

Intelligence artificielle au service de la science les progrès et les enjeux

Gaël Varoquaux

Inria : Probabl.



Machine learning for AI

The art of generalizing

Example: face recognition



Andrew



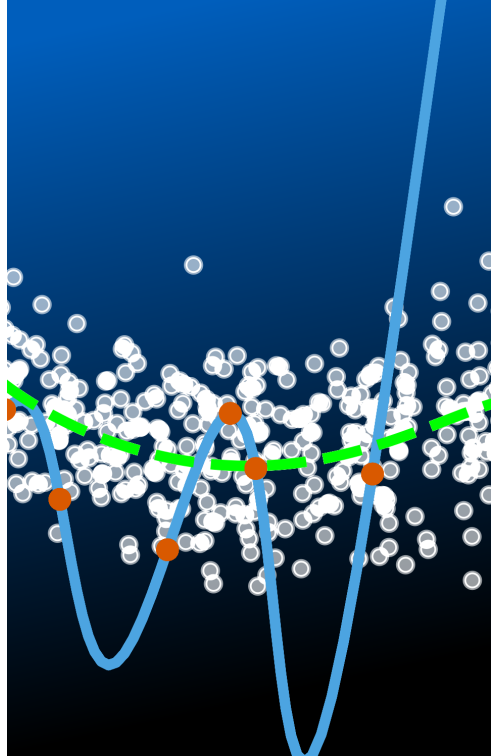
Bill



Charles



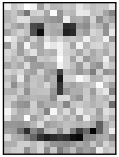
Dave



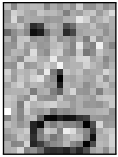
Machine learning for AI

The art of generalizing

Example: face recognition



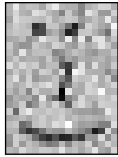
Andrew



Bill



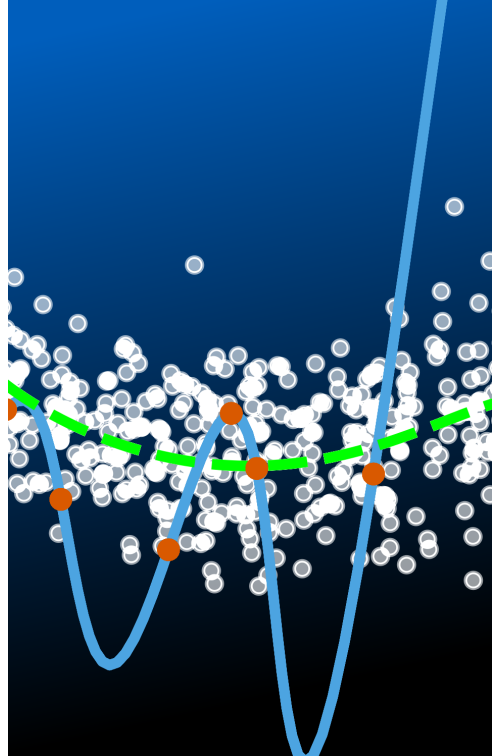
Charles



Dave



?



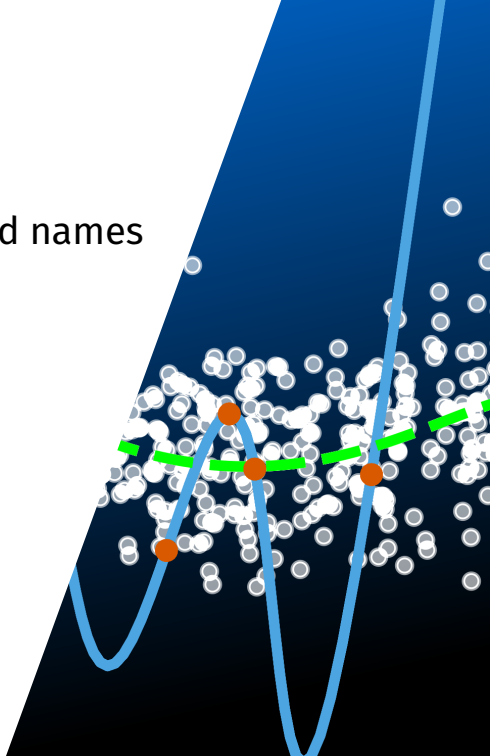
Machine learning for AI

The art of generalizing

A simple machine-learning method

- 1 Store all the known (noisy) images and names
- 2 From a new (noisy) image, find the most similar known image

