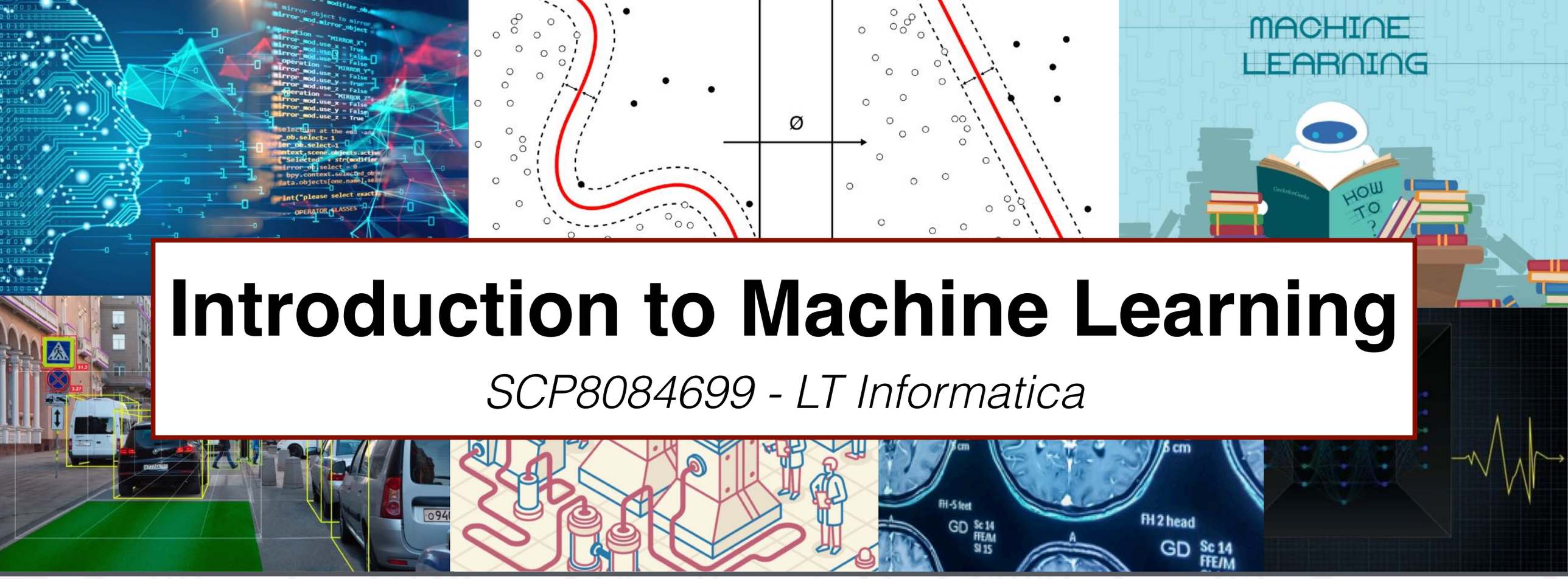


Introduction to Machine Learning

SCP8084699 - LT Informatica

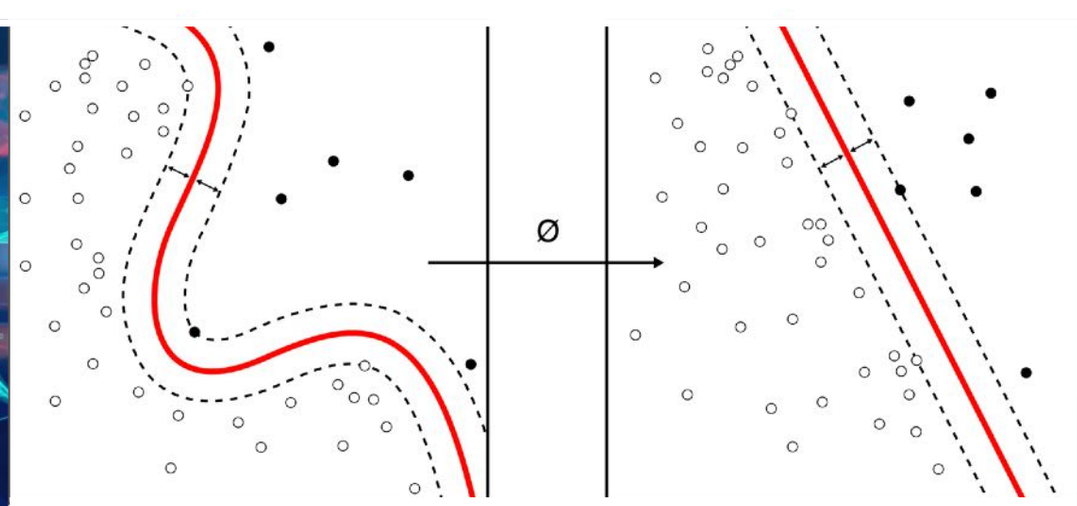
Prof. Lamberto Ballan

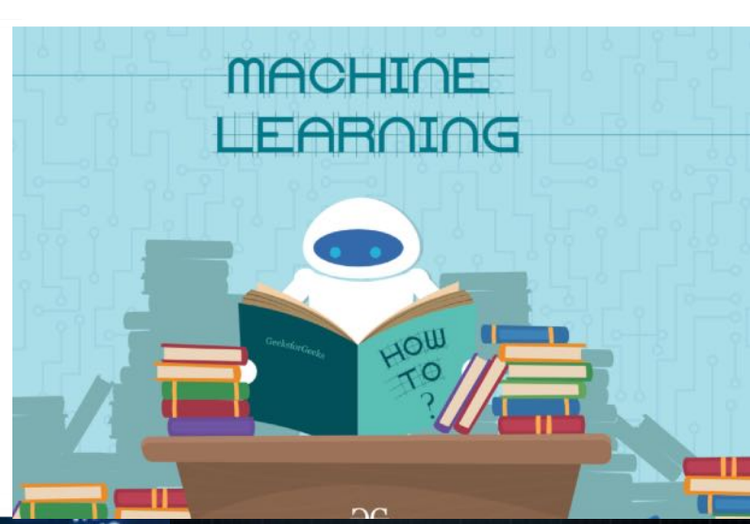
University of Padova, A.Y. 2022/23 February 28, 2023

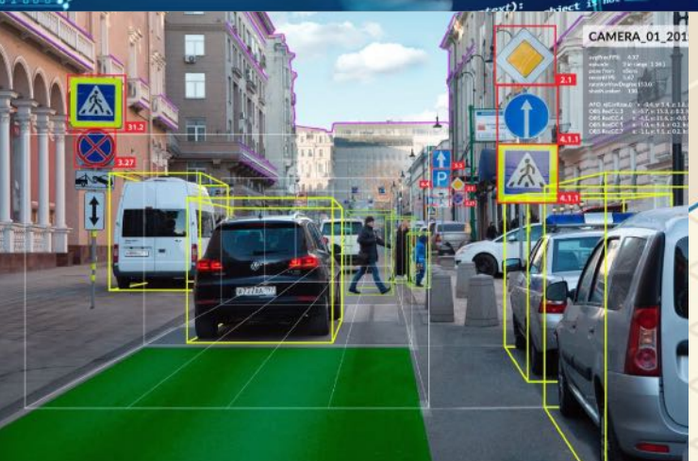
DIPARTIMENTO MATEMATICA
Department of Mathematics “Tullio Levi-Civita”

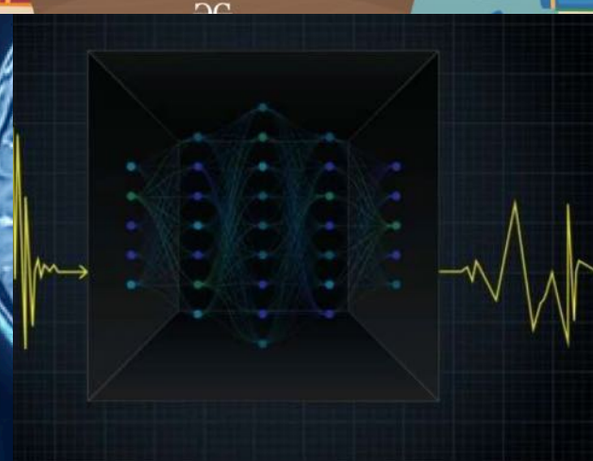
Welcome to IML

- Today's agenda:
  - Course logistics
  - Machine Learning overview; why is ML so cool ?





Who we are

Instructor

Prof. Lamberto Ballan
<lamberto.ballan@unipd.it>

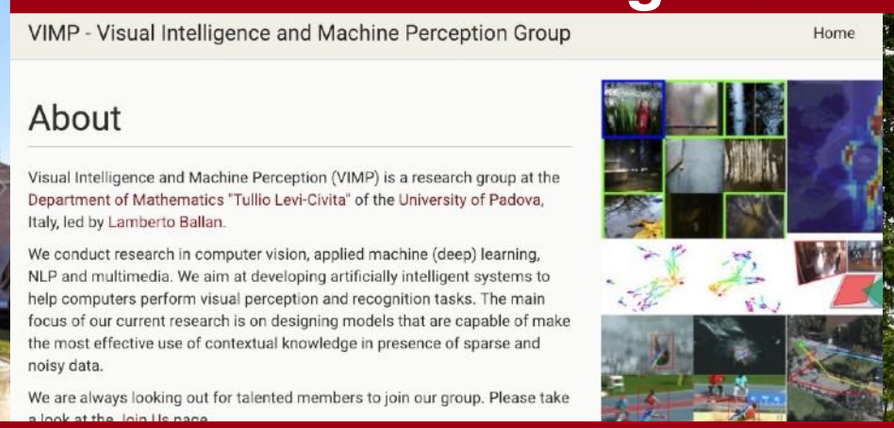
Teaching Assistant

Elena Izzo
<elena.izzo@phd.unipd.it>

Teaching Assistant

Luca Parolari
<luca.parolari@unipd.it>

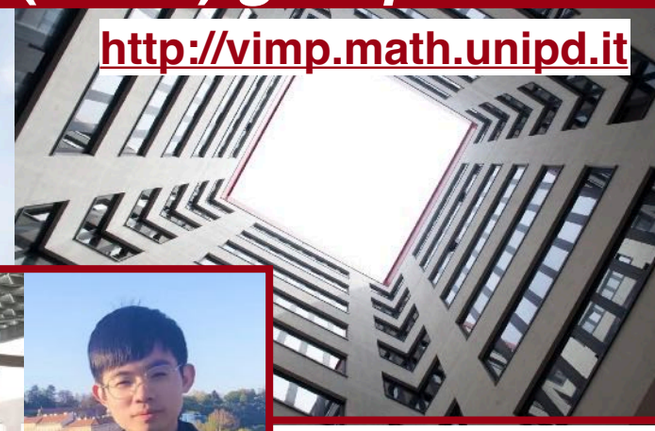
Visual Intelligence & Machine Perception (VIMP) *group*



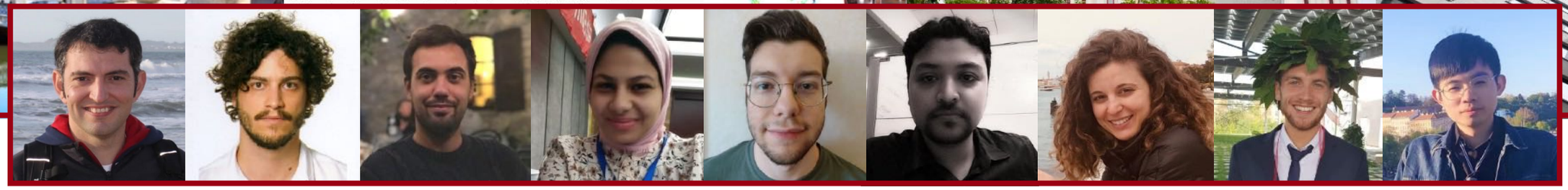
http://vimp.math.unipd.it

About me

Visual Intelligence & Machine Perception (VIMP) *group*



http://vimp.math.unipd.it



Ingegneria Informatica

PhD Ingegneria Informatica, TLC, Multimedia

1999 — 2006 — 2011 — 2014 — 2017

UNIVERSITÀ DEGLI STUDI DI PADOVA

...

