

Einführung in die Künstliche Intelligenz

Teacher

Prof. Kristian Kersting (Artificial Intelligence and
Machine Learning) and Dr. Martin Mundt

Homepage

see link to Moodle sent via TUCAN

Time

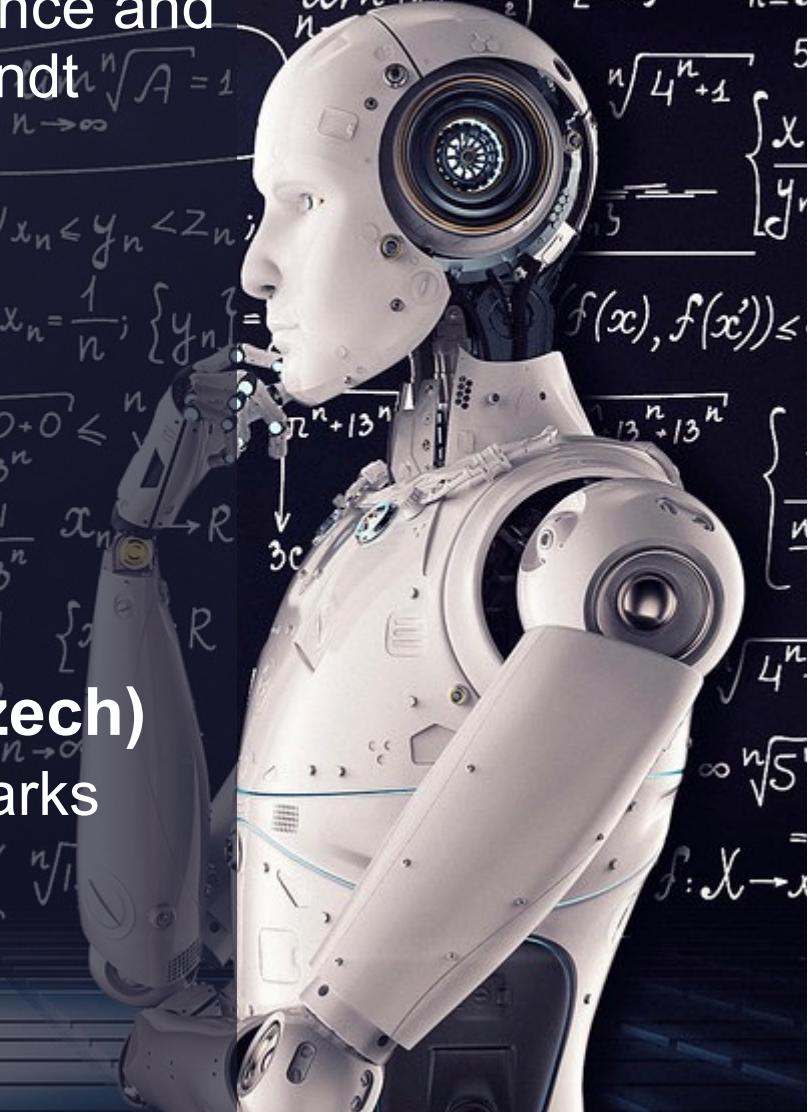
Wednesday 16:15 -17:55

2 VO + 1 UE

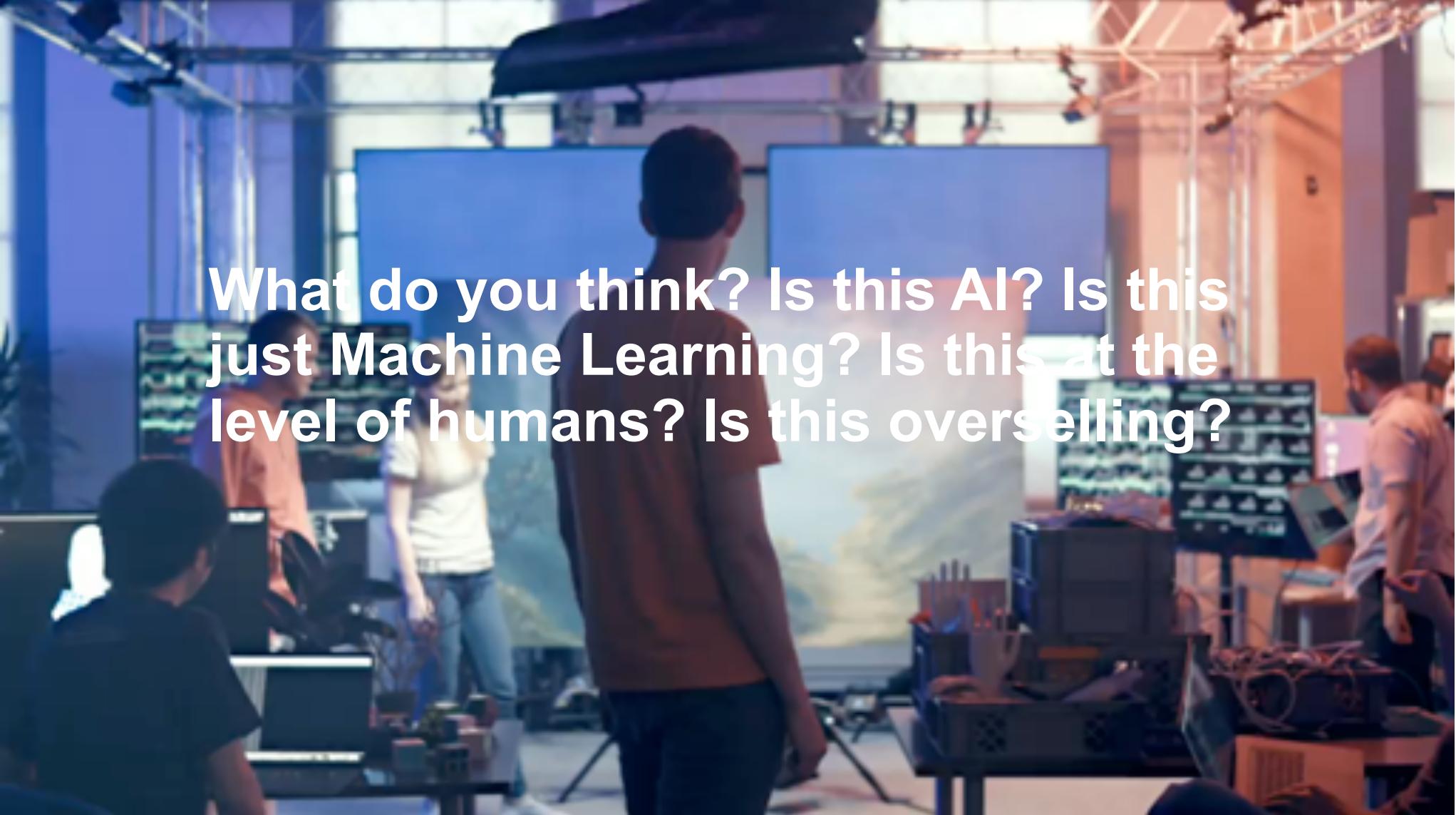
Lectures and exercises will be each 2h

Übungen (Karl Stelzner, Johannes Czech)

Just presentation of solutions, no (re)marks



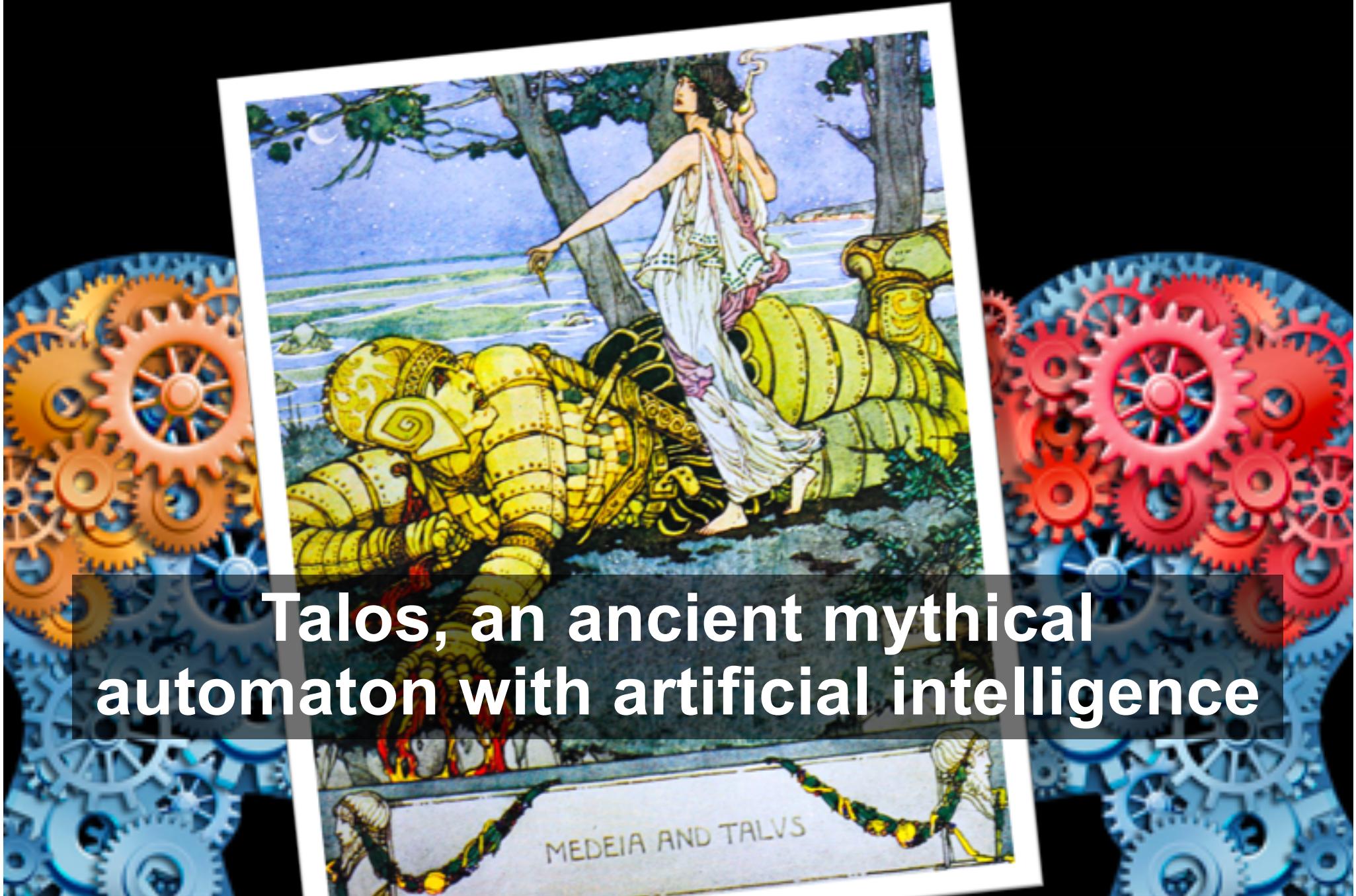
Solving Rubik's Cube?



What do you think? Is this AI? Is this just Machine Learning? Is this at the level of humans? Is this overselling?

OpenAI: <https://www.youtube.com/watch?v=x4O8pojMF0w>

The dream of AI is not new



The dream of an artificially intelligent entity is not new

The image consists of two main parts. On the left, there is a screenshot of a website. At the top, it says "ZEIT ONLINE". Below that is a navigation bar with links to "Politik", "Gesellschaft", "Wirtschaft", "Kultur", "Wissen", "Digital Campus", "Arbeit", "Entdecken", "Sport", "ZEITmagazin", "Podcasts", and "mehr". There is also a search bar and a "Z+" button. The main headline in the center of the screenshot reads "Gottfried Wilhelm Leibniz" and "Er wollte die Welt mit Intelligenz in den Griff bekommen". Below the headline is a quote: "... die aber mache nicht mit. Was wir dennoch von Gottfried Wilhelm Leibniz lernen können - 300 Jahre nach dem Tod dieses letzten deutschen Universalgenies." To the right of the screenshot is a black and white portrait of Gottfried Wilhelm Leibniz, showing his face and curly hair. The background of the entire image features a pattern of interlocking gears in blue and orange.