“Nearest neighbor” method



Machine learning for AI

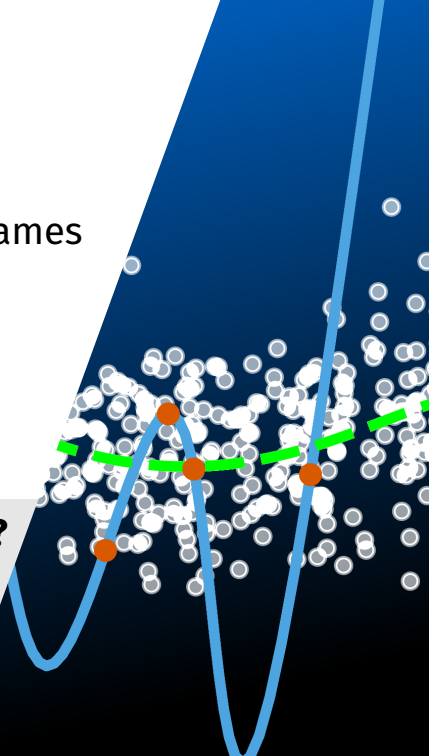
The art of generalizing

A simple machine-learning method

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“Nearest neighbor” method

How many errors on already-known images?



Machine learning for AI

The art of generalizing

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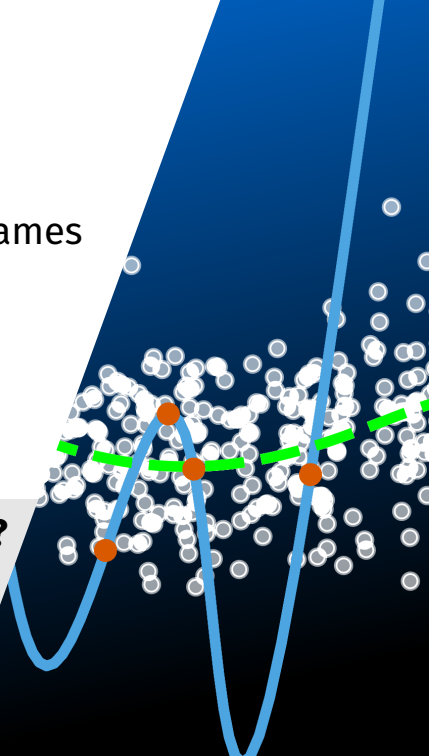
- 1 Store all the known (noisy) images and names
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“Nearest neighbor” method

How many errors on already-known images?

