L'IA sans mystère

Les réseaux de neurones expliqués

Prof. Gilles Louppe
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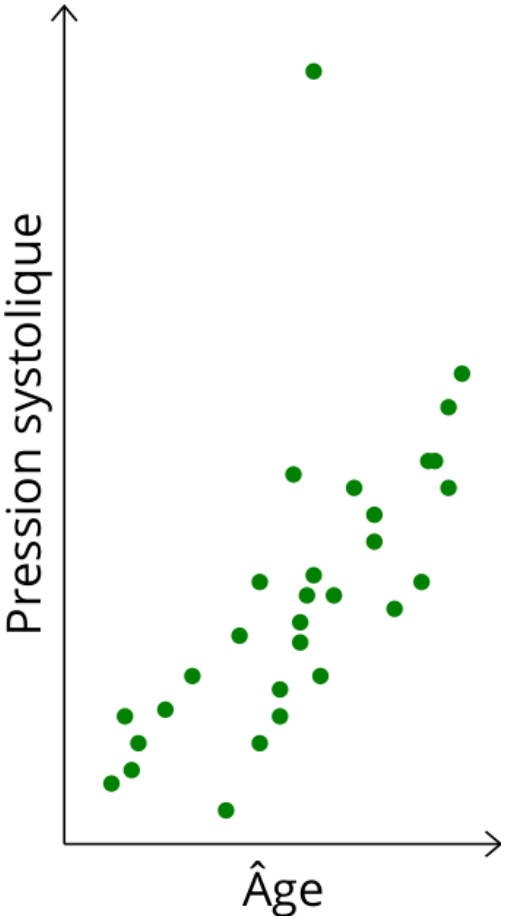
L'intelligence artificielle moderne ...

- se programme elle-même;
- résoud des problèmes complexes;
- lit, écrit, entend, parle et voit.

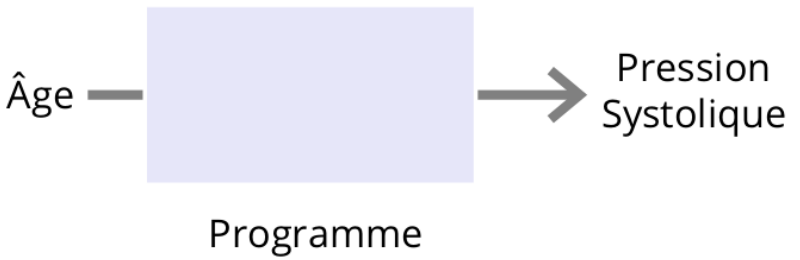
L'IA se programme elle-même

Comment estimer la pression artérielle d'un patient en l'absence de tensiomètre?



Les programmes classiques

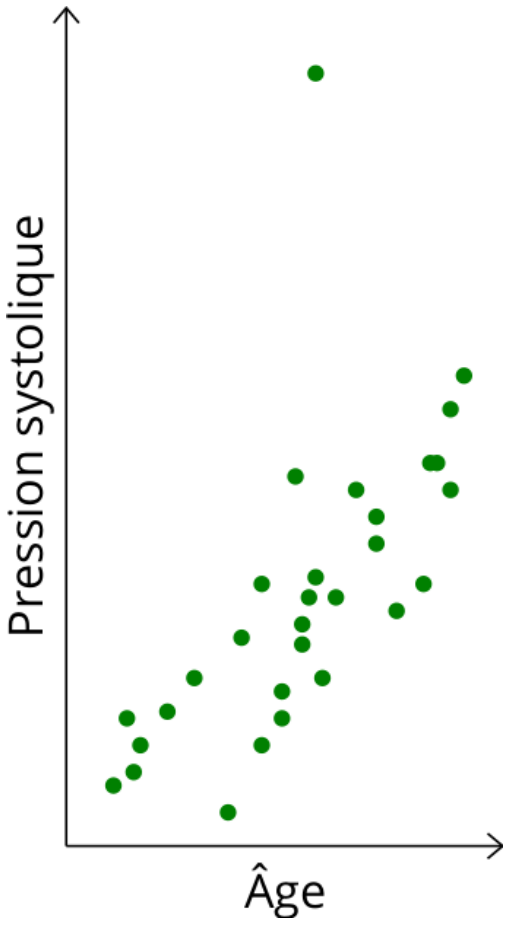
On écrit un programme qui prend l'âge d'un patient et retourne une pression artérielle en suivant une suite d'instructions pré-définies.




```
def blood_pressure(age):
    if age < 20:
        return 120
    elif age < 40:
        return 130
    else:
        return 140
```

Le machine learning

On écrit un programme qui apprend, de lui-même et sans instructions pré-établies, à prédire la pression artérielle à partir d'exemples.



