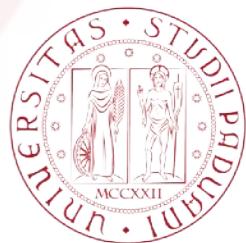




# Computer Vision & Cognitive Systems

SCQ5109806 - LM CS,DS,CYB,PD

Prof. Lamberto Ballan



# Welcome to CVCS

- Today's agenda:
  - ▶ A brief intro to computer vision and cognitive systems
  - ▶ CVCS overview, course logistics



# Who we are



## Instructor

Prof. Lamberto Ballan

<lamberto.ballan@unipd.it>



## Teaching Assistant

Elena Zoppellari

<elena.zoppellari@phd.unipd.it>



## Teaching Assistant

Jelin Raphael Akkara

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## Visual Intelligence & Machine Perception (VIMP) group

VIMP - Visual Intelligence and Machine Perception Group

### About

Visual Intelligence and Machine Perception (VIMP) is a research group at the Department of Mathematics "Tullio Levi-Civita" of the University of Padova, Italy, led by Lamberto Ballan.

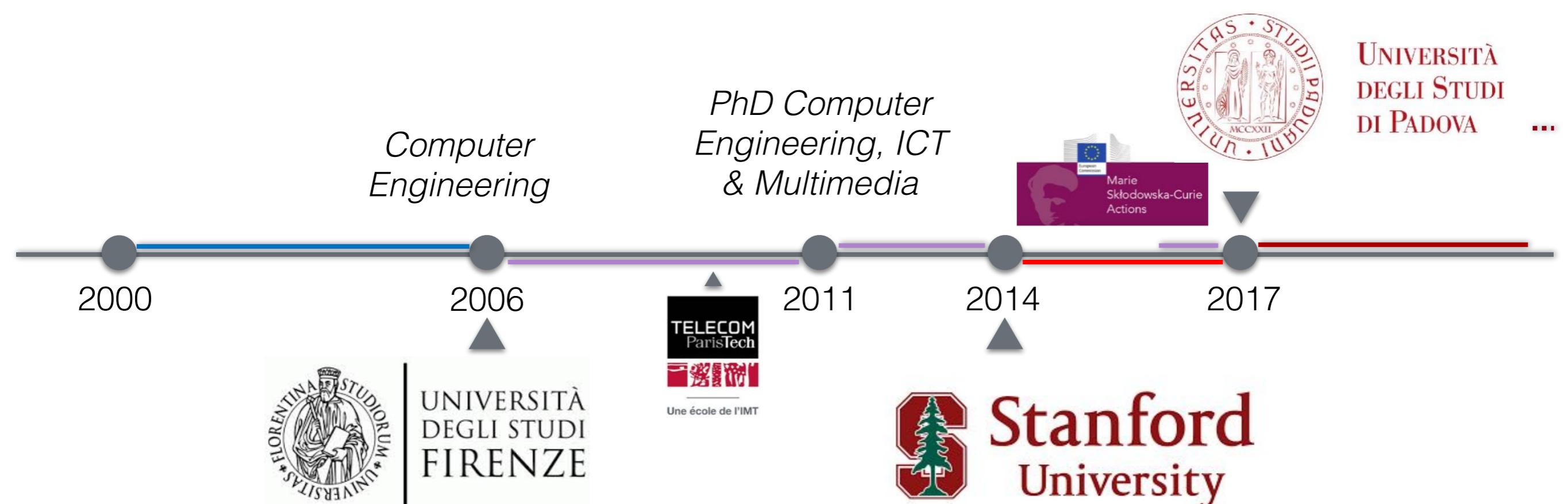
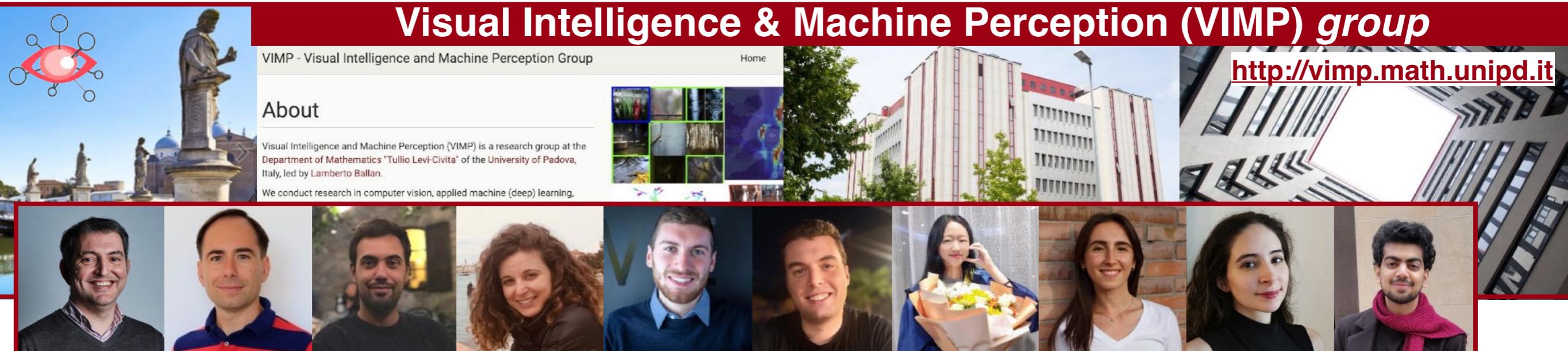
We conduct research in computer vision, applied machine (deep) learning, NLP and multimedia. We aim at developing artificially intelligent systems to help computers perform visual perception and recognition tasks. The main focus of our current research is on designing models that are capable of making the most effective use of contextual knowledge in presence of sparse and noisy data.

We are always looking out for talented members to join our group. Please take a look at the [Join Us page](#).



<http://vimp.math.unipd.it>

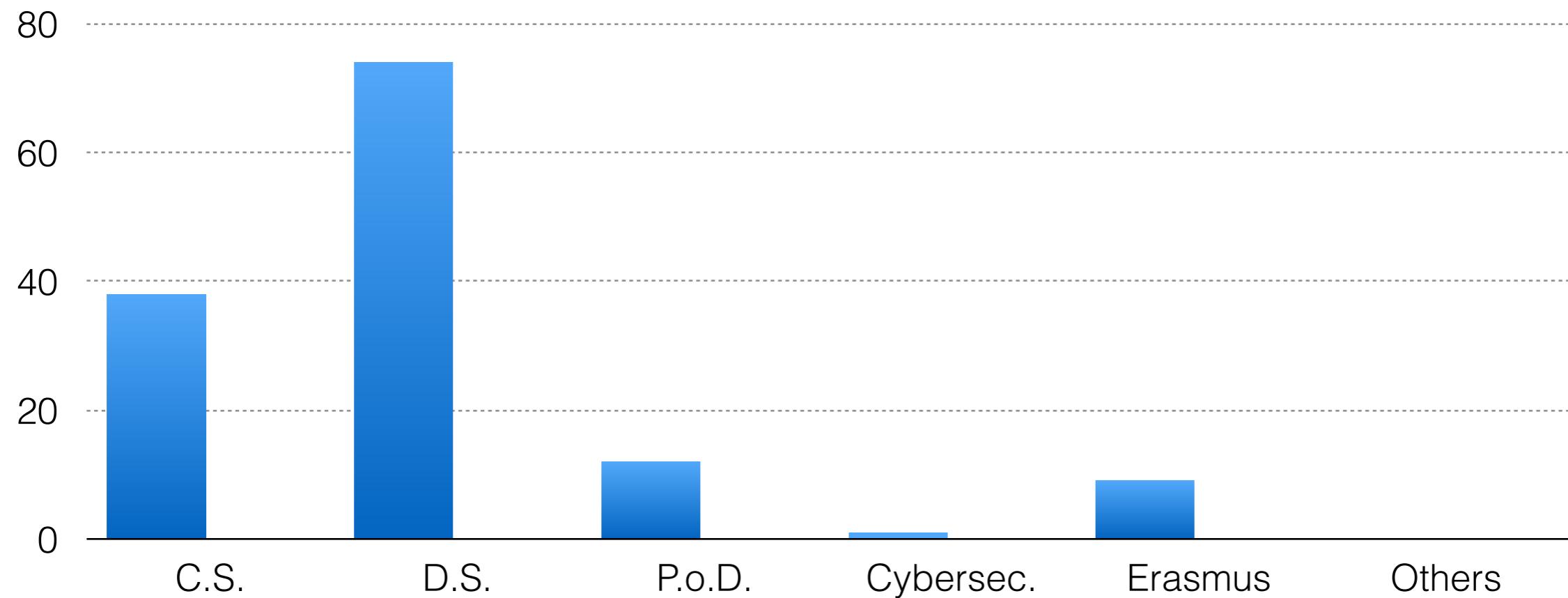
# About me



# Who you are

A.Y. 2024/25

(previous A.Y.: exams registered before September 29)

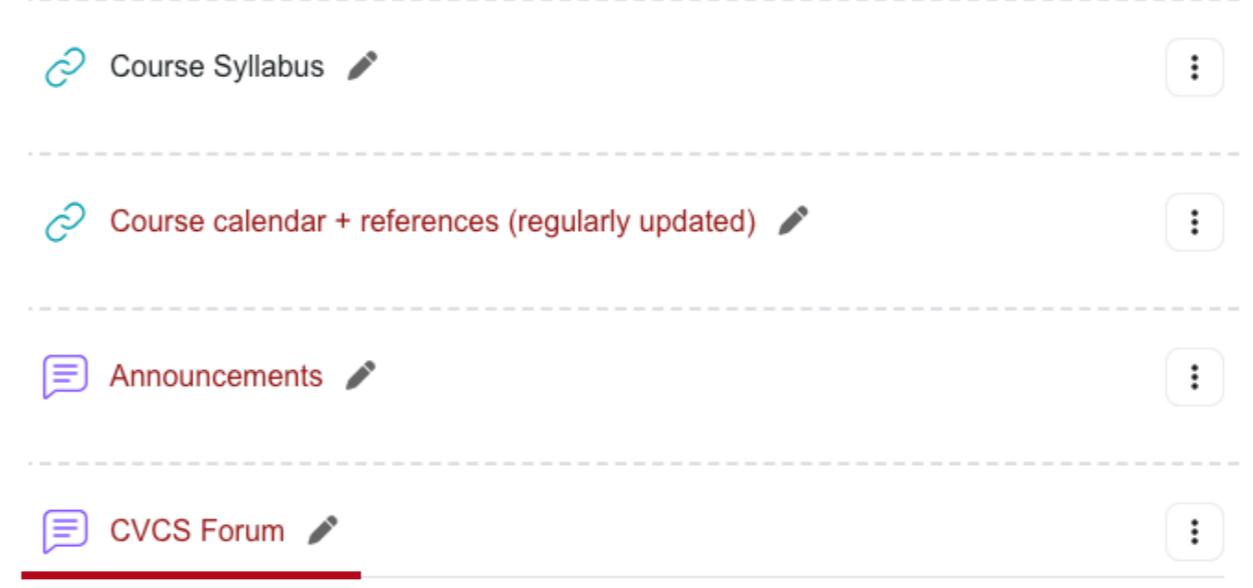


# Course schedule

- Monday, 14:30-16:15 & Tuesday, 12:30-14:15
  - ▶ All lectures will be also recorded and uploaded on Moodle
  - ▶ Approx. 32h (lectures) + 16h (laboratories)