UNIVERSITÀ DEGLI STUDI FIRENZE

Stanford University

Course schedule

- Tuesday, 10:30-12:15
  Thursday, 10:30-12:15
  (Torre Archimede 1C150, live streamed on Zoom)
  - All lectures will be also recorded and uploaded on Zoom
  - Approx. 40h (lectures) + 8h (laboratories)

Course material & how to contact us

- Moodle: https://elearning.unipd.it/math/course/view.php?id=882
  - Updated on a weekly basis: slides, references, etc.
  - Use this for most communication with course staff
  - Ask questions about logistics, homework, etc.
  - Participate to Q.A. (live) sessions on Zoom

Course material / Textbook

- Slides and other materials will be posted periodically on the class Moodle
- Additional teaching materials (optional):
  - "A Course in Machine Learning", *H. Daumé III* *download the book / chapters (free online)*
  - Stanford CS229 "Machine Learning" class notes: http://cs229.stanford.edu/syllabus-summer2020.html
- Other textbooks (optional):
  - "Machine Learning", *T. Mitchell*
  - "Pattern Recognition and Machine Learning", *C. Bishop* *download the book (free online)*

Exam

- Written exam (open questions, simple exercises)
  - Grade range: [0,…,31]
- Optional
  - Oral exam (note: this is optional but, depending on the outcomes of the written exam, you can be asked to do it)
    - The grade can be updated as it follows: +/- [0,…,3]
    - If you want to do the oral, you should ask for it within 3 days from the grades notification of the written exam
  - Bonus point (+1) for labs / participation to course activities

Exam

- We keep your grade only for the current and next exam trial (“appello”)
  - i.e. you can participate to the oral only in the current or next call (e.g. I & II, II & III, etc.)
- Midterm: there is the possibility to participate to the midterm (compitino) in April
  - It covers the 1st half of the course (up to 16/32); the 2nd half (16/32) will be done together with the first exam trial

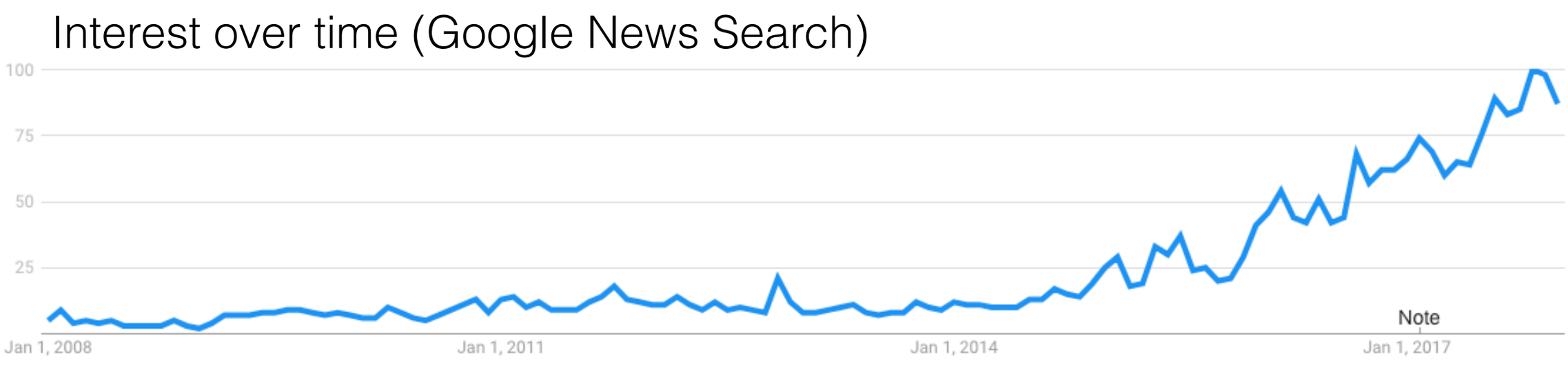
Course calendar

- Tentative schedule for the first part of the course:

	#week	*Date*		*Lecture / Topic*	*Reading Material / Reference*	*Hours*
L1	W1	Tuesday, 28 February 2023	10:30	Introduction and Basic Concepts		2
L2	W1	Thursday, 2 March 2023	10:30	Supervised Learning, Bias(es)		2
L3	W2	Tuesday, 7 March 2023	10:30	Linear Regression, Gradient Descent and Regularization		2
Lab0	W2	Thursday, 9 March 2023	10:30	Lab0: Intro to Python for ML, Numpy	*Notebooks, Tutorials*	2
L4	W3	Tuesday, 14 March 2023	10:30	Linear Classification, Logistic Regression		2
Lab1	W3	Thursday, 16 March 2023	10:30	Lab1: Linear Regression & G.D.		2
	W4	Tuesday, 21 March 2023	10:30			
Lab2	W4	Thursday, 23 March 2023	10:30	Lab2: Linear Classifiers, Logistic Reg.		2
L6	W5	Tuesday, 28 March 2023	10:30	ML system design, Babysitting		2
L7	W5	Thursday, 30 March 2023	10:30	Neural Networks - part 1		2
L8	W6	Tuesday, 4 April 2023	10:30	Neural Networks - part 2		2
Lab3	W6	Thursday, 6 April 2023	10:30	Lab3: Neural Networks		2
	W7	Tuesday, 11 April 2023				
Lab4	W7	Thursday, 13 April 2023	10:30	Lab4: Neural Networks 2		2
L9	W8	Tuesday, 18 April 2023	10:30	Support Vector Machines		2
Lab5	W8	Thursday, 20 April 2023	10:30	Lab5: SVM		2
	W9	Tuesday, 25 April 2023	10:30			
MT	W9	Thursday, 27 April 2023	10:30	Midterm (written exam)		2

Regularly updated: http://shorturl.at/kqGY7

The rise of Artificial Intelligence



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

A.Y. 2022/23: Introduction to Machine Learning

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

Will AI Take Over The World?

Shep Hyken, CONTRIBUTOR

FULL BIO

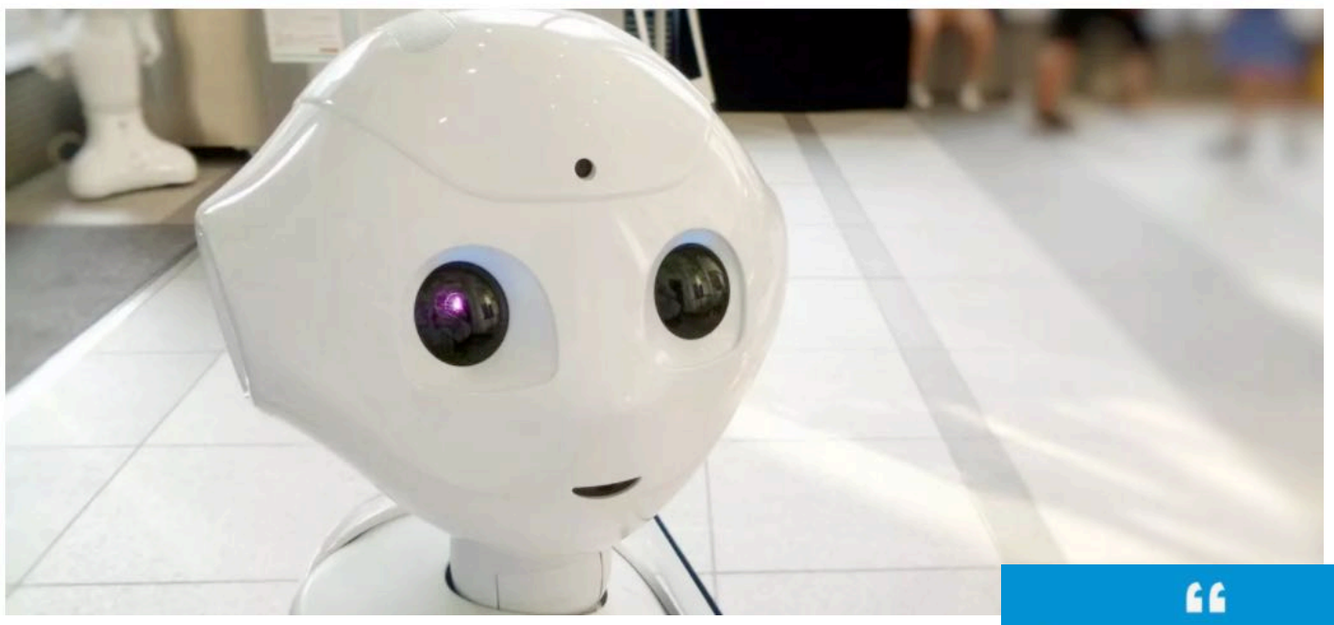
Opinions expressed by Forbes Contributors are their own.

The rise of Artificial Intelligence

WORLD ECONOMIC FORUM 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.

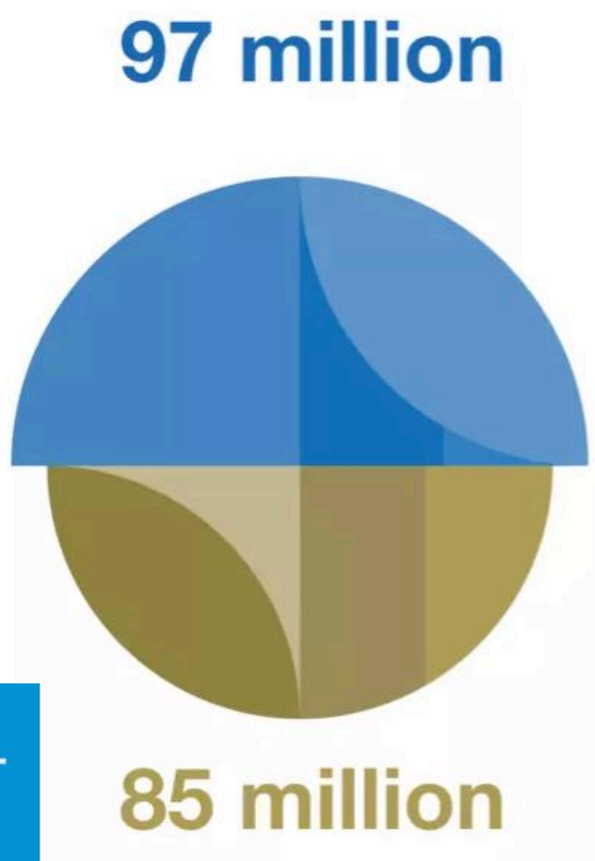


https://www.weforum.org/agenda/2020/10/dont-fear-ai-it-will-lead-to-long-term-job-growth/

> 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:

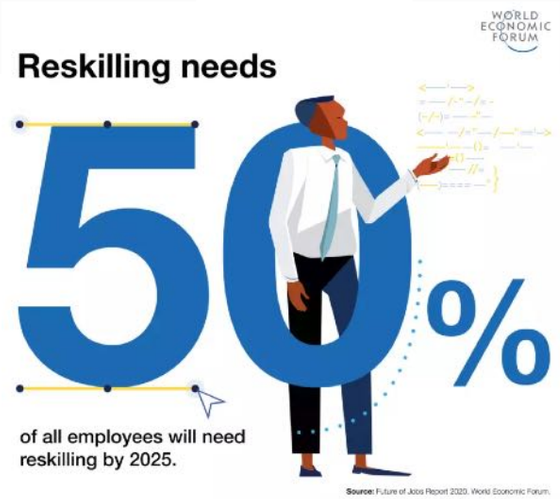


Growing job demand:

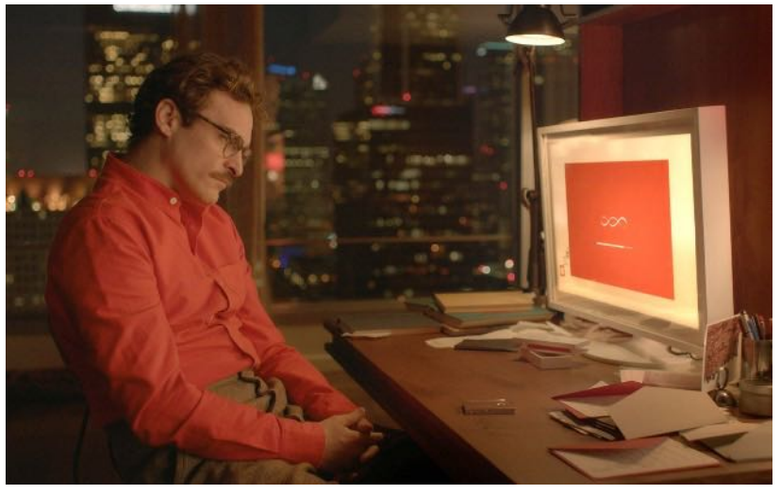
1. Data Analysts and Scientists
2. AI and Machine Learning Specialists
3. Big Data Specialists
4. Digital Marketing and Strategy Specialists
5. Process Automation Specialists
6. Business Development Professionals
7. Digital Transformation Specialists
8. Information Security Analysts
9. Software and Applications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

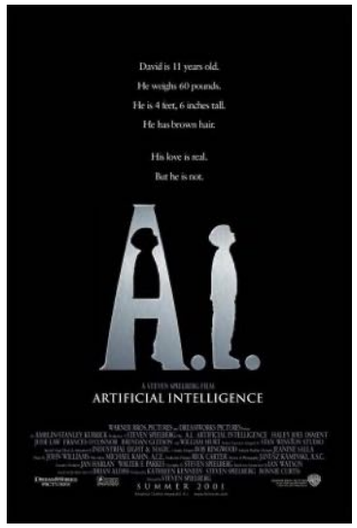
Decreasing job demand:

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



Artificial Intelligence





1950

Alan Turing

1955

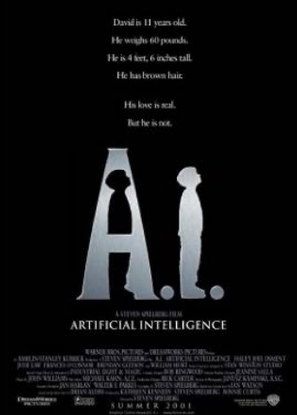
John McCarthy

2020

Google

A.I. in Science Fiction

What's in common?



