)



Technology Push

Trends in technology pushes architecture too



- Trends can be advances in technology
- Trends can be constraints technology couldn't overcome
- * "Technology" in CPU design refers to the physical layer
 - Manufacturing technology used for transistor implementation

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Advances in Technology

- Technology has been advancing at lightning speed
- Architecture and IT as a whole were beneficiaries
- Technology advance is summarized by Moore's Law
 - You probably heard of it at some point. Something about ...
 - "X doubles every 18-24 months at constant cost"
- Is X:
 - Computer performance?
 - CPU clock frequency?
 - Transistors per chip?

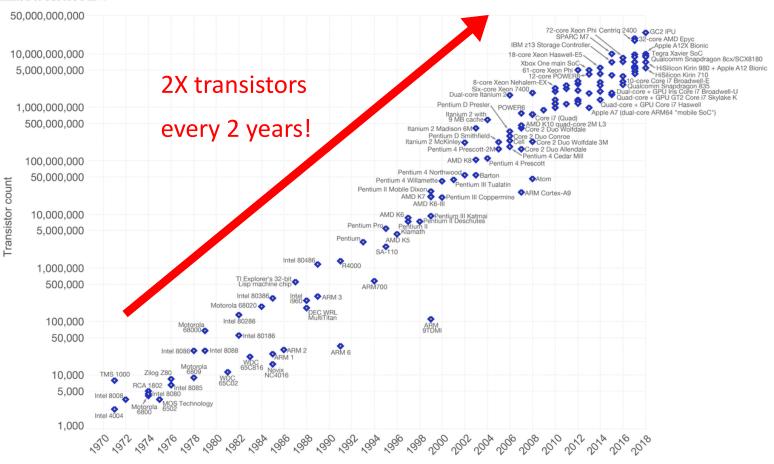




Moore's Law – The number of transistors on integrated circuit chips (1971-2018)

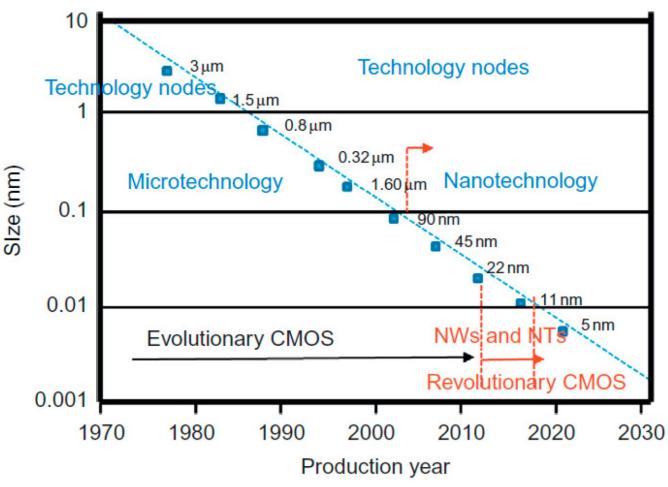


Moore's law describes the empirical regularity that the number of transistors on integrated circuits doubles approximately every two years. This advancement is important as other aspects of technological progress – such as processing speed or the price of electronic products – are linked to Moore's law.



Miniaturization of Transistors





Data source: Radamson, H.H.; He, X.; Zhang, Q.; Liu, J.; Cui, H.; Xiang, J.; Kong, Z.; Xiong, W.; Li, J.; Gao, J.; Yang, H.; Gu, S.; Zhao, X.; Du, Y.; Yu, J.; Wang, G. Miniaturization of CMOS. *Micromachines* **2019**, *10*, 293.

Moore's Law has been driven by transistor miniaturization

Future of Moore's Law



- The semiconductor industry has produced roadmaps
 - Semiconductor Industry Association (SIA): 1977~1997
 - International Technology Roadmap for Semiconductors (ITRS): 1998~2016
 - International Roadmap for Devices and Systems (IRDS): 2017~Present
- IRDS Lithography Projection (2020)

Year of Production	2018	2020	2022	2025	2028	2031	2034
Technology Node (nm)	7	5	3	2.1	1.5	1.0	0.7

- Looks like Moore's Law will continue into foreseeable future
- IRDS does not project significant increase in CPU chip size
- Increases in transistors will come from transistor density

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Moore's Law and Performance

- Million-dollar question: Did Moore's Law result in higher performance CPUs?
- What do you think? Are computers getting faster?
 - If not, why do you think so? What examples support your view?
 - If yes, is speed of improvement accelerating or decelerating?