

3 DAYS, 6 SESSIONS

AI SUMMER SCHOOL

July 1 – 3, 2024 | NCSR “Demokritos” Congress Centre

A HIAS summer school in AI, its foundations and recent advances.

A brief Introduction

PETROS KOUMOUTSAKOS



HARVARD

School of Engineering and Applied Sciences



**HELLENIC INSTITUTE
of ADVANCED STUDIES**





Making a difference with Science

HIAS NETWORK: Scientific excellence in Engineering and Information Technology, an asset for the Greek society



HIAS's extended team of scientists in the Greek diaspora...



...extensive experience, recognition and interdisciplinary expertise

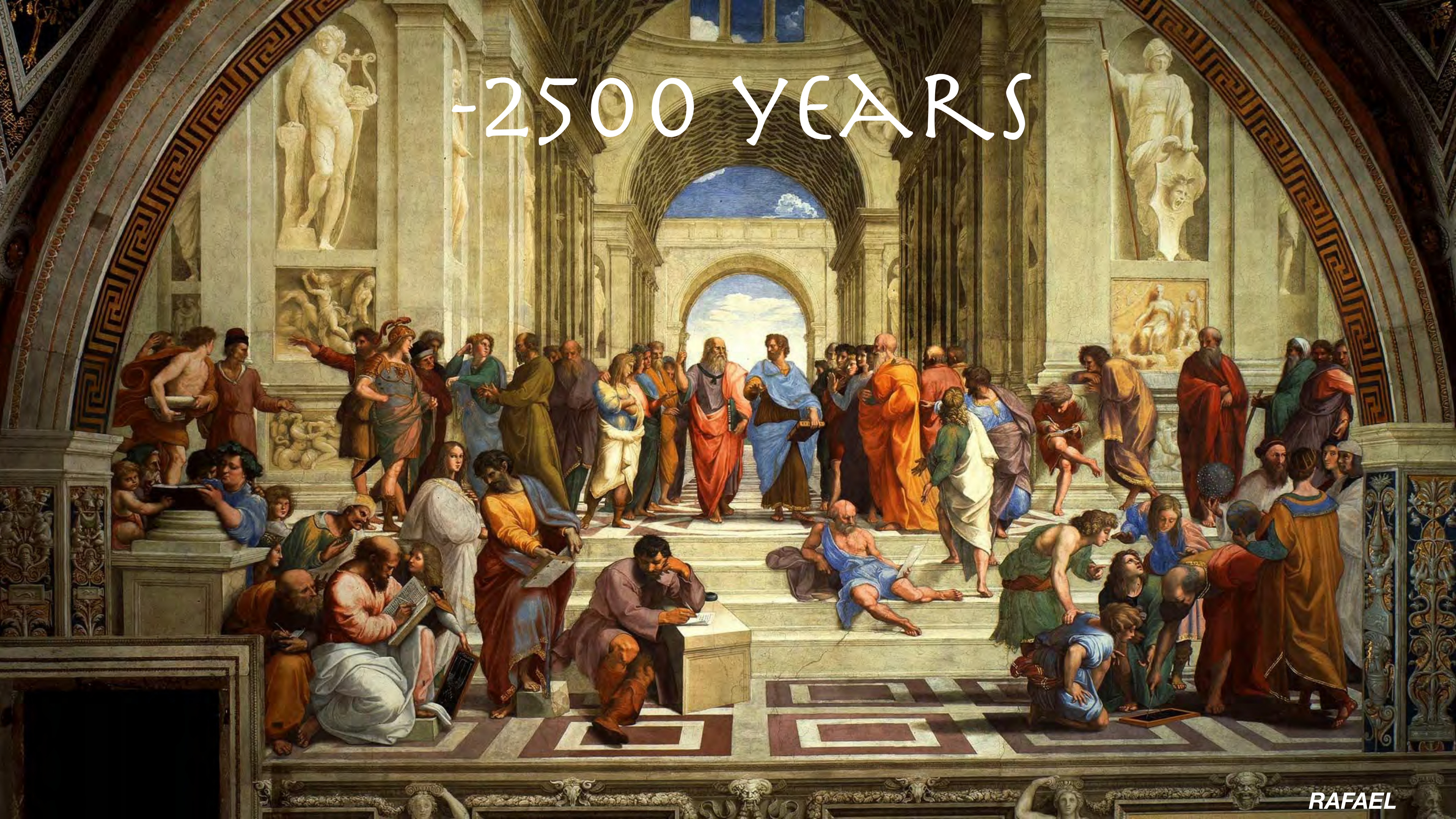
- **>200** members from **>65** top-rated universities, mostly US, EU, CH, UK
- **>20** of HIAS members are US National Academy members across Engineering, Science, Medicine
- **Multiple** members with several International awards, e.g., Turing award.

HIAS mission

Leverage the network of world class expertise in the Diaspora to serve Greece through:

- Serve as a **hub for science and technology driven innovation in Greece**
- Foster **bridges between the diaspora** and their peers in Greece
- Develop **international collaborations** to address societal challenges
- Contribute to **shaping a culture of scientific excellence in Greece**