Turing Test

- The **imitation game** (based on language):
  - 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

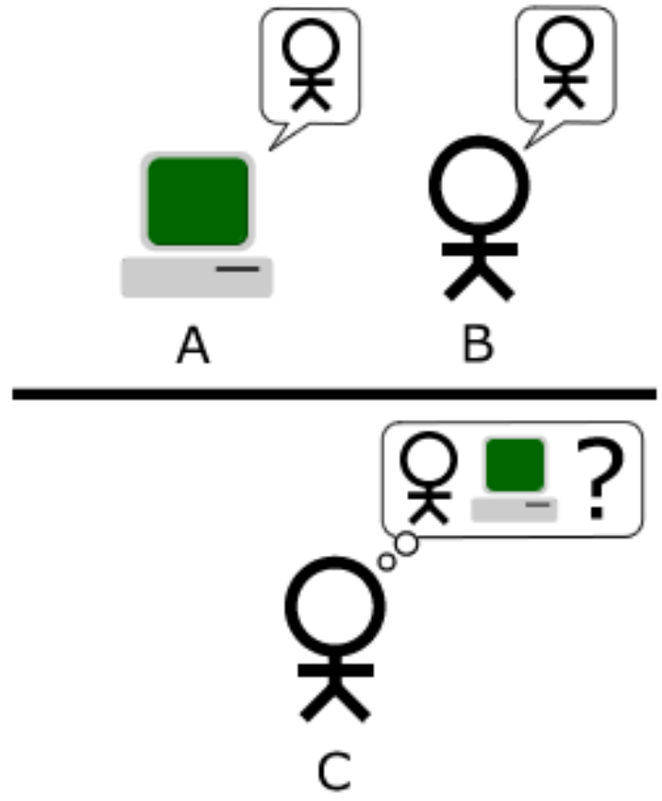
A. M. Turing (1950) Computing Machinery and Intelligence. *Mind 49:* 433-460.

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.



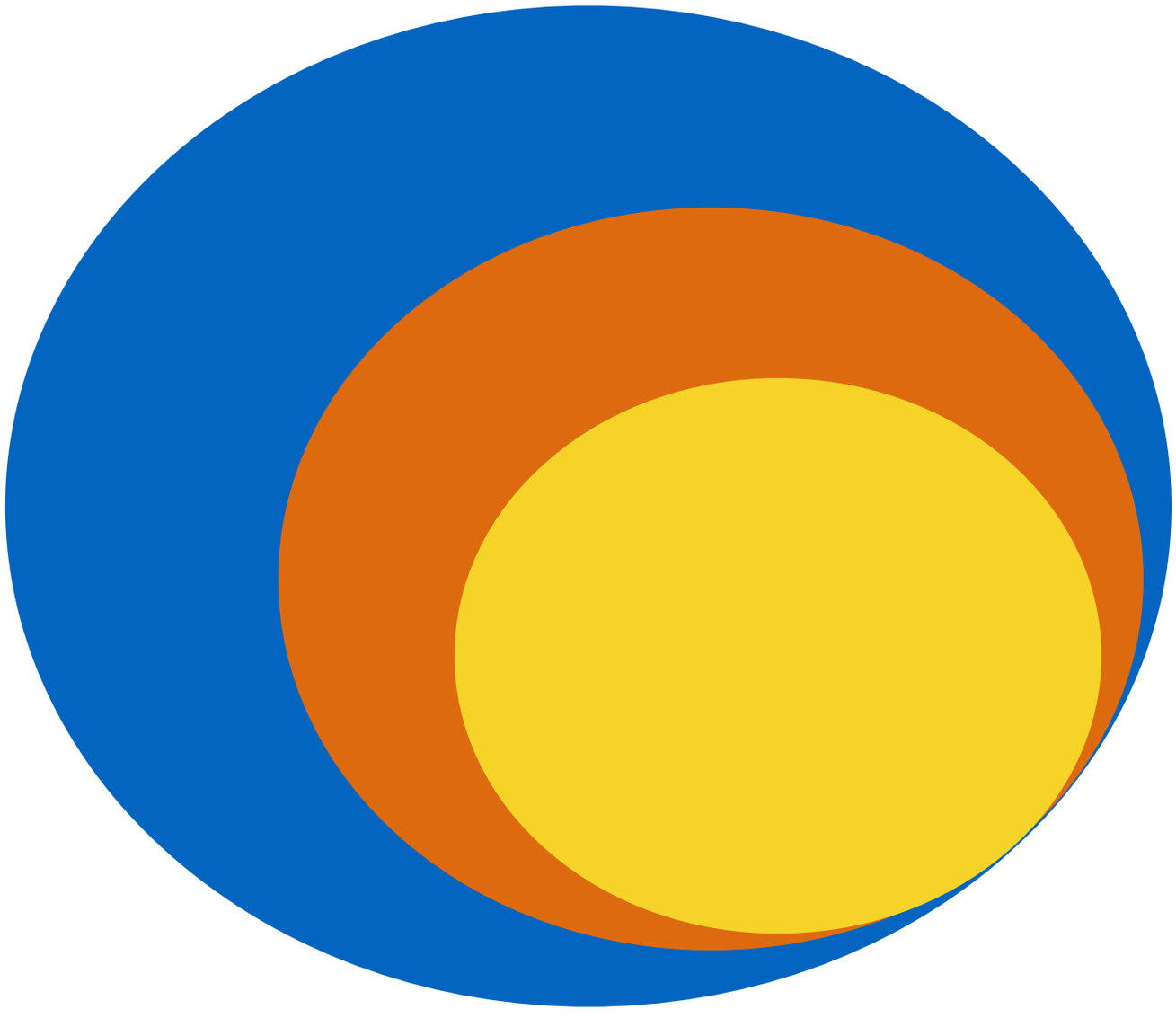
http://cogprints.org/499/1/turing.html

What is A.I.? A few definitions

- J. McCarthy, who coined the term in 1956, defines AI as *"the science and engineering of making intelligent machines"*

- A modern definition of AI: *"the ability of a digital computer or computer-controlled robot to perform tasks commonly associated with intelligent beings"*

AI, Machine and Deep Learning



Artificial Intelligence

The science to make things smart

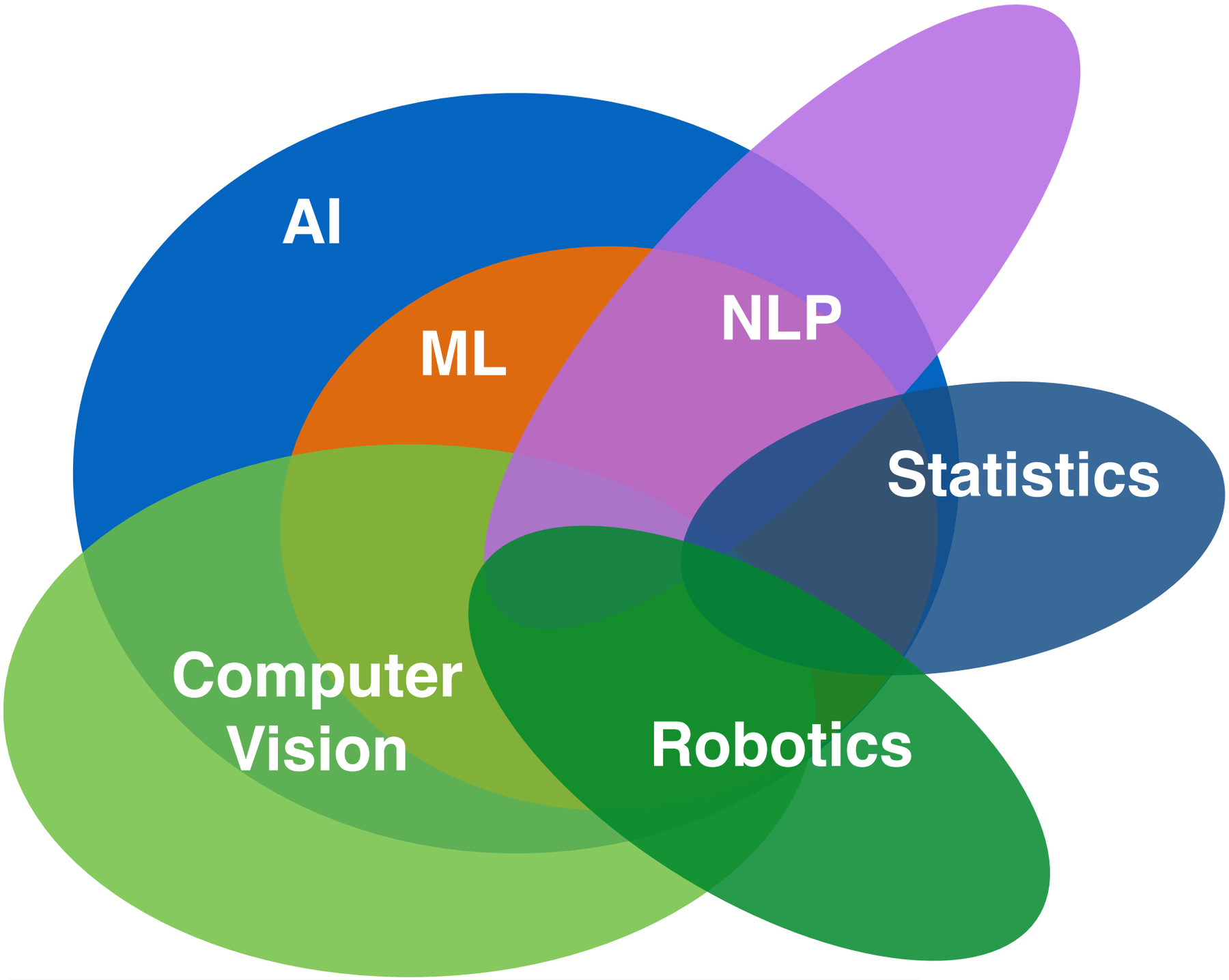
Machine Learning

Building machines that can learn

Deep Learning

A class of ML algorithms

AI, Machine Learning and Beyond



And more:

Biology

Neuroscience

Medicine

Physics

…

A.I. and Machine Learning @UniPD

- Laurea Magistrale in *Computer Science* 
  - Major in *Artificial Intelligence* (4 or 5 courses) + minor (2 or 3 courses)

Computability
Artificial Intelligence
Machine Learning
(Optional not INF)
...

Advanced Algorithms
Eco. & Manage. of Innovation
Deep Learning
Knowledge & Data Mining
...

Vision & Cognitive Systems
...