# Course material & how to contact us

- Moodle: <https://stem.elearning.unipd.it/course/view.php?id=13820>
  - ▶ Updated on a weekly basis: slides, references, etc
  - ▶ Use this for most communication with course staff
  - ▶ Ask questions about logistics, assignments, etc
  - ▶ Submit project report



Moodle enrolment key: vls10N-25

# Optional textbooks

- “Foundations of Computer Vision”, A. Torralba, P. Isola, W. T. Freeman (*MIT Press*)
- “Computer Vision: Algorithms and Applications (2nd edition)”, R. Szeliski <http://szeliski.org/Book/> (*free online*)
- “Deep Learning”, I. Goodfellow, Y. Bengio and A. Courville <http://www.deeplearningbook.org/> (*free online*)
- “Pattern Recognition and Machine Learning”, C. Bishop [download the book](#) (*free online*)

# Computer Vision & Cognitive Systems

- Introductory course to **Computer Vision** with an emphasis on high level vision and visual recognition
- Introduction to **Cognitive Systems** and Cognitive Services, *i.e.* APIs available on the cloud to support developers to build artificial intelligent applications
- Course philosophy:
  - **Going under the hood:** our main goal is to teach the theory and skills needed to apply these concepts
  - Students will **face practical problems**/exercises to test the acquired knowledge in a real scenario

# Prerequisites

- The student should have basic knowledge of:
  - Computer programming and algorithms
  - Mathematical analysis, probability theory and statistics, linear algebra
- CVCS is scheduled in the 1<sup>st</sup> semester / 2<sup>nd</sup> year
  - But, if you are familiar with machine learning concepts (e.g. you already took a course such as “Intro. to ML”), you can take the course also in the 1<sup>st</sup> year

# Related courses @UniPD (DM)

- Artificial Intelligence *1<sup>st</sup> semester*
  - LM Comp. Science (Sperduti)
- Machine Learning *1<sup>st</sup> semester*
  - LM Comp. Science (Aiolli), Data Science (Da San Martino), etc.
- Deep Learning *2<sup>nd</sup> semester*
  - LM Computer Science & Data Science (Sperduti, Navarin, Pasa)
- Natural Language Processing *2<sup>nd</sup> semester*
  - LM Computer Science & Data Science (Da San Martino)
- Knowledge Representation and Learning *2<sup>nd</sup> semester*
  - LM Computer Science & Data Science (Confalonieri, Serafini)

And more...

Cognition and Computation, Statistical Learning, Reinforcement Learning, Computer Vision (DEI), Robotics...

# Advanced Topics in DS (CS) 25/26

- “Vision and Learning for Physical Spaces”

8

+

16 hours



Lamberto  
Ballan



UNIVERSITÀ  
DEGLI STUDI  
DI PADOVA

Iro Armeni



Stanford  
University

<https://ir0.github.io/>

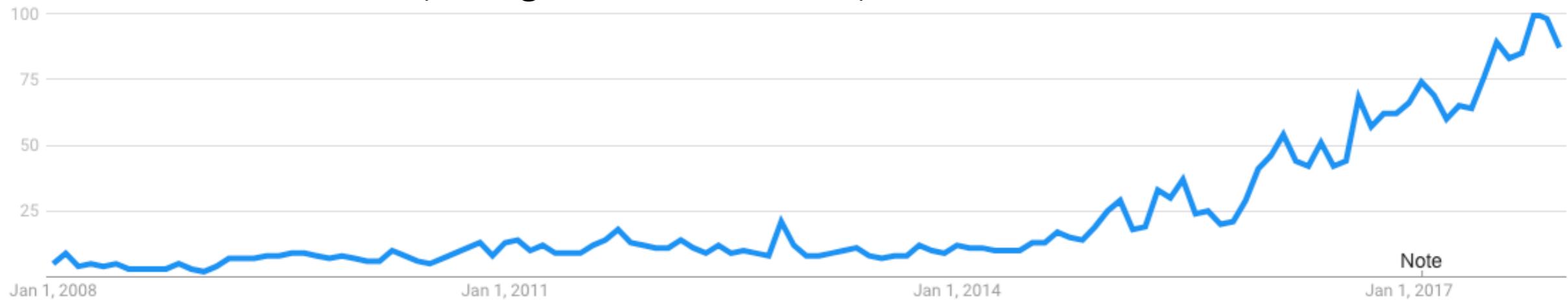


research group

(~mid) March 2026

# The rise of Artificial Intelligence

Interest over time (Google News Search)



## BENEFITS & RISKS OF ARTIFICIAL INTELLIGENCE

*"Everything we love about civilization is a product of intelligence, so amplifying our human intelligence with artificial intelligence has the potential of helping civilization flourish like never before – as long as we manage to keep the technology beneficial."*

Max Tegmark, President of the Future of Life Institute

DEC 17, 2017 @ 08:00 AM 5,830

## Will AI Take Over The World?



**Shep Hyken**, CONTRIBUTOR  
[FULL BIO](#)

Opinions expressed by Forbes Contributors are their own.



# The rise of Artificial Intelligence



Agenda Platforms Reports Events Videos

English ▾

Global Agenda JRS2020 Future of Work Artificial Intelligence

## Don't fear AI. It will lead to long-term job growth.



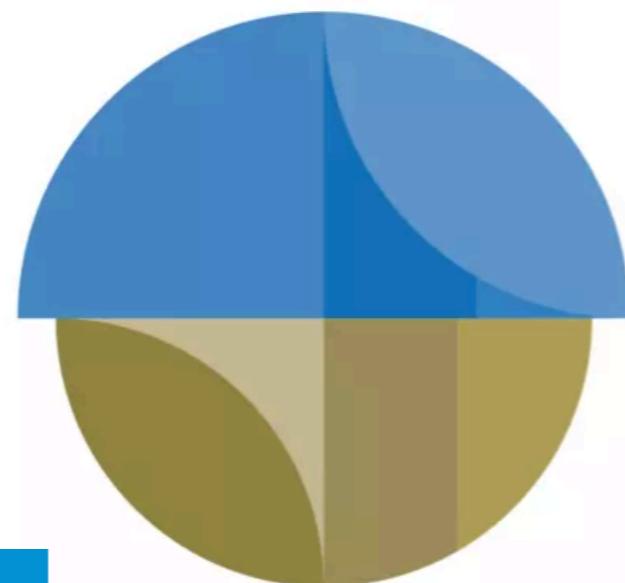
<https://www.weforum.org/agenda/2020/10/dont-fear-ai-it-will-lead-to-long-term-job-growth/>

“  
BY 2025, AN  
ESTIMATED 95%  
OF CUSTOMER  
INTERACTIONS  
WILL BE  
SUPPORTED BY  
AI TECHNOLOGY.  
— FORBES

## Job landscape

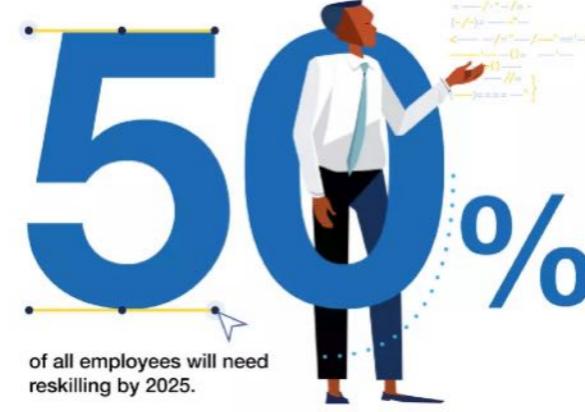
By 2025, new jobs will emerge and others will be displaced by a shift in the division of labour between humans and machines, affecting:

**97 million**



**85 million**

### Reskilling needs



#### Growing job demand:

1. Data Analysts and Scientists
2. AI and Machine Learning Specialists
3. Big Data Specialists
4. Digital Marketing and Strategy Specialists
5. Process Automation Specialists
6. Business Development Professionals
7. Digital Transformation Specialists
8. Information Security Analysts
9. Software and Applications Developers
10. Internet of Things Specialists

#### Decreasing job demand:

1. Data Entry Clerks
2. Administrative and Executive Secretaries
3. Accounting, Bookkeeping and Payroll Clerks
4. Accountants and Auditors
5. Assembly and Factory Workers
6. Business Services and Administration Managers
7. Client Information and Customer Service Workers
8. General and Operations Managers
9. Mechanics and Machinery Repairers
10. Material-Recording and Stock-Keeping Clerks

# Some success stories

## 1. Machine Translation

The screenshot shows the Google Translate interface. At the top, there are language selection boxes for English, Italian, Spanish, and Detect language. Below these are two text boxes. The left text box contains an English paragraph about a recurring anxiety dream involving a self-driving car. The right text box shows the Italian translation of the same paragraph. Between the text boxes are language swap arrows, a "Translate" button, and a "Turn off instant translation" link. The bottom right corner of the right text box has a "Suggest an edit" button.

Google Translate interface showing English to Italian translation:

**English** **Italian** **Spanish** **Detect language** ▾

Waymo's vehicles may not have the cool quotient of Tesla's Model S, but they manage to navigate a minefield of potential accidents. Of all my recurring anxiety dreams, my least favorite is the one where I'm in a car. It always begins with me driving, but eventually I realize that for some reason I'm sitting in the back seat. My arms can't reach the steering wheel, my legs can't reach the pedals, and I'm stuck in a spiral of terror, careening around turns and accelerating toward obstacles until, gasping, I wake up. This is a bit like the passenger experience in Waymo's self-driving cars. You climb into the back seat of a minivan, and watch in awe – or horror – as the wheel turns itself above an entirely empty driving seat.