-2500 YEARS

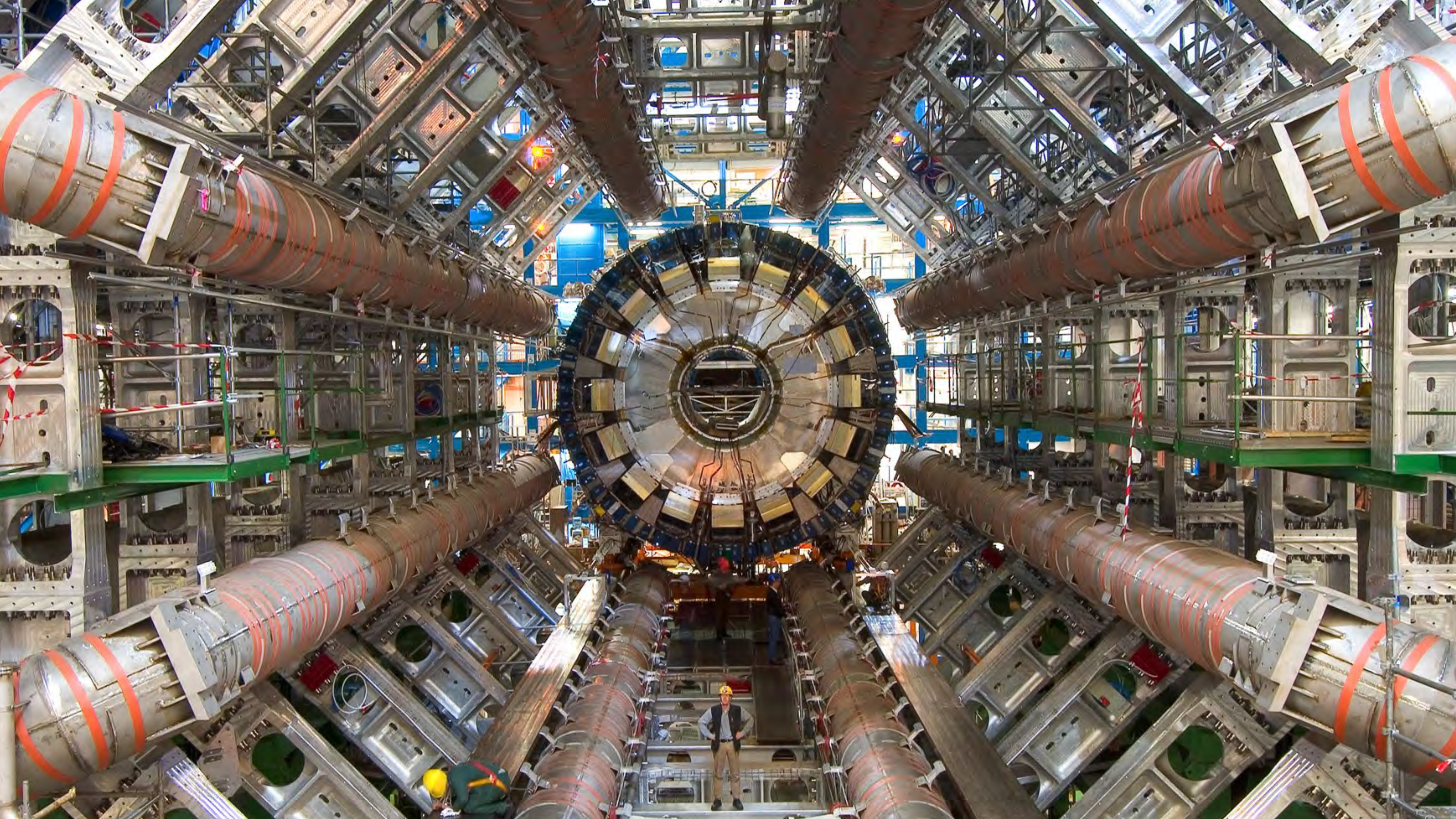


THE PURSUIT OF TRUTH



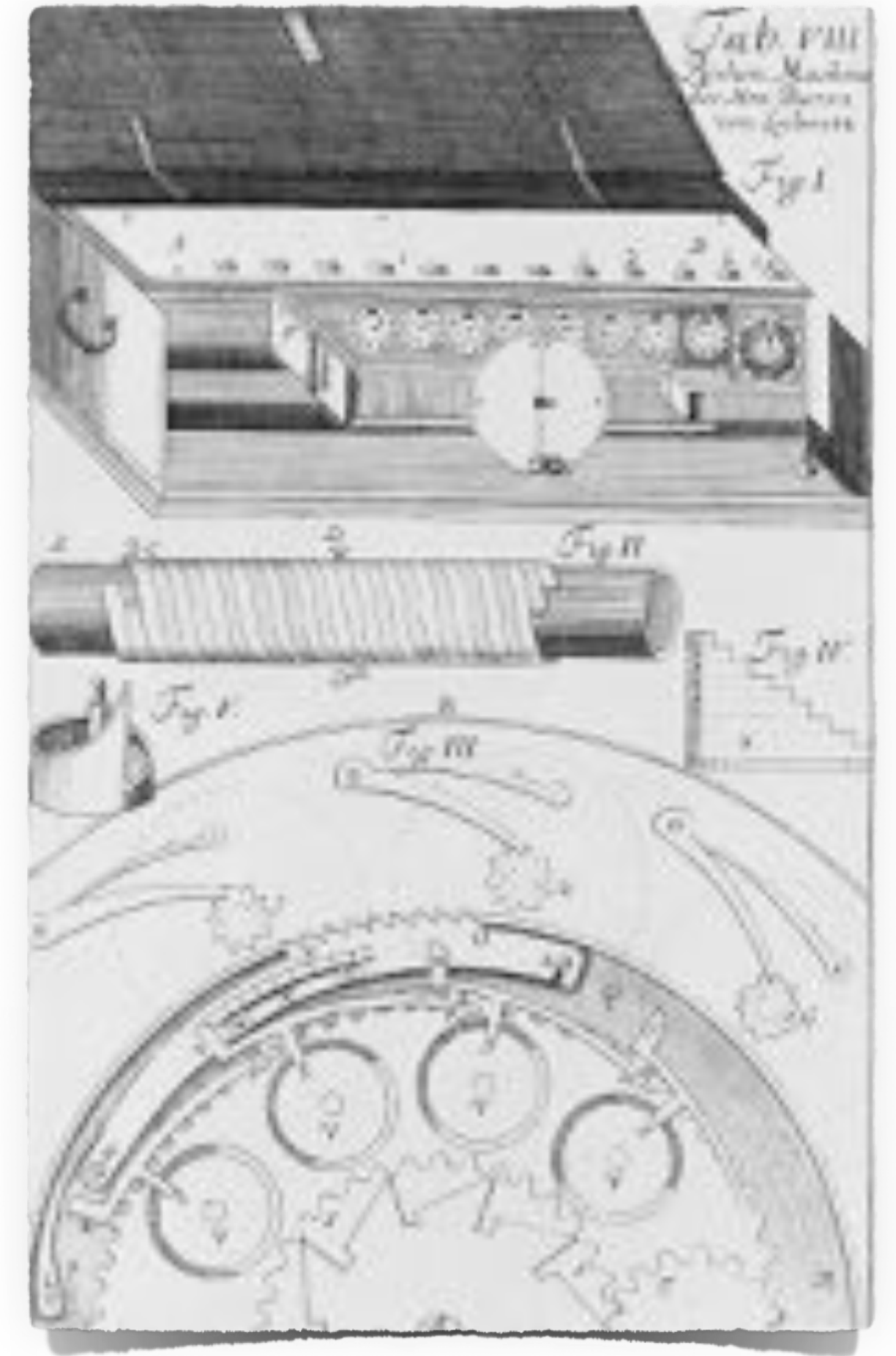
PLATO: *The Allegory of the Cave*

CREDIT: TED Ed



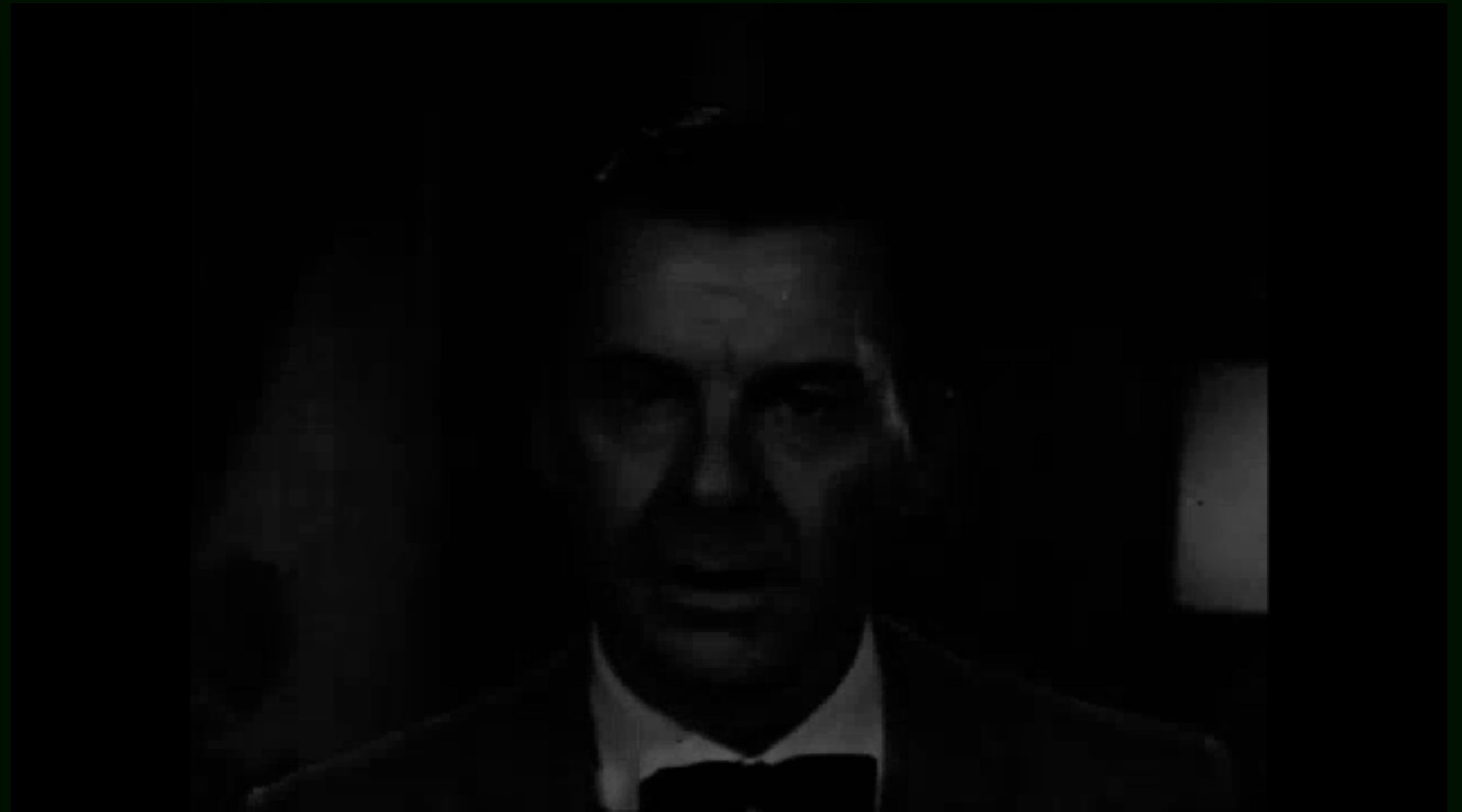
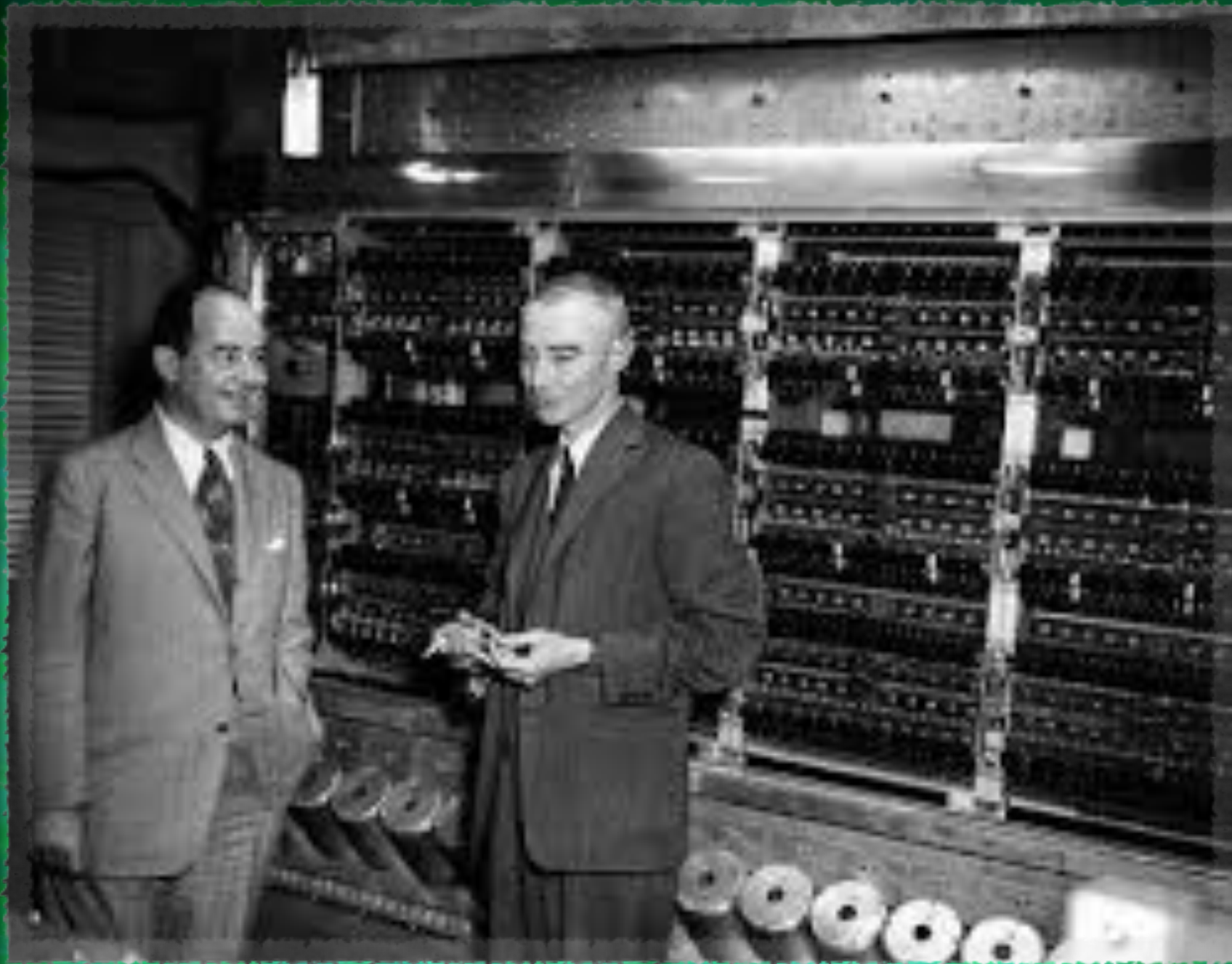
If **controversies** were to arise,
there would be no more need of disputation between
two philosophers than between **two accountants**.
For it would suffice to take their pencils in their hands,
and say to each other:

Calculemus—Let us calculate.



Euclid Descartes Russel Llull Hilbert Boole **Leibniz** Frege Newton Laplace Wittgenstein Turing Shannon

COMPUTING: The beginning..