Leibniz „philosophises about ‘artificial intelligence’ (AI). In order to prove the impossibility of thinking machines, Leibniz imagines of ‘a machine from whose structure certain thoughts, sensations, perceptions emerge“ — Gero von Radow, ZEIT 44/2016

AI today

the INQUIRER

Artificial intelligence will create the next industrial revolution, experts claim

We won't waste time on treatments that won't work, so the patient should get

Jane Kirby | 23 hours ago | 0 comments

Telegraph

Lifestyle > Cars > News

Self-driving Tesla 'saved' by steering him to hospital



V/S

Elon Musk @elonmusk

I've talked to Mark about this. His understanding of the subject is limited.

BBC NEWS

Technology

Stephen Hawking warns artificial intelligence could end mankind

Humans, who are limited by slow biological evolution, couldn't compete and would be

SCIENTIFIC AMERICAN DECEMBER 2016

Computers Now Recognize Patterns Better Than Humans Can

An approach to artificial intelligence that enables computers to recognize visual patterns better than humans are able to do

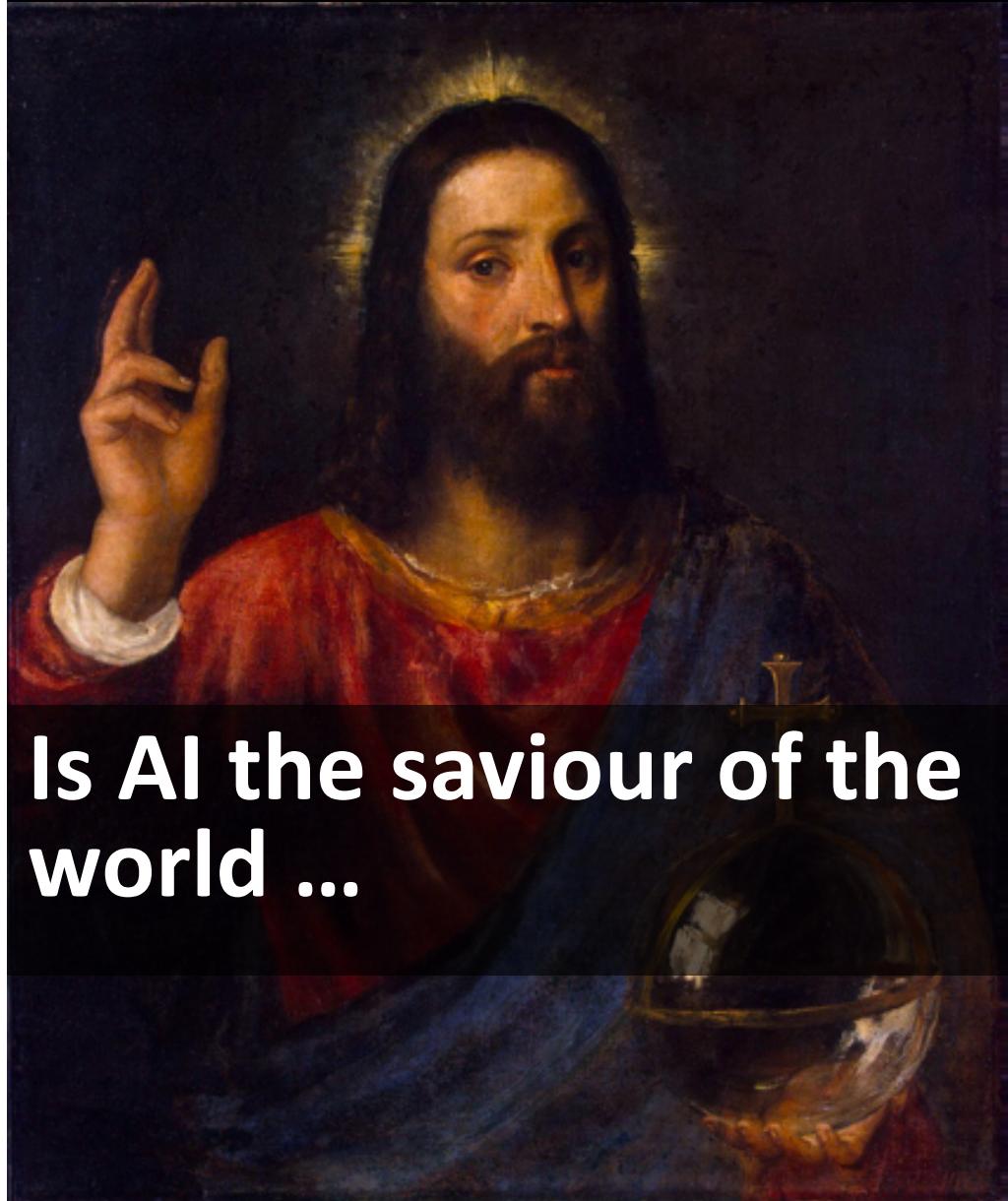
AI today

THE ECONOMIC IMPACT OF ARTIFICIAL INTELLIGENCE



Source: PwC

So, AI has many faces



Is AI the saviour of the world ...

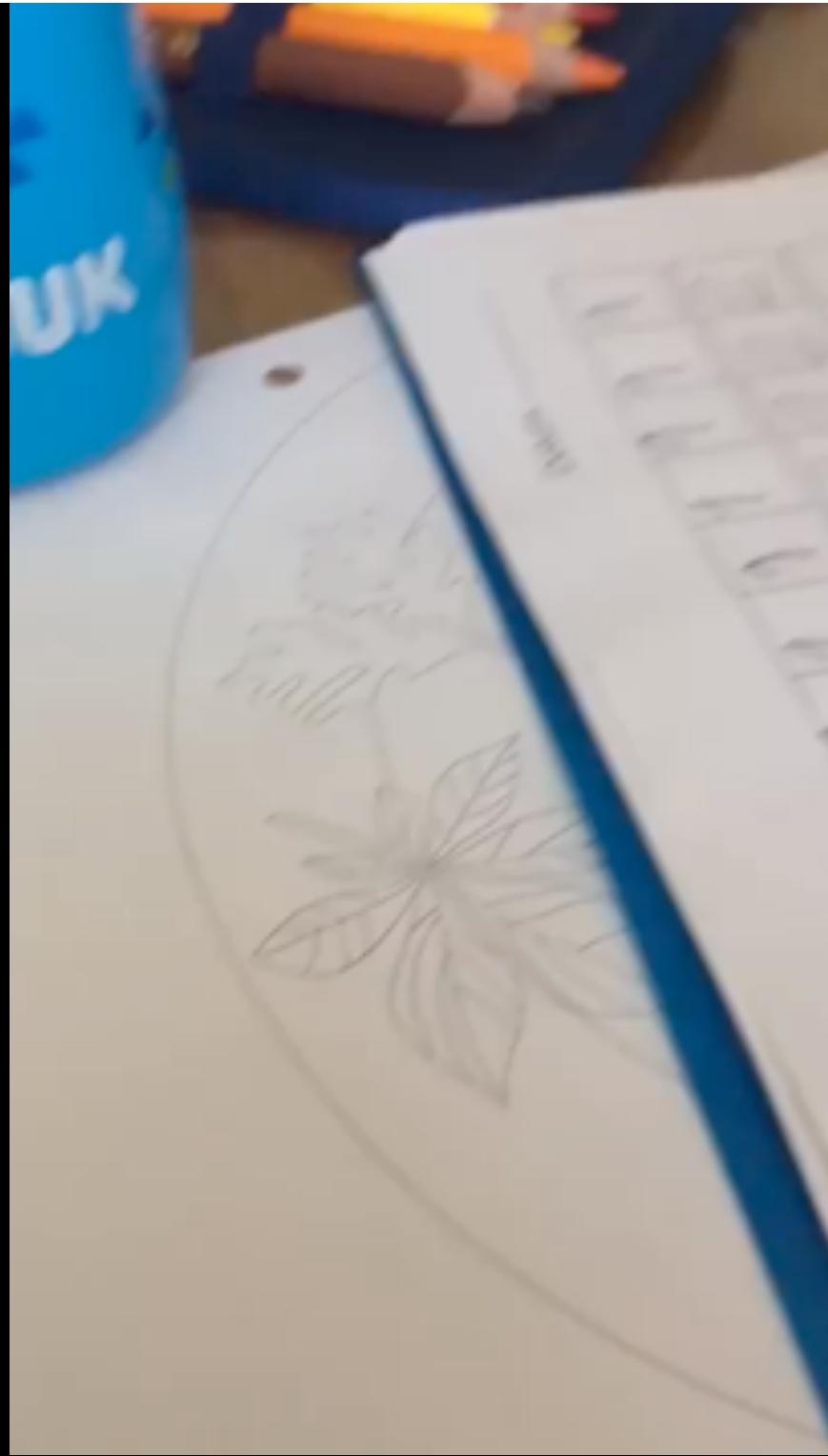


... or will autonomous self-aware robots bring about the downfall of humanity?

What is AI?



Humans
are
smart



Can
machines
be smart,
too?



What is actually Intelligence?





Is this smart?



Is this smart?

N24

$$\frac{6}{3} = 6$$

Is this smart?

**Intelligence has
many qualities.**

**It is difficult
to directly
capture/
measure it.**



What is AI?

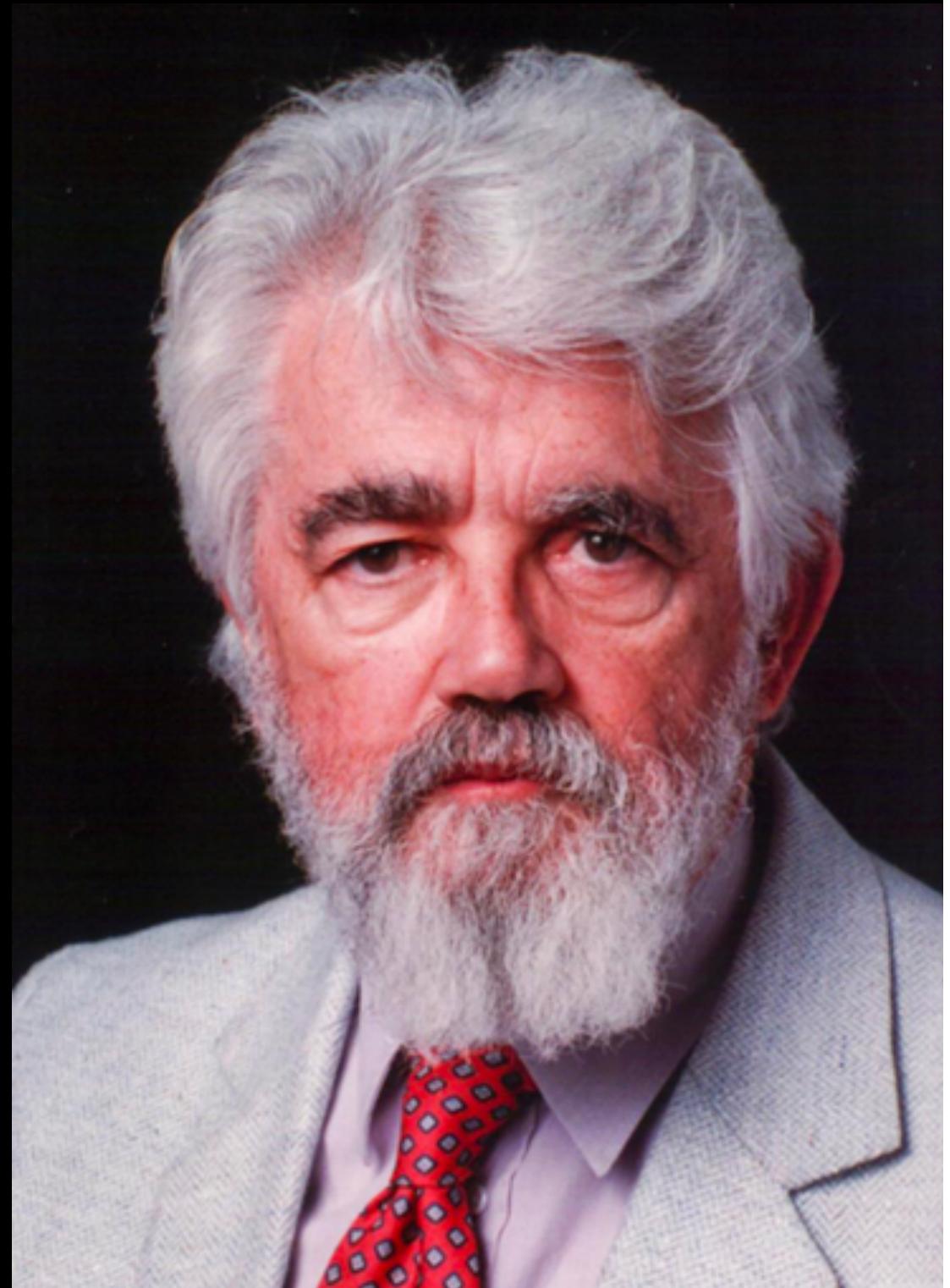


What is AI?