M.Sc. Thesis

  - Other majors: *Internet, Mobile and Security*; *Programming Languages and Systems*

A.I. and Machine Learning @UniPD

- Laurea Magistrale in *Data Science*

  - Curriculum in *Machine Learning for Intelligent Systems*

Statistical Learning 1
Stochastic Methods
Machine Learning
Cognition and Computation
Law and Data

Statistical Learning 2
Optimization for Data Science
Deep Learning
Knowledge & Data Mining
…

Vision & Cognitive Systems

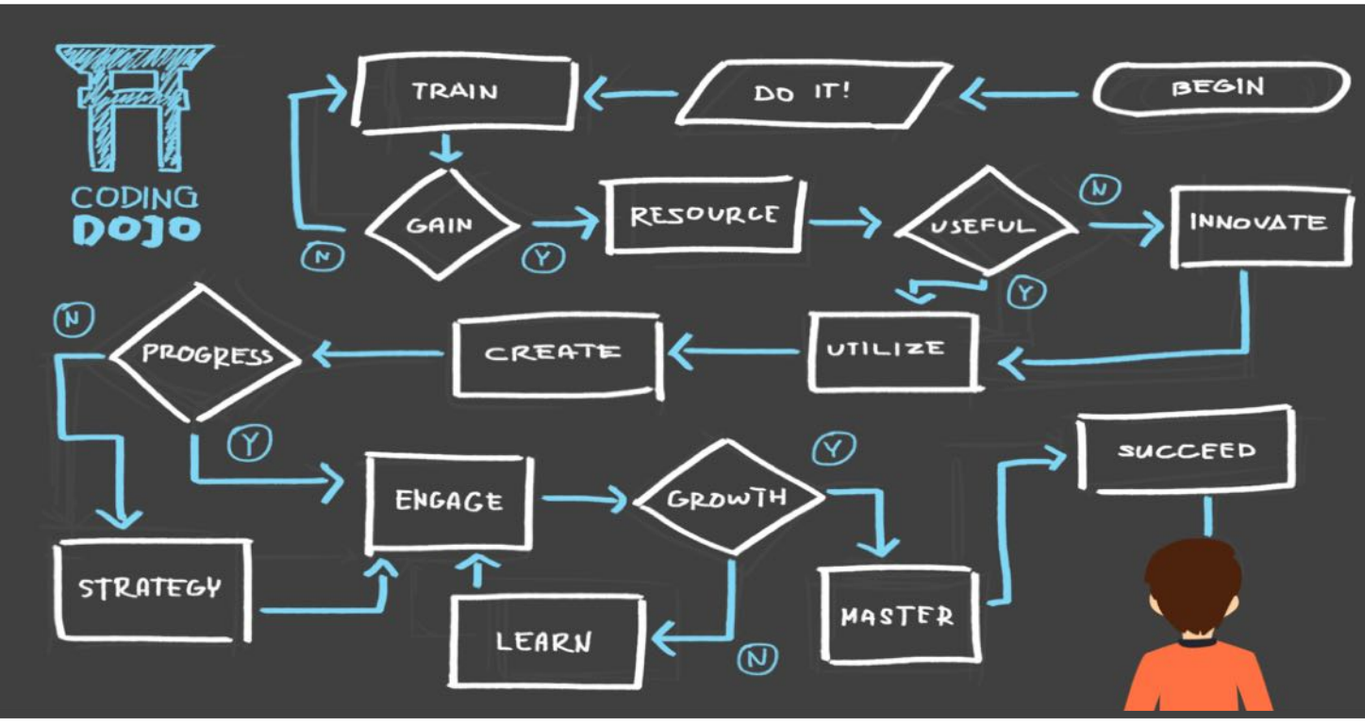
…

M.Sc. Thesis

  - Other curricula: *Biological Data Analytics*; *Mathematics of Data Science*; *Cognitive, Social & Eco. Data Analytics*

Algorithmic Approach

- How can we solve a specific problem?
  - As computer scientists (or mathematicians) we design an algorithm and write a program that encodes a set of rules that are useful to solve the problem



Algorithmic approach

When to use Machine Learning?

- First, why not to use a traditional algorithmic approach?
  - Impossible to **exactly formalise** the problem *(and so to give an algorithmic solution)*
  - Presence of **noise** and/or **uncertainty**
  - **High complexity** in formulating a solution, i.e. it cannot be done manually
  - Lack of **compiled knowledge** with respect to the problem to be solved

What is Machine Learning?

- Example: handwritten digit recognition

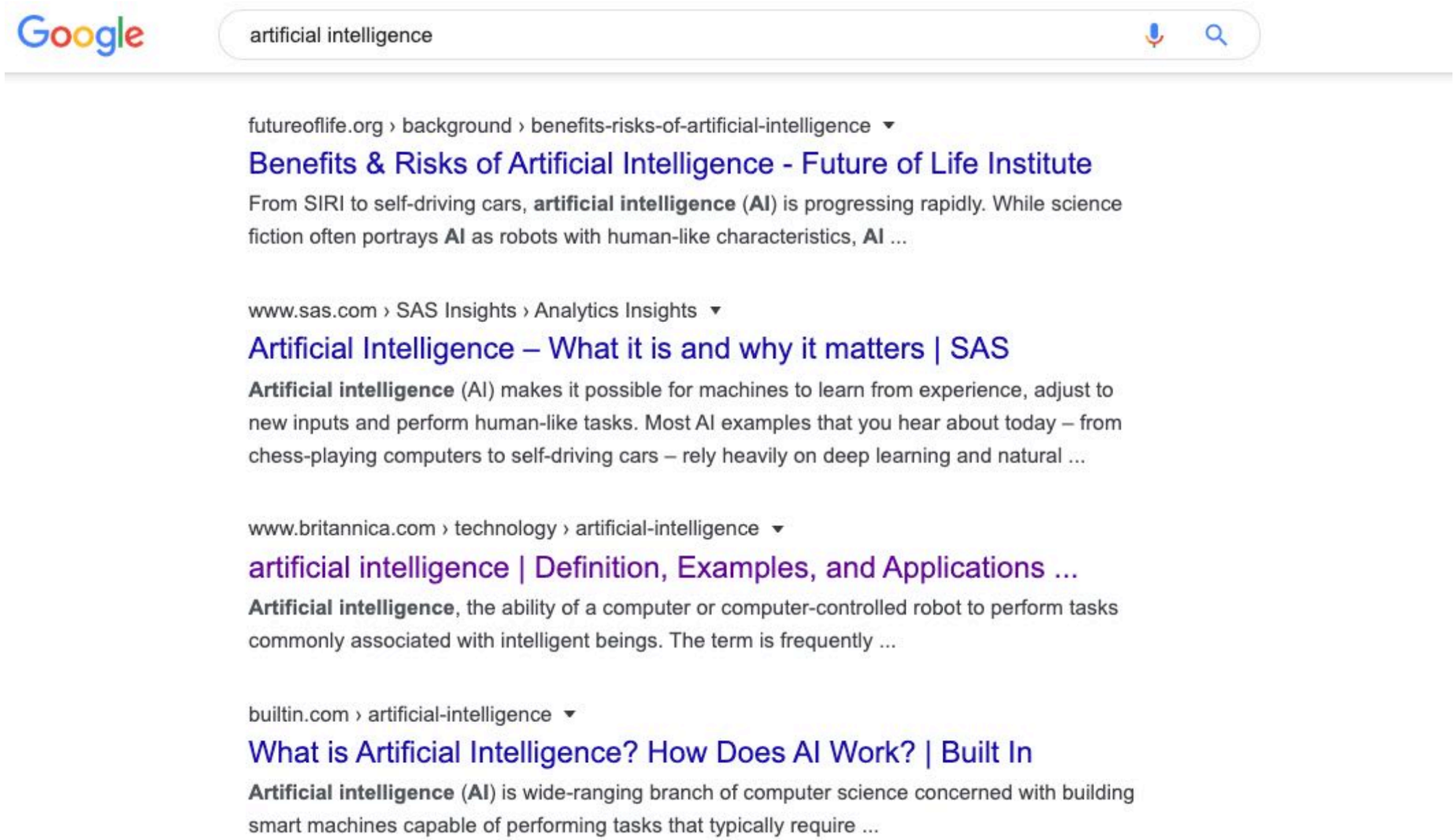
- Very hard to exactly formalize the problem
- Noise may be present and data may be ambiguous

What is Machine Learning?

- … and why is machine learning so cool?
- You probably use ML dozens of times a day without even knowing it:
  - a web search on Google works works well because a software based on ML has figure out how to rank pages
  - each time you check your e-mail a spam filter has learned how to distinguish spam from not-spam e-mails
  - when Facebook or Apple's photo application recognizes your friends in your pictures, that's also because of ML

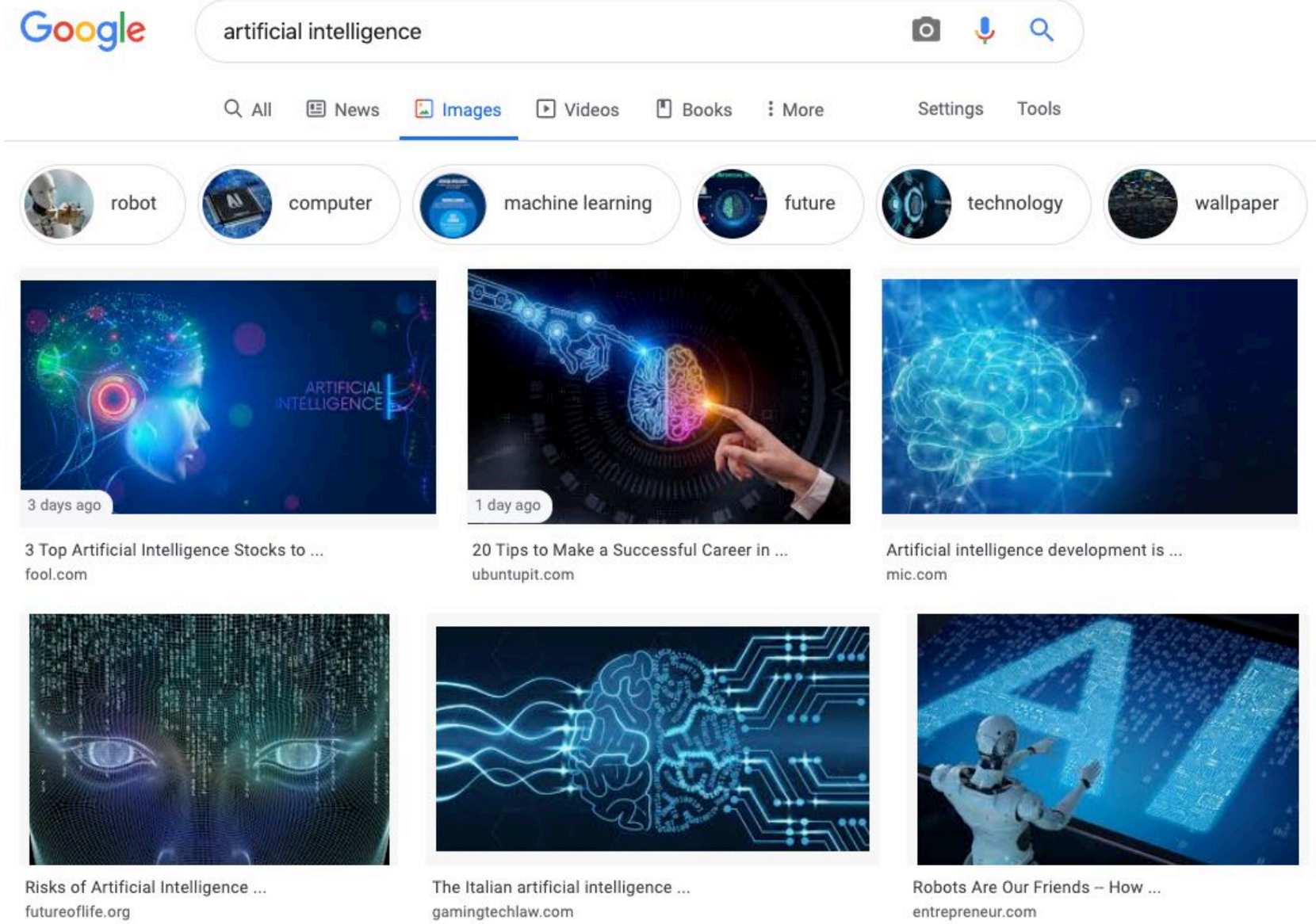
Learning is useful in many tasks

- **Information retrieval:** given a query, find documents (data) with similar content