1961

COMPUTERS

1981



1986



1988



1990



The Connection Machine

1992

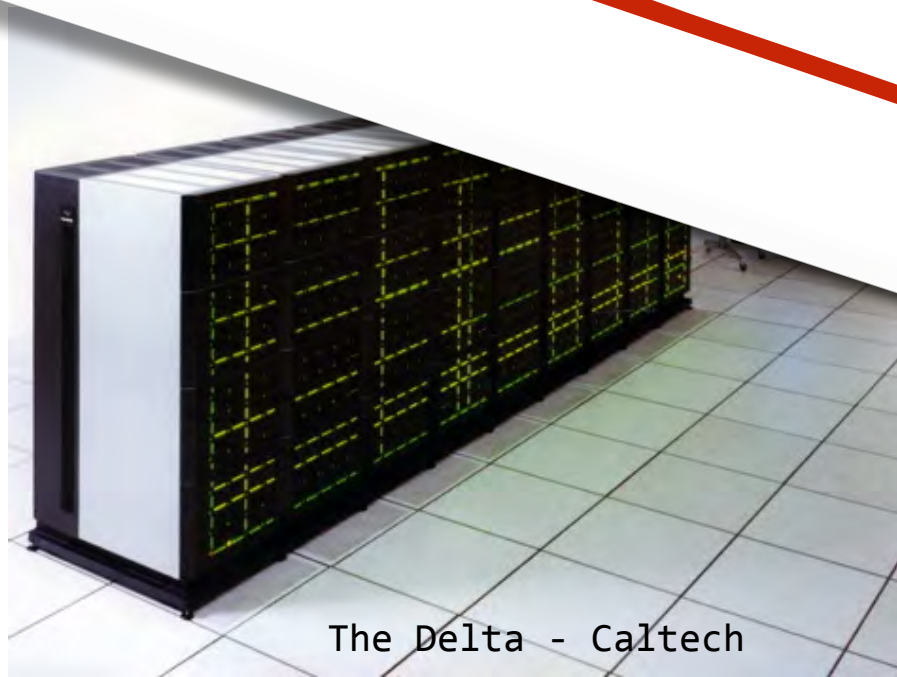


1992



CRAY X-MP - San Diego

1994



The Delta - Caltech

1996



Paragon - Caltech

1997



NEC SX-5

2013



2019



2020



©RIKEN

~1 Trillion X



nano macro

meso

WATER in CARBON NANOTUBES



SHOCK-BUBBLE INTERACTIONS



SCIENCE ADVANCES | RESEARCH ARTICLE

PHYSICS

Computing foaming flows across scales: From breaking waves to microfluidics

Petr Karnakov^{1,2}, Sergey Litvinov¹, Petros Koumoutsakos^{1,2*}

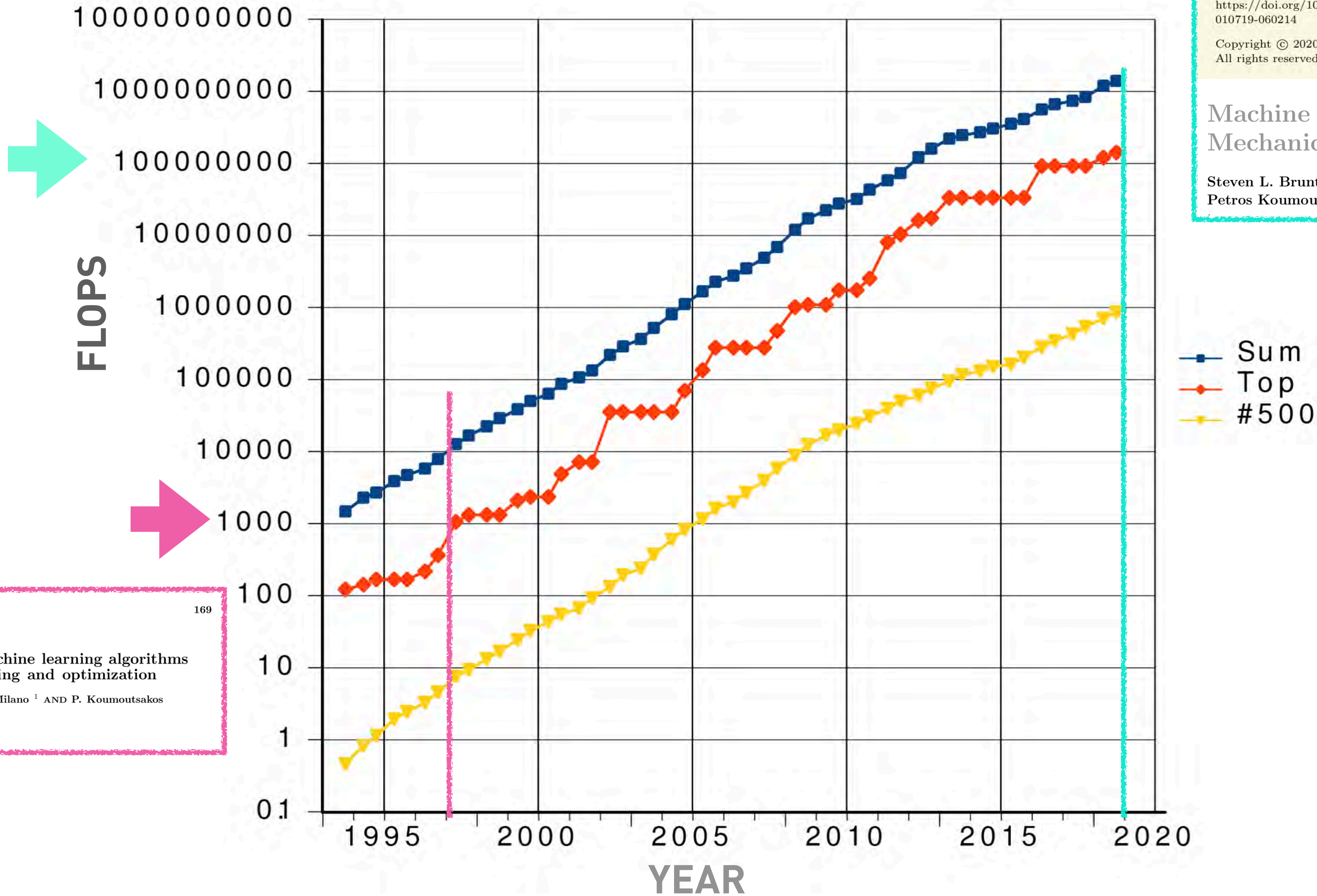
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1Y in 1997 ~ 3' in 2019

Annu. Rev. Fluid Mech. 2020. 52:1–31
<https://doi.org/10.1146/annurev-fluid-010719-060214>
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Machine Learning for Fluid Mechanics

Steven L. Brunton,¹ Bernd R. Noack,² and Petros Koumoutsakos^{3,4}



Center for Turbulence Research
Annual Research Briefs 1999 169

Application of machine learning algorithms to flow modeling and optimization

By S. Müller¹, M. Milano¹ AND P. Koumoutsakos

COMPUTERS : A Disruptive Technology

Deep Blue beat Kasparov

Posted by: Marco van der Spek Date: Oct 2, 2012

Category: Articles



<http://www.testnewsline.com/2012/10/02/deep-blue-beat-kasparov-because-of-bug/>

MindGoogle) winning Go against Lee Sedol, one of the world's top go players. March 11, 2016



ARTICLE

doi:10.1038/nature16961

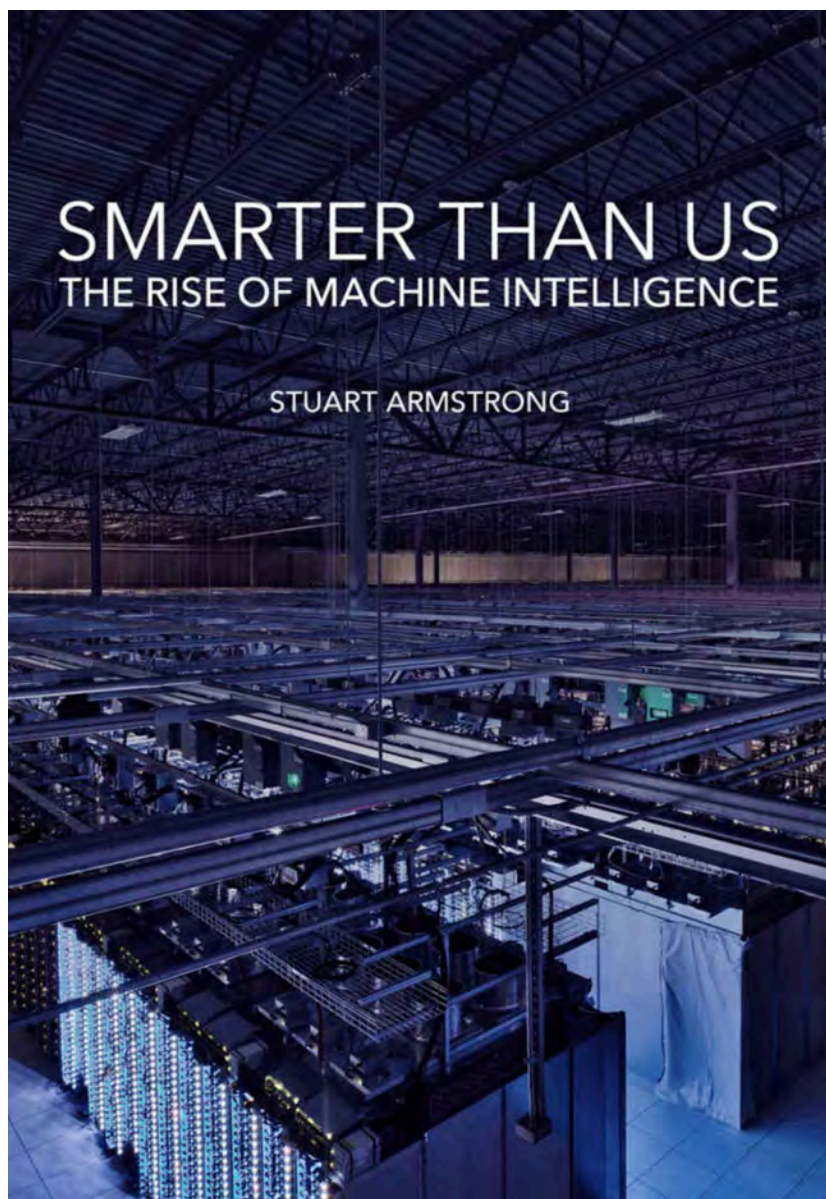
Mastering the game of Go with deep neural networks and tree search

