http://inst.eecs.berkeley.edu/~ee290-2/sp21/

Hardware for Machine Learning

Lecture 25: Conclusion

Sophia Shao

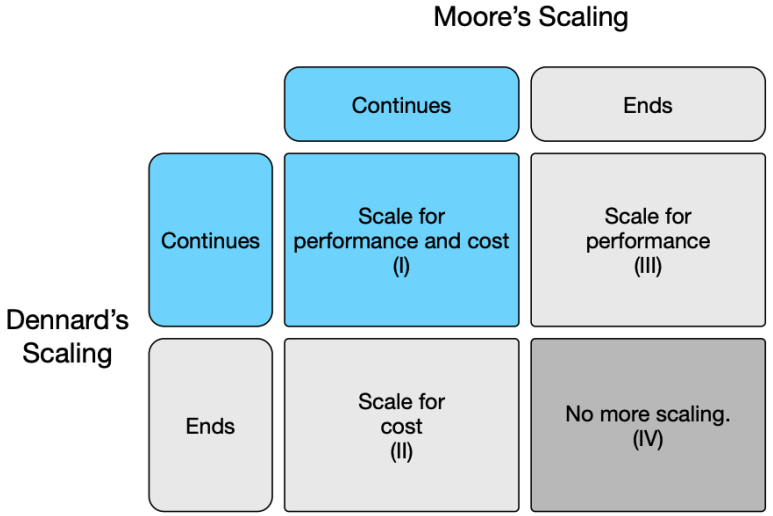
"It was the best of times, it was the worst of times, it was the age of wisdom, it was the age of foolishness, it was the epoch of belief, it was the epoch of incredulity, it was the season of Light, it was the season of Darkness, it was the spring of hope, it was the winter of despair."

Dickens, 1859

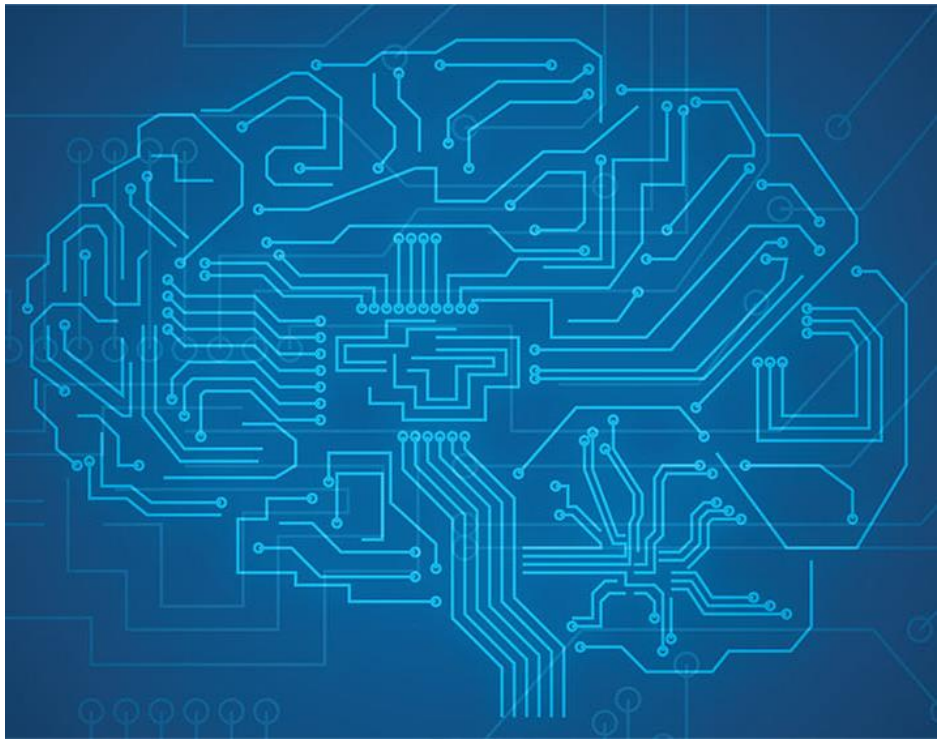
It is "***A New Golden Age of Computer Architecture"***