„the science and engineering of making intelligent machines, especially intelligent computer programs.

It is related to the similar task of using computers to understand human intelligence, but AI does not have to confine itself to methods that are biologically observable.“

- John McCarthy, Stanford (1956), coined the term AI, Turing Awardee



Learning

Thinking

Planning

AI = Algorithms for ...

Vision

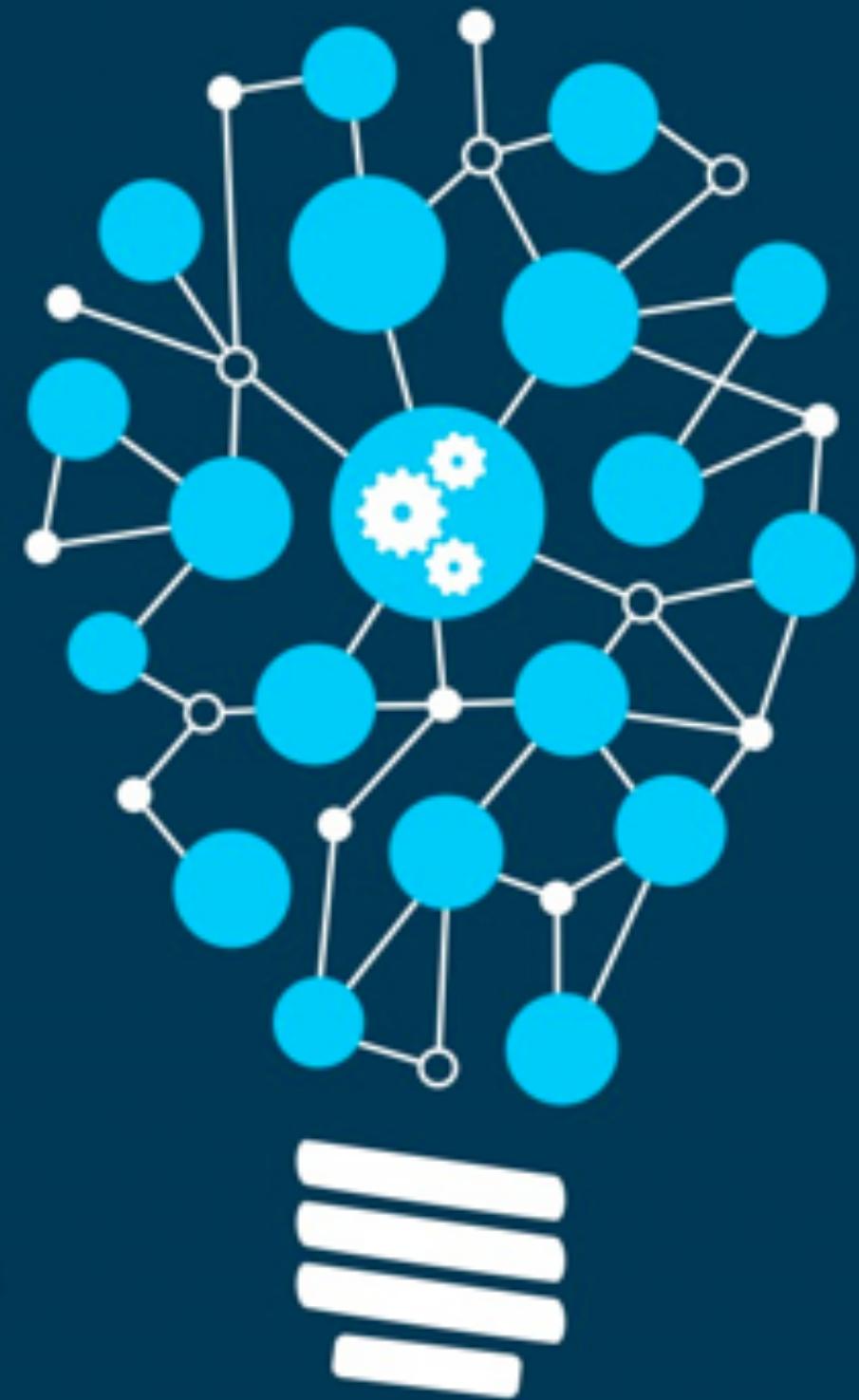
Behaviour

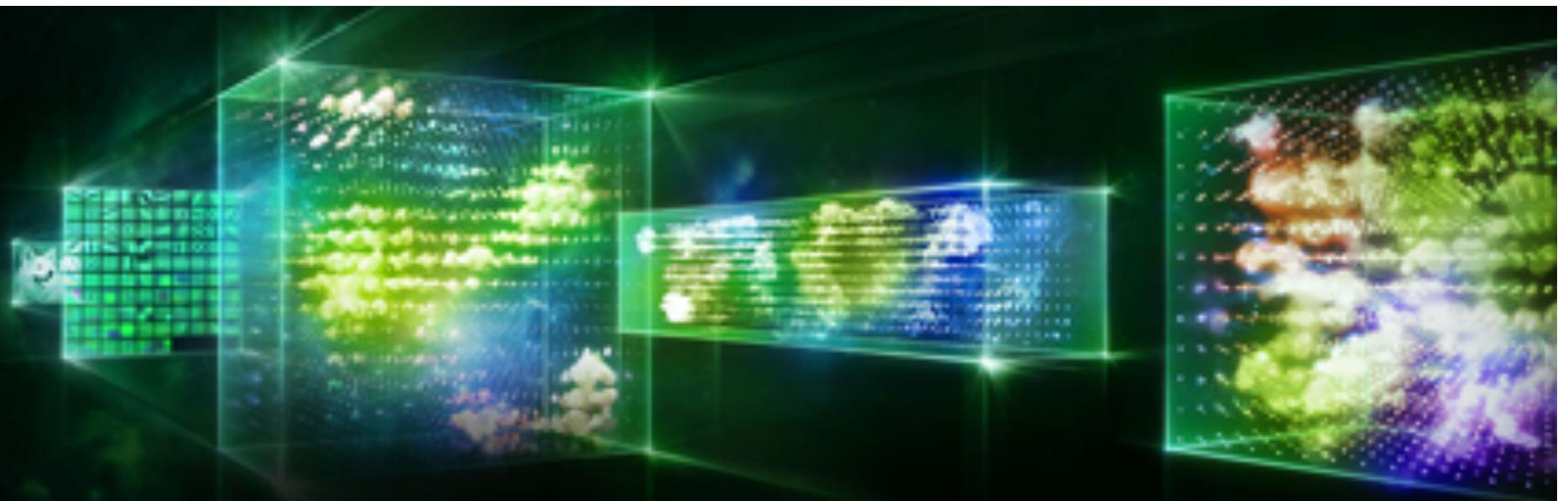
Reading

Machine Learning

**the science "concerned with
the question of how to
construct computer programs
that automatically improve with
experience"**

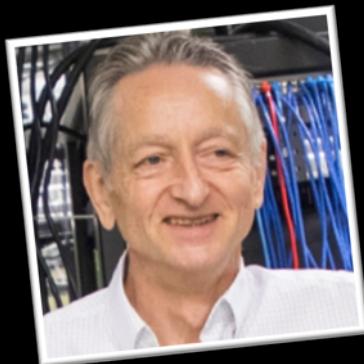
- Tom Mitchell (1997) CMU





Deep Learning

a form of machine
learning that makes
use of artificial
neural networks



Geoffrey Hinton
Google
Univ. Toronto (CAN)



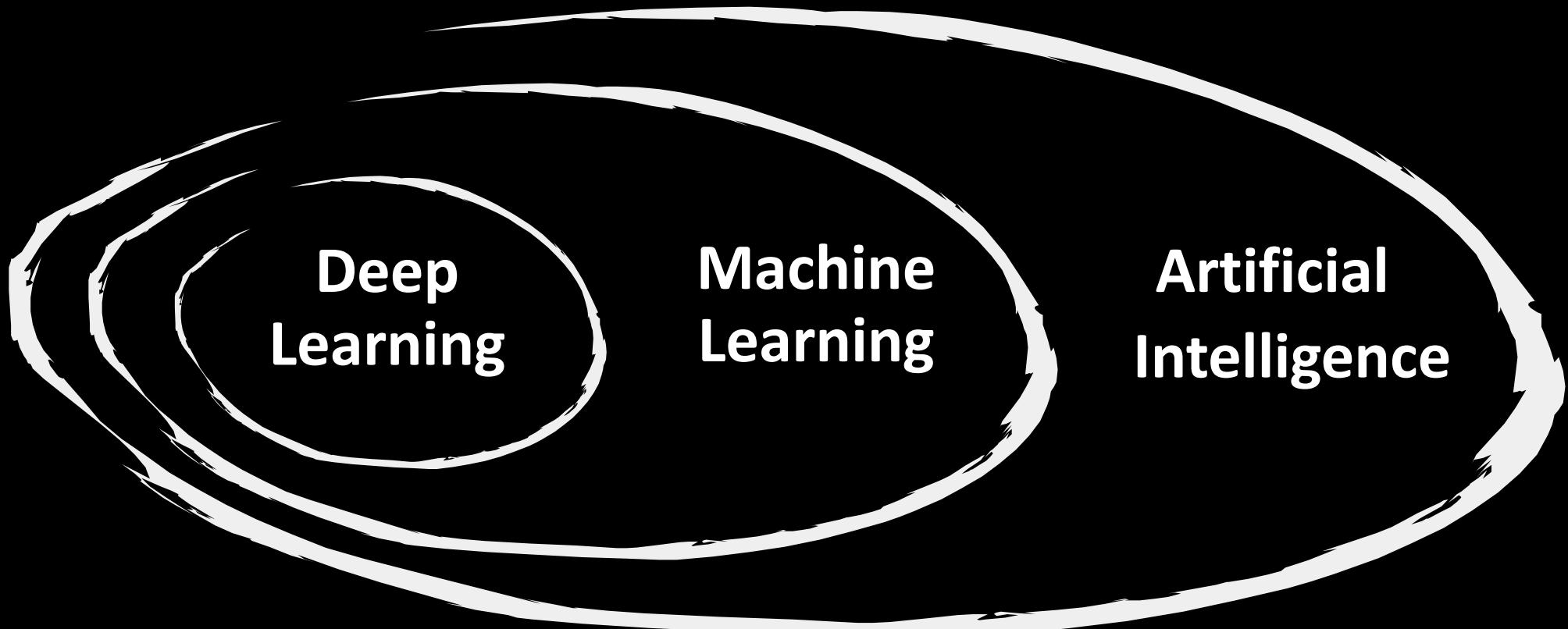
Yann LeCun
Facebook (USA)



Yoshua Bengio
Univ. Montreal (CAN)

Turing Awardees 2019

Overall Picture



A closer look at the history of AI

ONCE
UPON A TIME

1956 Birth of AI



John McCarthy
Turing Award 1971



Marvin Minsky
Turing Award 1969



Allen Newell
Turing Award 1975



Herbert A. Simon
Turing Award 1975
Nobel Prize 1978

**... and of
Cognitive Science**

Artificial Neural Networks

COGNITIVE SCIENCE 14, 179-211 (1990)

Learning representations by back-propagating errors

David E. Rumelhart*, Geoffrey E. Hinton†
& Ronald J. Williams*

* Institute for Cognitive Science, C-015, University of California,
San Diego, La Jolla, California 92093, USA
† Department of Computer Science, Carnegie-Mellon University,
Pittsburgh, Philadelphia 15213, USA

Finding Structure in Time

JEFFREY L. ELMAN
University of California, San Diego

COGNITIVE SCIENCE 9, 147-169 (1985)

A Learning Algorithm for Boltzmann Machines*

DAVID H. ACKLEY
GEOFFREY E. HINTON
*Computer Science Department
Carnegie-Mellon University*
TERRENCE J. SEJNOWSKI
*Biophysics Department
The Johns Hopkins University*