David Silver^{1*}, Aja Huang^{1*}, Chris J. Maddison¹, Arthur Guez¹, Laurent Sifre¹, George van den Driessche¹, Julian Schrittwieser¹, Ioannis Antonoglou¹, Veda Panneershelvam¹, Marc Lanctot¹, Sander Dieleman¹, Dominik Grewe¹, John Nham², Nal Kalchbrenner¹, Ilya Sutskever², Timothy Lillicrap¹, Madeleine Leach¹, Koray Kavukcuoglu¹, Thore Graepel¹ & Demis Hassabis¹

SCIENCE FILE - Los Angeles Times
9 March 2017

**No need for a poker face -
Software program DeepStack
beats the pros at Texas Hold 'Em**

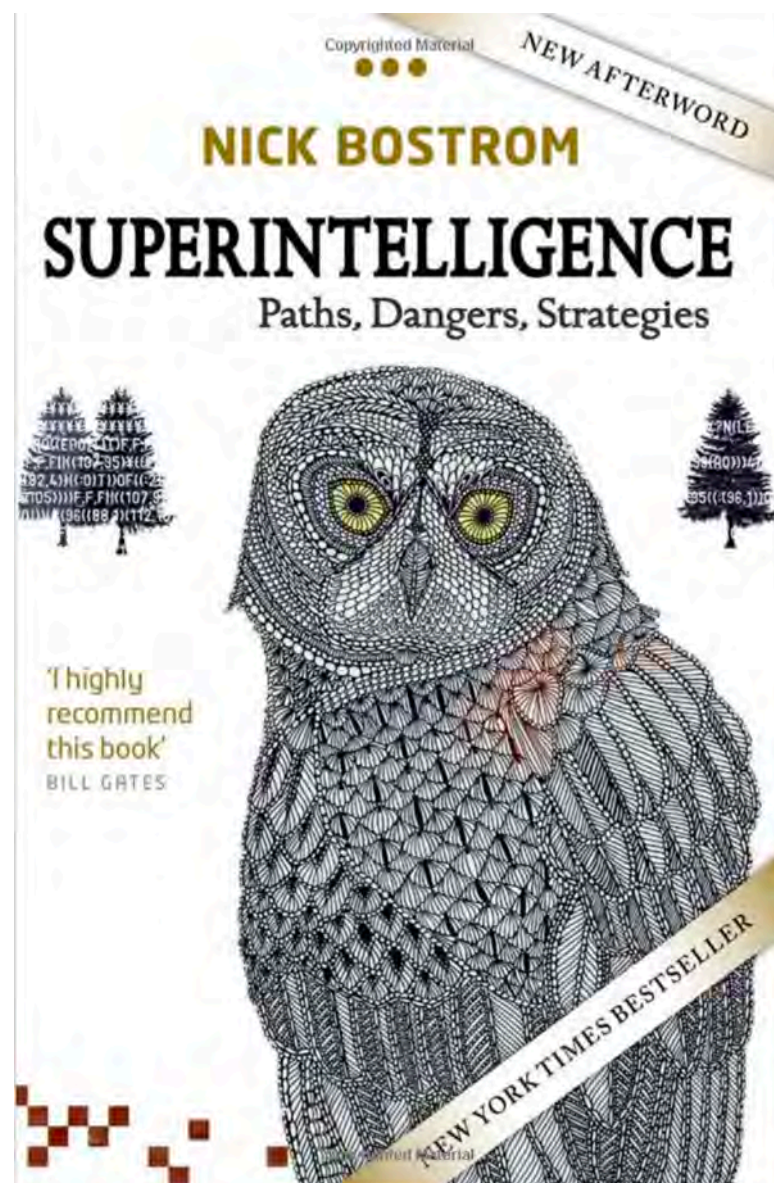




SMARTER THAN US

THE RISE OF MACHINE INTELLIGENCE

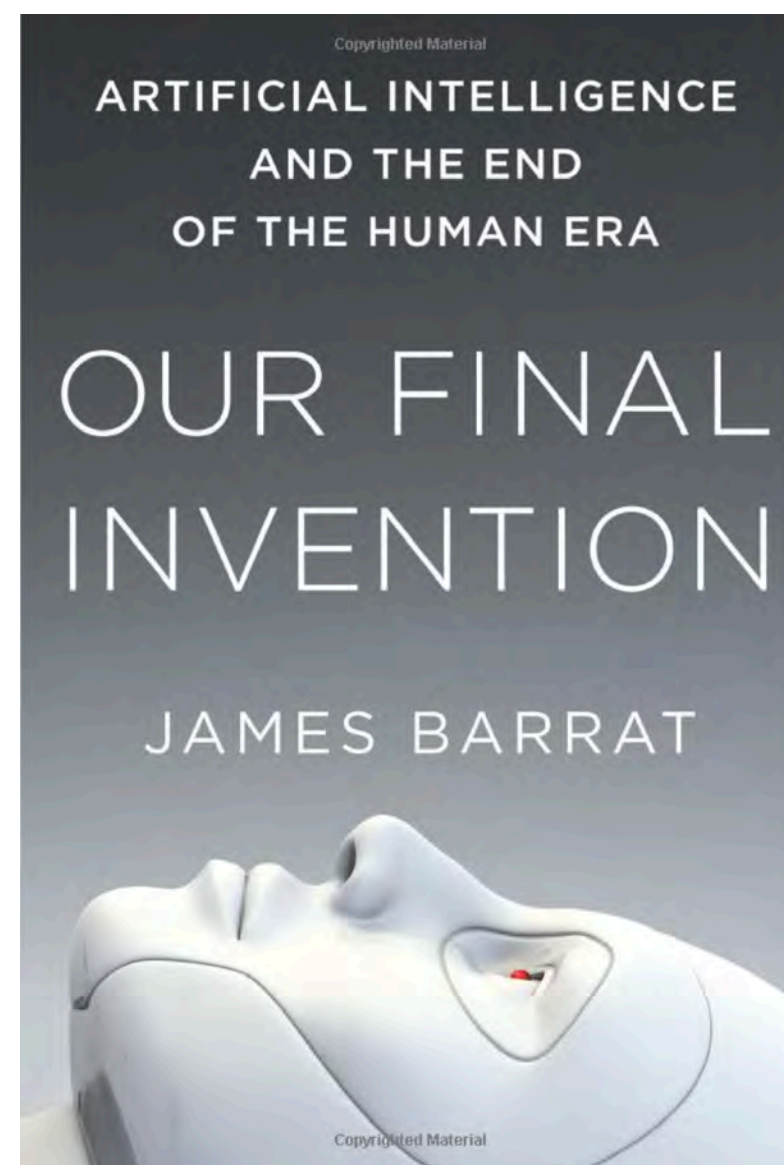
STUART ARMSTRONG



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NEW AFTERWORD
NICK BOSTROM
SUPERINTELLIGENCE
Paths, Dangers, Strategies

'I highly recommend this book'
BILL GATES

NEW YORK TIMES BESTSELLER



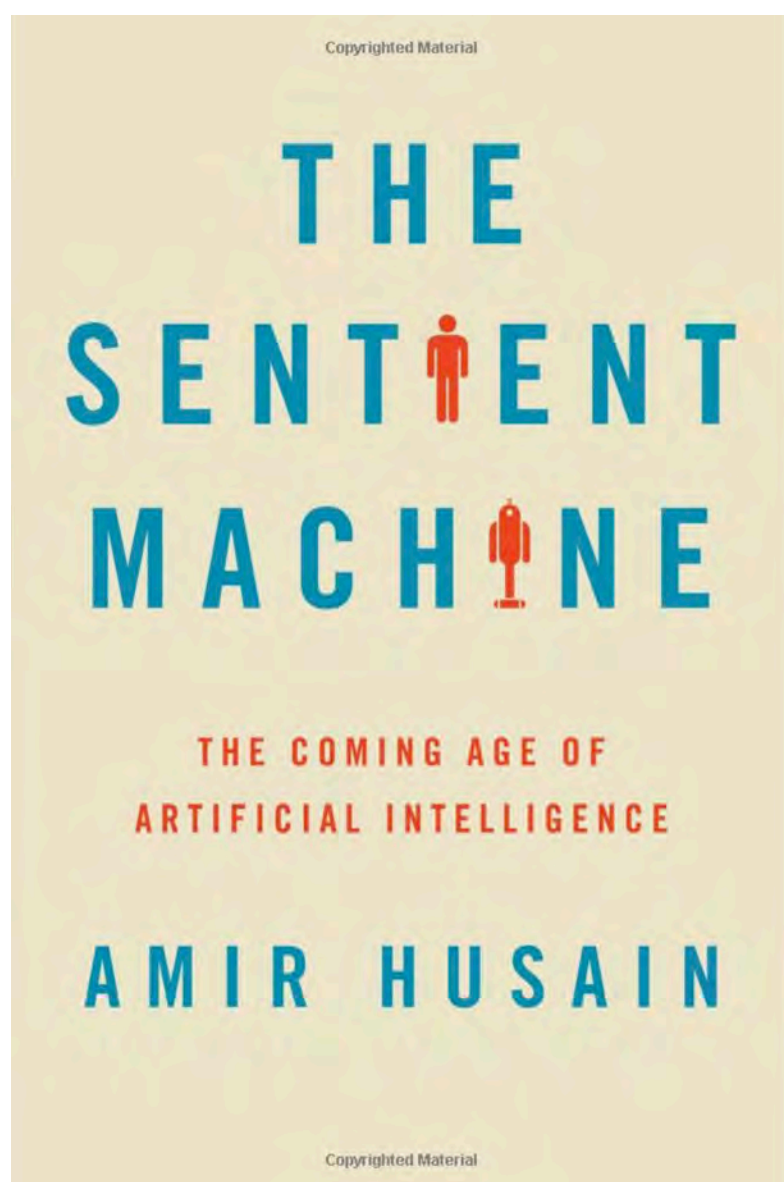
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ARTIFICIAL INTELLIGENCE
AND THE END
OF THE HUMAN ERA