John L. Hennessy, David A. Patterson, 2018

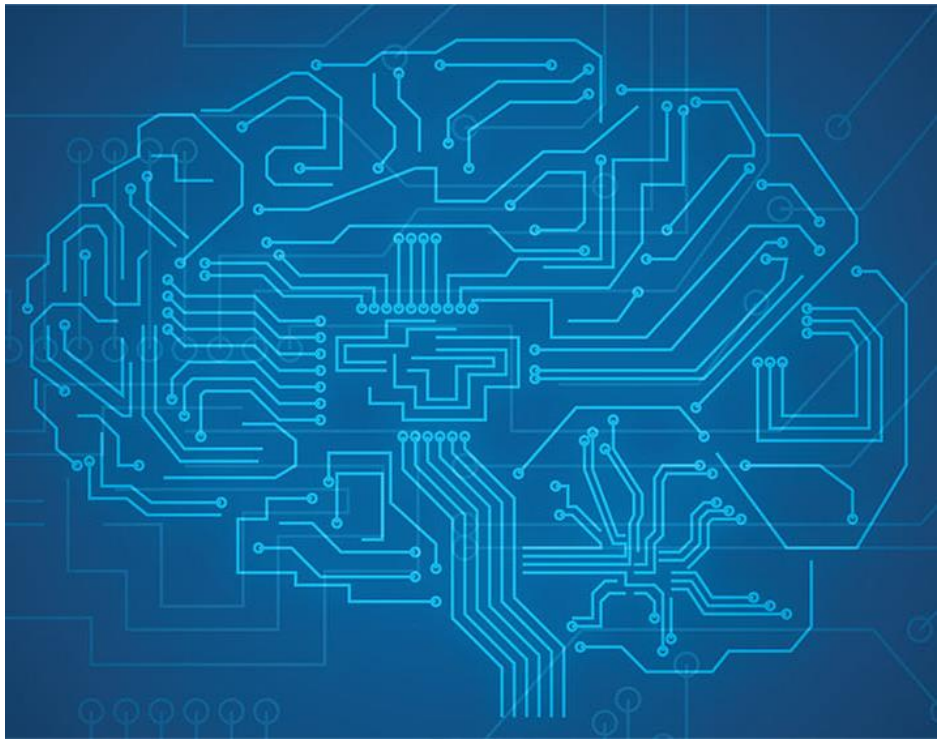
https://www.acm.org/hennessy-patterson-turing-lecture



Shao, Ph.D. Dissertation, 2016



Course Evaluation



Course Recap

A new course!

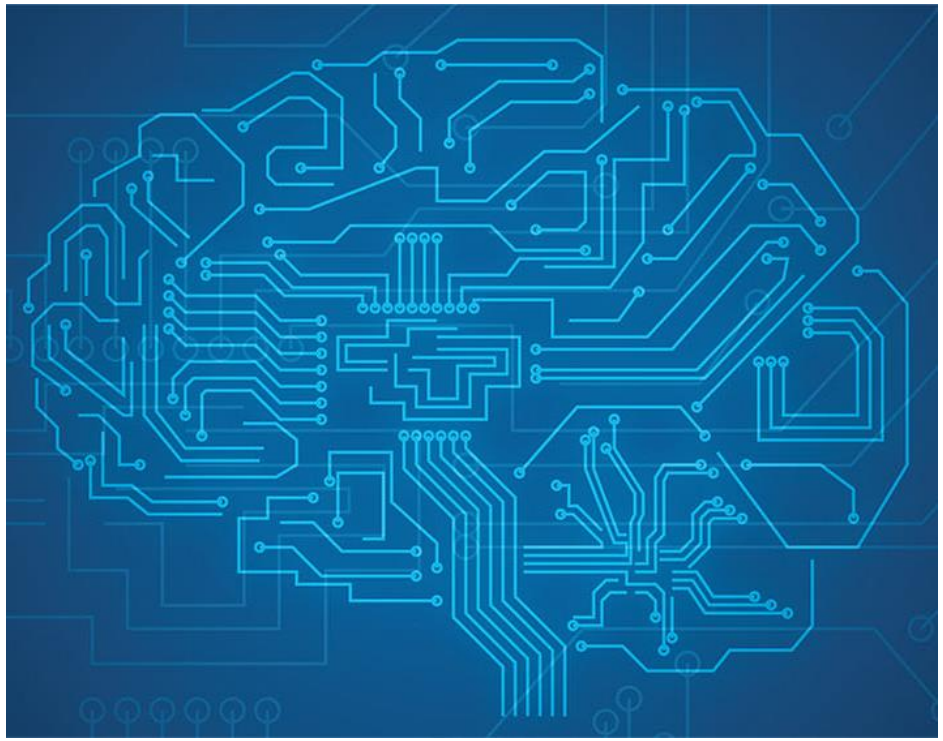
- A bridge between hardware and machine learning