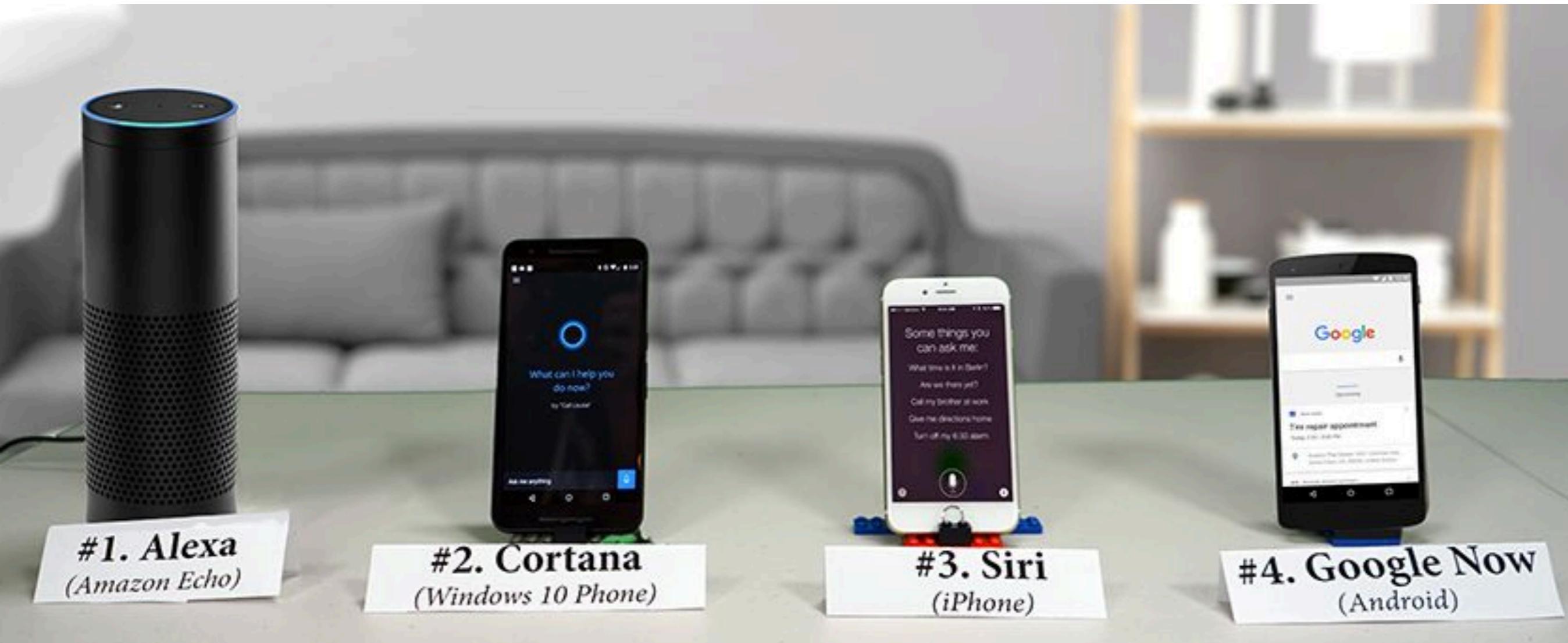
731/5000

I veicoli di Waymo potrebbero non avere il quoziente interessante di Tesla's Model S, ma riescono a navigare in un campo minato di potenziali incidenti. Tra tutti i miei ricorrenti sogni d'ansia, il mio preferito è quello in cui sono in auto. Comincia sempre con me alla guida, ma alla fine mi rendo conto che per qualche motivo sono seduto sul sedile posteriore. Le mie braccia non riescono a raggiungere il volante, le mie gambe non riescono a raggiungere i pedali, e sono bloccato in una spirale di terrore, girandomi intorno alle curve e accelerando verso ostacoli finché, senza fiato, mi sveglio. Questo è un po 'come l'esperienza dei passeggeri nelle auto a guida autonoma di Waymo. Salite sul sedile posteriore di un minivan e osservate con ammirazione - o orrore - mentre la ruota si gira sopra un posto di guida completamente vuoto.

Suggest an edit

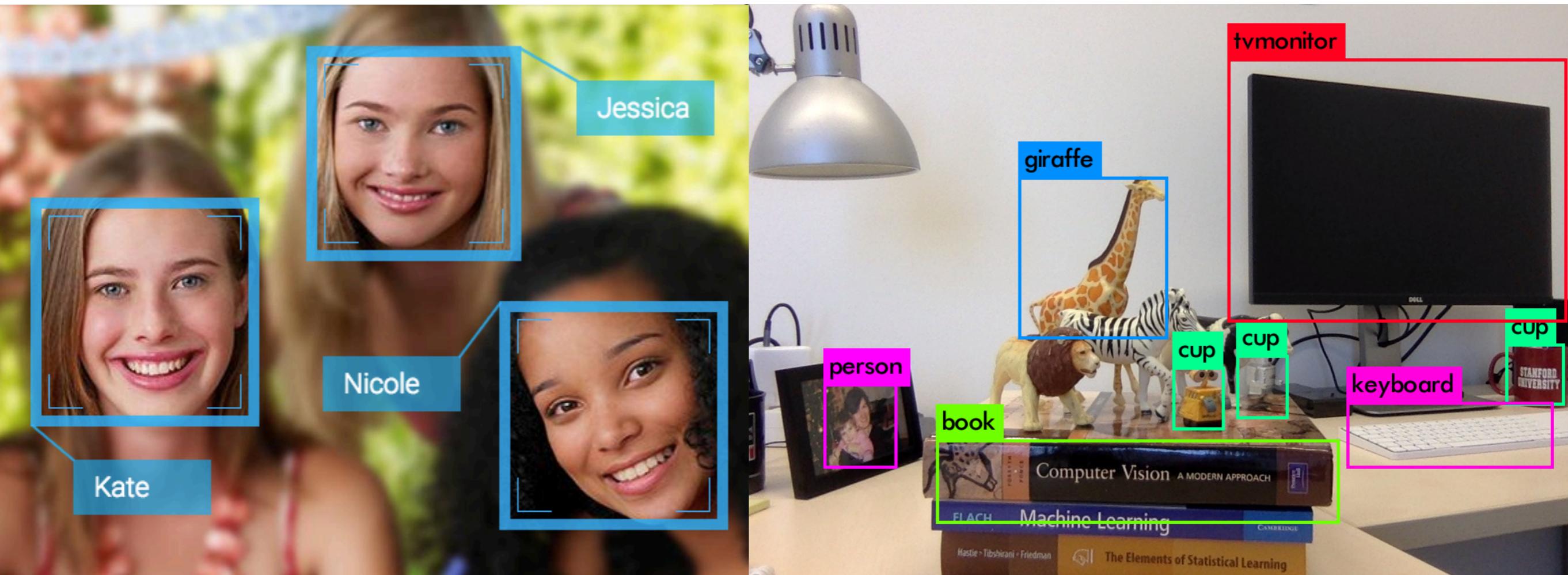
# Some success stories

## 2. Speech Recognition



# Some success stories

## 3. Face Recognition / Visual Recognition



# Cognitive Computing

- Machine Learning (~ Deep Learning)
- Natural Language Processing
- Speech Recognition
- **Computer Vision**

*learn from &  
make sense of*  
• Big Data



(A)Intelligent  
Applications  
  
Data-driven  
decisions

# Deep Learning revolution

- ACM Turing Award (*i.e. the “Nobel prize” in CS*) 2018:  
*“For conceptual and engineering breakthroughs that have made deep neural networks a critical component of computing.”*



# What about nowadays?

- Big models: LLMs (e.g. GPT, Gemini, Llama, ...)

The image shows a composite screenshot of the ChatGPT interface. On the left, a smartphone displays the mobile app's dark mode interface. The user has sent a message asking for brunch suggestions, and ChatGPT has responded with a list of 10 items, including fresh fruit salad, pastries, and bagels. On the right, the web version of ChatGPT is shown. A user has asked for feedback on a short story, and ChatGPT has provided a detailed response, highlighting punctuation, clarity, and narrative elements. The background of the entire screenshot is a dark teal color.

**OpenAI** Research API ChatGPT Safety Company Search Log in Try ChatG

ChatGPT 3.5

was quiet for a moment and then he started again.

Can you give me feedback on my short story?

**ChatGPT**

Your writing is engaging and provides insight into the protagonist's life. You effectively use descriptive language to paint a picture of the setting and the characters. The protagonist's desire to impress their father feels natural and adds depth to the story. Additionally, the pacing is well-balanced, with moments of tension and relaxation.

However, there are a few areas where you could improve:

1. Punctuation and grammar: There are some minor punctuation and grammar errors that could be polished for a smoother reading experience.
2. Clarity: Some parts of the story could benefit from a bit more clarity, particularly in the descriptions of the setting and the protagonist's internal thoughts.
3. Show, don't tell: While you do a good job of describing the physical world around the protagonist, you could provide more insight into the reader about the character's feelings and past experiences. Consider using more descriptive language or dialogue, or internal monologue to make the narrative more immersive.

Overall, your writing is well-crafted and engaging, with room for improvement. Keep up the good work! ●

Message ChatGPT... ChatGPT can make mistakes. Consider checking important information before sharing it.

ChatGPT

Get instant answers, find creative inspiration, learn something new.

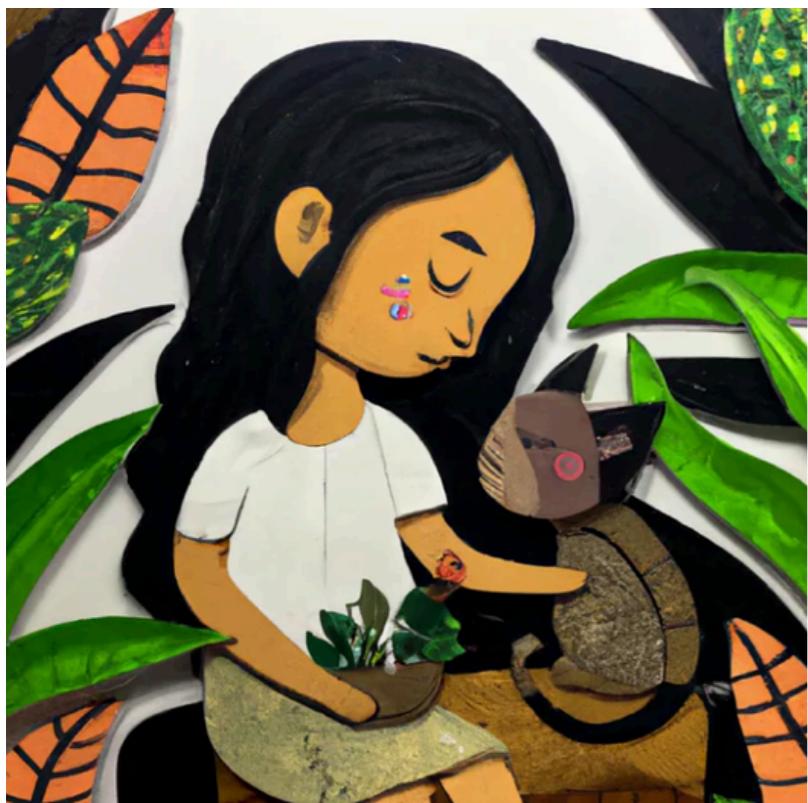
Download on the App Store GET IT ON Google Play Try on web

# What about nowadays?

- Generative AI: e.g. image generation tools based on diffusion models (DALL-E, MidJourney, ...)

**Prompt:** A paper craft art depicting a girl giving her cat a gentle hug. Both sit amidst potted plants, with the cat purring contentedly while the girl smiles. The scene is adorned with handcrafted paper flowers and leaves.

DALL-E 2



DALL-E 3



ChatGPT 5



# A.I. & the impossible possibilities

- Generative AI, LLMs, foundation models (ChatGPT...)

:

**Prompt:** I'd like the cat black and the girl with curly hairs.



1<sup>st</sup> image



ChatGPT 5

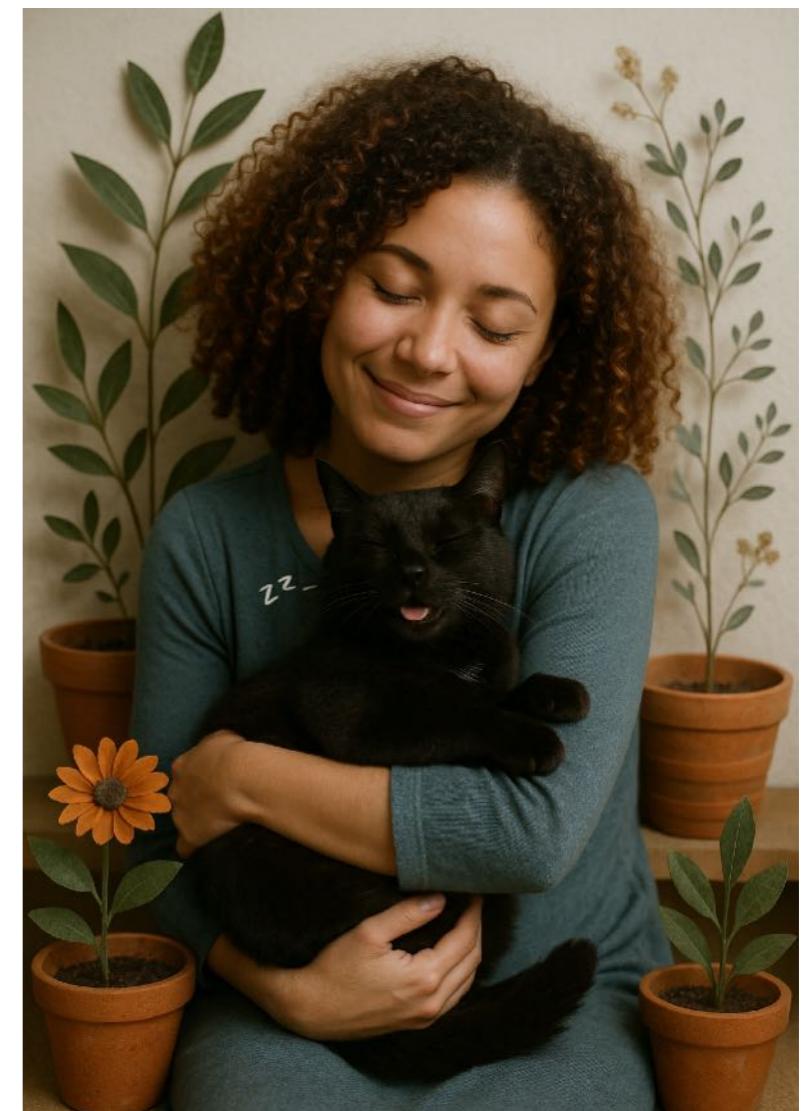
# A.I. & the impossible possibilities

- Generative AI, LLMs, foundation models (ChatGPT...)