OUR FINAL INVENTION

JAMES BARRAT



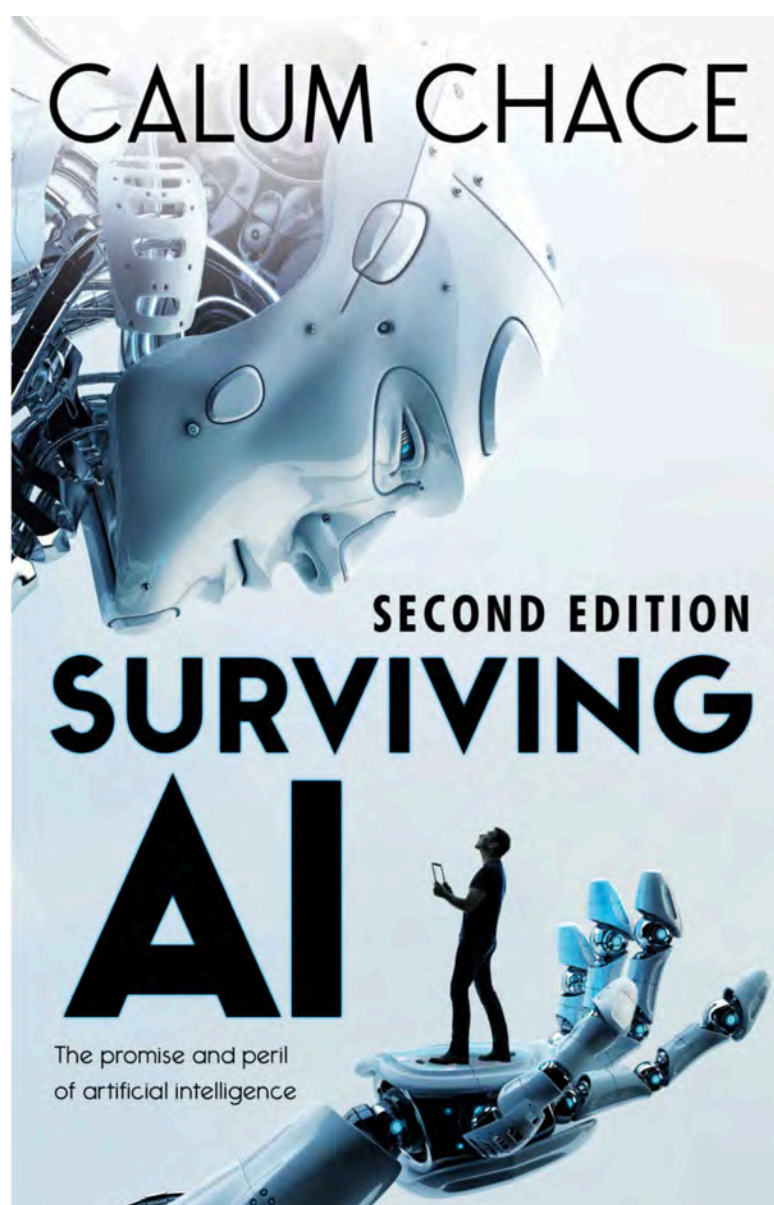
AI is humanity's
biggest existential
threat



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THE SENTIENT MACHINE

THE COMING AGE OF
ARTIFICIAL INTELLIGENCE

AMIR HUSAIN

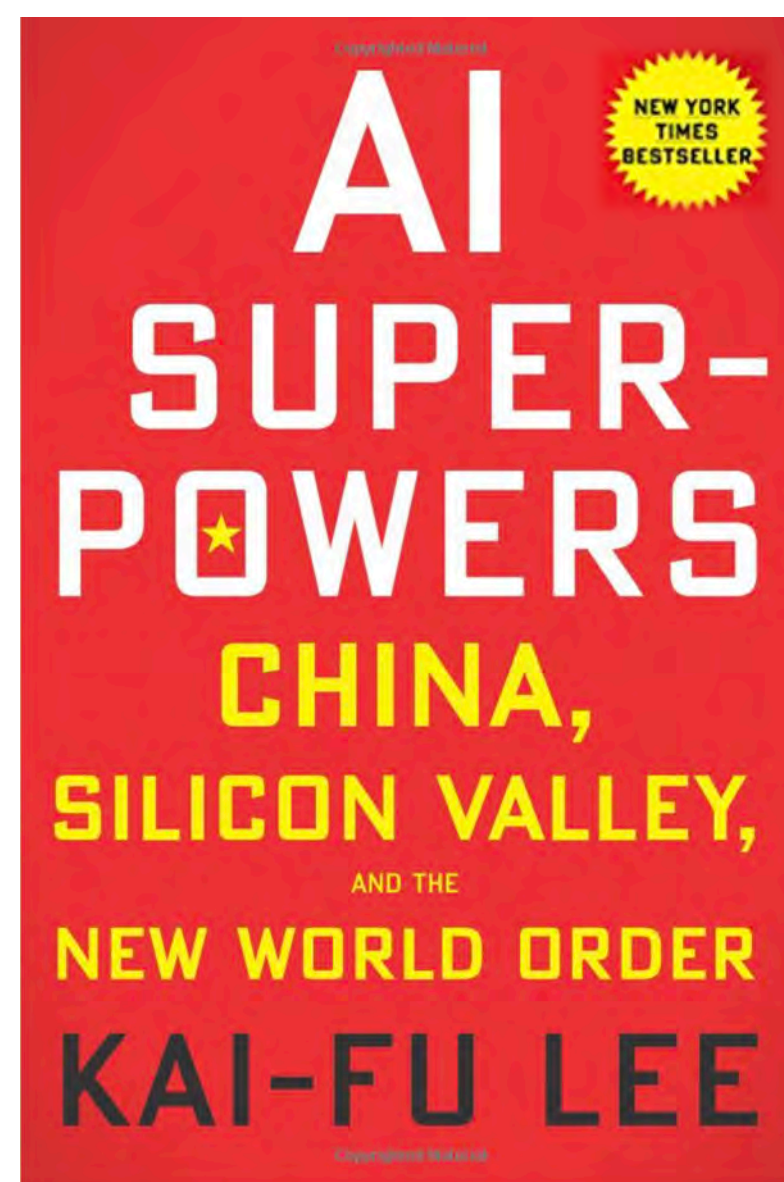


CALUM CHACE

SECOND EDITION

SURVIVING AI

The promise and peril
of artificial intelligence



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AI SUPER-POWERS

NEW YORK TIMES BESTSELLER

CHINA, SILICON VALLEY, AND THE NEW WORLD ORDER
KAI-FU LEE



AI is transformative, ...
worst or best thing that
ever happened to our
civilizations -
we just don't know

...computers have made arithmetic cheap.

Solving complex equations is done more easily and in less time ..

- ▶ **What will AI technology make cheap ?
Prediction.**
- ▶ **Prediction is central to decision-making
under uncertainty**
- ▶ **Better prediction under uncertainty ->
new opportunities for all companies**

HARVARD BUSINESS REVIEW PRESS

Prediction Machines



The Simple Economics of
Artificial Intelligence

AJAY
AGRAWAL

JOSHUA
GANS

AVI
GOLDFARB

Whereas others see transformational new innovation, we see a simple fall in price.

Economists keep promising us a productivity miracle from information technology, **most recently AI.**

BUT

the annual average growth rate of productivity in the U.S. nonfarm business has been **stuck at just 1.5 percent since 2007**, only marginally better than the dismal years 1973–1980.



WHAT IS
Artificial Intelligence
?

What is Artificial Intelligence ?

THINK LIKE HUMANS - Bellman 1978

"The automation of activities that we associate with human thinking, activities such as decision-making, problem solving, learning ..."

ACT LIKE HUMANS - Rich and Knight, 1991

"The study of how to make computers do things at which, at the moment, people are better"

THINK RATIONALLY - Winston 1992

"The study of the computations that make it possible to perceive, reason, and act"

ACT RATIONALLY - Schalkoff, 1990

"A field of study that seeks to explain and emulate intelligent behavior in terms of computational processes"

The Human Mind: Needs Help

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BOOKS FEBRUARY 27, 2017 ISSUE

WHY FACTS DON'T CHANGE OUR MINDS

New discoveries about the human mind show the limitations of reason.

By Elizabeth Kolbert

The vaunted human capacity for reason may have more to do with winning arguments than with thinking straight.

Why We Believe Obvious Untruths

Gray Matter

By PHILIP FERNBACH and STEVEN SLOMAN MARCH 3, 2017 - The New York Times

What really sets human beings apart is not our individual mental capacity. The secret to our success is our ability to jointly pursue complex goals by dividing cognitive labor. Hunting, trade, agriculture, manufacturing — all of our world-altering innovations — were made possible by this ability. Each of us knows only a little bit, but together we can achieve remarkable feats.



Illustration by Gérard DuBois

[Submitted on 20 May 2024]

Metacognitive Capabilities of LLMs: An Exploration in Mathematical Problem Solving

Aniket Didolkar, Anirudh Goyal, Nan Rosemary Ke, Siyuan Guo, Michal Valko, Timothy Lillicrap, Danilo Rezende, Yoshua Bengio, Michael Mozer, Sanjeev Arora

Metacognitive knowledge refers to humans' intuitive knowledge of their own thinking and reasoning processes. Today's best LLMs clearly possess some reasoning processes. The paper gives evidence that they also have metacognitive knowledge, including ability to name skills and procedures to apply given a task. We explore this primarily in context of math reasoning, developing a prompt-guided interaction procedure to get a powerful LLM to assign sensible skill labels to math questions, followed by having it perform semantic clustering to obtain coarser families of skill labels. These coarse skill labels look interpretable to humans.

To validate that these skill labels are meaningful and relevant to the LLM's reasoning processes we perform the following experiments. (a) We ask GPT-4 to assign skill labels to training questions in math datasets GSM8K and MATH. (b) When using an LLM to solve the test questions, we present it with the full list of skill labels and ask it to identify the skill needed. Then it is presented with randomly selected exemplar solved questions associated with that skill label. This improves accuracy on GSM8k and MATH for several strong LLMs, including code-assisted models. The methodology presented is domain-agnostic, even though this article applies it to math problems.

What is Intelligence ?



Intelligence is the computational part of the ability to achieve goals in the world.

A system having a goal or not, is not a property of the system itself. It is in the **relationship between the system and an observer.**

The system is most usefully understood/predicted/controlled in terms of **its outcomes rather than its mechanisms.**

Deep learning's Big Bang moment.