0: no errors

Test data \neq Train data

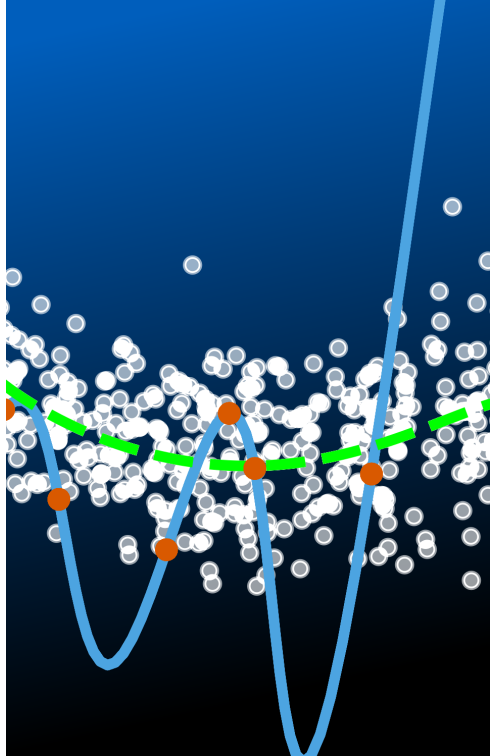


Machine learning for AI

The art of generalizing

Machine learning
is about fitting
very complex functions
on data

Predictions =
outputs of functions
on new data

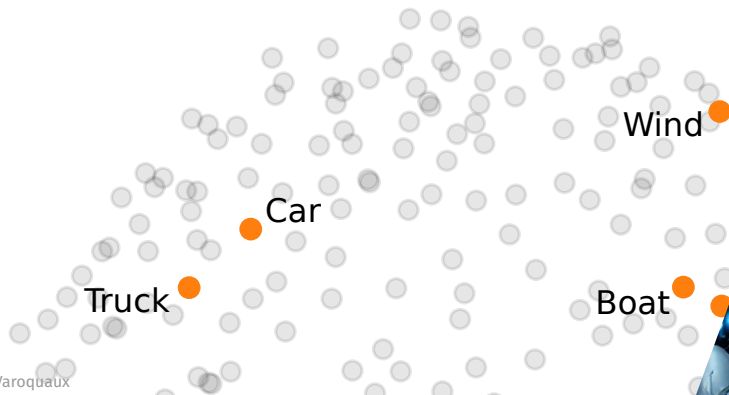


Demystifying Language models, the latest progress of AI



Language models as AI

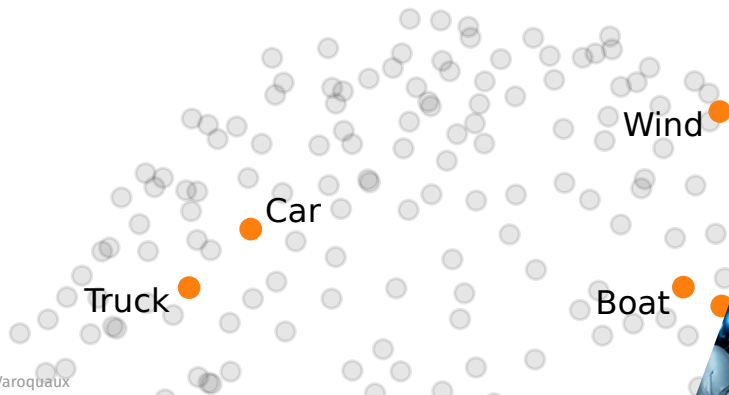
1. Words as embeddings in a semantic space



Language models as AI

1. Words as embeddings in a semantic space
2. Context gives meaning

“river bank” \neq
“bank of america”



Language models as AI

1. Words as embeddings in a semantic space
2. Context gives meaning

“river bank” \neq
“bank of america”

3. Learn to complete text

World knowledge

“Einstein was born in ...”

Likely words: “1879”, or “Ulm”



Language models as AI

1. Words as embeddings in a semantic space
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“bank of america”

3. Learn to complete text

World knowledge

“Einstein was born in ...”

Likely words: “1879”, or “Ulm”

4. Huge “associative” memory



Language models as AI

Associative memory is powerful

Please solve $3x^3 + 24x^2 - 18x + 90 = 0$

First, let's check if there are any obvious factors or roots. We can try possible rational roots such as $\pm 1, \pm 2, \pm 3, \pm 5, \pm 6, \pm 10, \pm 15, \pm 30$.

After checking these values, we find that $x = -5$ is a root. We can use synthetic division or polynomial division to factor out $(x + 5)$ from the cubic equation.

Performing polynomial division:

$$3x^3 + 24x^2 - 18x + 90 = (x + 5)(3x^2 - 3x + 18)$$

Now, we need to solve the quadratic equation $3x^2 - 3x + 18 = 0$.

Using the quadratic formula:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

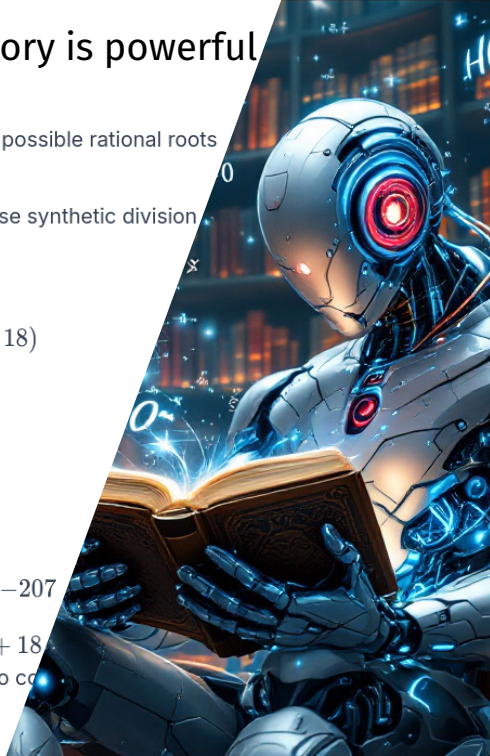
where $a = 3$, $b = -3$, and $c = 18$.