Biological
Cybernetics
© by Springer-Verlag 1980

Biol. Cybernetics 36, 193-202 (1980)

Neocognitron: A Self-organizing Neural Network Model for a Mechanism of Pattern Recognition Unaffected by Shift in Position

Kuniyuki Fukushima

NHK Broadcasting Science Research Laboratories, Kinuta, Setagaya, Tokyo, Japan

Psychological Review
1981, Vol. 88, No. 2, 135-170

Copyright 1981 by the American Psychological Association, Inc.
0033-295X/81/8802-0135\$00.75

Psychological Review
Vol. 65, No. 6, 1958

THE PERCEPTRON: A PROBABILISTIC MODEL FOR INFORMATION STORAGE AND ORGANIZATION IN THE BRAIN¹

F. ROSENBLATT

Cornell Aeronautical Laboratory

Toward a Modern Theory of Adaptive Networks: Expectation and Prediction

Richard S. Sutton and Andrew G. Barto
*Computer and Information Science Department
University of Massachusetts—Amherst*

Artificial Neural Networks

COGNITIVE SCIENCE 4, 179–211 (1990)

Learning representations by back-propagating errors

David E. Rumelhart*, Geoffrey E. Hinton†
& Ronald J. Williams*

* Institute for Cognitive Science C-015, University of California,
San Diego, La Jolla, California 92093, USA
† Department of Computer Science, Carnegie-Mellon University,
Pittsburgh, Philadelphia 15213, USA

Finding Structure in Time

JEFFREY L. ELMAN

University of California, San Diego

COGNITIVE SCIENCE 1, 147–169 (1985)

A Learning Algorithm for Boltzmann Machines*

DAVID H. ACKLEY
GEOFFREY E. HINTON
*Computer Science Department
Carnegie-Mellon University*
TERRENCE J. SEJNOWSKI
*Biophysics Department
The Johns Hopkins University*

Biological
Cybernetics

Biol. Cybernetics 36, 193–202 (1980)

Neocognitron: A Self-organizing Neural Network Model for a Mechanism of Pattern Recognition Unaffected by Shift in Position

Kuniyuki Fukushima

NHK Broadcasting Science Research Laboratories, Kinuta, Setagaya, Tokyo, Japan

Psychological Review
1981, Vol. 88, No. 2, 135–170

Copyright 1981 by the American Psychological Association, Inc.
0033-295X/81/8802-0135\$00.75

Psychological Review
Vol. 65, No. 6, 1958

THE PERCEPTRON: A PROBABILISTIC MODEL FOR INFORMATION STORAGE AND ORGANIZATION IN THE BRAIN¹

F. ROSENBLATT

Cornell Aeronautical Laboratory

Toward a Modern Theory of Adaptive Networks: Expectation and Prediction

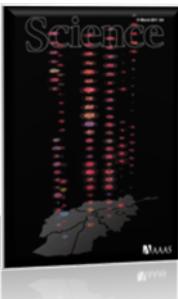
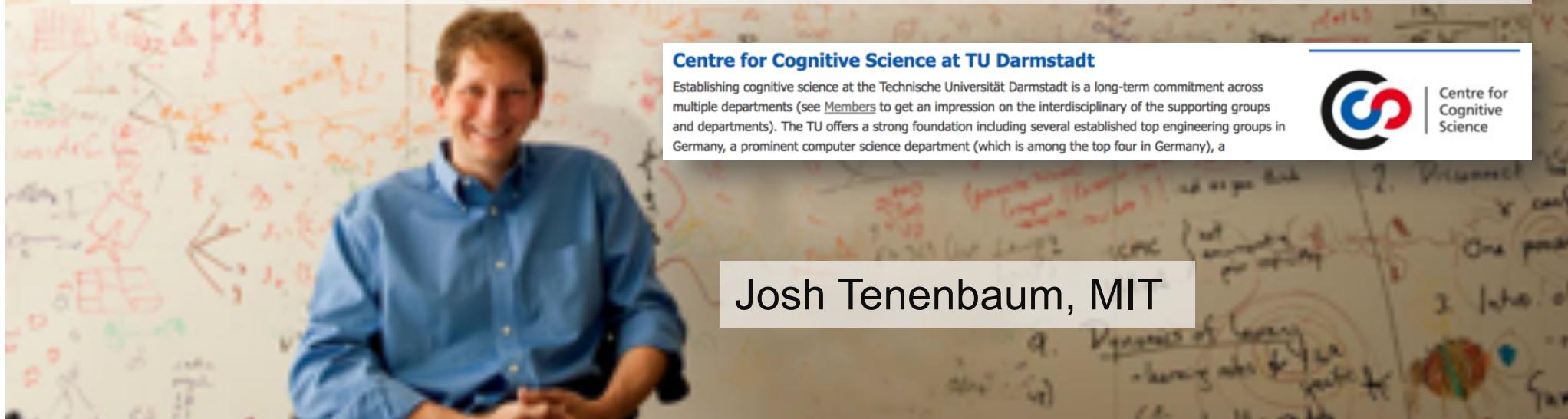
Richard S. Sutton and Andrew G. Barto
*Computer and Information Science Department
University of Massachusetts—Amherst*

slide after C. Rothkopf (TUD), after J. Tenenbaum (MIT)

Algorithms of intelligent behaviour teach us a lot about ourselves

The twin science: cognitive science

"How do we humans get so much from so little?" and by that I mean how do we acquire our understanding of the world given what is clearly by today's engineering standards so little data, so little time, and so little energy.



Lake, Salakhutdinov, Tenenbaum, Science 350 (6266), 1332-1338, 2015
Tenenbaum, Kemp, Griffiths, Goodman, Science 331 (6022), 1279-1285, 2011

Three levels of description

VISION



David Marr

FOREWORD BY
Shimon Ullman
AFTERWORD BY
Tomaso Poggio

1982



Computational

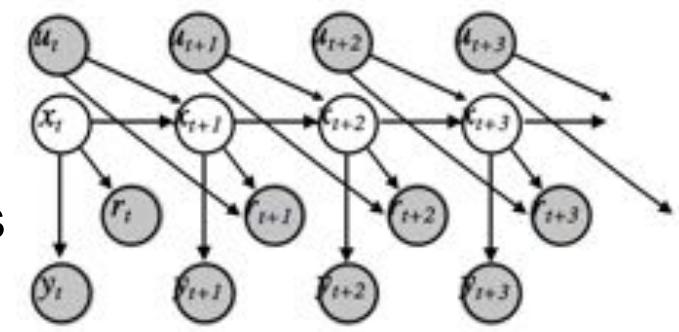
Why do things work the way they work? What is the goal of the computation? What are the unifying principles?

maximize:

$$R_t = r_{t+1} + r_{t+2} + \cdots + r_T$$

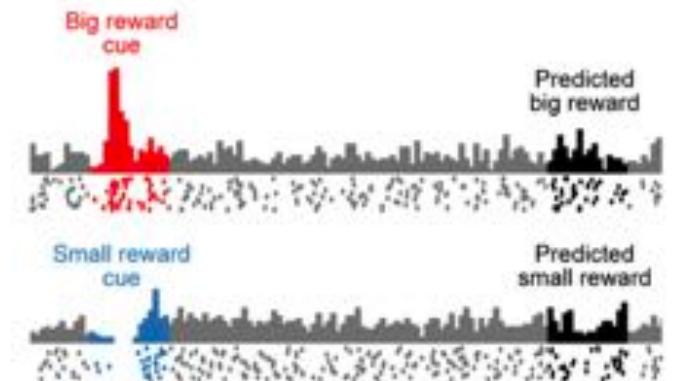
Algorithmic

What representation can implement such computations? How does the choice of the representation determine the algorithm

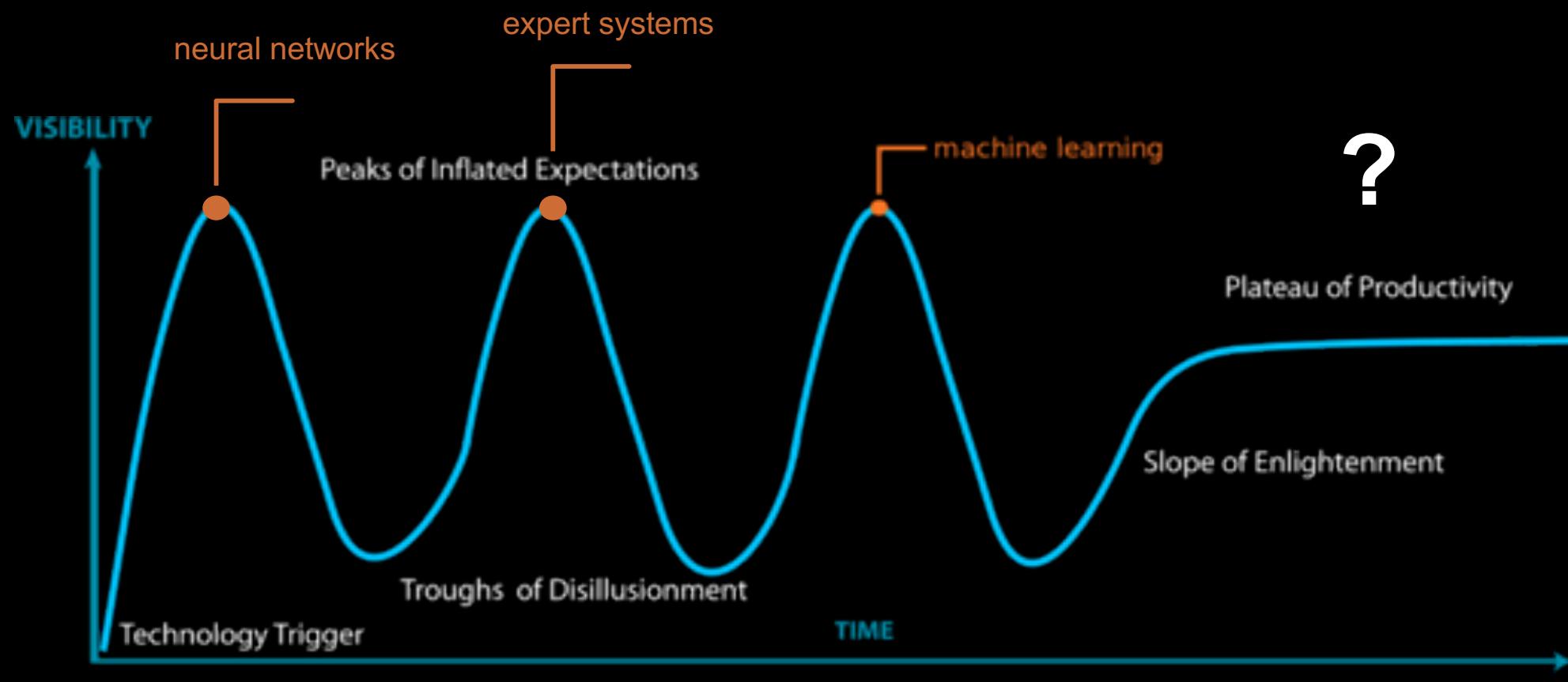


Implementational

How can such a system be built in hardware?
How can neurons carry out the computations?