ImageNet Classification with Deep Convolutional Neural Networks

Alex Krizhevsky
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University of Toronto
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Geoffrey E. Hinton
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hinton@cs.utoronto.ca

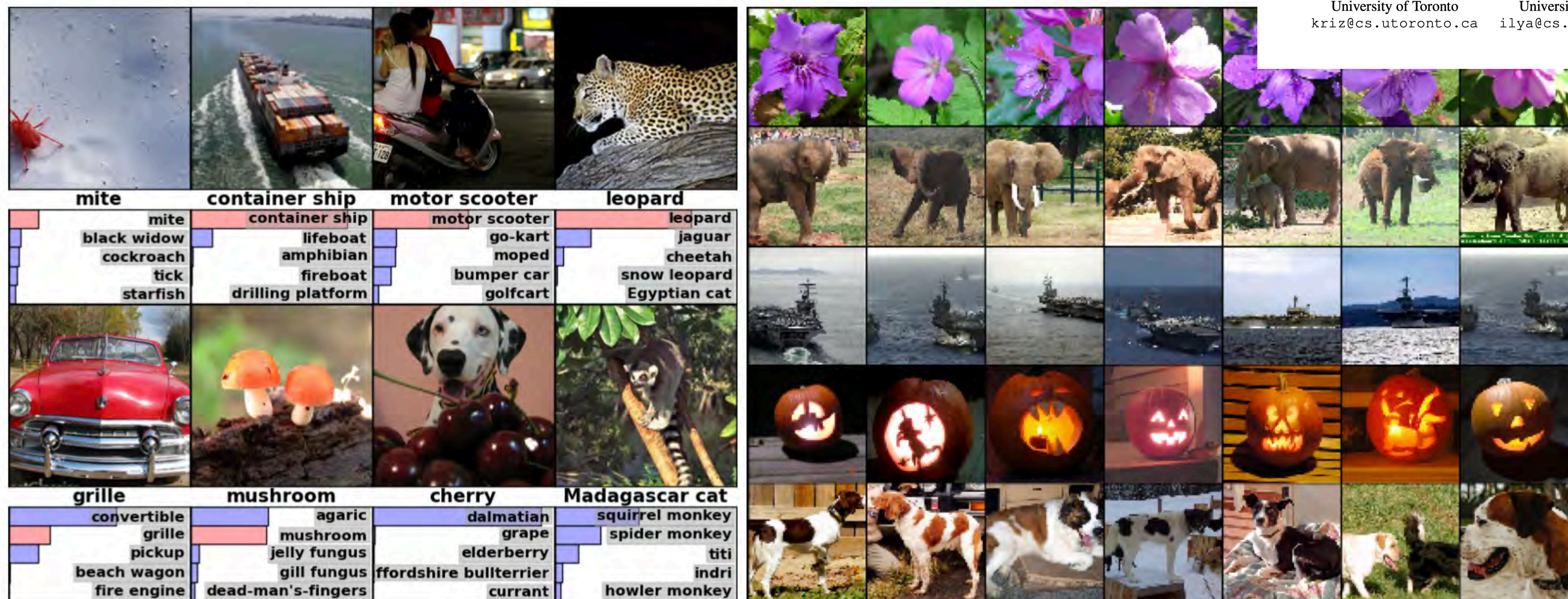


Figure 4: **(Left)** Eight ILSVRC-2010 test images and the five labels considered most probable by our model. The correct label is written under each image, and the probability assigned to the correct label is also shown with a red bar (if it happens to be in the top 5). **(Right)** Five ILSVRC-2010 test images in the first column. The remaining columns show the six training images that produce feature vectors in the last hidden layer with the smallest Euclidean distance from the feature vector for the test image.

JPMorgan Software Does in Seconds What Took Lawyers 360,000 Hours

by **Hugh Son**

February 27, 2017, 7:31 PM EST Updated on February 28, 2017, 7:24 AM EST

- New software does in seconds what took staff 360,000 hours
- Bank seeking to streamline systems, avoid redundancies

At JPMorgan Chase & Co., a learning machine is parsing financial deals that once kept legal teams busy for thousands of hours. The program, called COIN, for Contract Intelligence, does the mind-numbing job of interpreting commercial-loan agreements that, until the project went online in June, consumed 360,000 hours of work each year by lawyers and loan officers. The software reviews documents in seconds, is less error-prone and never asks for vacation.

NATURE | LETTER



日本語要約

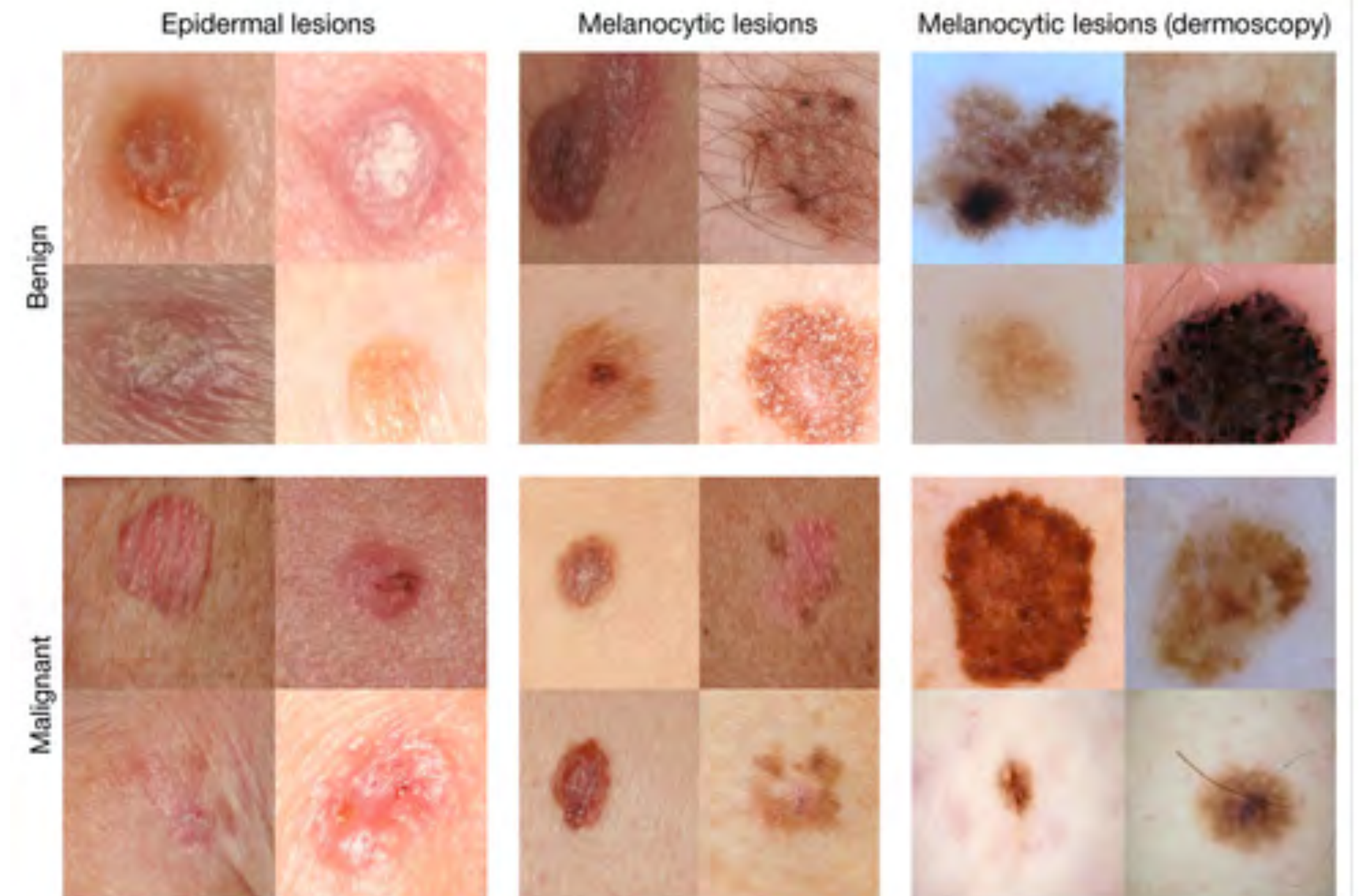
Dermatologist-level classification of skin cancer with deep neural networks

Andre Esteva, Brett Kuprel, Roberto A. Novoa, Justin Ko, Susan M. Swetter, Helen M. Blau & Sebastian Thrun

[Affiliations](#) | [Contributions](#) | [Corresponding authors](#)

Nature 542, 115–118 (02 February 2017) | doi:10.1038/nature21056

Received 28 June 2016 | Accepted 14 December 2016 | Published online 25 January 2017