- Goal:
  - **Build** efficient hardware for accelerating machine learning applications.

- Approach:
  - Understand key machine learning characteristics
  - Exploit core hardware optimizations
  - Guest lectures with state-of-the-art industry practices

Course Topics

- Core topics:
  - Deep Neural Networks
  - Quantization
  - Development Platforms
  - Kernel Computation
  - Dataflows
  - State-of-the-art Accelerators
  - Mapping
  - Sparsity
  - Hardware-Software Co-design
  - Other networks
  - Advanced Technology
  - Training
  - Accelerator-Level Parallelism
  - End-to-End Deployment



Labs and Project

- Three labs with two weeks / lab
  - Lab 1: Quantization
  - Lab 2: Processing Element design (Verilog)
  - Lab 3: Application Mapping

PyTorch

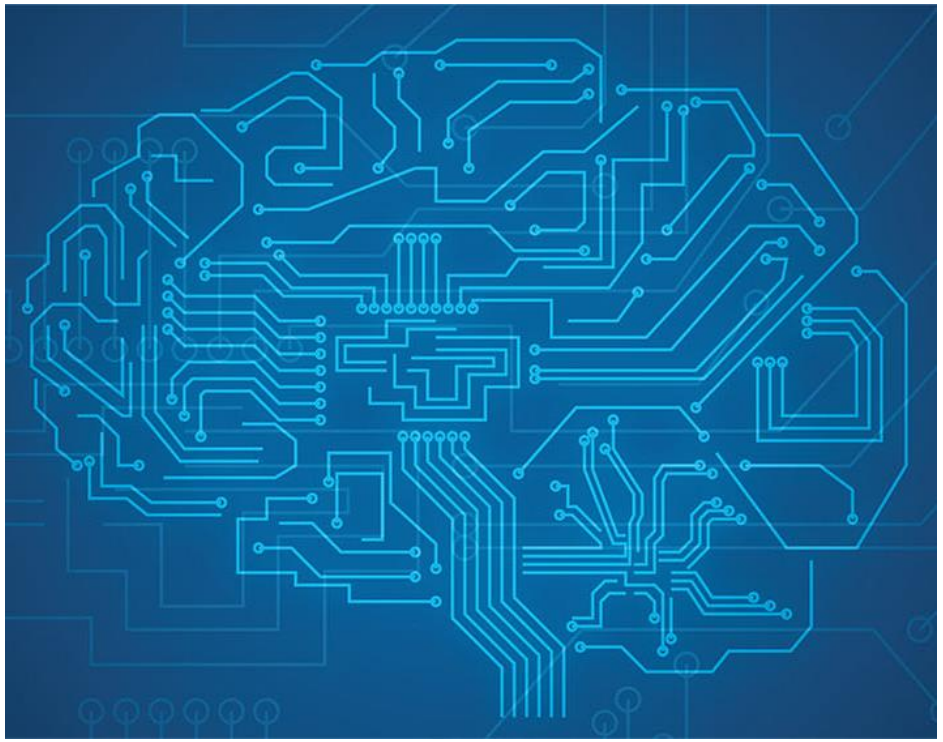
CHIPYARD

FireSim

- Project:
  - Open-ended research project.
  - Done with a partner (recommended).