First, calculate the discriminant:

$$\Delta = b^2 - 4ac = (-3)^2 - 4 \cdot 3 \cdot 18 = 9 - 216 = -207$$

Since the discriminant is negative, the quadratic equation $3x^2 - 3x + 18 = 0$ has no real roots. Therefore, the original cubic equation has one real root and two complex roots.

The real root is $x = -5$.



Language models as AI

Associative memory is powerful

me > varoquau > test.py > ...



Write a Python code to compute the first 100 prime number, using numpy if needed

Ask Copilot



GPT-4o



0

Accept

Close



```
def is_prime(num):
    if num < 2:
        return False
    for i in range(2, int(np.sqrt(num)) + 1):
        if num % i == 0:
            return False
    return True

def first_n_primes(n):
    primes = []
    candidate = 2
    while len(primes) < n:
        if is_prime(candidate):
            primes.append(candidate)
        candidate += 1
    return primes

if __name__ == "__main__":
    primes = first_n_primes(100)
    print(primes)
```



Language models as AI

This associate memory
makes intellectual work
more productive

How much will it
“revolutionize”
science?



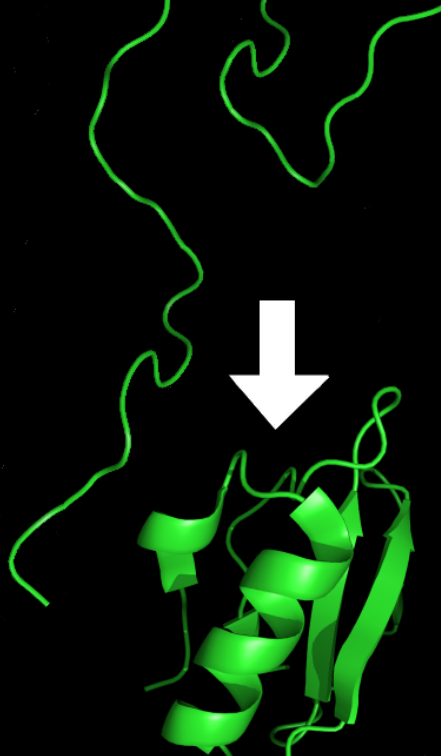
Protein Folding

A success story of AI for science

Folding gives biological
function

Folding is created by
the sequence of amino acids

Bio-engineering problem:
predict folding from sequence



Protein Folding

Folding data

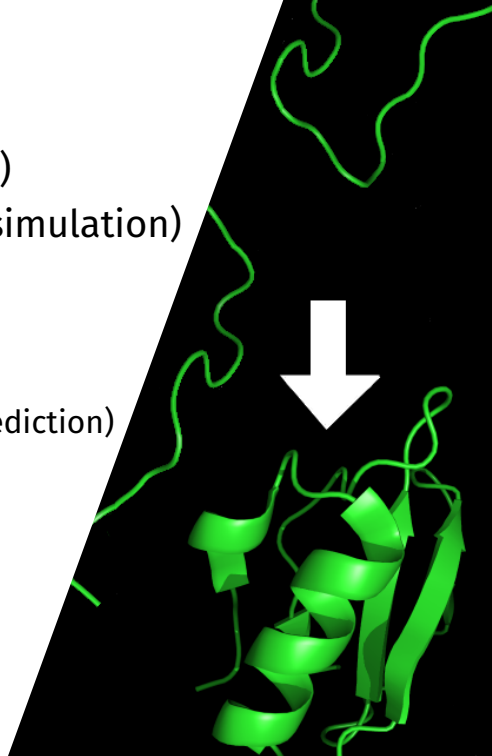
- Experimental (X-ray crystallography)
- Computational (ab-initio quantum simulation)

Prediction research program

- On-going challenge since 1994
- CASP (Critical Assessment of Structure Prediction)

Alpha fold

- Google, 2018 and later
- Graph-based deep learning
- 2024 Chemistry Nobel prize



AI for health

Much health-related data
can we use it for the better?