The history of AI in a nutshell



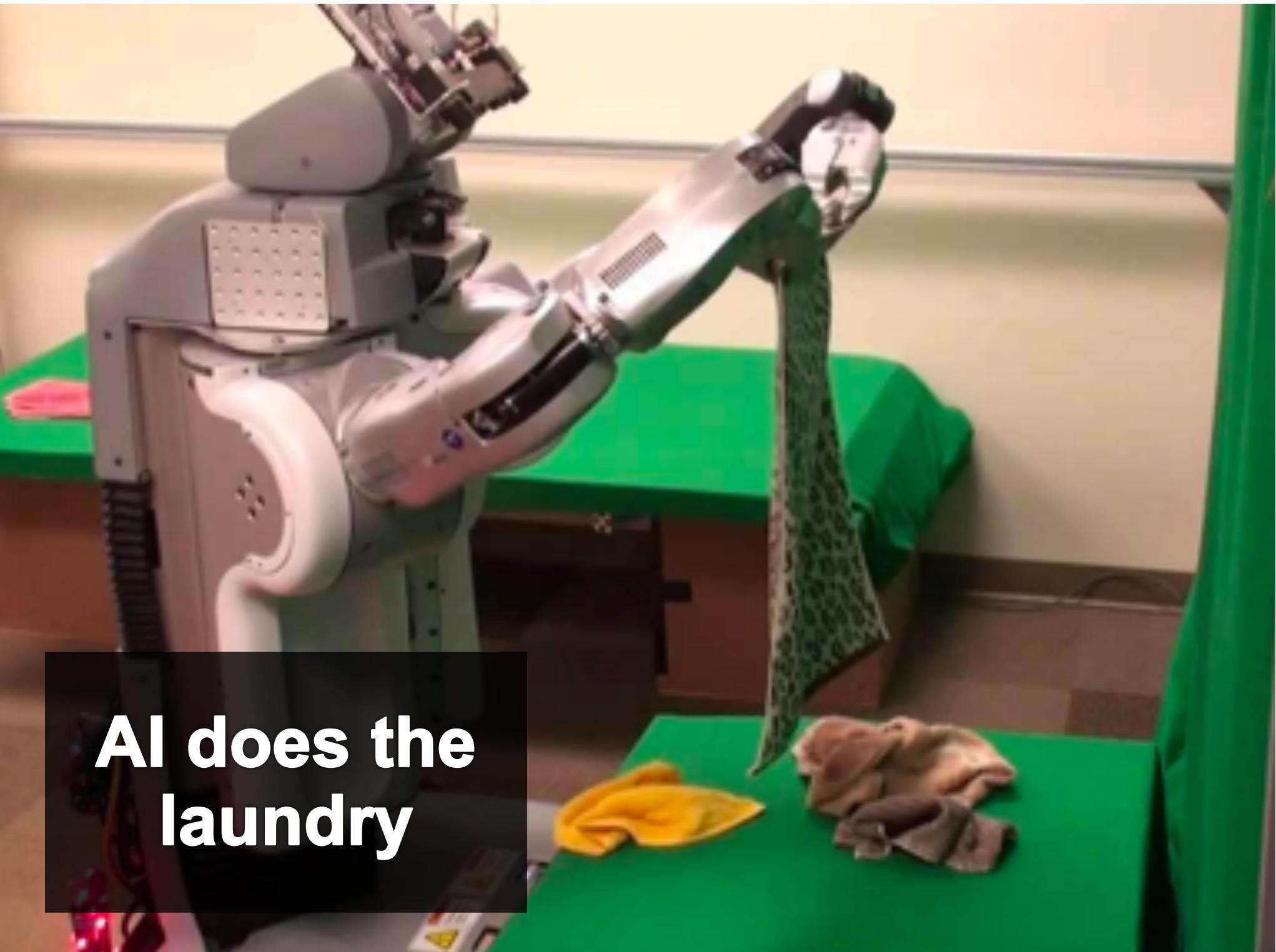
1956

2019

What's different now than it used to be?

- #1 models are bigger
- #2 we have more data
- #3 we have more compute power
- #4 the systems actually work for several tasks





AI does the laundry

AI drives cars





THINK

सोचिए

\$24,000

Who is Stoker?
A FAMOUS VICTORIAN ERA
ENGLISH NOVELIST

\$1,000

\$77,147

Who is Bram
Stoker?

\$ 17,973

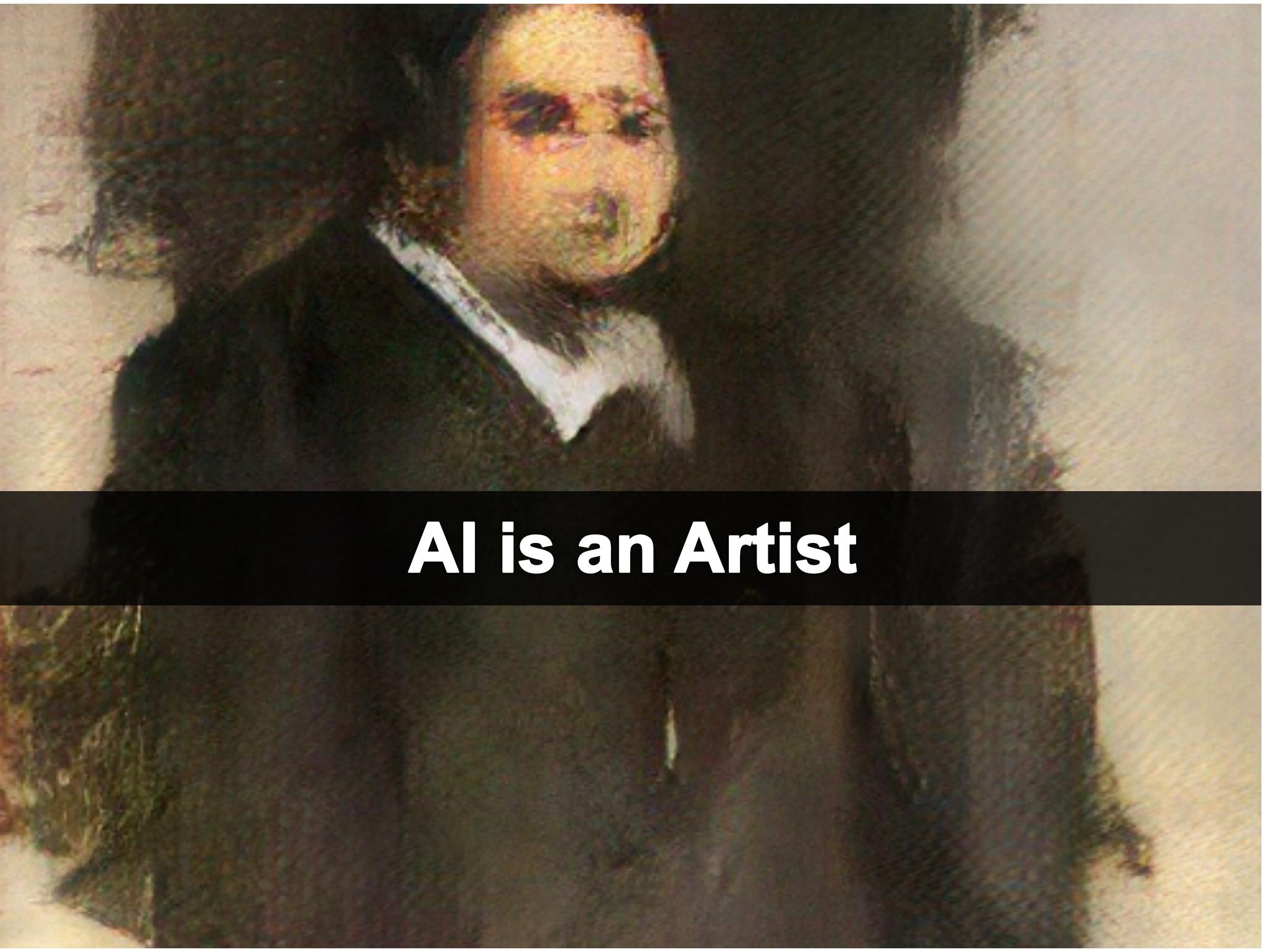
\$21,600

WHO IS
BRAM STOKER?

\$5600



AI knows a lot

A portrait painting of a man with light-colored hair, wearing a dark suit jacket over a white shirt and a patterned tie. He is looking towards the right of the frame. The background is dark and textured.

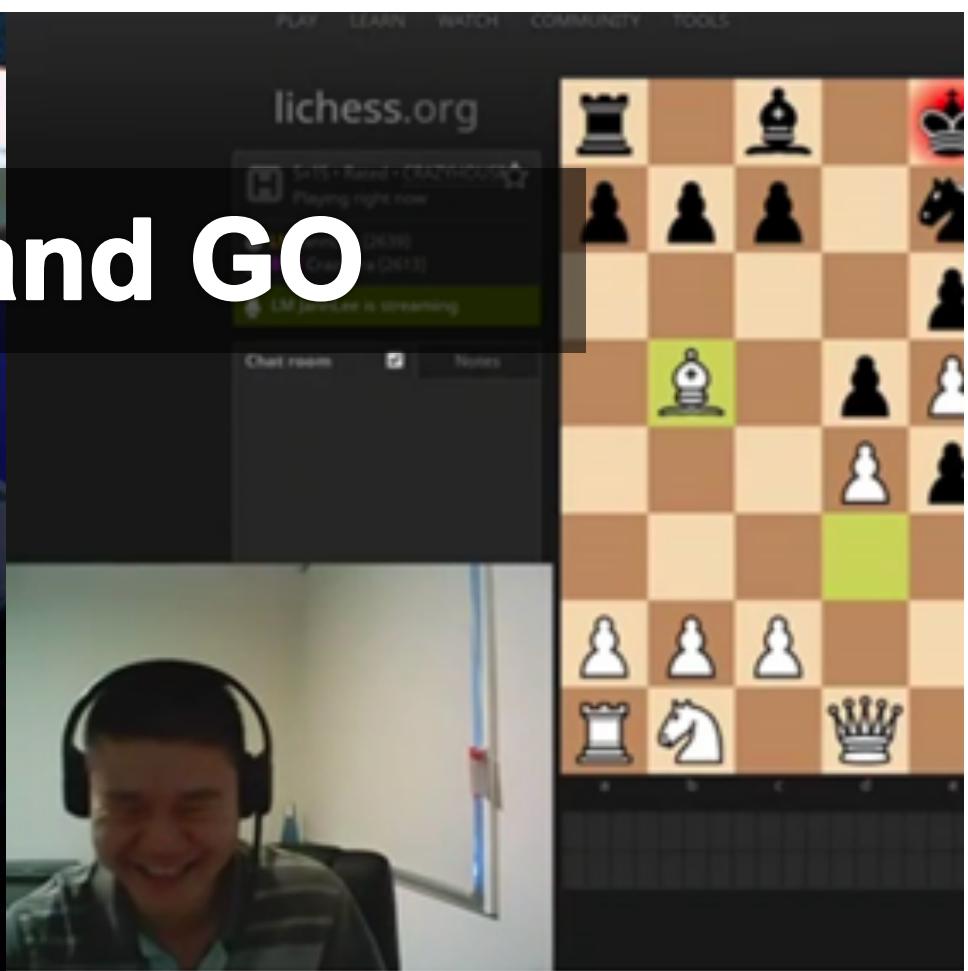
AI is an Artist



Schachmatt durch „CrazyAra“

Künstliche Intelligenz schlägt mehrfachen Weltmeister im Einsetzschach

Der von den TU-Studierenden Johannes Czech, Moritz Willig und Alena Beyer entwickelte Bot „CrazyAra“ hat den Schachprofi Justin Tan in einem Online-Match der Schach-Variante „Crazyhouse“ mit 4:1 geschlagen. Gelernt hat der Bot mittels künstlicher neuronaler Netze, was ihm erlaubt, vorausschauend Entscheidungen zu treffen. Das Besondere: Die Studierenden konnten damit einen Erfolg auf einem Feld feiern, das sonst von Giganten wie Google dominiert wird.