Administrivia

- Project Presentation:
  - **15** mins presentation + **5** mins Q&A
  - Tentative:
    - Monday, 5/3, 2-5:30pm
- Project Report:
  - Max 8 pages
  - 2-column format. Use Latex (e.g., with overleaf)
  - Provide a link to your code repository.



Hardware for X

Lessons of last 50 years of Computer Architecture

- Software advances can inspire architecture innovations.
- Raising the hardware/software interface creates opportunities for architecture innovation.
- Ultimately the marketplace settles architecture debates.

turing lecture

DOI:10.1145/3282307

Innovations like domain-specific hardware, enhanced security, open instruction sets, and agile chip development will lead the way.

BY JOHN L. HENNESSY AND DAVID A. PATTERSON

A New Golden Age for Computer Architecture

WE BEGAN OUR Turing Lecture June 4, 2018[11] with a review of computer architecture since the 1960s. In addition to that review, here, we highlight current challenges and identify future opportunities, projecting another golden age for the field of computer architecture in the next decade, much like the 1980s when we did the research that led to our award, delivering gains in cost, energy, and security, as well as performance.

"Those who cannot remember the past are condemned to repeat it." —George Santayana, 1905

Software talks to hardware through a vocabulary called an instruction set architecture (ISA). By the early 1960s, IBM had four incompatible lines of computers, each with its own ISA, software stack, I/O system, and market niche—targeting small business, large business, scientific, and real time, respectively. IBM engineers, including ACM A.M. Turing Award laureate Fred Brooks, Jr., thought they could create a single ISA that would efficiently unify all four of these ISA bases.

They needed a technical solution for how computers as inexpensive as

» key insights

- Software advances can inspire architecture innovation.
- Elevating the hardware/software interface creates opportunities for architecture innovation.
- The marketplace ultimately settles architecture debates.

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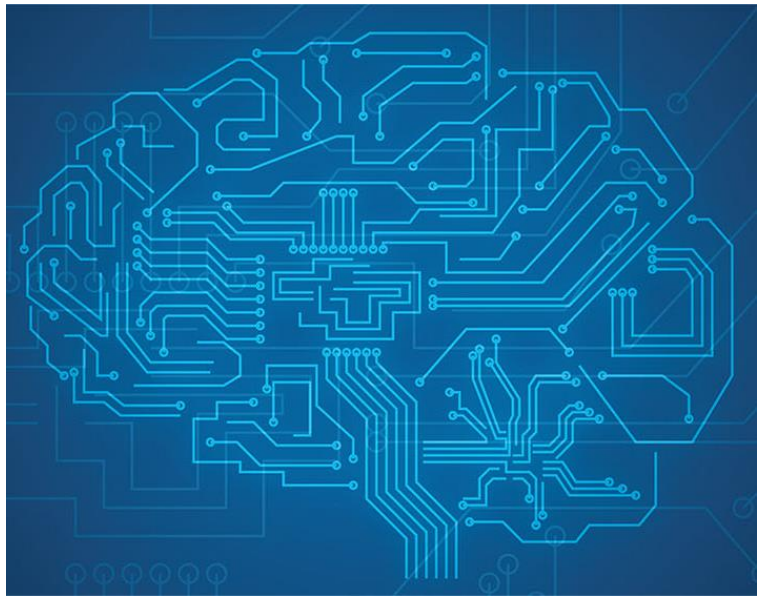
A New Golden Age for Computer Architecture: History, Challenges, and Opportunities

HW for ML is part of the architecture history.

- Software advances can inspire architecture innovations.
  - **The Cambrian explosion of ML drives the demand for ML Hardware.**
- Raising the hardware/software interface creates opportunities for architecture innovation.
  - **Domain-specific operators redefine the HW/SW interface in specialized architecture.**
- Ultimately the marketplace settles architecture debates.
  - **Who will win the ML HW war in the end?**



This is only a start.

- Growing complexity of ML algorithms.
  - Broader application domains: computer vision -> natural language processing
  - Tighter hardware requirements: from edge devices to datacenters

- Growing demands for powerful hardware in other domains.
  - Genome sequencing, robotics, graphics, data analytics, and others.
  - Hardware for X.