Diagnostics:

from complex data *eg* radiology

Prognostics:

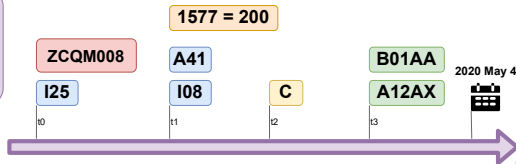
predict future health evolution



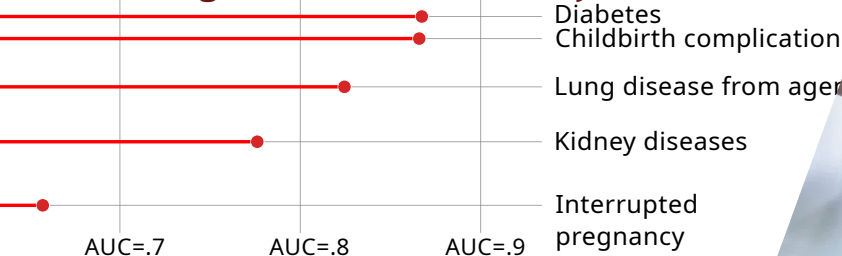
AI for health

Predicting future from health records

Anna
Age = 54
Gender = Female
Insurance Status = RG
Residence = Le Havre



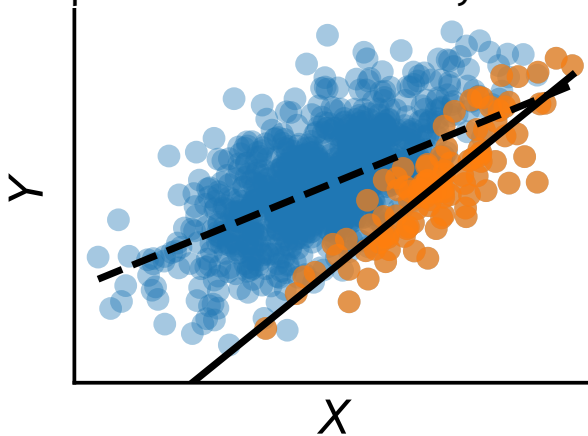
Predicting new conditions in a year



AI for health

But bias can break associations

eg hospitals don't see healthy individuals



data \neq real world

Not fixed by bigger models, more data



Big AI

A bigger-is-better narrative

Vision and language models

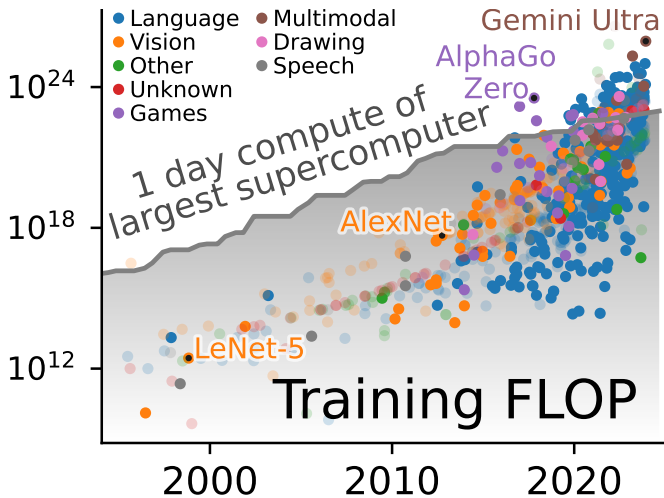
*“our results can be improved simply by **waiting for faster GPUs and bigger datasets**”*

AlexNet Paper
[Krizhevsky... 2012]



Biiiiiiiiig AI

[Varoquaux... 2024]



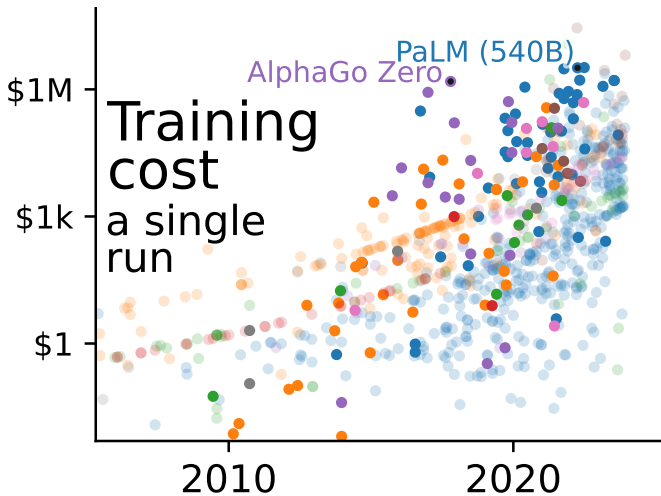
*“leverag[ing] **computation** [is] ultimately the **most effective** [...] The ultimate reason for this is **Moore’s law**”*

[Sutton 2019]