:

**Prompt:** Can you generate the same picture but photo realistic?

**ChatGPT 5**



*prev. images*

# A.I. & the impossible possibilities

- Generative AI, LLMs, foundation models (ChatGPT...)

A screenshot of a CNN Business article. At the top, there is a logo for "CHATGPT" featuring a stylized knot icon above the word "CHATGPT". To the right of the logo is a large black upward-pointing arrow. Below the logo, the CNN Business navigation bar includes links for Markets, Tech, Media, Calculators, and Videos. The main headline, "ChatGPT passes exams from law and business schools", is displayed in large, bold, black text with a yellow brushstroke underline. Below the headline is a photo of Samantha Murphy Kelly, the author, followed by her name and the update time: "Updated 1:35 PM EST, Thu January 26, 2023". Below the author information are social sharing icons for Facebook, Twitter, Email, and LinkedIn. A partial view of the mobile application interface is visible at the bottom of the screen.

Forbes

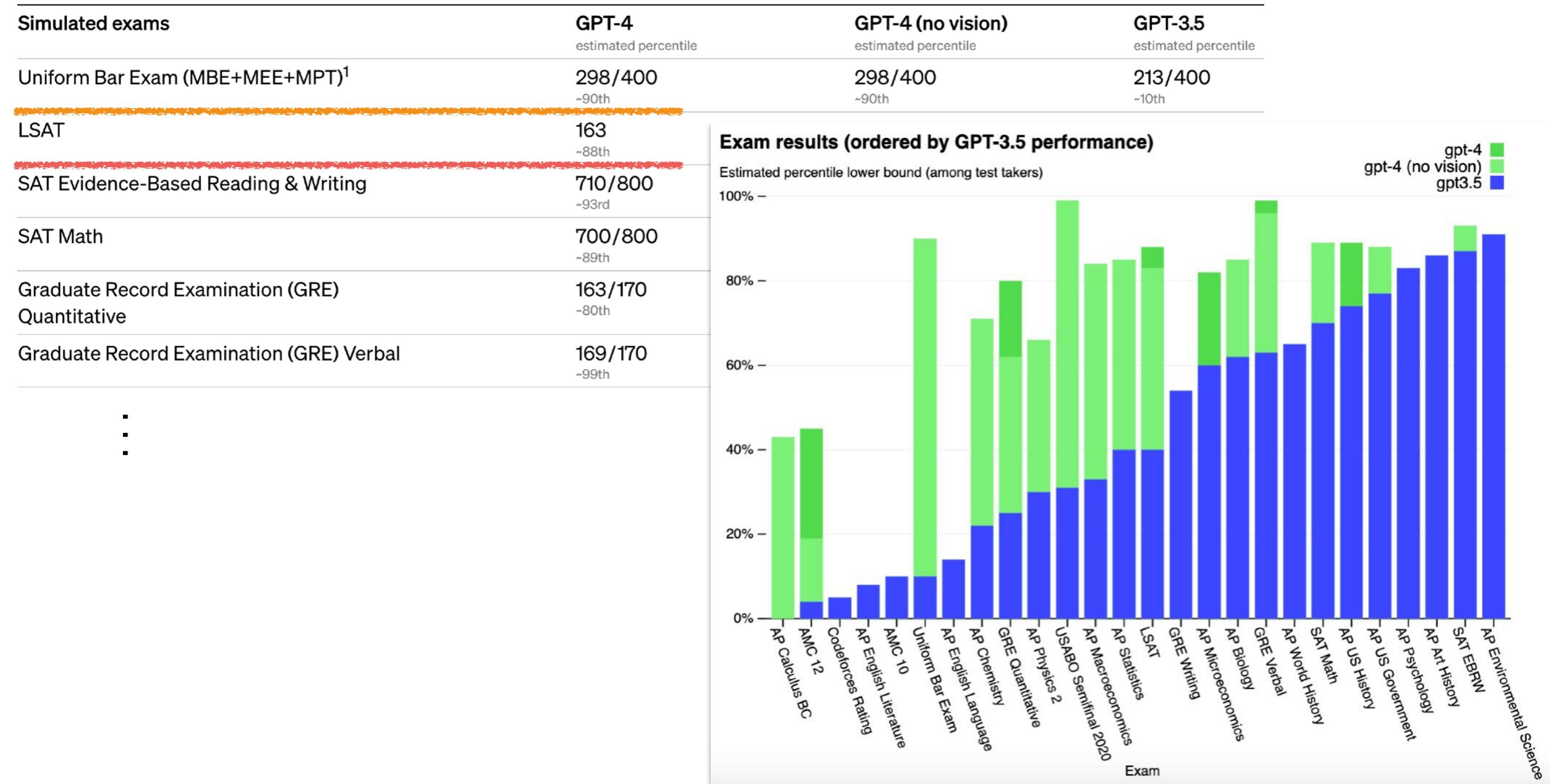
[Bookmark](#) [Comment 0](#)

Mar 14, 2023, 06:40pm EDT

Conceptual background of Artificial intelligence , humans and cyber-business on programming ... [+] GETTY

In 1997, IBM’s Deep Blue defeated the reigning world champion chess player, Garry Kasparov. In 2016, Google’s AlphaGo defeated one of the worlds top Go players in a five-game match. Today, OpenAI released GPT-4, which it claims beats 90% of humans who take the bar to become a lawyer,

# A.I. & the impossible possibilities



# Human and Artificial Intelligence

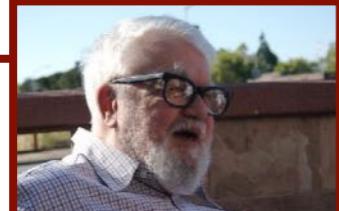
- We have reached a point in which human and machine capabilities are comparable on several cognitive tasks...
- But comparing human and artificial intelligence is not a new thing; this is a “long story”, as old as the A.I. field itself!

1950

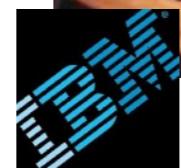


Alan Turing

1955



John McCarthy



Google

2010



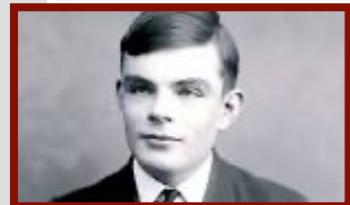
2020

# Human and Artificial Intelligence

- The **imitation game** (a.k.a. Turing Test):

- The interrogator (C) is unable to see players (A, B) and can communicate with them only through written notes
- The interrogator tries to determine which player is a computer and which is a human

A. M. Turing (1950) Computing Machinery and Intelligence. *Mind* 49: 433-460.

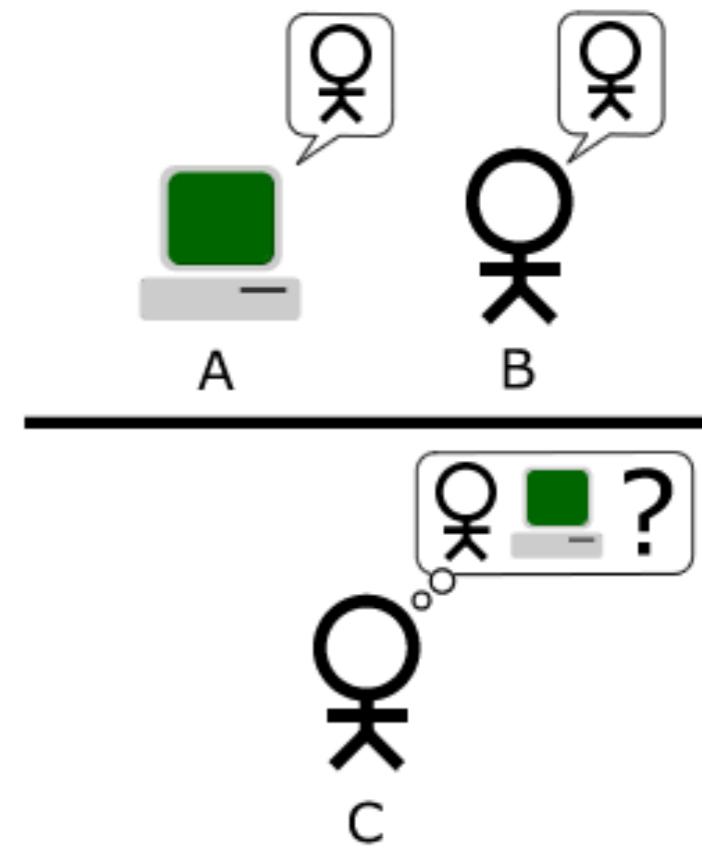


## COMPUTING MACHINERY AND INTELLIGENCE

By A. M. Turing

### 1. The Imitation Game

I propose to consider the question, "Can machines think?" This should begin with definitions of the meaning of the terms "machine" and "think." The definitions might be framed so as to reflect so far as possible the normal use of the words, but this attitude is dangerous. If the meaning of the words "machine" and "think" are to be found by examining how they are commonly used it is difficult to escape the conclusion that the meaning and the answer to the question, "Can machines think?" is to be sought in a statistical survey such as a Gallup poll. But this is absurd. Instead of attempting such a definition I shall replace the question by another, which is closely related to it and is expressed in relatively unambiguous words.



# Human and Artificial Intelligence

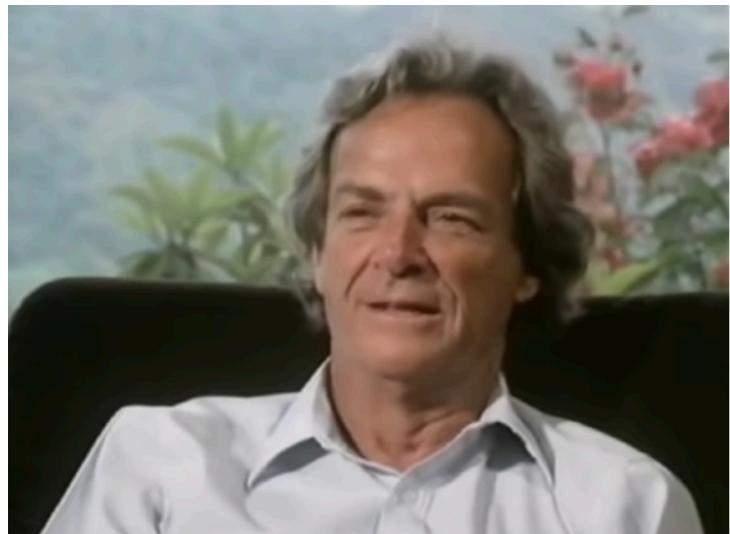
## Audience Question:

(Re-recorded by me because the question is poorly audible)

Do you think there will ever be  
a machine that will think like human beings  
and be more intelligent than human beings?