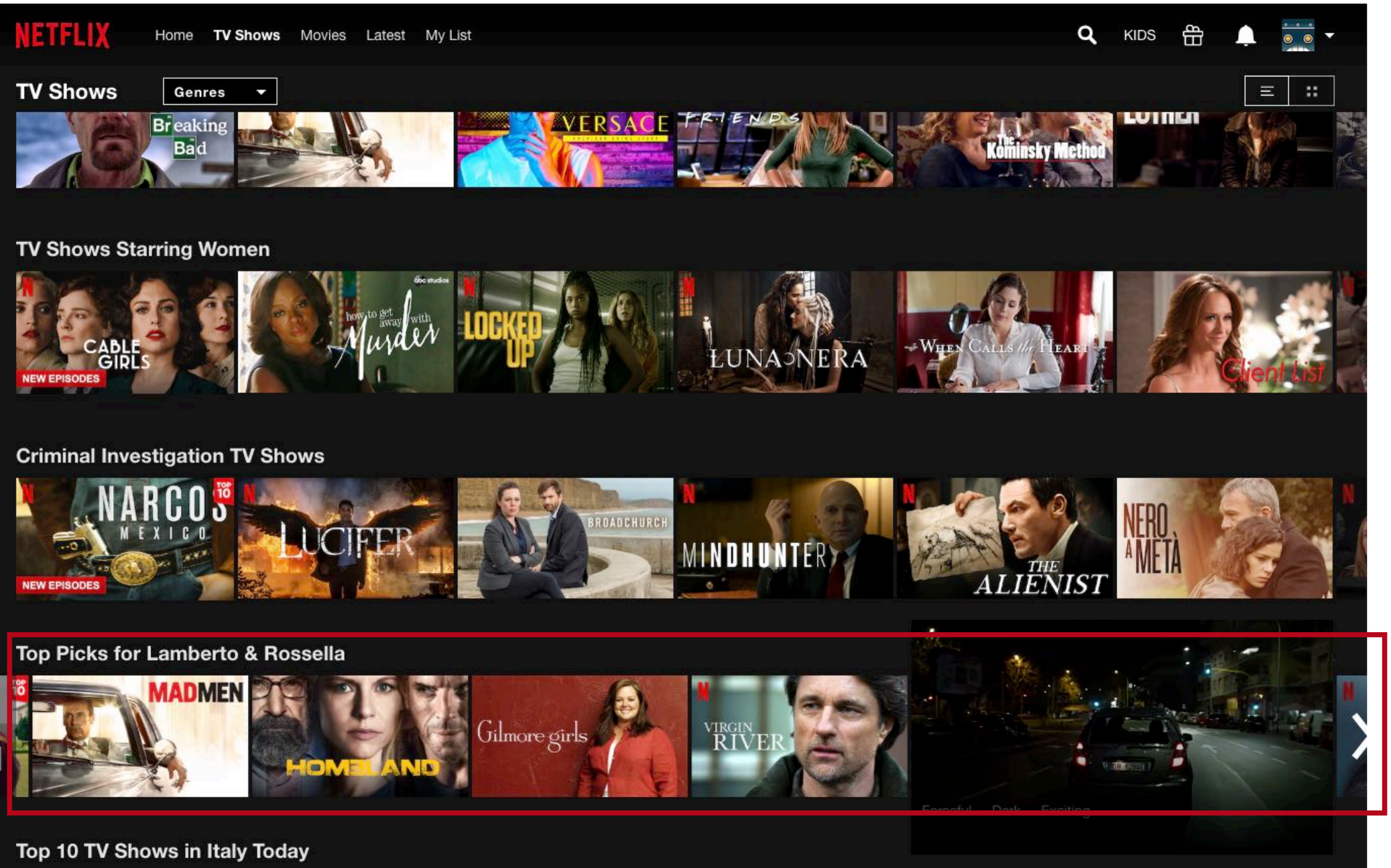
Learning is useful in many tasks

- **Information retrieval:** given a query, find documents (data) with similar content



Learning is useful in many tasks

- **Recommender systems:** commercial platforms, advertisement, social media, etc.



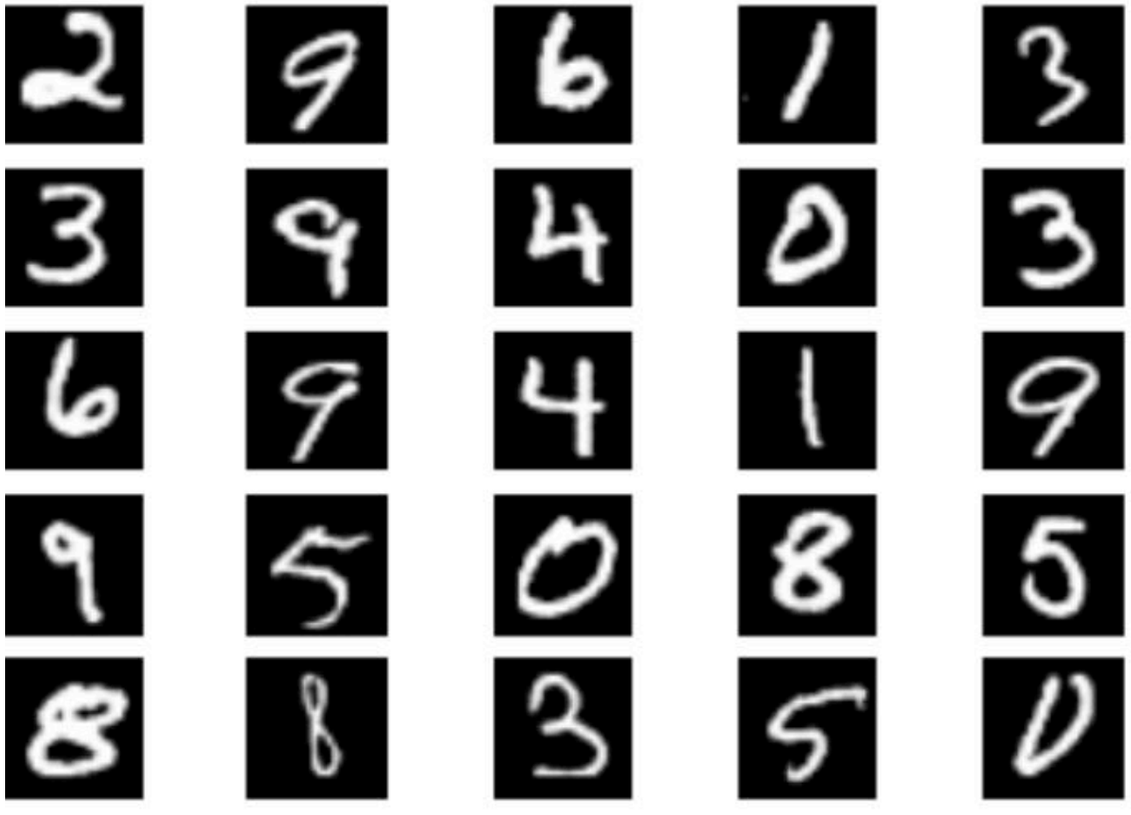
Netflix, Amazon

Learning is useful in many tasks

- **Classification:** determine to which discrete category a specific example belongs to

Example 1

What digit is is this?



E.g. Licence plate recognition

Learning is useful in many tasks

- **Classification:** determine to which discrete category a specific example belongs to

Example 2

Is this a dog?

What about this one?

Learning is useful in many tasks

- **Classification:** determine to which discrete category a specific example belongs to

Example 3

Does he/she have diabetes?

What about Covid-19?

WIRED BUSINESS CULTURE GEAR IDEAS SCIENCE MORE SIGN IN

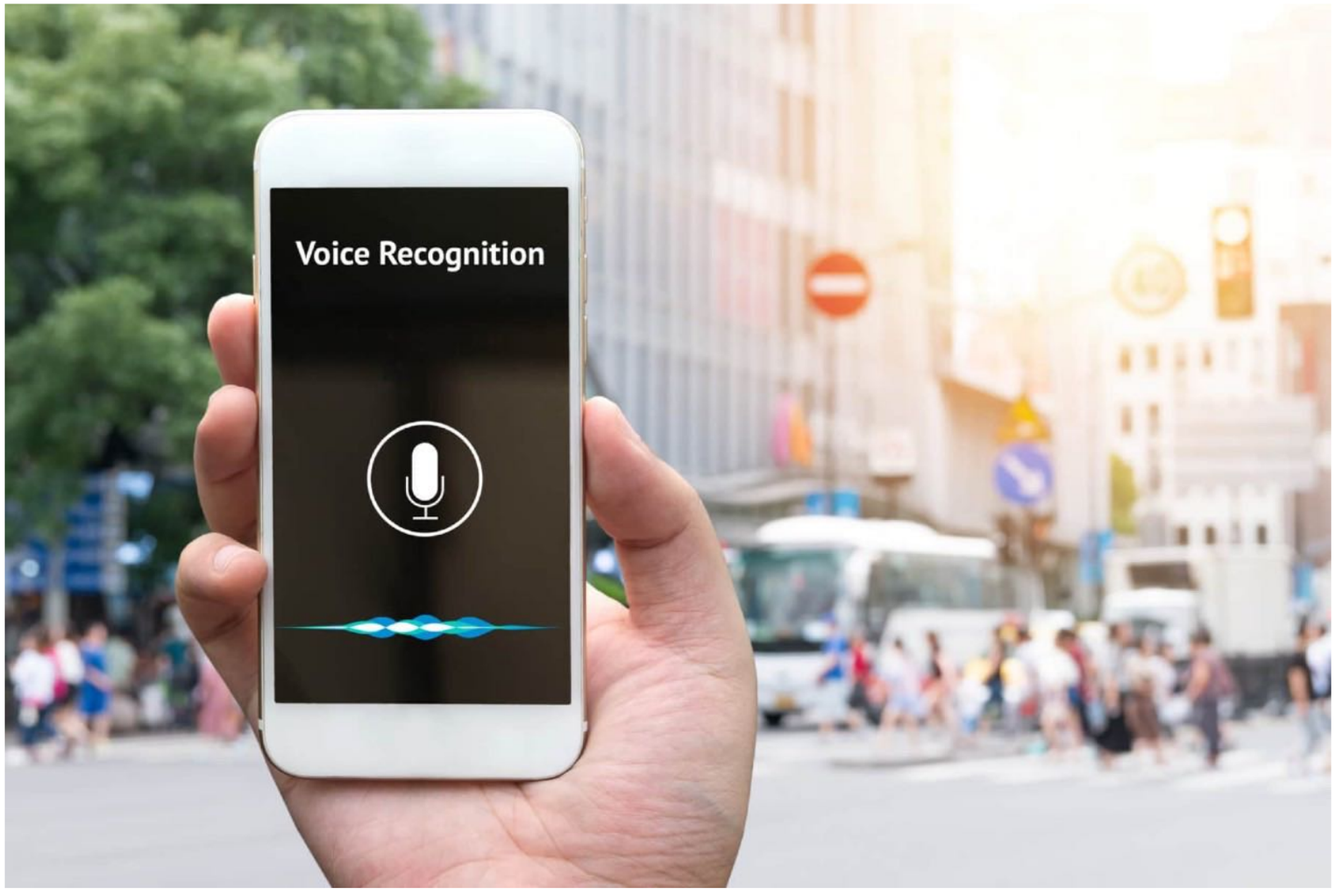
TOM SIMONITE BUSINESS 02.26.2020 07:00 AM

Chinese Hospitals Deploy AI to Help Diagnose Covid-19

Software that reads CT lung scans had been used primarily to detect cancer. to look for signs of pneumonia caused by coronavirus.

Learning is useful in many tasks

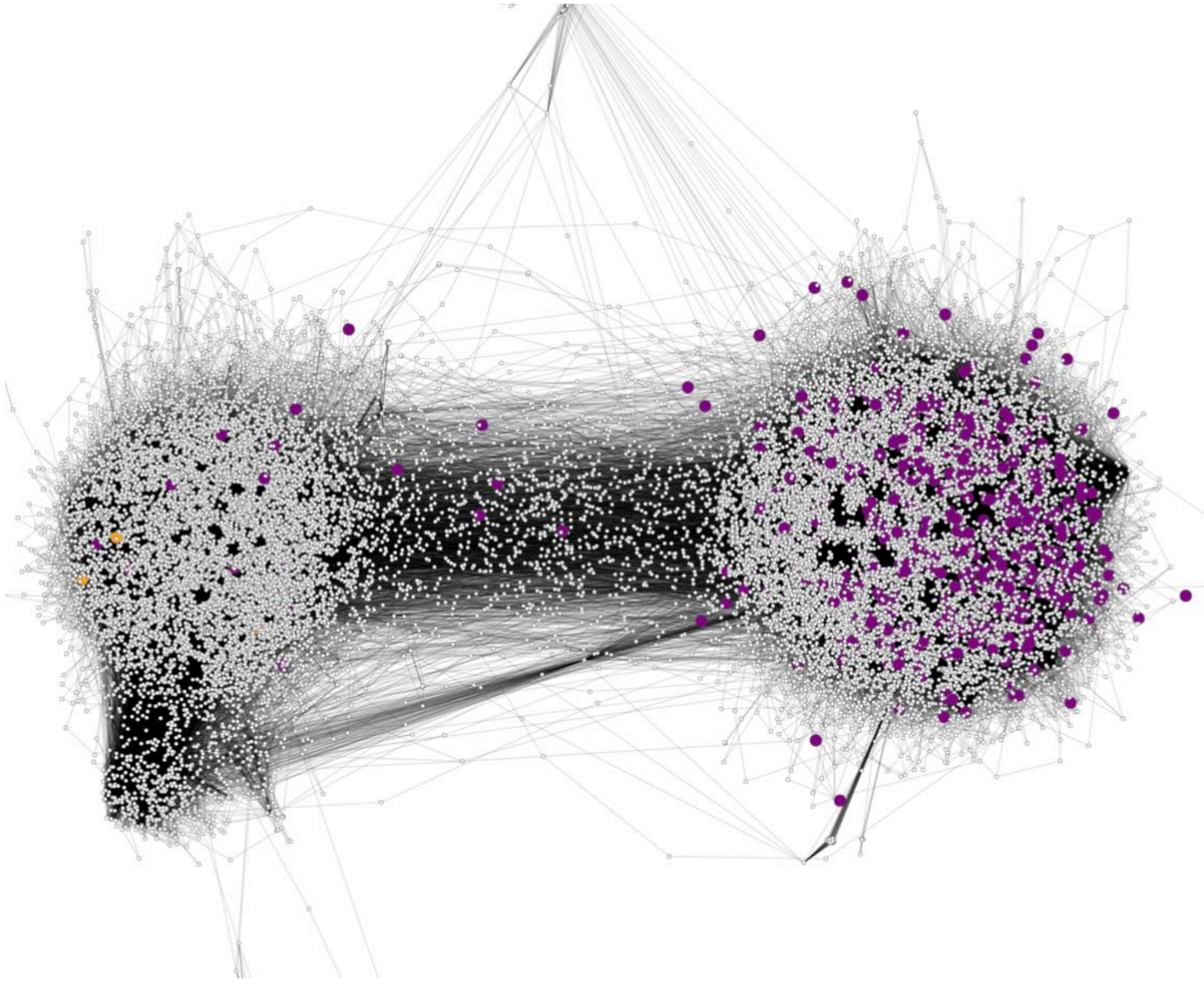
- **Recognizing patterns:** the automated recognition of patterns and regularities in data