Biiiiiiiiig AI

[Varoquaux... 2024]



money, not Moore's law



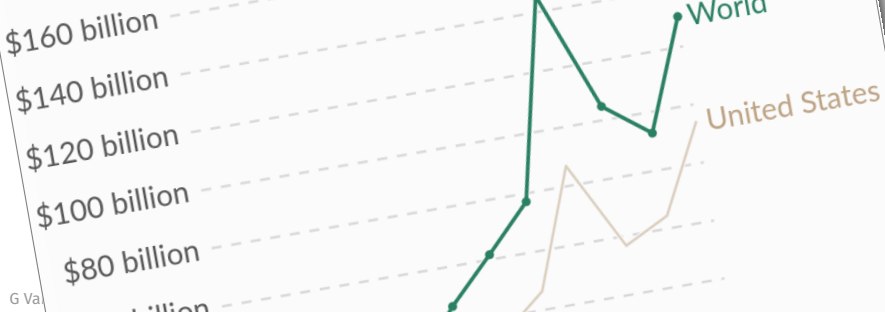
Financial consequences

It costs a lot to run AI

~ Belgium government budget:

130 Billion €

Annual private investment in artificial intelligence



The New York Times

Artificial Intelligence



OpenAI

...ing Fast and Burn
of Money

...or more outside investors,
The New York Times show
... ChatGPT and a serious ne

Financial consequences

It costs a lot to run AI

~ Belgium government budget:

130 Billion €

But the promises are amazing