DATA

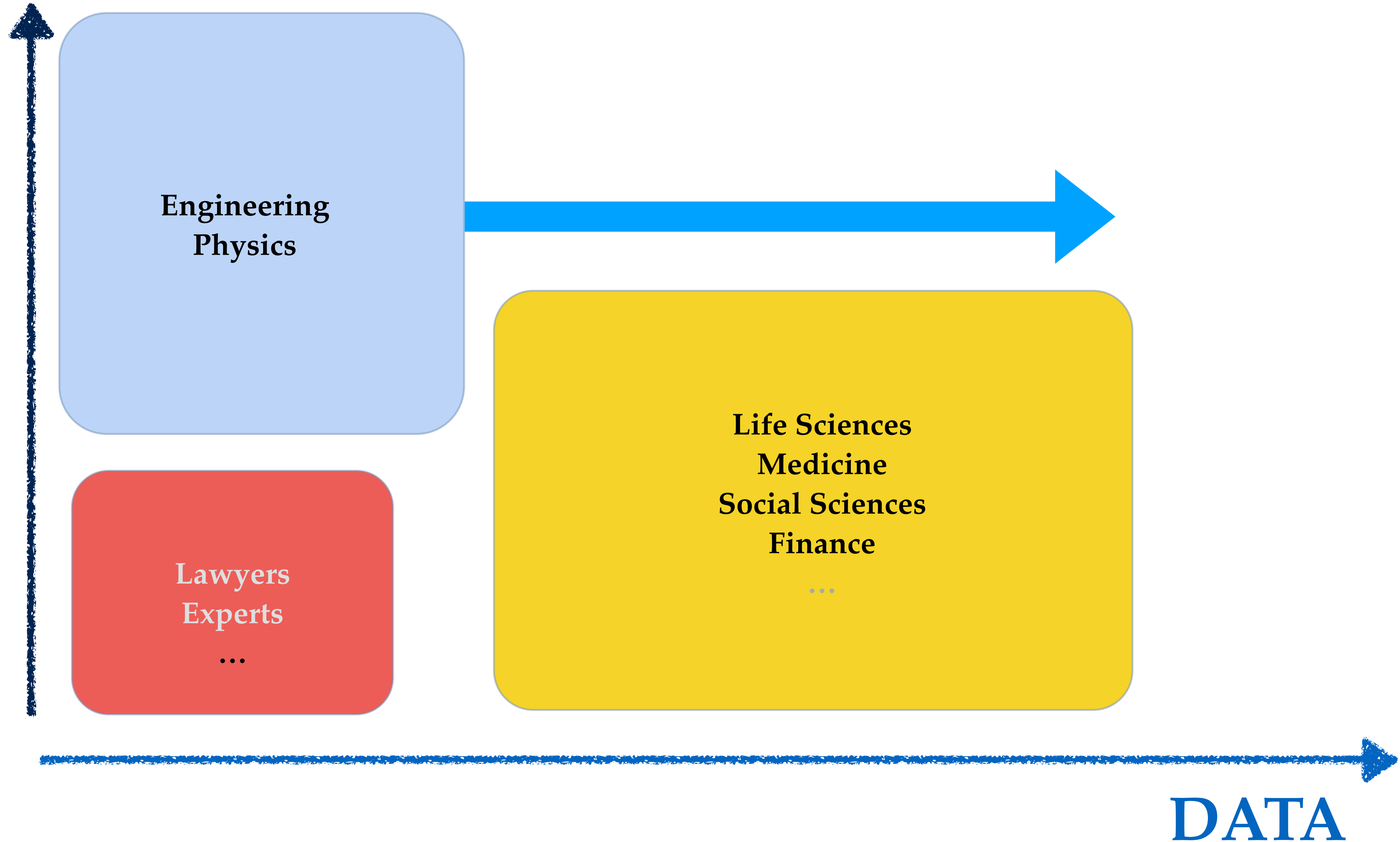


2017:
5B Devices
1B people

2020:
32B Devices
2B people

SOLVING PROBLEMS

FIRST PRINCIPLES

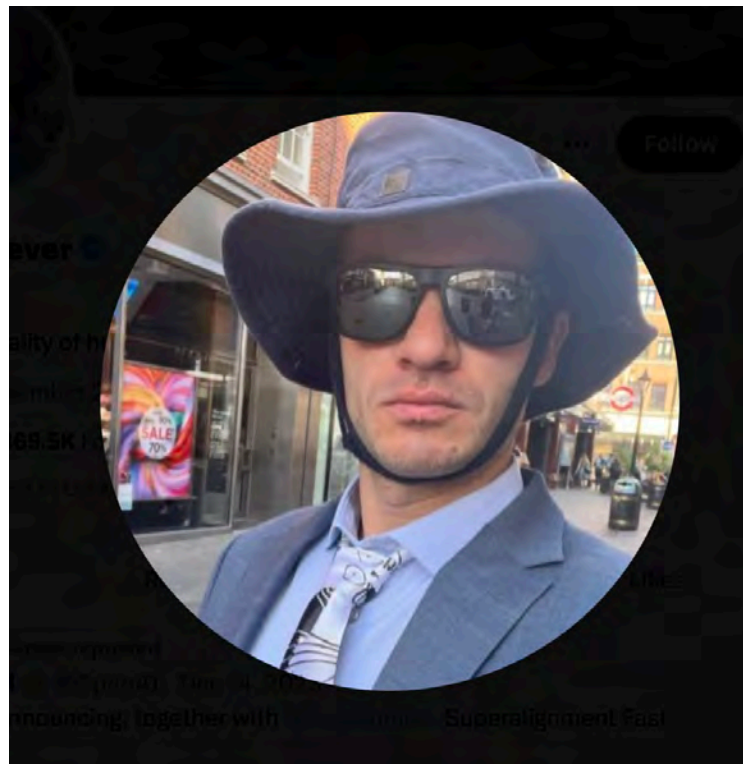


How to solve hard problems?

Use lots of training data.

And a big deep neural network.

And success is the only possible outcome.








Ilya Sutskever (2015),
co-founder of OpenAI

FOUNDATIONAL MODELS

Foundation models are AI neural networks trained on massive unlabeled datasets to handle a wide variety of jobs from translating text to analyzing medical images.

Data

- Text 
- Images 
- Speech 
- Structured Data 
- 3D Signals 


Training

Foundation Model



Adaptation

Tasks

Question Answering 

Sentiment Analysis 



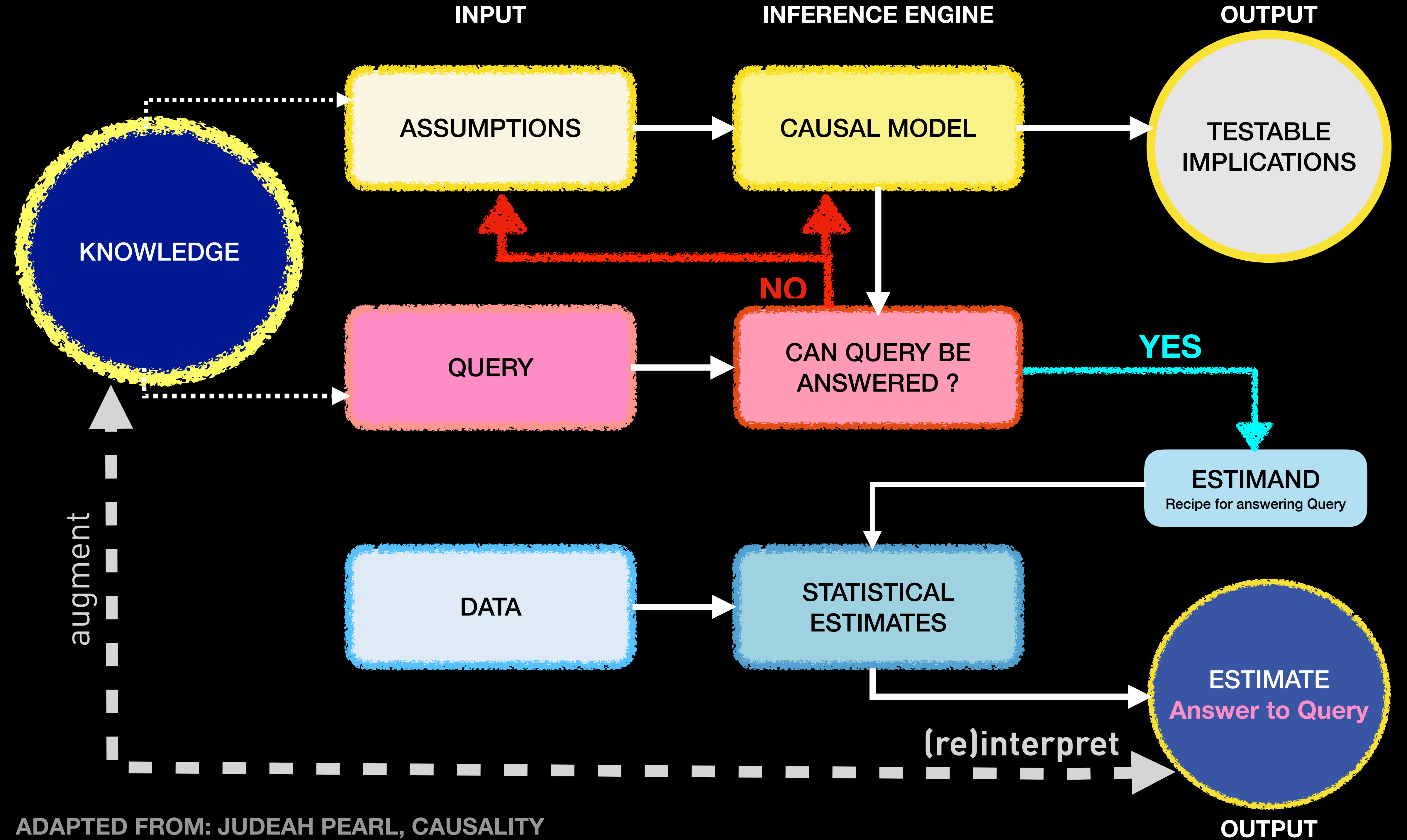
Information Extraction 

Image Captioning 

Object Recognition 

Instruction Following 



ADAPTED FROM: JUDEAH PEARL, CAUSALITY

CLOSING THOUGHTS

Comment

<https://doi.org/10.1038/s42254-024-00726-z>

On roads less travelled between AI and computational science

Petros Koumoutsakos

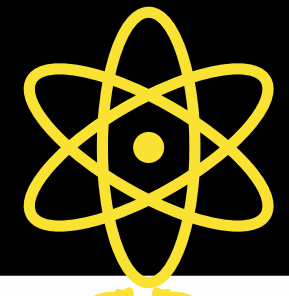
 Check for updates

Computational science and artificial intelligence have been drivers and benefactors of advances in algorithms and hardware, each in different ways, and originally with different targets. Petros Koumoutsakos argues that the intellectual space between these two fields is home to exciting opportunities for scientific discovery.