CrazyAra vs JannLee (Man vs Machine - Crazyhouse Chess on lichess.org) · 2 days ago
Category: Chess

AI assists you



But

But

The New York Times

Opinion

A.I. Is Harder Than You Think



By Gary Marcus and Ernest Davis

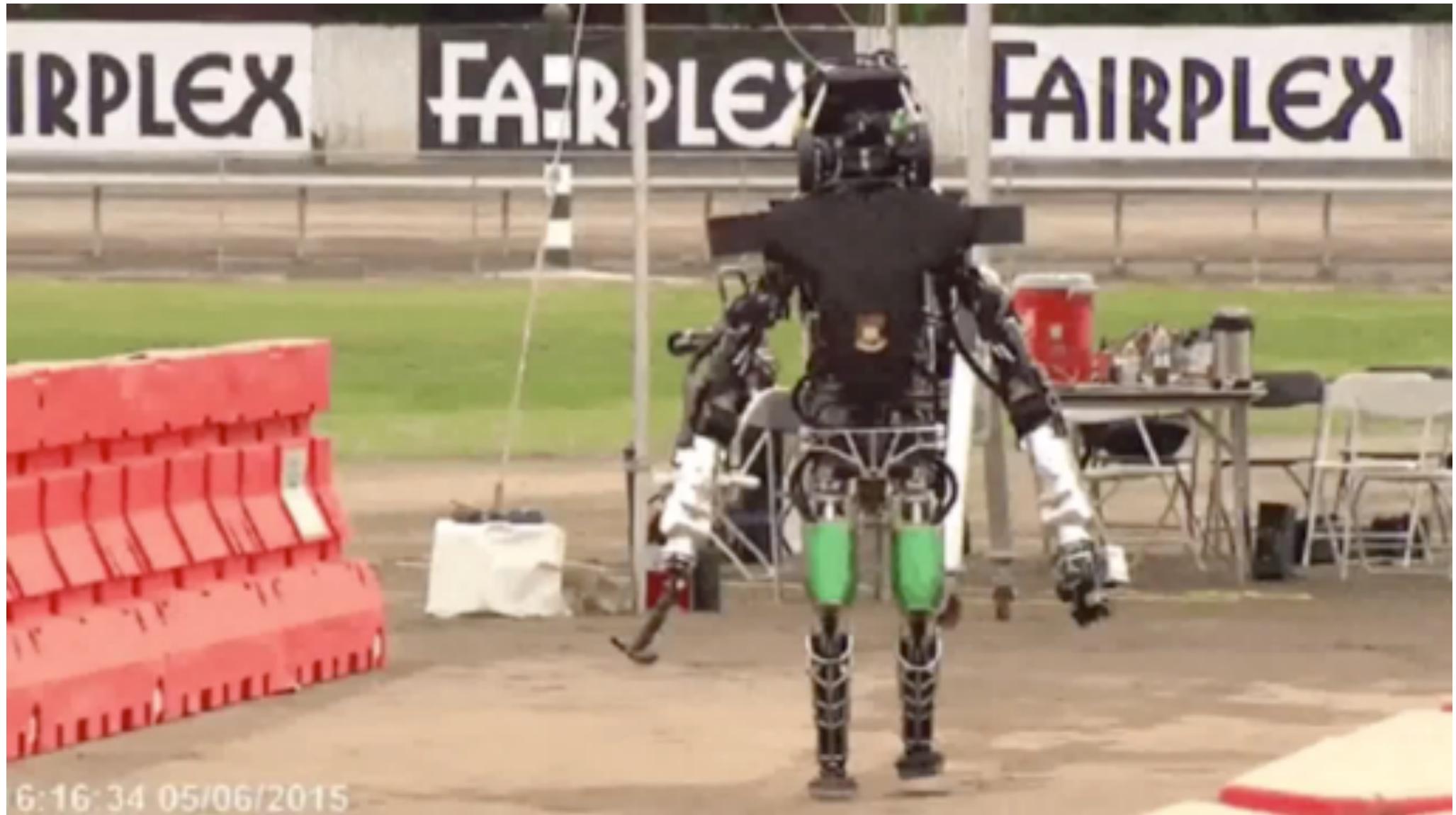
Mr. Marcus is a professor of psychology and neural science. Mr. Davis is a professor of computer science.

May 18, 2018

Current AI has many isolated talents



Current AI is not superhuman



DARPA challenge (2015)

Current AI is not superhuman



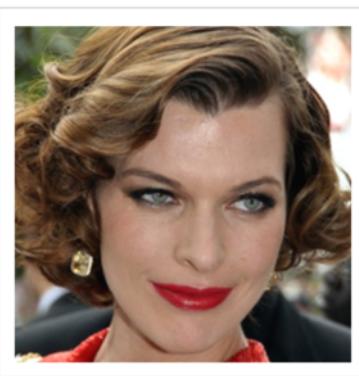
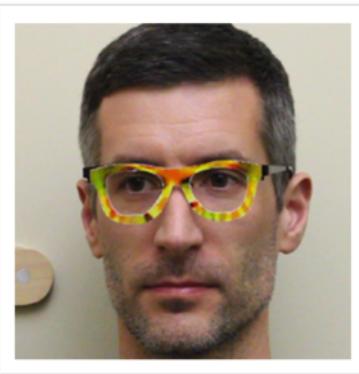
And this also holds as of today

Fundamental Differences

The screenshot shows a web page from the journal **Current Biology**. At the top, there is a search bar with the placeholder "Search" and a dropdown menu set to "All Content". Below the search bar are two radio buttons: one selected for "Current Biology" and another for "All Journals". The main navigation menu includes "Explore", "Online Now", "Current Issue", "Archive", "Journal Information", and "For Authors". The current issue information indicates "Volume 27, Issue 18, p2827–2832.e3, 25 September 2017". On the left, under the heading "REPORT", is the title "Humans, but Not Deep Neural Networks, Often Miss Giant Targets in Scenes". Below the title are the authors' names: Miguel P. Eckstein¹, Kathryn Koehler, Lauren E. Welbourne, Emre Akbas. To the right of the article summary is a sidebar with options to "Switch to Standard View", "PDF (1 MB)", "Download Images (pdf)", "Email Article", and "Add to My Reading List". The central part of the page features a photograph of a bathroom sink area. On the light-colored wooden counter, there is a large blue and white striped rolled-up item (possibly a large target or a long object), a black electric shaver, a small white container, a green and white toothbrush, and a yellow bottle of mouthwash. In the background, a white toilet is visible, and a white bathtub with a silver faucet is partially seen.

as of today

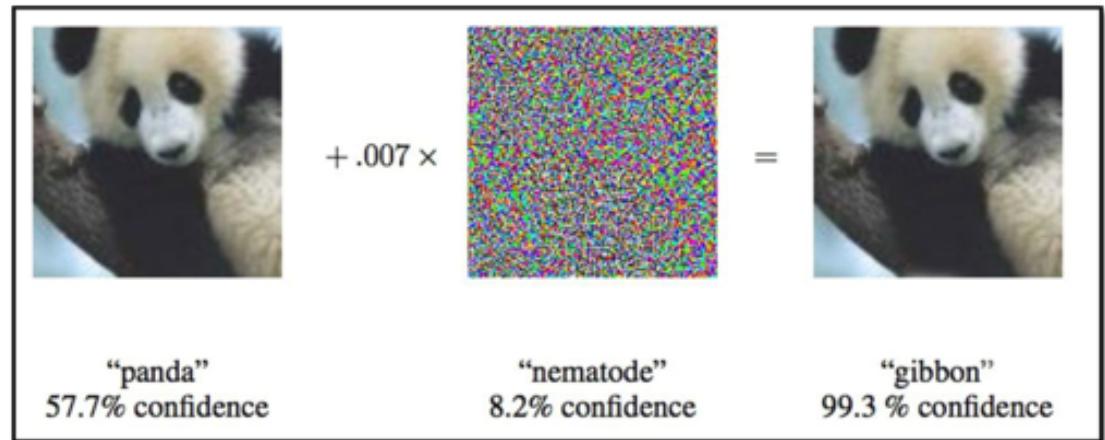
Fundamental Differences



Sharif et al., 2015



Brown et al. (2017)



Google, 2015

REPORTS | PSYCHOLOGY

Semantics derived automatically from language corpora contain human-like biases

Aylin Caliskan^{1,*}, Joanna J. Bryson^{1,2,*}, Arvind Narayanan^{1,*}

* See all authors and affiliations

Science 14 Apr 2017;
Vol. 356, Issue 6334, pp. 183-186
DOI: 10.1126/science.aal4230



And this is where our journey begins, based on a text Book

The course will mostly follow

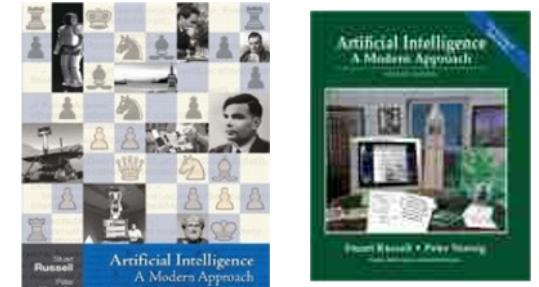
Stuart Russell und Peter Norvig: *Artificial Intelligence: A Modern Approach*. Prentice Hall, 3rd edition, 2010.

Deutsche Ausgabe:

Stuart Russell und Peter Norvig: *Künstliche Intelligenz: Ein Moderner Ansatz*. Pearson-Studium, 2004. ISBN: 978-3-8273-7089-1.
3. Auflage 2012

Home-page for the book:

<http://aima.cs.berkeley.edu/>



Course slides

in English (lecture is in German)
will be available from Homepage (Moodle)

What is Artificial Intelligence

Different definitions due to different criteria

Two dimensions:

Thought processes/reasoning vs. behavior/action

Success according to human standards vs.
success according to an ideal concept of intelligence:
rationality.

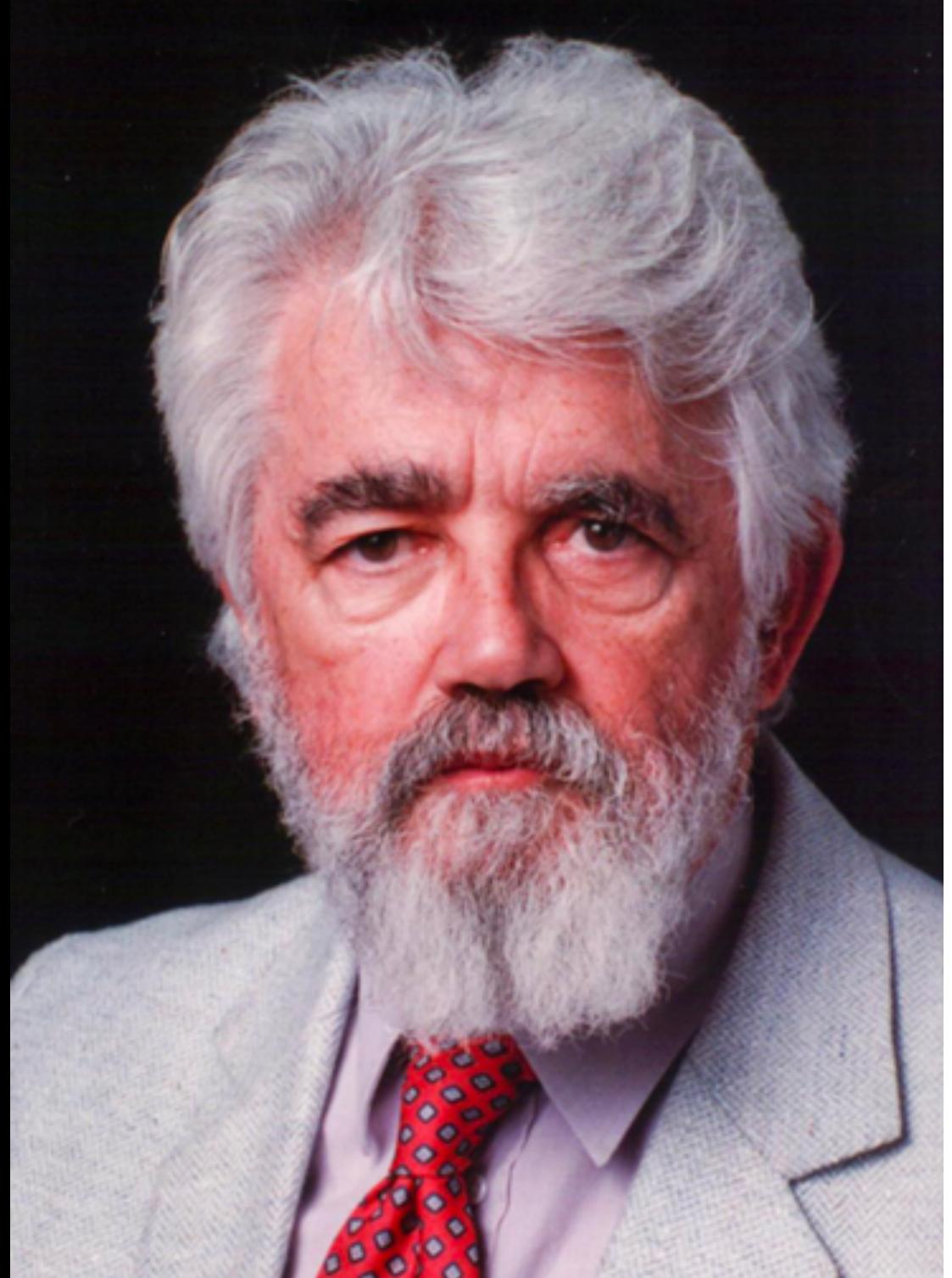
Systems that think like humans	Systems that think rationally
Systems that act like humans	Systems that act rationally

What is AI?