**Nvidia CEO predicts the death of coding —
Jensen Huang says AI will do the work, so
kids don't need to learn**

News

By [Benedict Collins](#) published February 26, 2024

Jensen Huang believes coding languages are a thing of the past



The New York Times

Artificial Intelligence ▾



OpenAI

Our World

growing Fast and Burn
of Money

estors,
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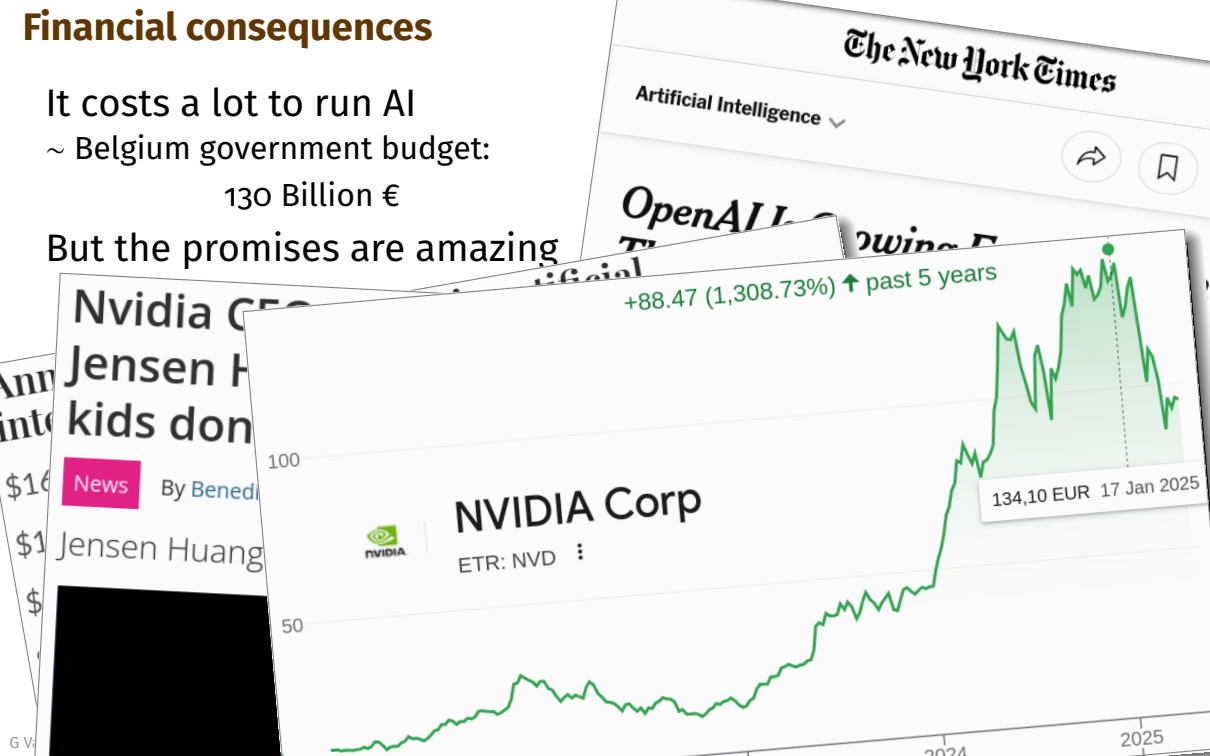
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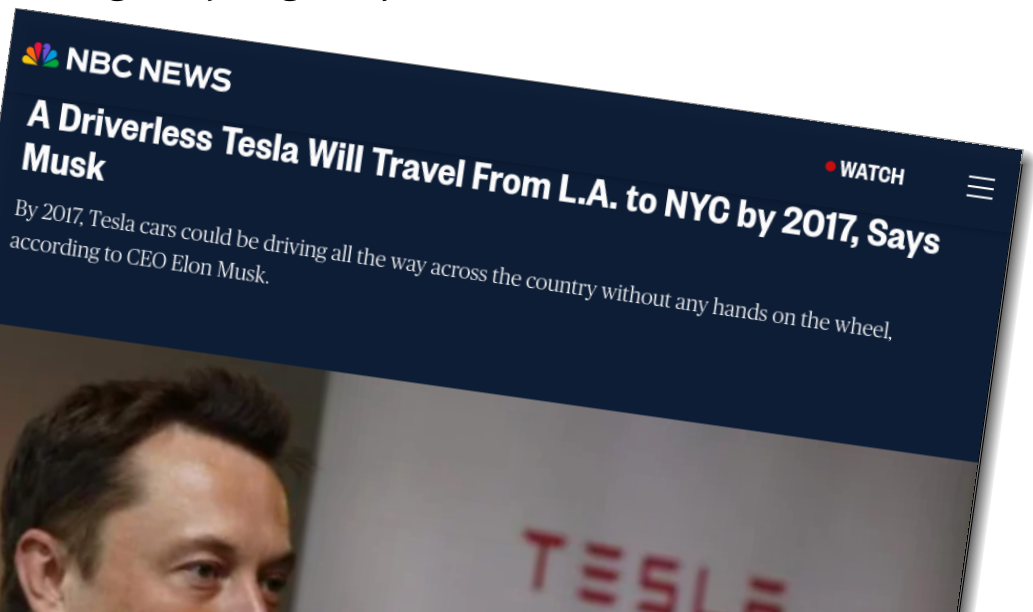
130 Billion €