Richard Feynman - September 26th, 1985

# Human and Artificial Intelligence



First, intelligence has to be defined.

If you were to ask me: “are they better chess player than any human can possibly can be?”, yes, I’ll get you; someday! They are better chess players than most human being right now.

Kasparov vs. IBM Deep Blue (May 1997): 2.5-3.5

One of the things, by the way, that we always do, is that we want the machine to be better than anybody.

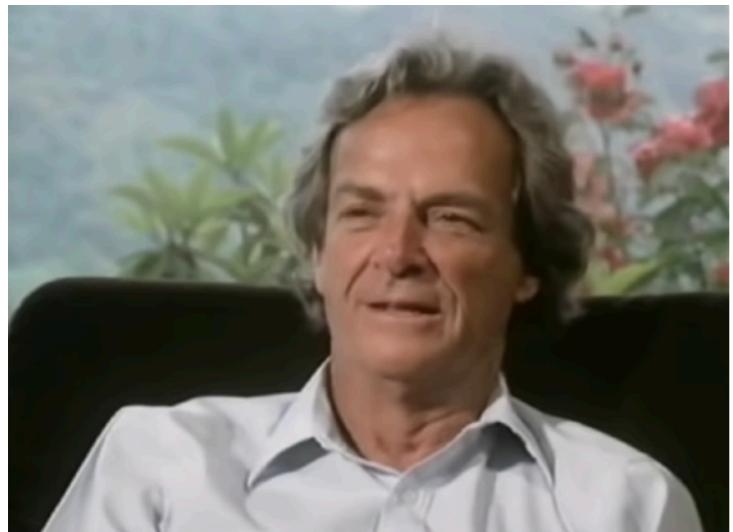
Richard Feynman - September 26th, 1985

# Human and Artificial Intelligence



Richard Feynman - September 26th, 1985

# Human and Artificial Intelligence



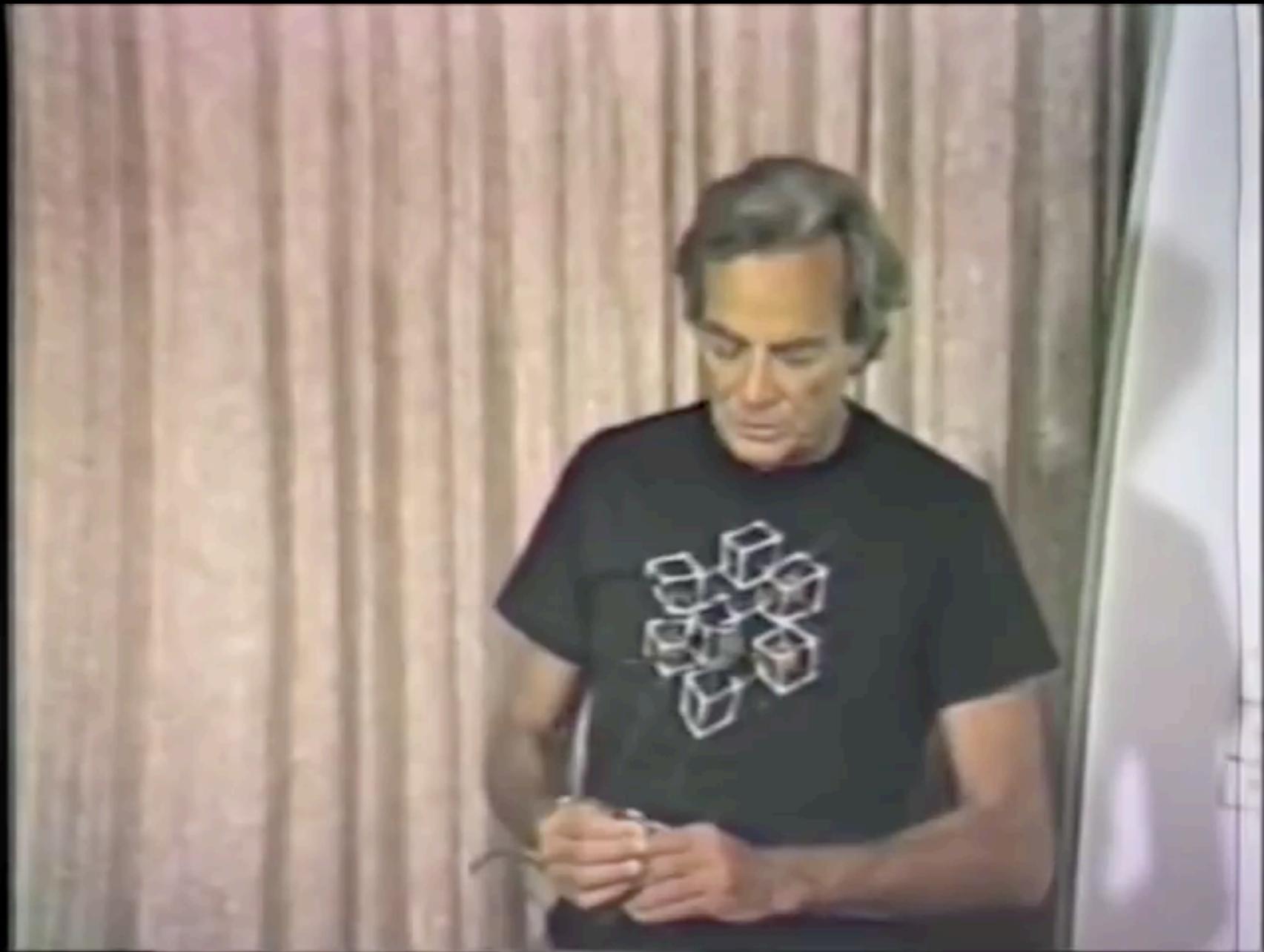
But with regard to the question of whether to make machines to think like human beings, I would say no.

*(Cheetah and airplane examples)*

It's different, right?... so there's no question that the later machines are not going to think like people think.

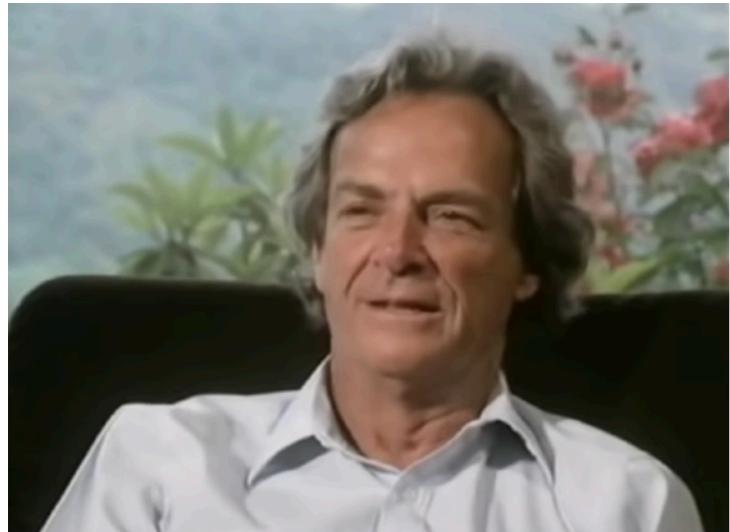
Richard Feynman - September 26th, 1985

# Human and Artificial Intelligence



Richard Feynman - September 26th, 1985

# Human and Artificial Intelligence

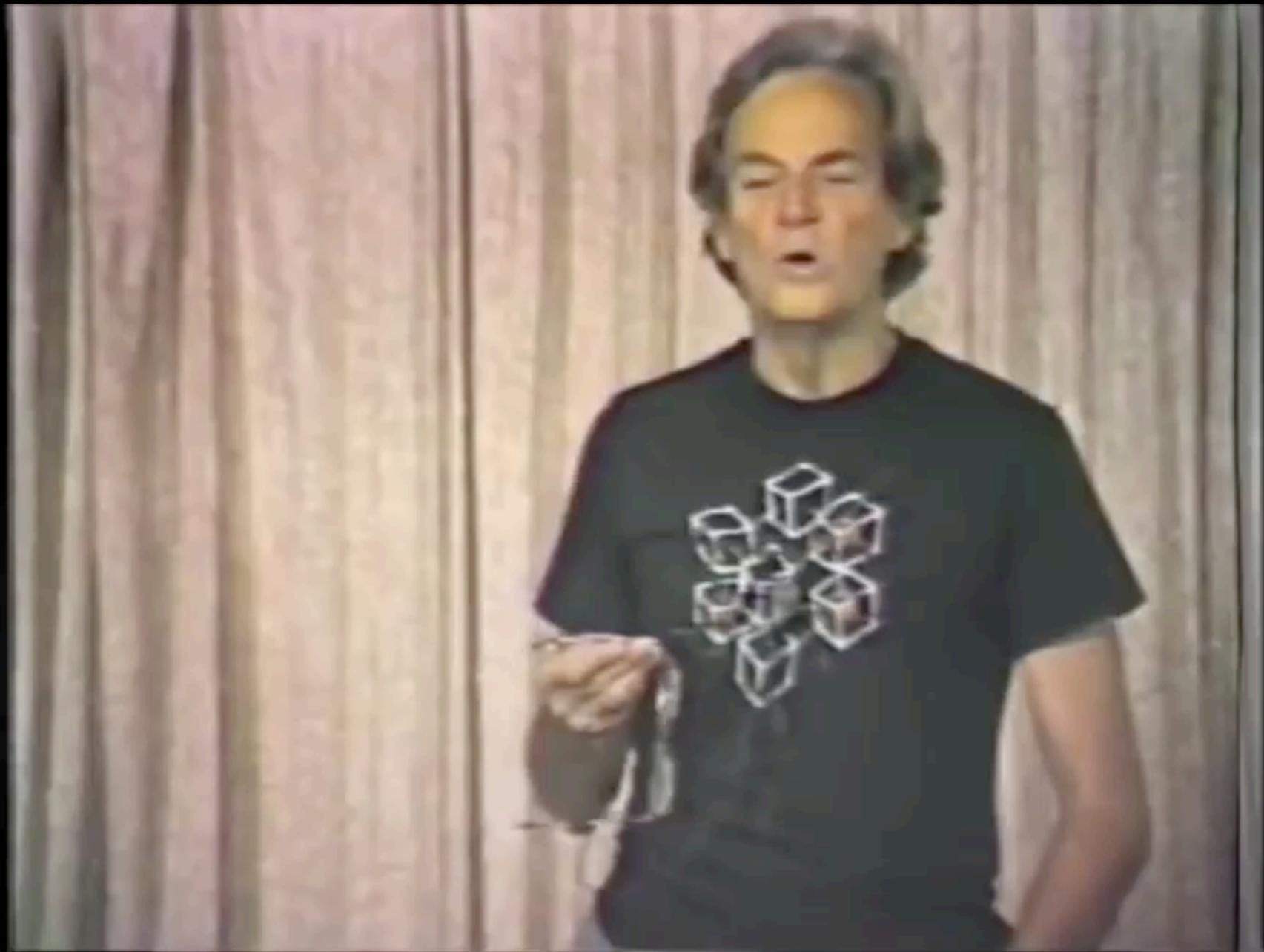


It's different. We're never going to change how they do arithmetic to make it more humans; that would be going backwards!