Speech recognition

Learning is useful in many tasks

- **Recognizing patterns:** the automated recognition of patterns and regularities in data



Network analysis
(e.g. how fake news spread over social media)

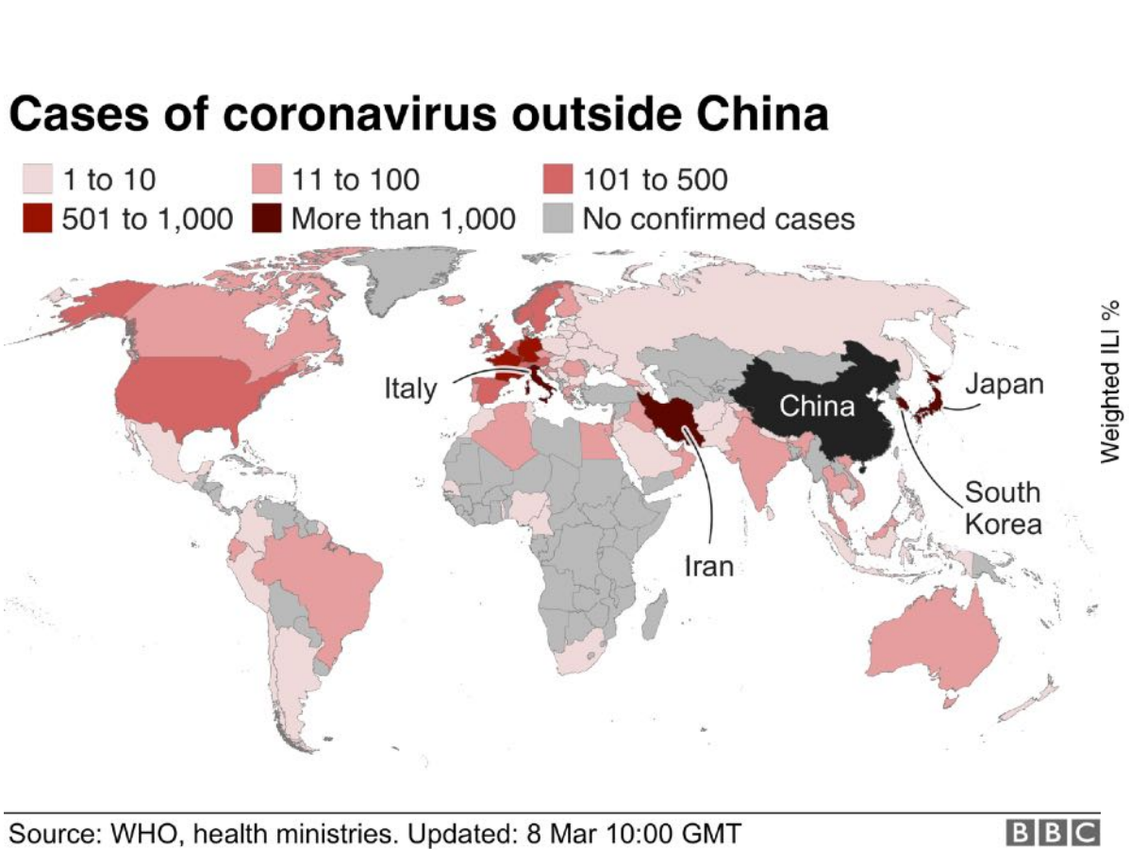
Learning is useful in many tasks

- **Predicting events:** models capable of predicting events are especially valued by decision makers

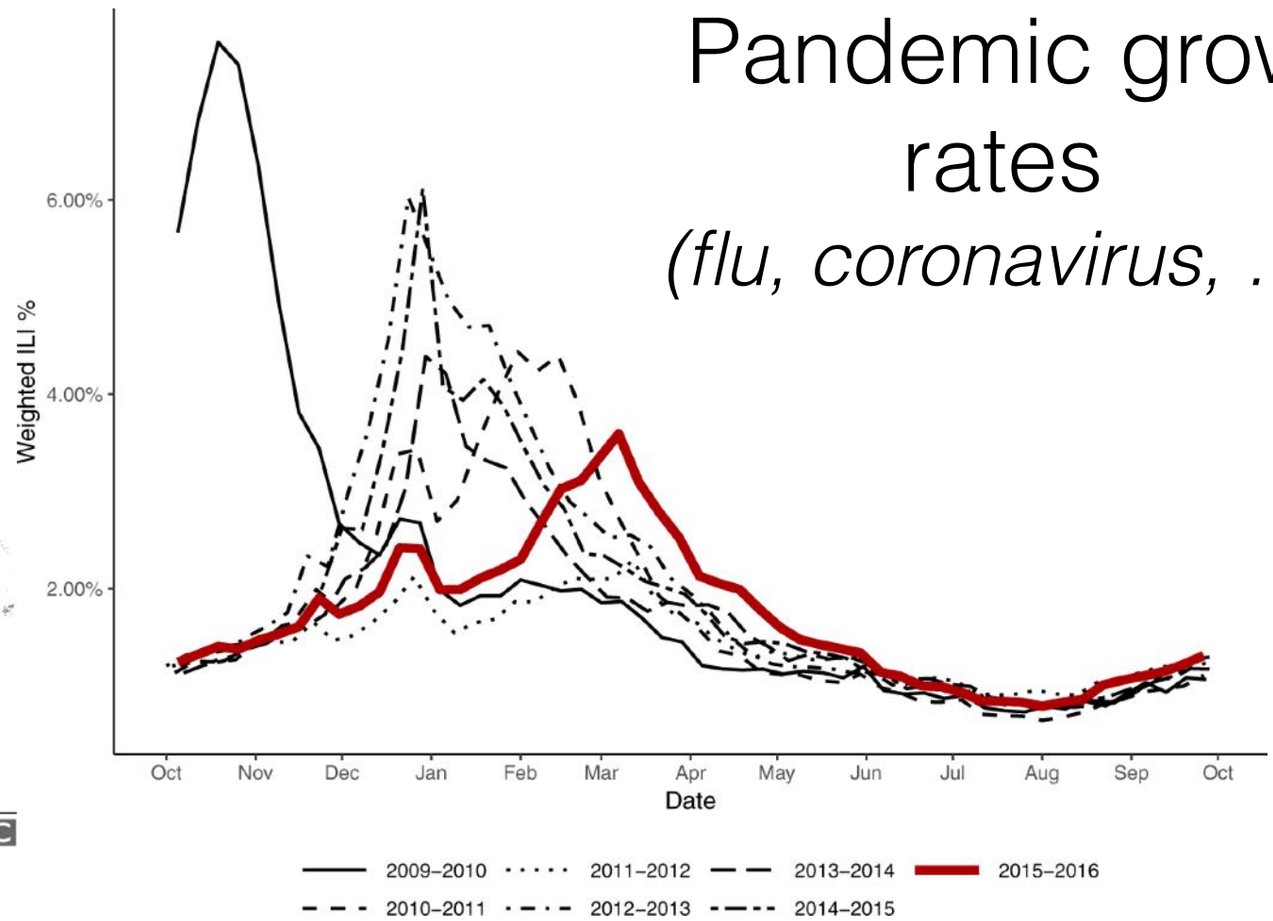
Finance

Learning is useful in many tasks

- **Predicting events:** models capable of predicting events are especially valued by decision makers

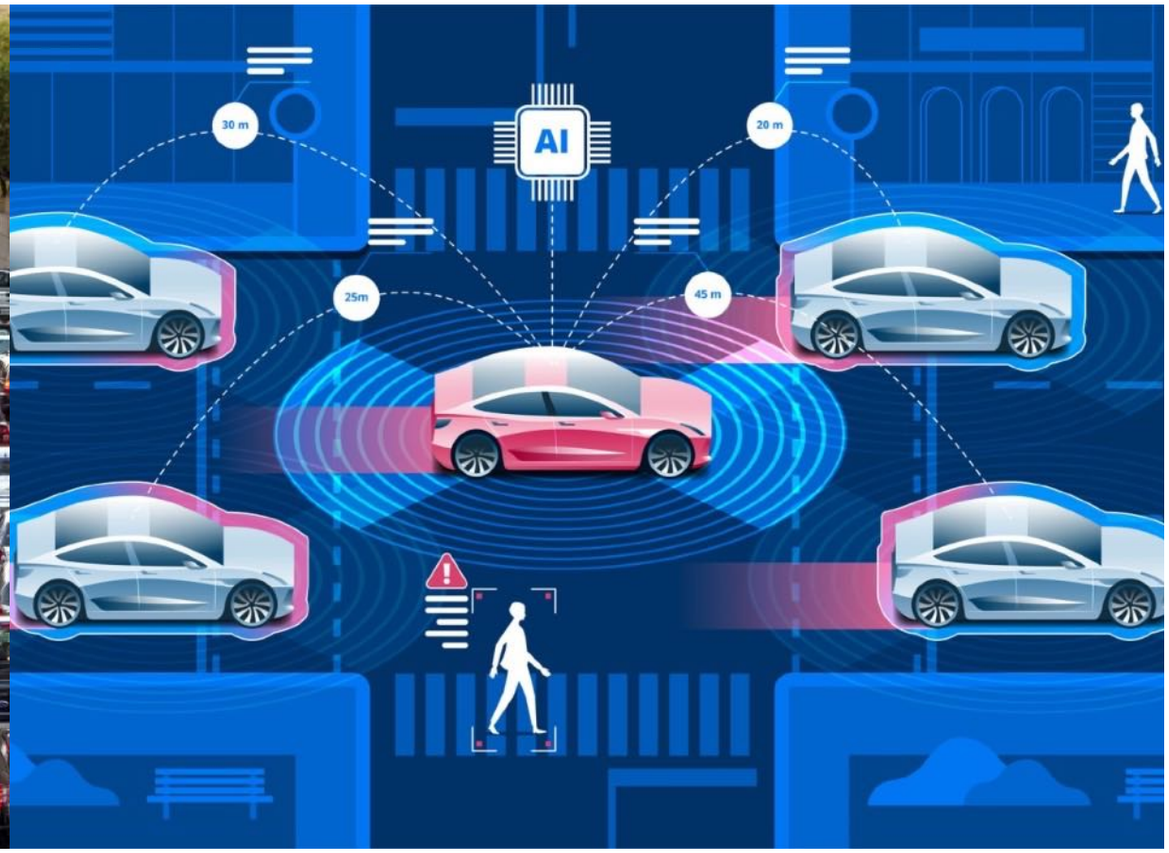


Pandemic grow rates
(flu, coronavirus, …)