„the science and engineering of making intelligent machines, especially intelligent computer programs.

It is related to the similar task of using computers to understand human intelligence, but AI does not have to confine itself to methods that are biologically observable.“

- John McCarthy, Stanford (1956), coined the term AI, Turing Awardee



Definitions of Artificial Intelligence

Systems that think like humans	Systems that think rationally
<p>“The exciting new effort to make computers think . . . <i>machines with minds</i>, in the full and literal sense.” (Haugeland, 1985)</p> <p>“[The automation of] activities that we associate with human thinking, activities such as decision-making, problem solving, learning . . .” (Bellman, 1978)</p>	<p>“The study of mental faculties through the use of computational models.” (Charniak and McDermott, 1985)</p> <p>“The study of the computations that make it possible to perceive, reason, and act.” (Winston, 1992)</p>
Systems that act like humans	Systems that act rationally
<p>“The art of creating machines that perform functions that require intelligence when performed by people.” (Kurzweil, 1990)</p> <p>“The study of how to make computers do things at which, at the moment, people are better.” (Rich and Knight, 1991)</p>	<p>“Computational Intelligence is the study of the design of intelligent agents.” (Poole <i>et al.</i>, 1998)</p> <p>“AI . . . is concerned with intelligent behavior in artifacts.” (Nilsson, 1998)</p>

Figure 1.1 Some definitions of artificial intelligence, organized into four categories.

Systems that think like humans

How do humans think?

Requires scientific theories of internal brain activities (cognitive model):

Level of abstraction? (knowledge or circuitry?) Validation?

Predicting and testing human behavior

Identification from neurological data

Cognitive Science brings together computational models from AI and experimental techniques from psychology to construct precise and testable theories of the mind. Cognitive Science is often viewed distinct from AI but this is wrong. As at TU Darmstadt, both are twin disciplines!

Cognitive Neuroscience: How does the brain work at the neuronal level?

Other AI-relevant Course Topics @ TUD

Machine Learning (Peters, Roth, Kersting)

Robotics (Peters, von Stryk)

Search and Optimization (Weihe)

Natural Language Processing (Gurevych)

Fuzzy Logic and Genetic Algorithms (Adamy)

Vision and Perception (Roth, Fellner, Kuijper)

Cognitive Science (Rothkopf, Kersting, Jäkel)

Hardware (Koch)

Serious Games (Göbel)

Bioinformatics (Köppl, Hamacher)

...

Systems that think rationally

Capturing the laws of thought

Aristotle: What are ‘correct’ argument and thought processes?

Correctness depends on irrefutability of reasoning processes.

Syllogisms:

first patterns of correct formal reasoning

“Socrates is a man, all man are mortal → Socrates is mortal”

This study initiated the field of logic.

The logicist tradition in AI hopes to create intelligent systems using logic programming.

Problems:

It is hard to formalize knowledge exactly

→ Feigenbaum Bottleneck in expert systems

Practical constraints

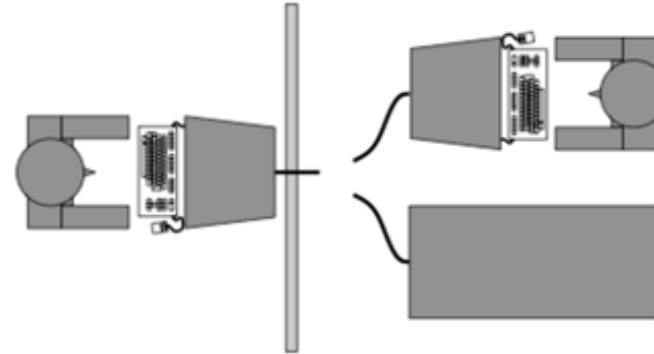
it is easy to write a logically optimal chess player...

Not all intelligence is mediated by logic behavior

Systems that act like humans

When does a system behave intelligently?

Turing (1950) Computing Machinery and Intelligence
Operational test of intelligence: imitation game



Test still relevant now, yet might be the wrong question.
Requires the collaboration of major components of AI: knowledge,
reasoning, language understanding, learning, ...

Problem with Turing test:

not reproducible, constructive or amenable to mathematical analysis.

Systems that act rationally

Rational behavior: “doing the right thing”

The “Right thing” is that what is expected to maximize goal achievement given the available information.

Can include thinking, yet in service of rational action

Action without thinking: e.g. reflexes.

Two advantages over previous approaches

More general than law of thoughts approach

in many situations, a provably correct action does not exist

More amenable to scientific development

rationality can be defined and optimized

On the other hand

perfect rationality is only feasible in ideal environments.

rationality is often not a very good model of reality.

humans are, e.g., very bad in estimating probabilities...

Foundations of AI

Different fields have contributed to AI in the form of ideas, viewpoints and techniques.

Philosophy: Logic, reasoning, mind as a physical system, foundations of learning, language and rationality.

Mathematics: Formal representation and proof algorithms, computation, (un)decidability, (in)tractability, probability.

Psychology: adaptation, phenomena of perception and motor control.

Economics: formal theory of rational decisions, game theory.

Linguistics: knowledge representation, grammar.

Neuroscience: physical substrate for mental activities.

Control theory: homeostatic systems, stability, optimal agent design.

Subdisciplines of AI

Natural Language Processing

Knowledge Representation

Automated Reasoning

Planning

Machine Learning

Computer Vision

Robotics

...

See also <https://gi.de/themen/beitrag/was-ist-eine-professur-fuer-kuenstliche-intelligenz-1/> (in German)

A Brief History of AI

Greek mythology:

Hephaestus built Talos, a giant intelligent bronze robot



13th century:

brazen head: oracle in the form of a talking head made of brass supposedly owned by Roger Bacon and Albertus Magnus

15th century:

da Vinci drafted robot design

16th century:

Rabbi Loew made the giant Golem of clay to protect the Jewish community in Prague remains are still supposed to be there...



17th century:

Descartes – “animals are complex machines”

The dream of an artificially intelligent entity is not new

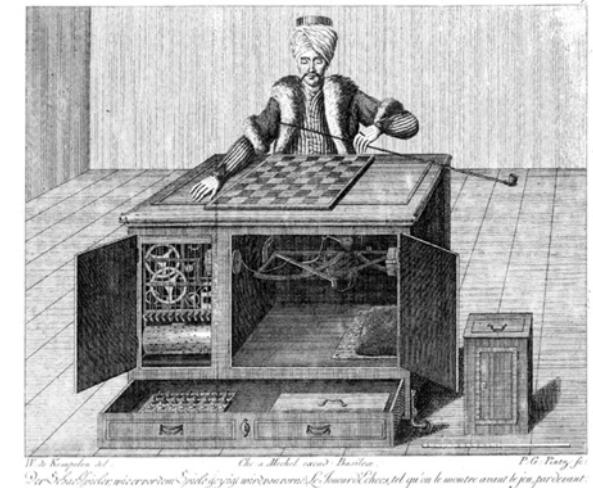
The image consists of two main parts. On the left, there is a screenshot of a website. At the top, it says "ZEIT ONLINE". Below that is a navigation bar with links to "Politik", "Gesellschaft", "Wirtschaft", "Kultur", "Wissen", "Digital Campus", "Arbeit", "Entdecken", "Sport", "ZEITmagazin", "Podcasts", and "mehr". There is also a search bar and a "Z+" button. The main headline in the center of the screenshot reads "Gottfried Wilhelm Leibniz" and "Er wollte die Welt mit Intelligenz in den Griff bekommen". Below the headline is a quote: "... die aber machte nicht mit. Was wir dennoch von Gottfried Wilhelm Leibniz lernen können – 300 Jahre nach dem Tod dieses letzten deutschen Universalgenies." To the right of the screenshot is a black and white portrait of Gottfried Wilhelm Leibniz, showing his face and curly hair. The background of the entire image features a pattern of interlocking gears in blue and orange.

Leibniz „philosophises about ‘artificial intelligence’ (AI). In order to prove the impossibility of thinking machines, Leibniz imagines of ‘a machine from whose structure certain thoughts, sensations, perceptions emerge“ — Gero von Radow, ZEIT 44/2016

A Brief History of AI

18th century:

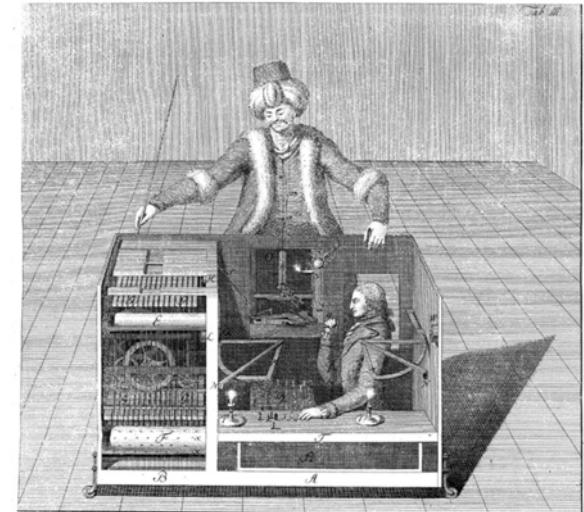
von Kempelen's chess-playing Turk
amazing piece of mechanical engineering
played and won chess games all over
the world (e.g., against Napoleon)



A Brief History of AI

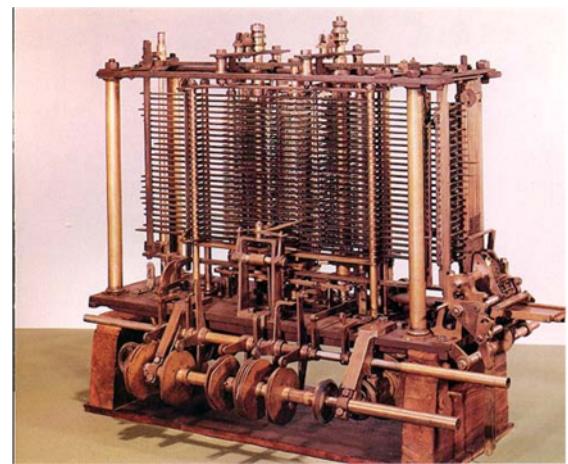
18th century:

von Kempelen's chess-playing Turk
amazing piece of mechanical engineering
played and won chess games all over
the world (e.g., against Napoleon)
unfortunately a hoax...



19th century:

Charles Babbage's Analytical Engine



1920:

first use of word “robot” in Karel Capek's play *R.U.R (Rossum's Universal Robots)*

1940's:

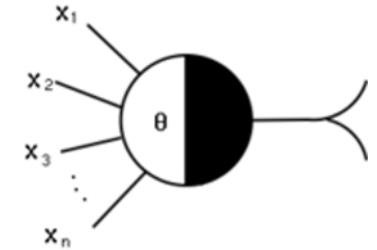
Isaac Asimov – “Three Laws of Robotics”

A Brief History of AI

1943:

McCulloch and Pitts model artificial neurons

1951: Marvin Minsky and Dann Edmonds
constructed the first neural network computer



1950

Claude Shannon: algorithm for playing Chess
foresees strategies that are still used today

Shannon Type-A Strategy:

brute-force minimax search until a fixed horizon

Shannon Type-B Strategy

pruning uninteresting lines (as humans do)

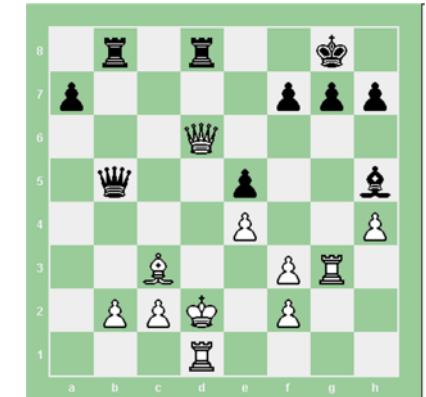
preferred by Shannon (and contemporaries)

1951

Turing's chess algorithm

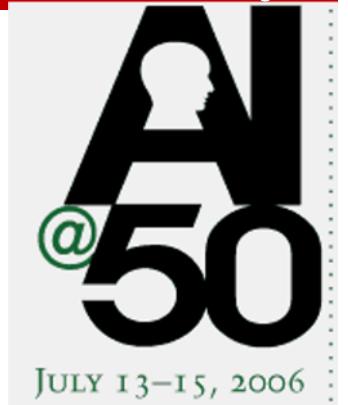
computation with paper and pencil

first recorded man-machine (chess) game



<http://www.chessgames.com/perl/chessgame?gid=1356927>

The Dartmouth Conference



1956:

John McCarthy invites 10 scientists with various backgrounds to a 2-week workshop at Dartmouth College bringing together top minds on automata theory, neural nets and the study of intelligence.