We know many things that a computer does much better than a human (and you'd better remember that, if you'd like to compare machines to humans!).

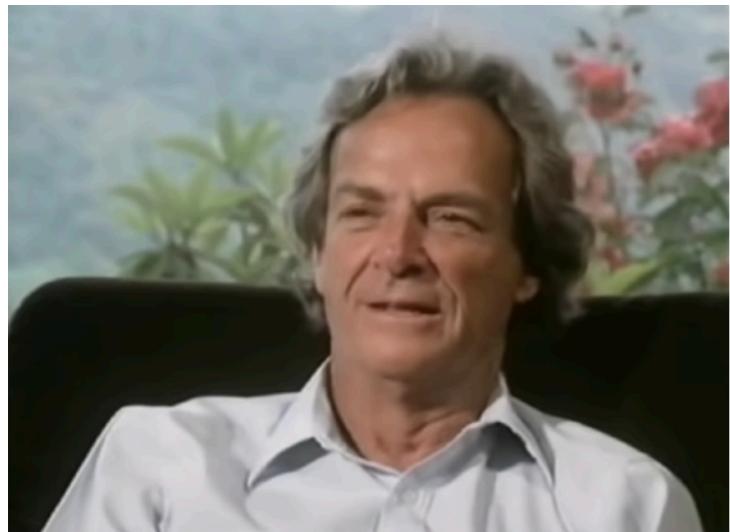
Richard Feynman - September 26th, 1985

# Human and Artificial Intelligence



Richard Feynman - September 26th, 1985

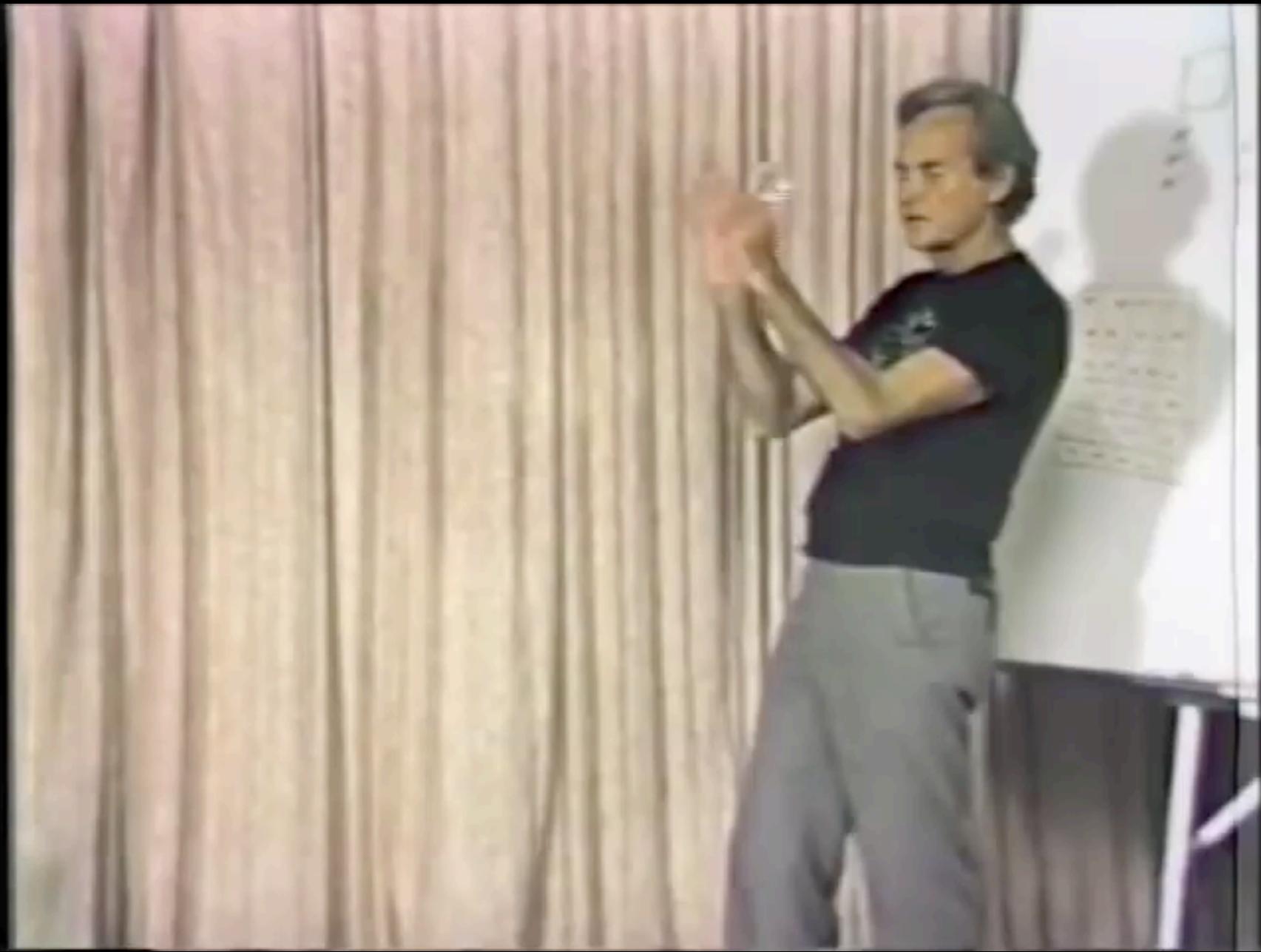
# Human and Artificial Intelligence



To recognize things, to recognize patterns, seems to be something that we have not be able to put into a definite procedure.

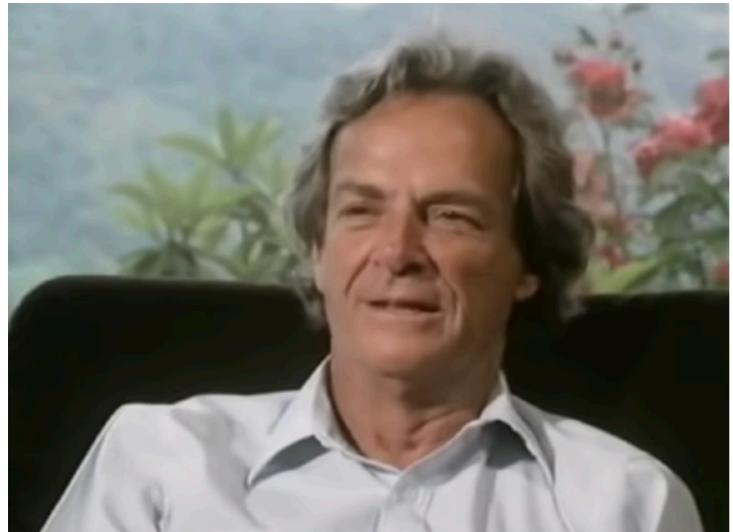
Richard Feynman - September 26th, 1985

# Human and Artificial Intelligence



Richard Feynman - September 26th, 1985

# Human and Artificial Intelligence



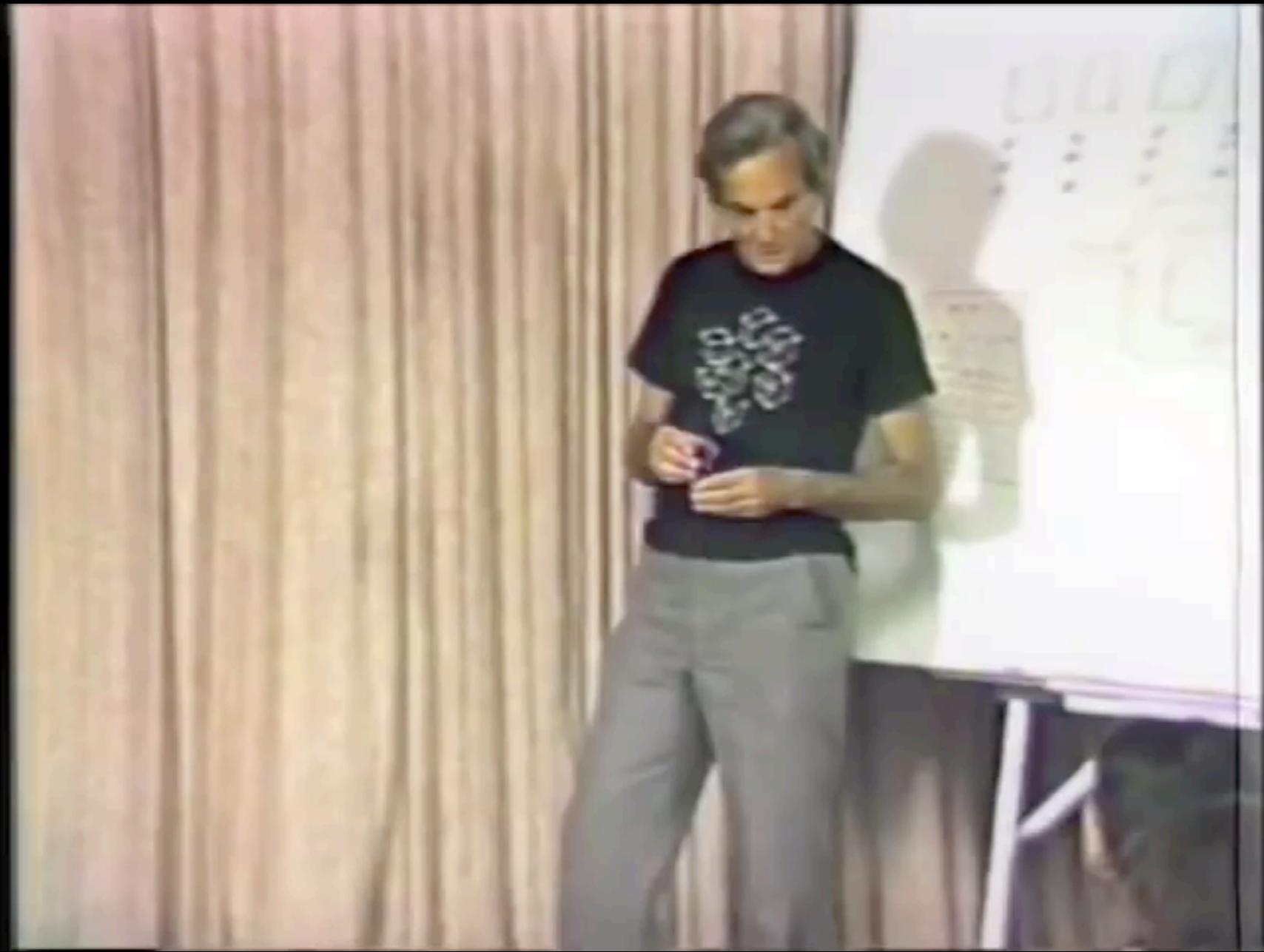
You would say: “I have a good procedure to recognize Jack; let’s just take a lots of pictures of Jack in different circumstances, and then ask the machine to compare them”.

The trouble is that the actual new circumstance is different; the lighting is different, the distance is different, the tilt of the head is different. You have to figure out how to allow for all that.