Learning is useful in many tasks

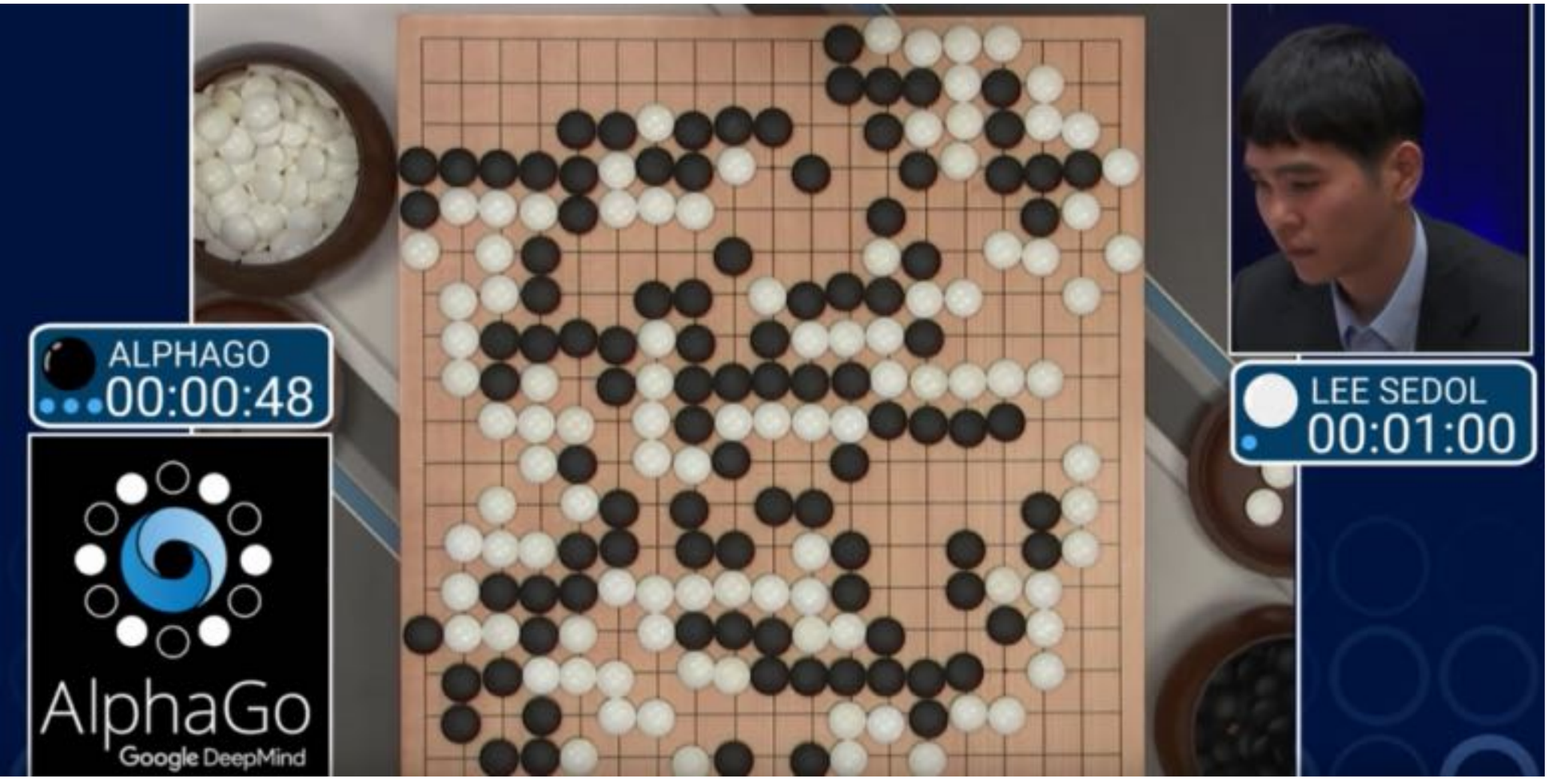
- **Predicting events:** models capable of predicting events are especially valued by decision makers



Smart mobility

Learning is useful in many tasks

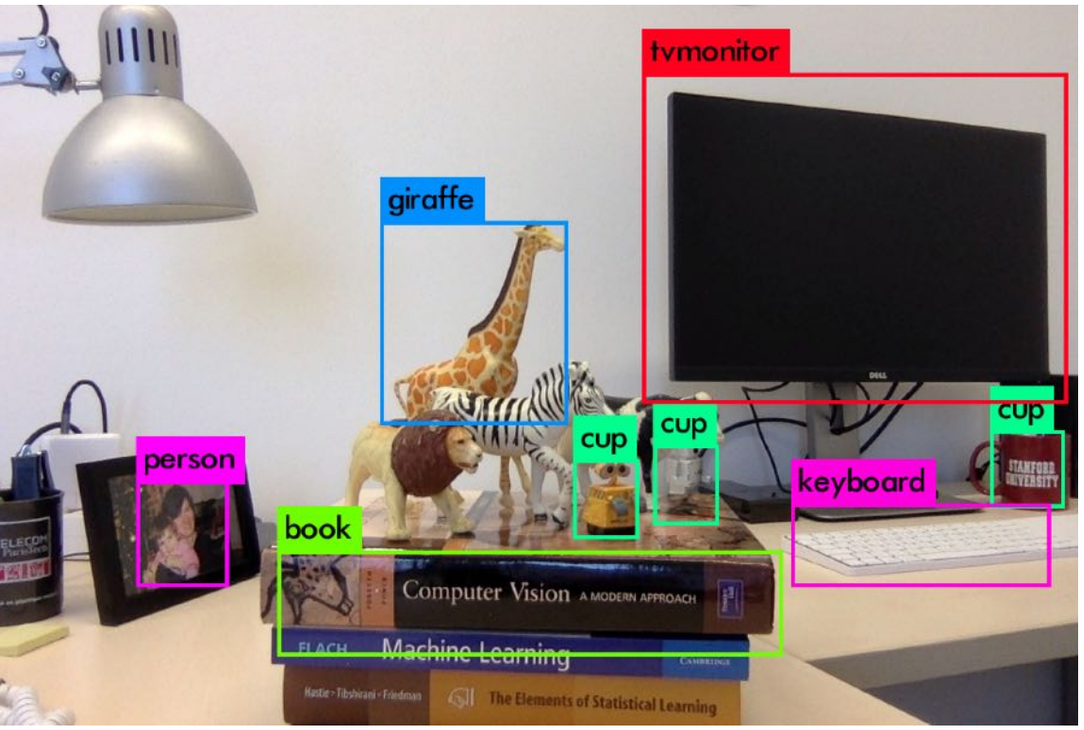
- **Finding optimal "strategies":** this might be related to games, paths, processes, etc.



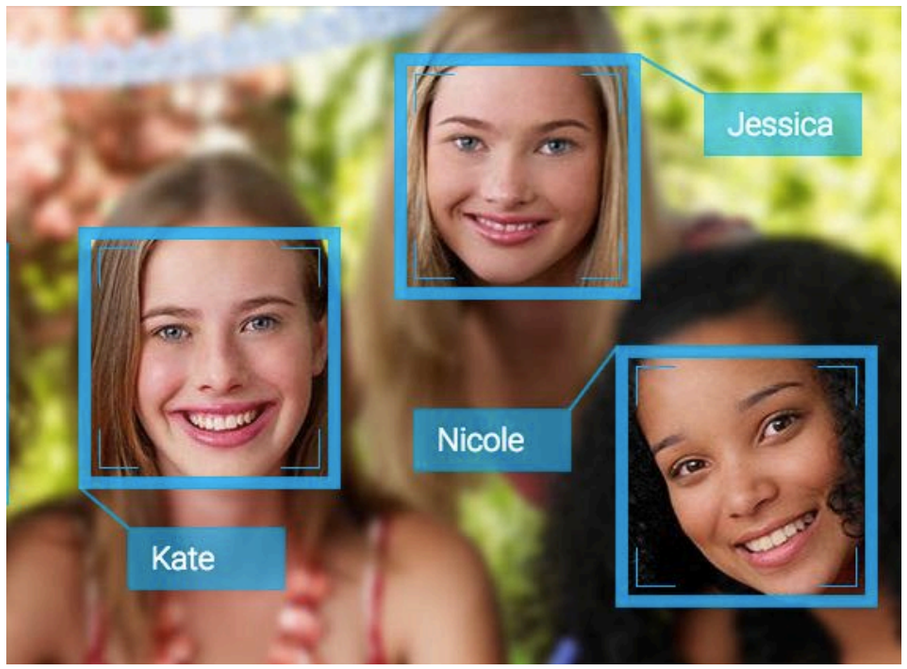
DeepMind AlphaGo

https://www.youtube.com/watch?v=8tq1C8spV_g

Learning is fundamental in vision



Object Recognition



Face Recognition

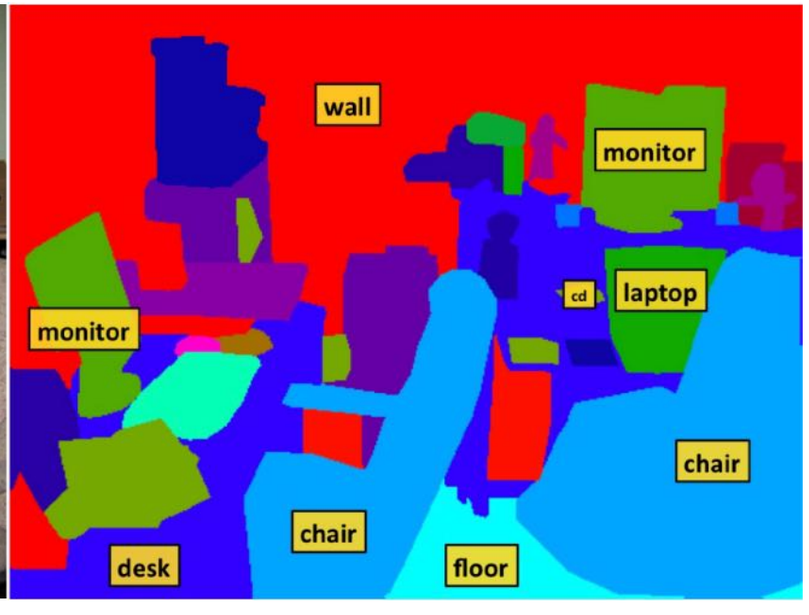


Image Segmentation

Learning is fundamental in NLP

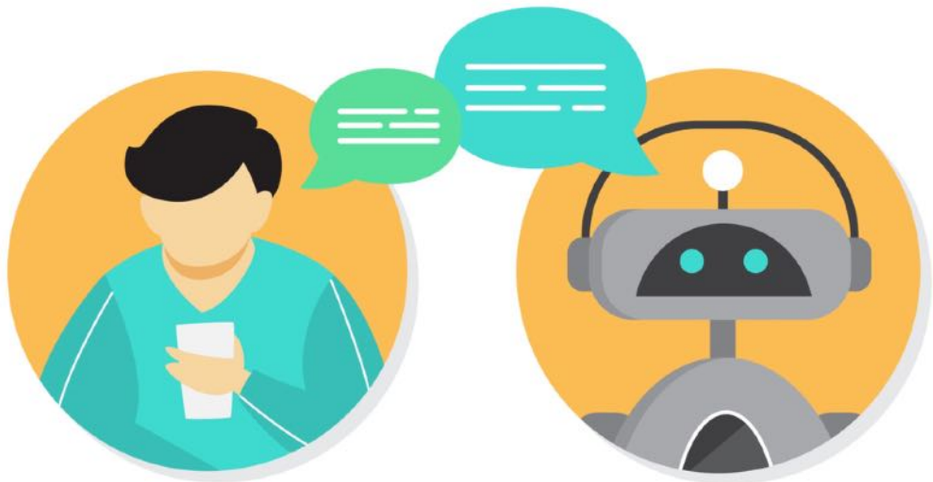
Back in 2000 , People Magazine PUBLISHER highlighted Prince Williams' PERSON style who at the time was a little more fashion-conscious , even making fashion statements at times .

Now-a-days the prince mainly wears navy COLOR suits ITEM (sometimes double-breasted DESIGN) , light blue COLOR button-ups ITEM with classic LOOK pointed DESIGN collars PART , and burgundy COLOR ties ITEM .

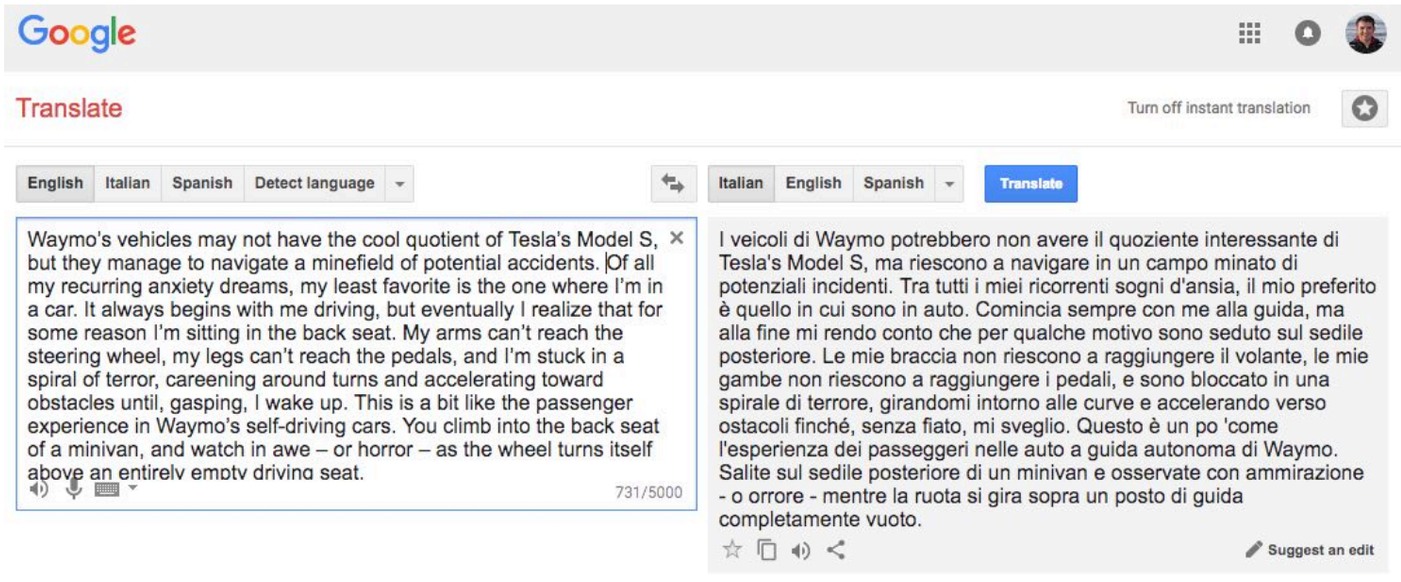
But who knows what the future holds ...