For the next 20 years the field was dominated by these participants

John McCarthy, Herbert Simon, Allan Newell, Marvin Minsky, Arthur Samuel, etc.

Allen Newell and Herbert Simon (CMU): The Logic Theorist
first nonnumerical thinking program used for theorem proving
proved various theorems of Whitehead's *Principia Mathematica*
a joint publication by AN, HS, and LT was rejected...

→ Term “Artificial Intelligence” is coined

Great Expectations (1952-1969)

Newell and Simon (CMU): the General Problem Solver.

Imitation of human problem-solving
successfully solved simple puzzles
→ physical symbol system hypothesis

Arthur Samuel (IBM, 1952-)

investigated game playing (checkers) with great success at IBM
program beat a regional master
pioneered many ideas in game playing and machine learning
including alpha-beta search, reinforcement learning, etc.

John McCarthy (MIT, 1958-)

Inventor of Lisp (second-oldest high-level language)
Logic-oriented Advice Taker
separation between knowledge and reasoning

Marvin Minsky (MIT)

various students working on micro-worlds (e.g., block's world)

A Dose of Reality (1966-1973)

Progress was slower than (unrealistic) expectations
Simon and Newell's (1958) predictions

1. That within ten years, a digital computer will be the world's chess champion, unless the rules bar it from competition.
 2. That within ten years a digital computer will discover and prove an important new mathematical theorem.
 3. That within ten years a digital computer will write music that will be accepted by critics as possessing considerable aesthetic value.
 4. That within ten years most theories in psychology will take the form of computer programs, or of qualitative statements about the characteristics of computer programs.
- ... The simplest way I can summarize is to say that there are now in the world machines that can think, that learn and that create. Moreover, their ability to do these things is going to increase rapidly until — in a visible future — the range of problems they can handle will be coextensive with the range to which the human mind has been applied.

A Dose of Reality (1966-1973)

Progress was slower than (unrealistic) expectations

Simon and Newell's (1958) predictions

came more or less true after 40 (instead of 10) years

but in very different ways than they had imagined

Difficulties

Difficulty of knowledge representation

e.g., attempt for Machine Translation of Russian Scientific papers

the spirit is willing but the flesh is weak

A Dose of Reality (1966-1973)

Progress was slower than (unrealistic) expectations

Simon and Newell's (1958) predictions

came more or less true after 40 (instead of 10) years

but in very different ways than they had imagined

Difficulties

Difficulty of knowledge representation

e.g., attempt for Machine Translation of Russian Scientific papers

the spirit is willing but the flesh is weak
→ the vodka is good but the meat is rotten

In 1966 no machine translations were used

nowadays they are routinely used

but most still give awful results

A Dose of Reality (1966-1973)

Progress was slower than (unrealistic) expectations
some of Simon and Newell's (1958) predictions came more or less true after 40 (instead of 10) years
but in very different ways than they had imagined

Difficulties

Difficulty of knowledge representation

Lack of scalability

under-estimation of the combinatorial explosion in search
things that work well in micro-worlds do not work in real world
e.g., theorem proving only worked with very few facts

Lighthill report (1973) focused on this issue

stopped AI funding in UK in all but two universities

Fundamental limitations on techniques and representations

Minsky and Papert (1969) noted that perceptrons are only linear separators

killed research in neural networks for decades

Knowledge-Based Systems (1969-1979)

DENDRAL project (Buchanan et al. 1969)

task:

infer molecular structure from formula of the molecule and the mass spectrum

First successful knowledge-intensive system

recognized importance of domain-specific knowledge

Expert systems

MYCIN to diagnose blood infections (Feigenbaum et al.)

with ~450 rules, it performed better than junior doctors

knowledge had to be tediously acquired from experts

(→ Knowledge Engineering Bottleneck)

introduction of uncertainty in reasoning

Increase in knowledge representation research

Logic, frames, Schank's scripts, semantic nets, ...

CYC project (started by Lenat 1984)

attempt to encode common-sense knowledge

The AI industry (1980-present)

R1 (McDermott, 1982)

expert system for configuring computers at DEC
saved about \$40 million a year in 1986

Fifth generation project in Japan (1981)

10-year plan with strong focus on Logic Programming
did not quite live up to its ambitious goals

Similar programs in US and UK put an end to the AI winter
in UK, the Alvey report reinstated funding for “Intelligent
Knowledge-Based Systems” (to avoid the name AI)

Neural Networks revival

seminal work *Parallel Distributed Processing* by Rumelhart and
McClelland (1986)

soon became popular in industrial applications

AI industry grew from a few million dollars in 1980 to billions of
dollars in 1988

Current Trends in AI

exploit the strengths of the computer

- fast repetitious computations

- elementary statistics (counting and probabilities)

and do not try to model human thought processes

- brute-force methods perform much better in many areas

aviation was only possible when planes stopped to flap their wings...

focus on particular tasks and not on solving AI as a whole

“Intelligent prostheses”

- tools that support us in tasks that would otherwise require human intelligence

“AI-complete problems”

- informal notion for very hard problems that cannot be solved unless the system has human-like knowledge and reasoning

strong scientific standards developed in the 1980s

solid experimentation and scientific verification of hypotheses

The Science of AI

Conference Series

1969 - : Biennial International Joint Conference on AI (IJCAI)

1980 - : Annual National Conference on AI (AAAI)

1982 - : Biennial European Conference on AI (ECAI)

Magazines

AI Magazine (published by AAAI)

IEEE Intelligent systems

Journals

Artificial Intelligence (Elsevier)

Journal of Artificial Intelligence Research

pioneered free on-line publication (<http://www.jair.org>)



Since the 1980s various subfields emerged, joined forces with related fields

many journals and annual conferences in subareas



AI plays chess and GO

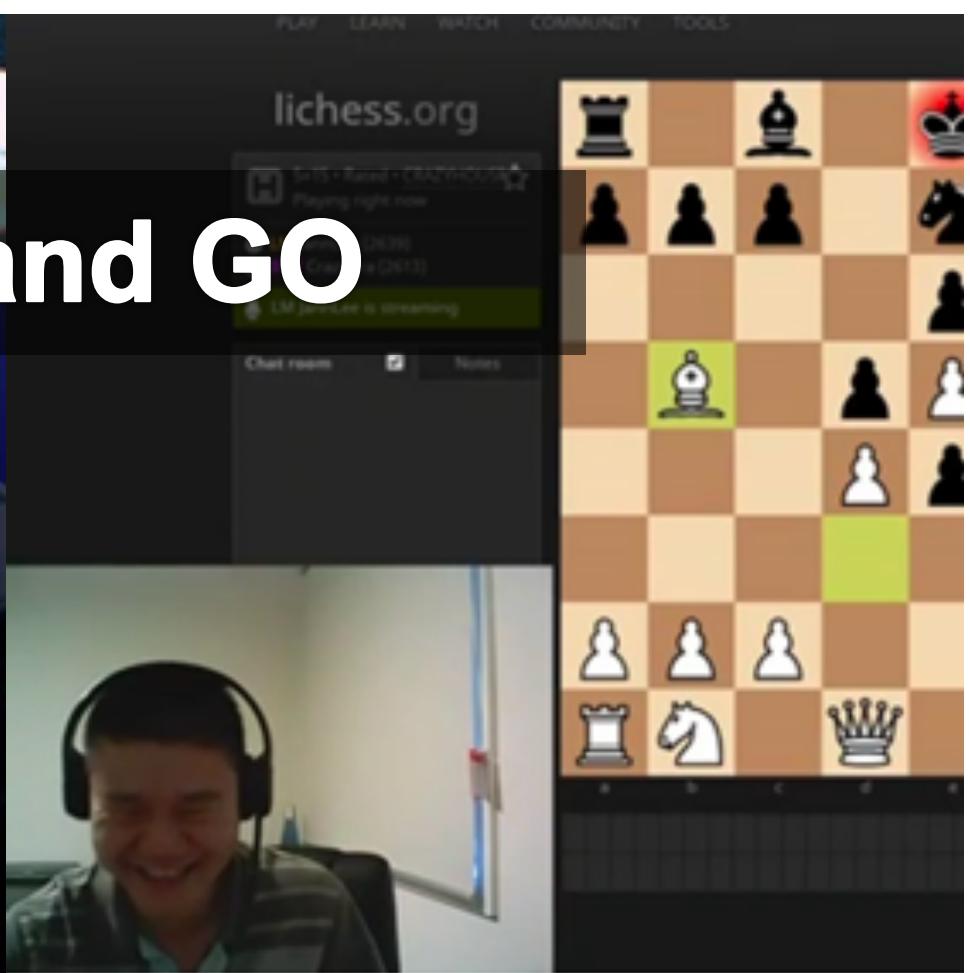


Schachmatt durch „CrazyAra“

Künstliche Intelligenz schlägt mehrfachen Weltmeister im Einsetschach

Der von den TU-Studierenden Johannes Czech, Moritz Willig und Alena Beyer entwickelte Bot „CrazyAra“ hat den Schachprofi Justin Tan in einem Online-Match der Schach-Variante „Crazyhouse“ mit 4:1 geschlagen. Gelernt hat der Bot mittels künstlicher neuronaler Netze, was ihm erlaubt, vorausschauend Entscheidungen zu treffen. Das Besondere: Die Studierenden konnten damit einen Erfolg auf einem Feld feiern, das sonst von Giganten wie Google dominiert wird.

19.02.2019



CrazyAra vs JannLee (Man vs Machine - Crazyhouse Chess on lichess.org) - 2 days ago

Category: Chess

State of the Art

Autonomous Planning and Scheduling

NASA's on-board autonomous planning program controlled the scheduling of operations for a spacecraft

During the 1991 Gulf War, US forces deployed an AI logistics planning and scheduling program

DARPA: this application payed back 30 years of investment in AI

Game Playing

TD-Gammon learned an evaluation function for backgammon that led to changes in backgammon theory

Deep Blue defeated the reigning world chess champion Garry Kasparov in 1997

increased IBM stocks by several billion \$

2017: AlphaGo beat the No. 1 Go Player in the world

2018: AlphaZero beats best chess programs after 4 hours of training



State-of-the-Art

Natural Language Understanding

translation systems are frequently used

Speech recognition

United Airlines has an entire booking system based on automated speech recognition and dialog management

Puzzles

Proverb solves crossword puzzles better than most humans

although it does not “understand” the clues

combination of constraint satisfaction, statistics, web retrieval, ...

IBM's Watson has won at
Jeopardy quiz show

Now the basis of IBM's
cognitive computing initiative
<http://www.ibm.com/de/watson>



AI knows a lot

SPIEGEL TV WISSE



State of the Art

Robotics

self-driving cars are on the verge to consumer products

robot assistants are routinely used in microsurgery

Roomba vacuum robots sold



Scientific Discovery

machine learning system helped to discover new quasars

automated theorem prover proved Robbins conjecture unsolved
for decades

Data Mining and Knowledge Discovery has developed into a new
industry

Deep Learning

Unexpected and unprecedented breakthroughs in diverse areas
such as computer vision, language understanding, game
playing, etc.

Recommended Books

Douglas R. Hofstadter, *Gödel, Escher, Bach*, Basic Books, New York 1979.

→ classic, inspiring, readable, original intro into AI

Peter Norvig, *Paradigms of Artificial Intelligence Programming: Case Studies in Common LISP*, Morgan Kaufmann, 2000.

→ AI techniques in LISP

Ivan Bratko, *Prolog Programming for AI*, Addison-Wesley, 3rd edition, 2000.

→ AI techniques in Prolog

Haugeland, John (ed.), *Mind Design II: Philosophy, Psychology, and Artificial Intelligence*, Cambridge, Mass.: MIT Press, 1981.

→ collection of classic Philosophical articles

<http://www.aaai.org/AITopics/>

→ Web site of the Association for the Advancement of Artificial Intelligence