**This is computer vision and pattern recognition!**

Richard Feynman - September 26th, 1985

# Human and Artificial Intelligence



Richard Feynman - September 26th, 1985

# Human and Artificial Intelligence

- **Moravec's paradox** (1988): logic and reasoning are way easier to handle by machines than sensory-motor or perception skills

Steven Pinker (linguist and cognitive scientist):

*"The main lesson of 35 years of AI research is that the hard problems are easy and the easy problems are hard. The mental abilities of a four-year-old that we take for granted – recognizing a face, lifting a pencil, walking across a room, answering a question – in fact solve some of the hardest engineering problems ever conceived... As the new generation of intelligent devices appears, it will be the stock analysts and petrochemical engineers and parole board members who are in danger of being replaced by machines. The gardeners, receptionists, and cooks are secure in their jobs for decades to come."*

Book: "The Language Instinct", 1994

# Computer Vision & Cognitive Systems

- What is this course about then?
  - We will mostly focus on vision and, in particular, on high-level computer vision tasks (visual recognition)
    - We will start from the very foundations
    - Then we will dive into machine (deep) learning architectures for vision
  - We will talk about, and try to design, cognitive systems that are able to exploit multiple modalities (e.g. vision and language) and to interact with the environment

# CVCS: Syllabus

- ▶ Introduction  
*AI revolution; from human cognition to machine intelligence and cognitive systems;*
- ▶ Brief Introduction to Machine (Deep) Learning  
*Classification; supervised learning; training and testing; bias*
- ▶ (Early) Computer vision and image processing  
*Image formation and filtering; feature detectors and descriptors*
- ▶ Visual Recognition and Representation Learning in Vision  
*Bag-of-Features; spatial pyramids and pooling; CNNs*
- ▶ Beyond Image Classification and Supervised Learning  
*R-CNN and segmentation; image captioning; sequential data in vision tasks; predictive vision; self-supervised learning*