Duchess Kate PERSON did wear an Alexander McQueen BRAND dress ITEM to the wedding OCCASION in the fall of 2017 SEASON .

Named Entity Recognition



Question Answering



Machine Translation

Machine Learning: a definition

- "*ML is the field of study that gives computers the ability to learn without being explicitly programmed.*"
  - This is an older (informal) definition by Arthur Lee Samuel who popularised the term in 1959

A.L. Samuel, "Some Studies in Machine Learning Using the Game of Checkers", IBM Journal of Research & Dev. 1959

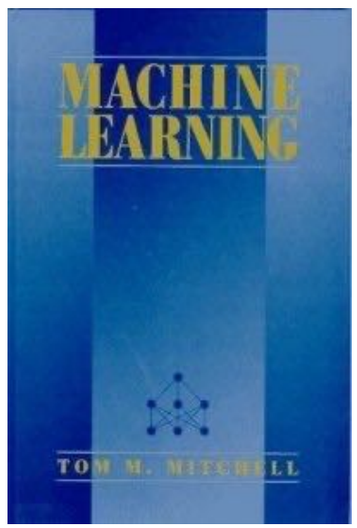
Machine Learning: a definition

- "*A computer program is said to learn from experience E with respect to some class of tasks T and performance measure P, if its performance at tasks in T, as measured by P, improves with experience E.*"

  - Tom Mitchell provides a more modern definition (1998)

    - Example: playing checkers

      - Experience E = the experience of playing many games of checkers
      - Task T = the task of playing checkers
      - Performance measure P = percent of games won against opponents



Machine Learning in a nutshell



- **Learning algorithm**: an algorithm that is able to learn from data

- Three main ingredients:
  - The Task
  - The Performance Measure
  - The Experience

The Task

- A task is described in terms of how the machine learning algorithm should process an *example*



- How is an example represented?
  - As a collection of features *(that can be "measured")*

Features

1. Color: Red
2. Type: Fruit
3. Shape: Round
4. …

The Task

- The task is defined by the problem we want to tackle and the desired output
- Example: classification

Apple

Orange

Mango

The Performance Measure

- How good is the machine learning system?
  - We need to measure its performance, i.e. how good is the function/model returned by the learning algorithm
- The performance measures depends on the task
  - Example (classification): *accuracy* is the proportion of examples for which the model gives the correct output

O:	mango	apple	orange	mango	orange	apple	orange	orange	apple	orange
	1	1	1	1	1	0	0	1	1	0

accuracy = 70%

The Experience

- The experience is provided by the available data
- Which kind of data?
  - Real-valued features, discrete features, …
- How do we get data
  - Obtained once for all (batch), acquired incrementally by interacting with the environment (online learning)
- How can data be used?
  - Learning paradigms

Main Learning Paradigms

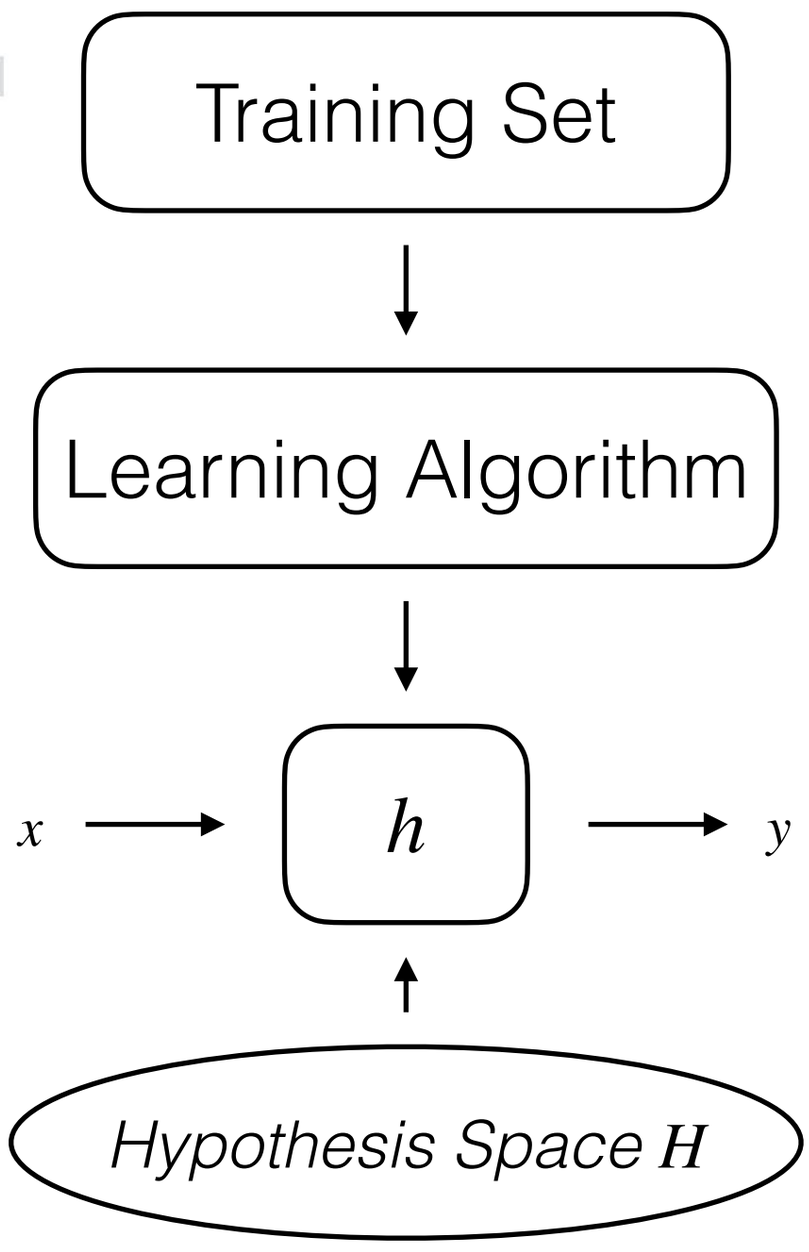
- **Supervised Learning**
  - **Goal:** give the "right answer" for each example in the data
  - Given examples $\{(x^{(i)}, y^{(i)})\}$, learn a function (description) which captures the information content of the examples
  - Basically we look for a function $h(\cdot)$ which is able to map in a predictive way $x^{(i)}$'s to $y^{(i)}$'s, *i.e.* $h: X \rightarrow Y$
  - An expert (or teacher) provides the supervision
    (i.e. the values of $h(\cdot)$ corresponding to the instances $x^{(i)}$)
  - **Output:** Classification (discrete-valued) *vs* Regression (real-valued output)

Main Learning Paradigms

- **Supervised Learning**

$\{(x^{(i)}, y^{(i)})\}$

Size in feet² (x)	Price ($) in 1K's (y)
2104	460
1416	232
1534	315
852	178
…	…

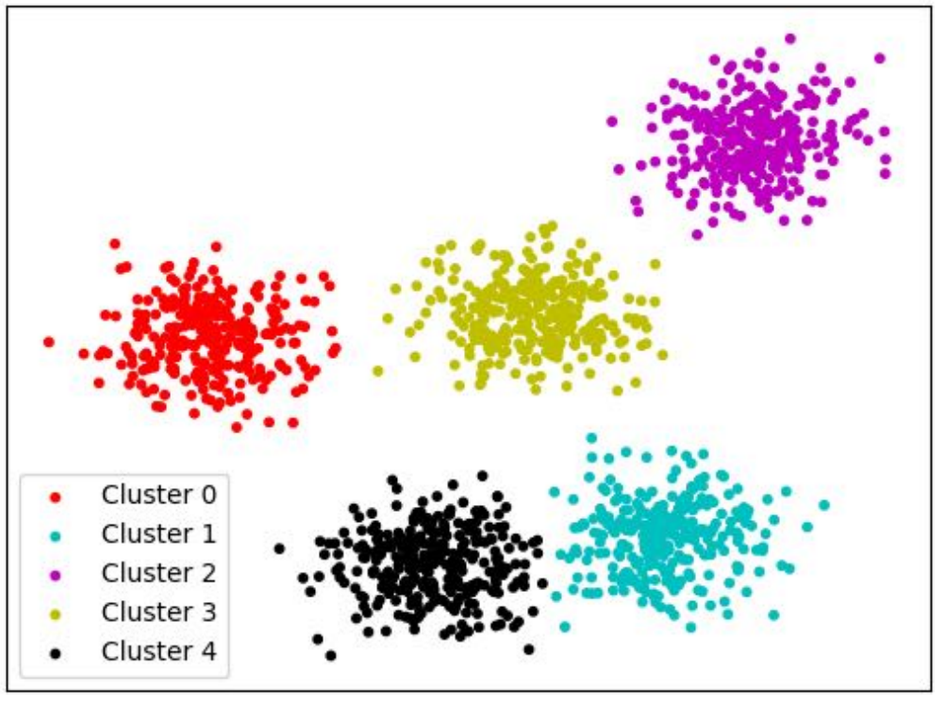


h approximates the unknown target f

$h \sim f: X \rightarrow Y$

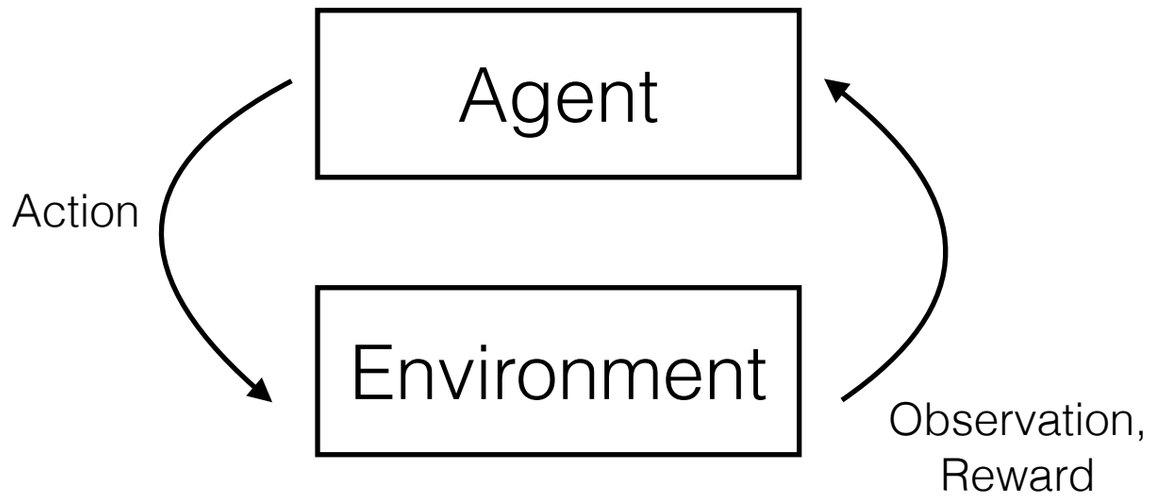
Main Learning Paradigms

- **Unsupervised Learning**
  - **Goal:** find regularities / patterns on the data
  - Given examples $\{x^{(i)}\}$, discover regularities on the whole input domain
  - There is no expert (*i.e.* no supervision)



Main Learning Paradigms

- **Reinforcement Learning**
  - Agent which may
    - be in state s
    - execute action a
      (among the ones admissible in state s)



    - and operates in an environment e, which in response to action a in the state s returns
      - the next state and a reward *r* (which can be positive, negative or neutral)
  - The goal of the agent is to maximize a function of the rewards

Other Learning Strategies

- Active Learning
- Online Learning and Incremental Learning
- Weak-supervised Learning
- Self-supervised Learning
- Deep Learning and Representation Learning
- Federated Learning

IML: Syllabus

- Introduction: what is ML, main learning paradigms
- Linear regression, linear classification, logistic regression
- Neural Networks
- Evaluating a learning algorithm, model selection, boundaries
- Non-parametric methods, decision trees
- Probabilistic classifiers, Naive Bayes
- SVM, Kernel Methods
- Unsupervised Learning: clustering, dimensionality reduction
- Applications (in vision and NLP), cognitive services / ML APIs

Contact

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

✉ lamberto.ballan@unipd.it

🏠 http://www.lambertoballan.net

🏠 http://vimp.math.unipd.it

@ twitter.com/lambertoballan