But the promises are amazing



Beware of inflated promises

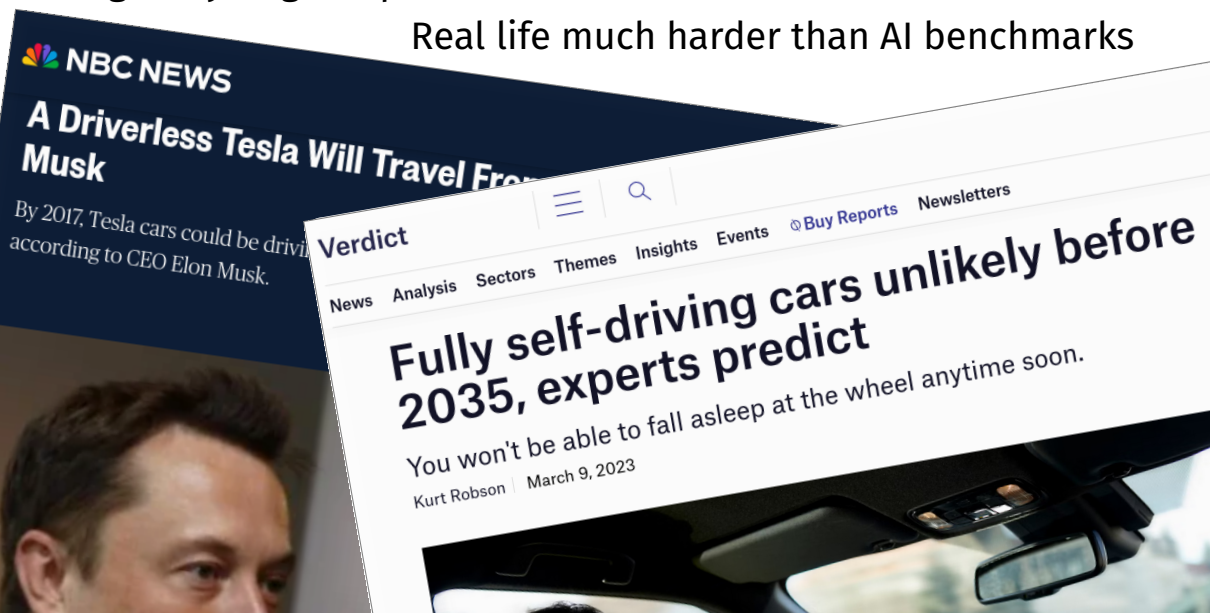
Long story of great promises



Beware of inflated promises

Long story of great promises

Real life much harder than AI benchmarks



Sustainability consequences

- Perturbing the US power grid
- Consumption equivalent to Japan

Bloomberg

AI NEEDS SO
MUCH POWER,
IT'S MAKING
YOURS WORSE

iea

Reports / Electricity 2024

Electricity 2024

Analysis and forecast to 2026

Download PDF

Electricity consumption from data centres, artificial intelligence (AI) and the cryptocurrency sector could double by 2026. Data centres are significant drivers of growth in electricity demand in many regions. After globally consuming an estimated 460 terawatt-hours (TWh) in 2022, data centres' total electricity consumption could reach more than 1 000 TWh in 2026. This demand is roughly equivalent to the electricity consumption of Japan. Updated regulations and efficiency improvements, including on efficiency, will be crucial to managing the growing demand from data centres.



Technology | The Big Take

by Nicoletti, Naureen Malik and Andre Tartakovsky
for **Bloomberg Technology**
December 27, 2024

Sustainability consequences

- Perturbing the US power grid
- Consumption equivalent to Japan

Battle of narrative

The Guardian Eur ▾

News Opinion Sport Culture Lifestyle

Environment Climate crisis Wildlife Energy Pollution

Technology

⚙ This article is more than 7 months old

Data center emissions probably 662% higher than big tech claims. Can it keep up the ruse?

...in-house data centers of Google, Microsoft, ...be 7.62 times higher than official tally

Electricity consumption could double by 2026. ...regions. After globally ...electricity consumption ...equivalent to the electricity ...improvements, including on eff ...from data centres.

Download PDF

DS SO
OWER,
KING
ORSE

Take
and Andre Tar
ogy
4

18

Centralizing compute & data

- Data centers solves compute



Centralizing compute & data

- ~~Data centers solves compute~~
Cloud is the ideal spying system
- There will *always* be incumbents elites abusing dominant positions

And I really worry
that Musk and DOGE
are the premises of fascism



A close-up, slightly low-angle shot of a man in a dark military uniform. He is wearing a peaked cap with a silver emblem. His expression is serious and contemplative as he looks off-camera to the left. The lighting is dramatic, with strong highlights on his face and uniform, and deep shadows in the background.

Are we the baddies?

Varoquaux, Luccioni, Whittaker, FAcCT 2025
Hype, Sustainability, and the Price of the Bigger-is-Better Paradigm in AI

Open source for better AI

Digital **commons** for a better society

- To bring in different stakeholders
- To control how data is used
- To enable inspecting AIs

Sovereignty calls for open source



Open source for better AI

Scikit-learn, machine-learning in Python

- **Open** source
- Driven by a **community**
- **Simplifies** adoption
- Runs on **commodity** hardware



- Most used machine learning package
- People like small models

Sustainability = **Probabl.ai**

- A virtuous business proposal
- “Own your data science”



AI & science

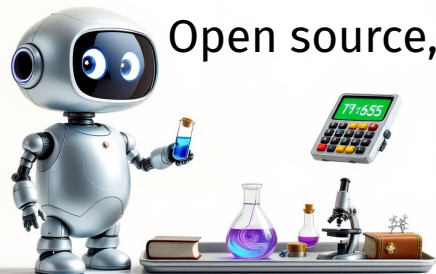
Promises and progresses

But no magic bullet

Let us keep in mind society at large

Need sovereign and lightweight solutions

Open source, scikit-learn, probabl.ai...



References I

- A. Krizhevsky, I. Sutskever, and G. E. Hinton. Imagenet classification with deep convolutional neural networks. *Advances in neural information processing systems*, 25, 2012.
- R. Sutton. The bitter lesson. *Incomplete Ideas (blog)*, 13(1), 2019.
- G. Varoquaux, A. S. Luccioni, and M. Whittaker. Hype, sustainability, and the price of the bigger-is-better paradigm in ai. *arXiv preprint arXiv:2409.14160*, 2024.