# Our focus: vision/visual recognition

- The Big (visual) Data Era

**flickr**

6 billion images

**YouTube**

100 hours uploaded  
per minute



**3.5 trillion  
photographs**



**Almost 90% of web traffic is visual!**

the simple image sharer  
**imgur**

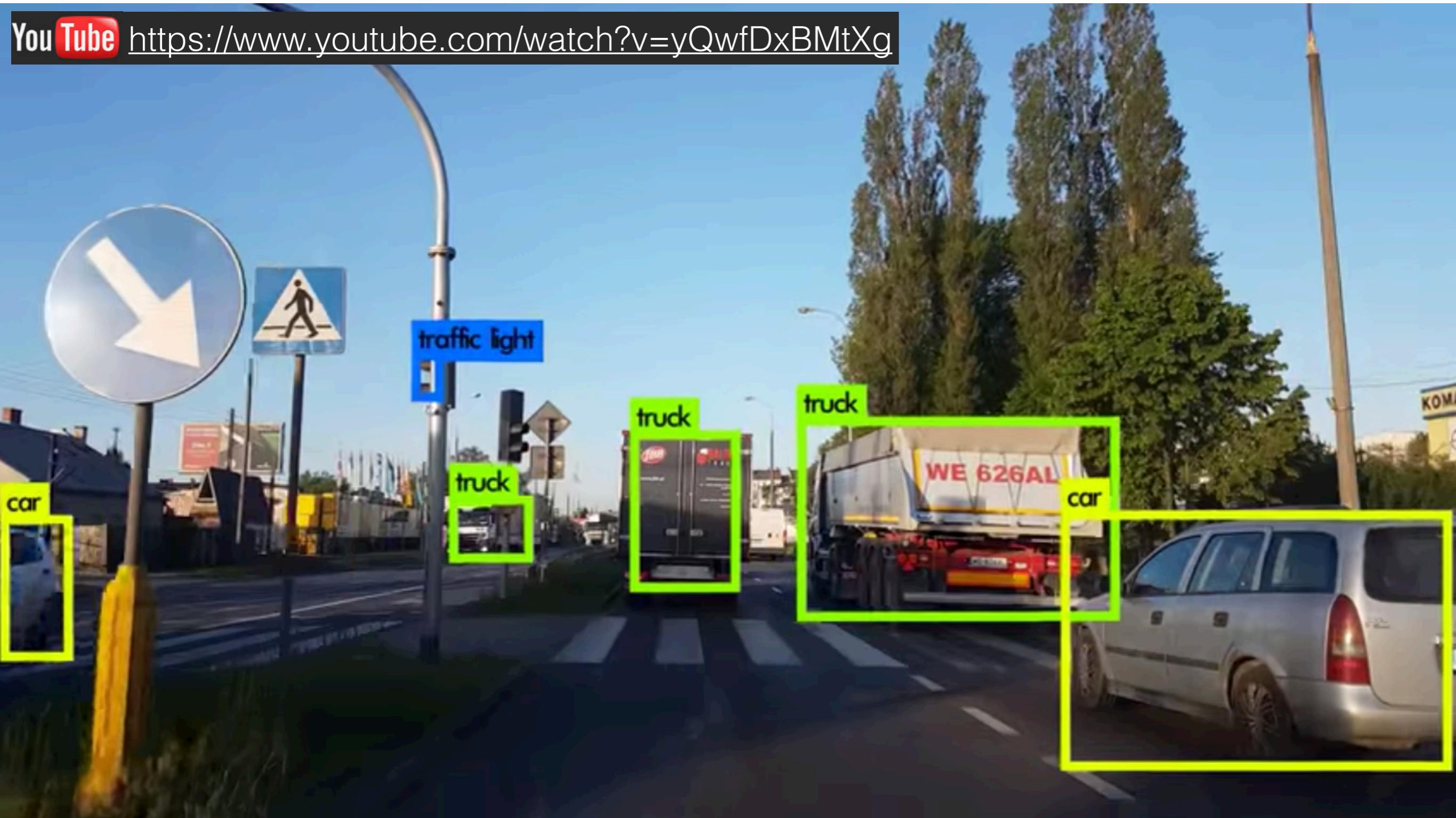
1 billion images  
served daily

**facebook**

70 billion images

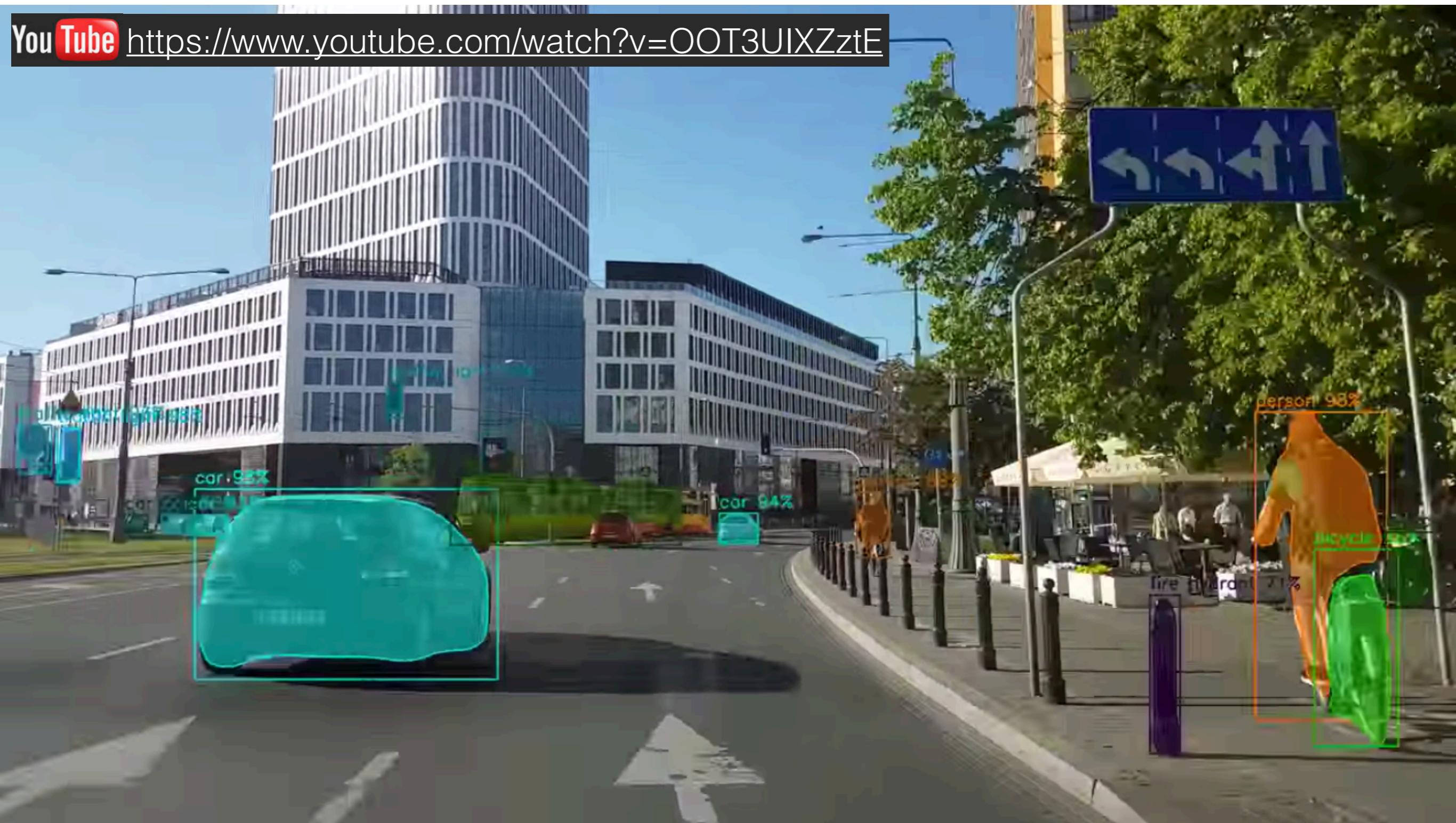
# Demo: visual recognition

YouTube <https://www.youtube.com/watch?v=yQwfDxBMtXg>



# Demo: visual recognition

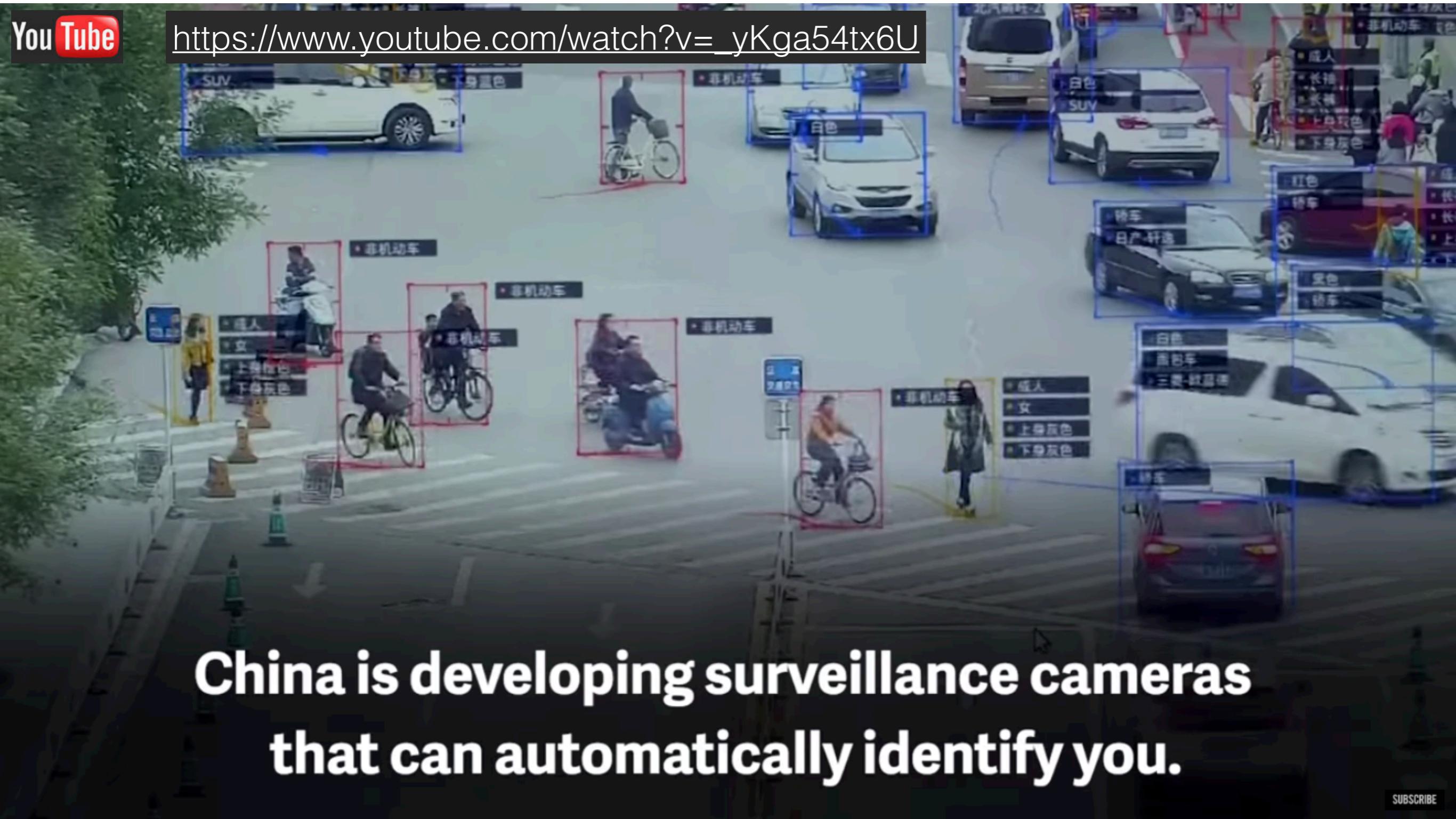
**You**Tube <https://www.youtube.com/watch?v=OOT3UIXZztE>



# Demo: visual recognition



[https://www.youtube.com/watch?v=\\_yKga54tx6U](https://www.youtube.com/watch?v=_yKga54tx6U)



**China is developing surveillance cameras  
that can automatically identify you.**

SUBSCRIBE

# Demo: AI-generated content

YouTube [https://www.youtube.com/watch?v=RVDu\\_u\\_a578](https://www.youtube.com/watch?v=RVDu_u_a578)



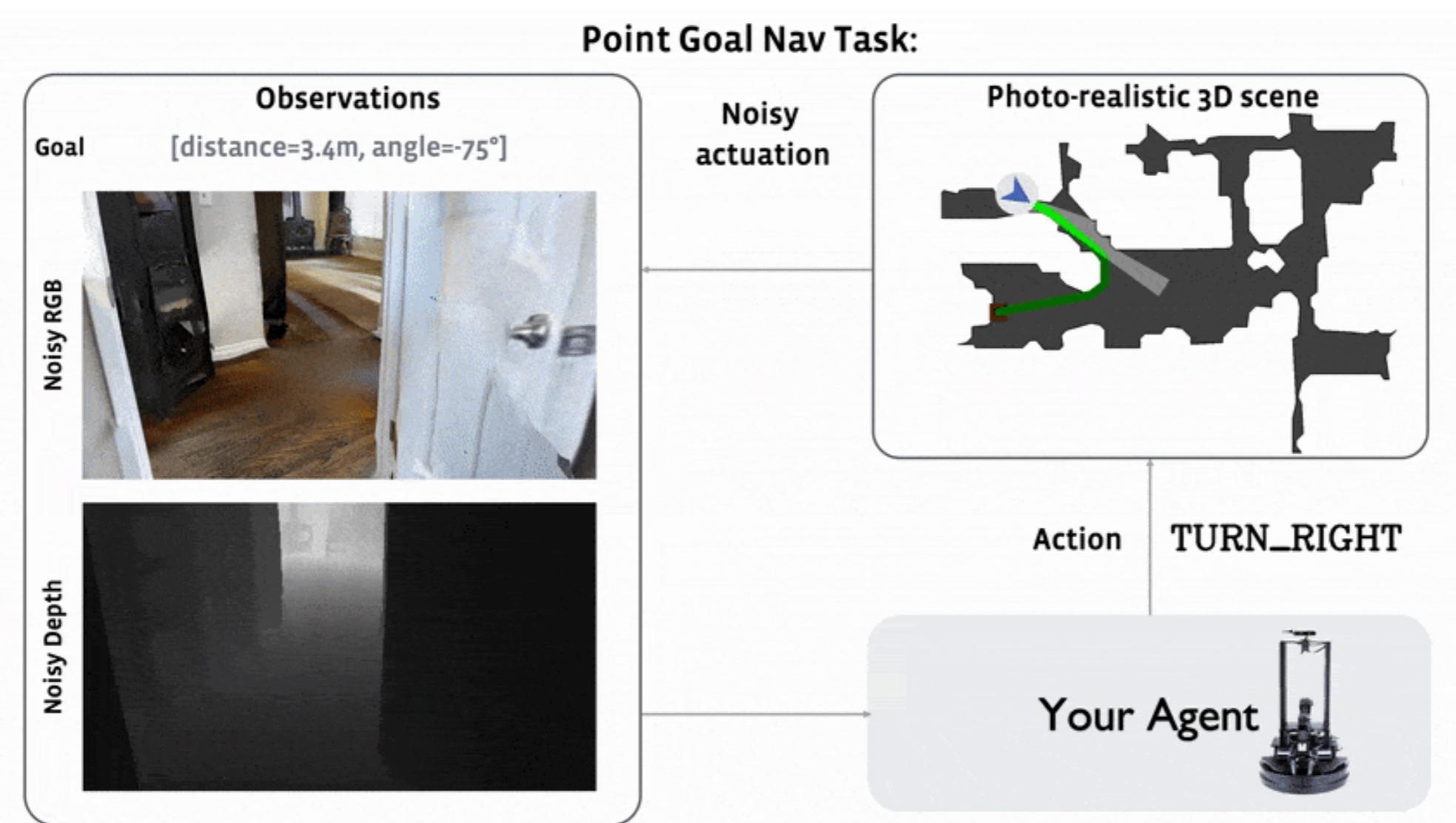
# Demo: video captioning

YouTube <https://www.youtube.com/watch?v=FmSsek5luHk>



an airplane is parked on the runway at the airport

# Demo: embodied computer vision



# CVCS: Syllabus

- ▶ Introduction  
*AI revolution; from human cognition to machine intelligence and cognitive systems*
- ▶ Brief Introduction to Machine (Deep) Learning  
*Classification; supervised learning; training and testing; bias*
- ▶ (Early) Computer vision and image processing  
*Image formation and filtering; feature detectors and descriptors*
- ▶ Visual Recognition and Representation Learning in Vision  
*Bag-of-Features; spatial pyramids and pooling; CNNs*
- ▶ Beyond Image Classification and Supervised Learning  
*R-CNN and segmentation; image captioning; sequential data in vision tasks; predictive vision; self-supervised learning*

# Course calendar

- Tentative schedule for the first weeks:

#week		Date	Lecture / Topic	Reading Material / Reference
L1	W1	Monday, 29 September 2025	14:30 Course Introduction	
L2	W1	Tuesday, 30 September 2025	12:30 Intro: ML "crash course" - part 1	
L3	W2	Monday, 6 October 2025	14:30 Intro: ML "crash course" - part 2	
Lab0-1		(uploaded on Moodle)	<i>Lab0-1: Tools, Numpy, ML &amp; linear models</i>	Notebooks, Tutorials
L4	W2	Tuesday, 7 October 2025	12:30 Foundations of Computer vision, Image Formation	Szeliski's book: chapter 1
L5	W3	Monday, 13 October 2025	14:30 Images, convolution, filters - part 1	
Lab2	W3	Tuesday, 14 October 2025	12:30 Lab2: Image filtering	Szeliski's book (CV Algorithms & Applications): chapters 2-3
L6	W4	Monday, 20 October 2025	14:30 Edges, corners and features - part 1	

[https://docs.google.com/spreadsheets/d/1Ow4BYVvQXM3p\\_Eyu9Bkfku1j-ExKnElGr2VTn2nIYEw](https://docs.google.com/spreadsheets/d/1Ow4BYVvQXM3p_Eyu9Bkfku1j-ExKnElGr2VTn2nIYEw)

# Exam

- The exam will consist of two parts:
  - Written exam/test about the various topics covered in the course (grade range [0,...,10])
    - Pre-exam (“compitino”) in early / mid December
    - Preliminary written exam before each “official” exam date
  - Project (the most important one!) (range: [0,...,21])
    - You should submit a report (more details on Moodle)
    - Present your work during the oral exam
  - Bonus (1 point) for lab assignments / contests

# Projects

- Students are asked to work on a project
- They must submit a **written report** addressing in a critical fashion all the issues dealt in the project
  - ▶ The report should be submitted (approx.) one-week before the exam date on Moodle
  - ▶ The report should follow the format uploaded on Moodle: max 6 pages + references
- They will present and **discuss the project** and answer to the questions (mostly about the project)
  - ▶ They should prepare a presentation (slides): ~30 min

# Projects

- **Project-V1:** compare different cognitive services or public implementations (across different modalities or APIs) for a specific application [2 stud]
- **Project-V2:** combine different models/frameworks on a specific benchmark or task [2-3 stud]
- **Project-V3:** build your intelligent application / algorithm (using the appropriate frameworks such as TensorFlow, PyTorch, etc.) [2-3 stud]

*Note: you should work in a group (if you want to work alone you should motivate this choice and ask for permission in advance)*

# Exam, projects and grading

- How to pick a project topic?
  - You'll be given some project ideas/examples (early Dic.)
  - But you are free to choose other topics and we encourage a “bottom-up” approach
- Your final grade will be obtained taking into account:
  - *Test\_grade* (written exam about the content of the course)
  - *Proj\_grade* (shared among the members of the group)
    - “Refined” taking into account the outcomes of the oral exam (project presentation/answers), on an individual basis
  - **Final Grade** = ROUND (*test\_grade* + *proj\_grade*)  
*(grade range [0,...,31]; sufficient iff  $\geq 18$ )*

# Exam, projects and grading

- Grading / evaluation:

	Grading scale	letter	4-s	%	ITA (31-s)	Written Project exam	10-scale
Excellent	A+	4	1	30L	21	9-10	
	A+	4	0.97	30	20		
	A	4	0.93	29	20		
Very Good	A-	3.7	0.9	28	19	8-8.5	
	B+	3.3	0.87	27	18		
Good	B	3	0.83	26	17	7-7.5	
	B-	2.7	0.8	25	17		
Satisfactory	C+	2.3	0.77	24	16	6-6.5	
	C	2	0.73	23	15		
	C-	1.7	0.7	22	15		
Barely Passing	D+	1.3	0.67	21	14	5-5.5	
	D	1	0.65	20	14		
	-	-	0.6	19	13		
Fail	E/F (fail)		-	-	12	4-4.5	
			-	-	-		

# Contact

- **Office:** Torre Archimede, room 6CD3
- **Office hours** (ricevimento): Friday 9:00-11:00

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