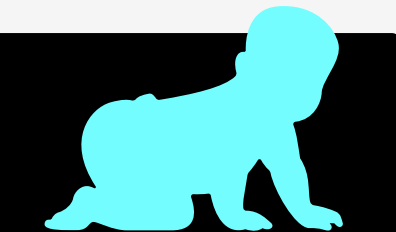
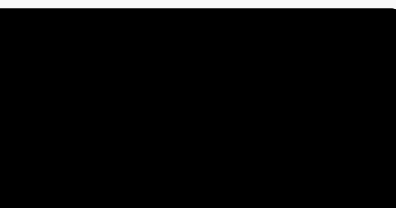
'importance sampling'. There are plenty of opportunities for cross-fertilizing exchanges in algorithms and their applications. Similarly, stochastic and gradient optimization methods have been developed across both communities, but recent works on automatic differentiation indicate that the paths are intersecting again. The emergence and homogenization properties of foundational models that are gaining ground in AI also have counterparts in CoS where emergence is often the outcome of nonlinear differential equations, whereas the concept of homogenization can be recognized for example in particle simulations of phenomena ranging from atoms to galaxies³. At the same time the paths of scientific inquiry in AI and CoS may diverge, but I argue that repeated intersection can be exciting. There are many problems where

THE LADDER OF CAUSATION

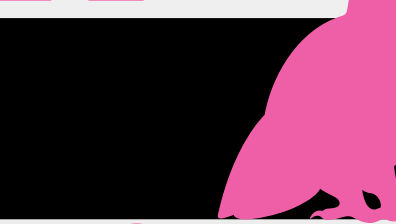
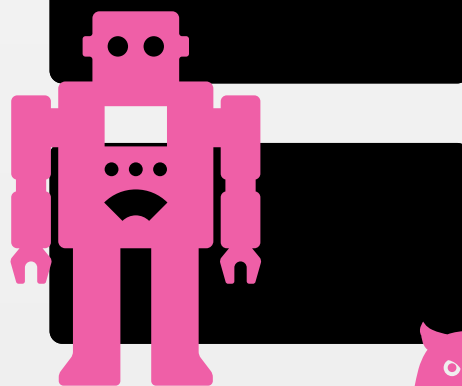
(adapted from the “Book of Why” by J. Pearl)



IMAGINE



DO



SEE

III. COUNTER FACTUALS

ACT: **Imagining, Retrospection, Understanding**

ASK: *What if I had done ... ? Why ?*

Did X cause Y ? What if I acted differently ?

What if X had not occurred ?

EXAMPLE:

Was it the aspirin that stopped my headache ?

II. INTERVENTION

ACT: **Doing, Intervening**

ASK: *What if I do ... ? How ?*

How can I make D ?

How would D be if I do H ?

EXAMPLE:

What if I take aspirin ?

I. ASSOCIATION

ACT: **Seeing, Observing**

ASK: *What if I see ... ?*

How are variables related ?

How would seeing D change my belief in H ?

EXAMPLE:

I sneeze -did I catch a cold ?

Artificial Intelligence to Assist Mathematical Reasoning



Proceedings of a Workshop

PLANNING COMMITTEE ON ARTIFICIAL INTELLIGENCE TO ASSIST MATHEMATICAL REASONING: A WORKSHOP

PETROS KOUMOUTSAKOS (NAE), Harvard University, *Chair*

JORDAN ELLENBERG, University of Wisconsin–Madison

MELVIN GREER, Intel Corporation

BRENDAN HASSETT, Brown University

YANN LECUN (NAS/NAE), Meta Platforms, Inc.; New York University

HEATHER MACBETH, Fordham University

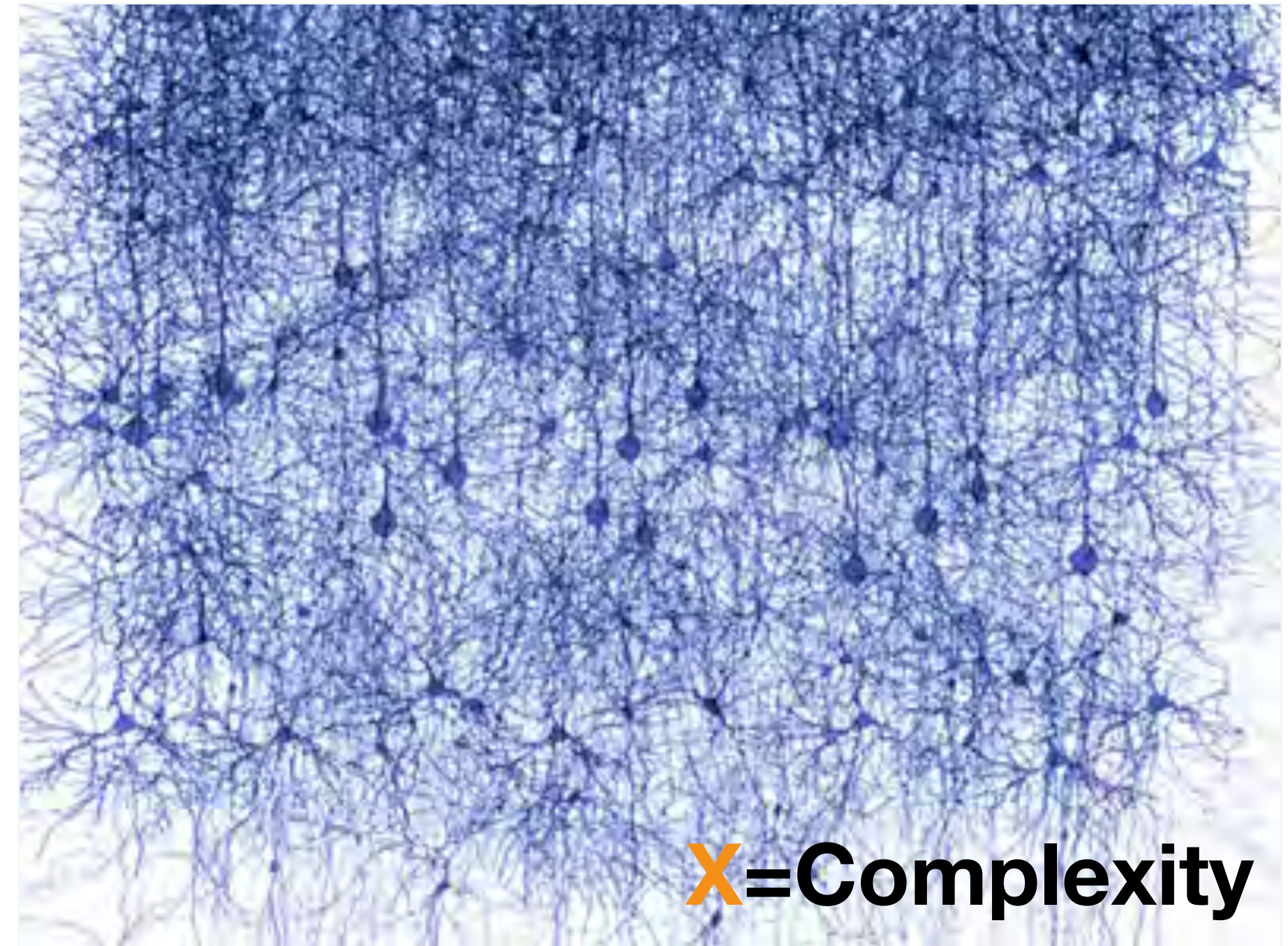
TALIA RINGER, University of Illinois at Urbana-Champaign

KAVITHA SRINIVAS, IBM Research

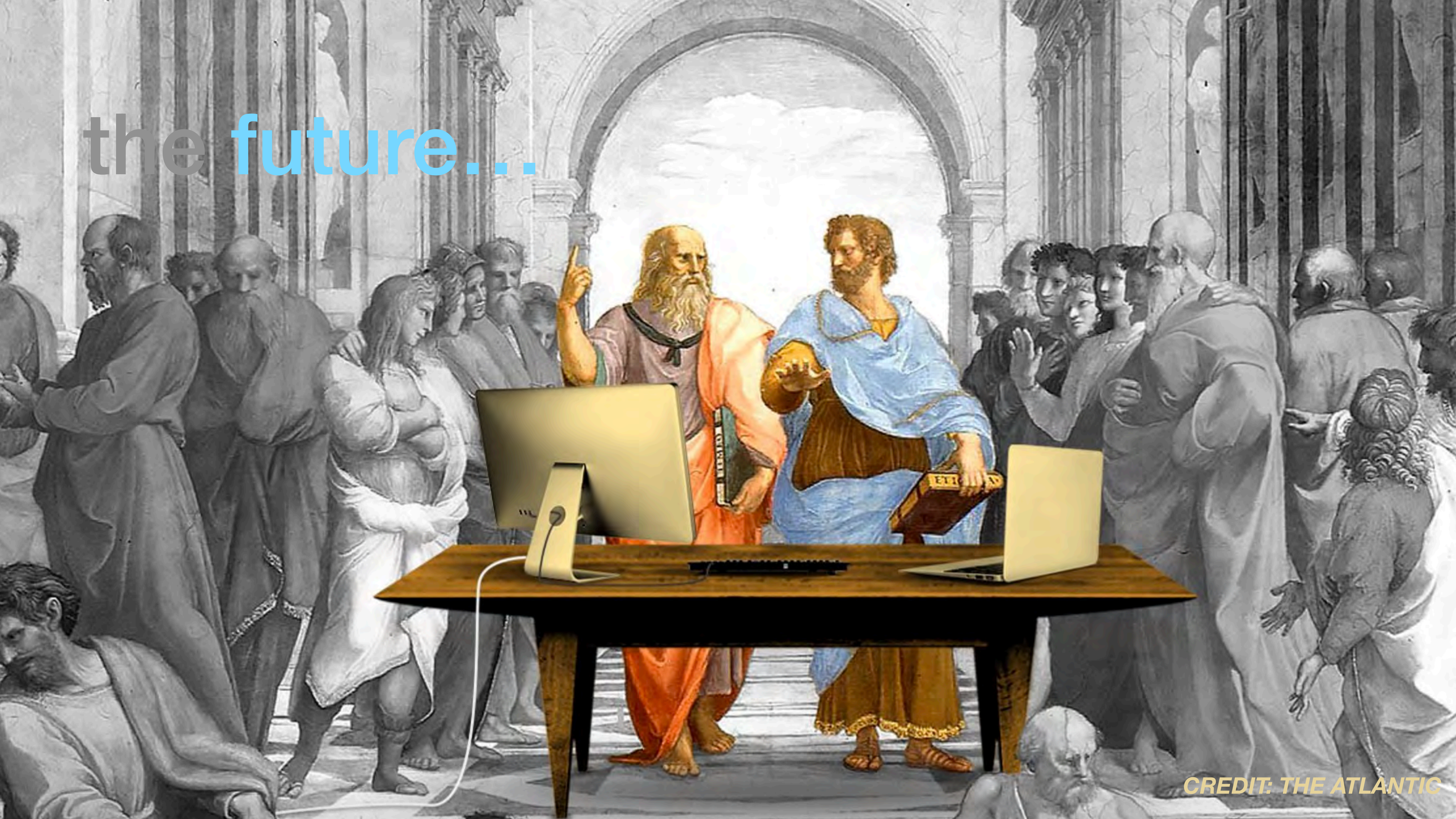
TERENCE TAO (NAS), University of California, Los Angeles

AI + COMPUTING + THINKING

for X



the future...



CREDIT: THE ATLANTIC

THANK YOU !