- Growing challenges in managing diverse HW/SW systems.
  - Chip architect -> System architect

Time to become a modern Renaissance Person

- Modern hardware designers need to understand more than just hardware.
  - Driving applications, e.g., ML
  - Compiler
  - Operating system
  - Computer architecture
  - Digital/Analog circuit design
  - Devices
- Willing to break abstractions.
  - Time for vertically integrated ideas!

Getty Images

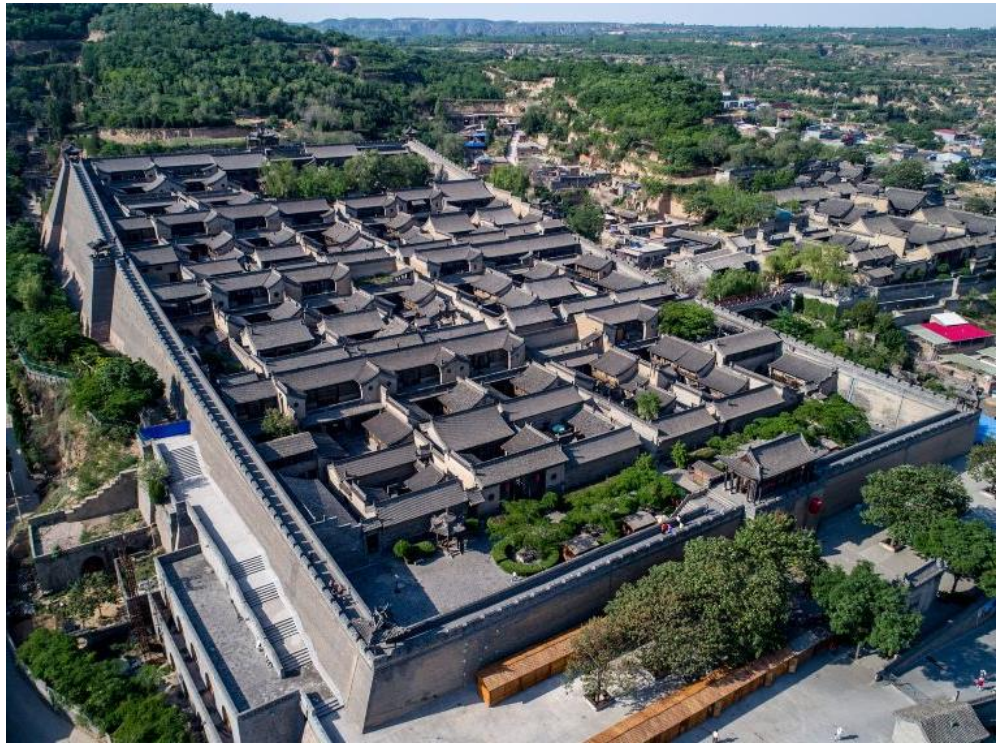
Architecture is a reflection of time.

- Computing system evolves with the demand of applications and the behaviors of underlying technologies.
- Be brave: build hardware that reflects your time!
- "*A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die and a new generation grows up that is familiar with it*." Max Planck

By Benh LIEU SONG (Flickr) - Louvre Courtyard, Looking West, CC BY-SA 4.0

Architecture is a conversation with space.

- Computing system also becomes increasingly spatially-distributed.
  - From Skyscrapers to Hutongs
- Be considerate: understand your neighbors as yourself.
- "*If you know the enemy and know yourself, you need not fear the result of a hundred battles. If you know yourself but not the enemy, for every victory gained you will also suffer a defeat. If you know neither the enemy nor yourself, you will succumb in every battle*." Sun Tzu, The Art of War.



Wang Family Compound

Thanks Abe!

Abraham (Abe) Gonzalez

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Office Hours:
Thu 10-11am

Thanks to all of you!

- It's a new course.
  - Thanks all of you for working with us to put this course together!
- We had a lot of fun!
- Hope you had too!
- Stay Curious. Stay Optimistic!