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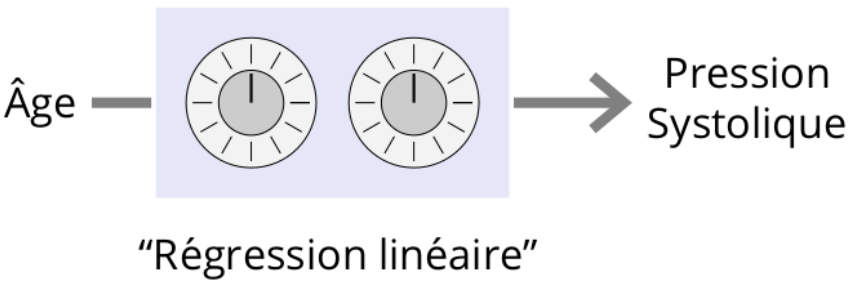
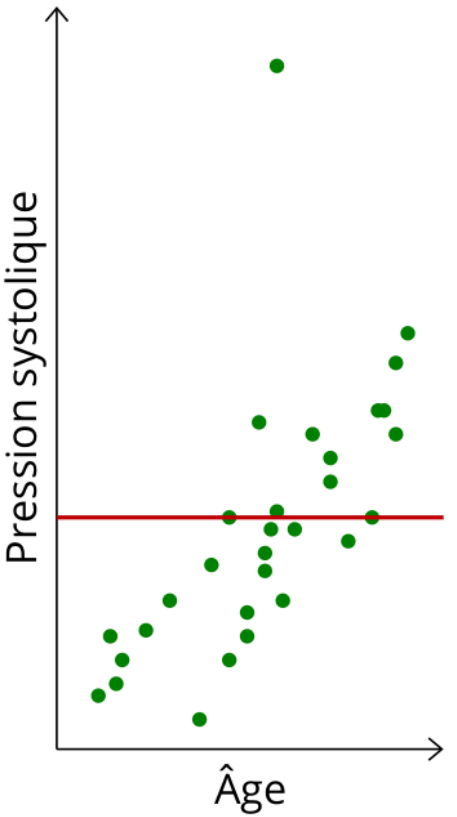


"Régression linéaire"



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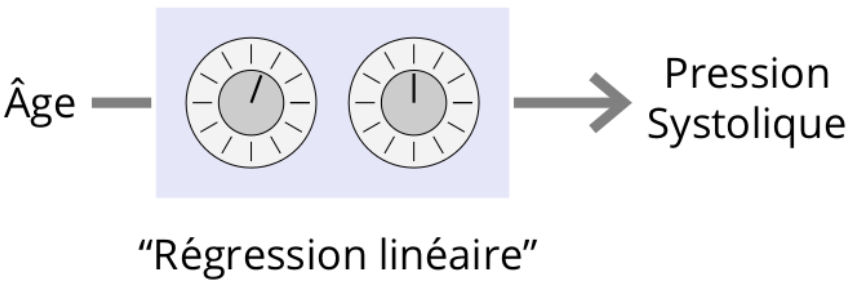

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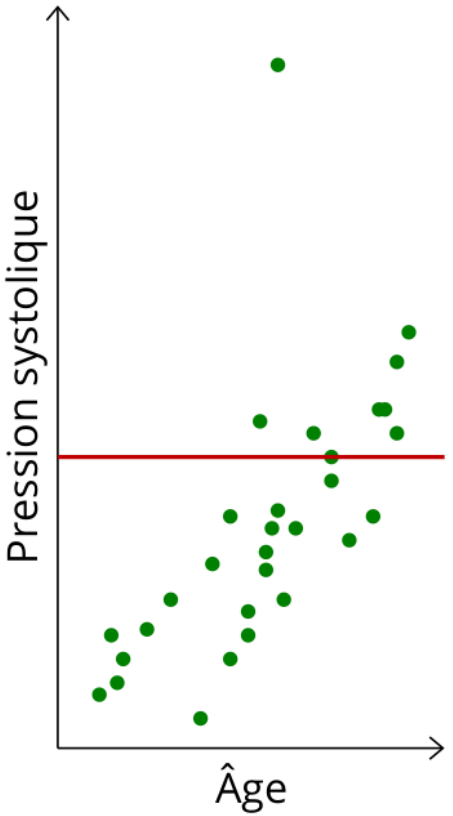

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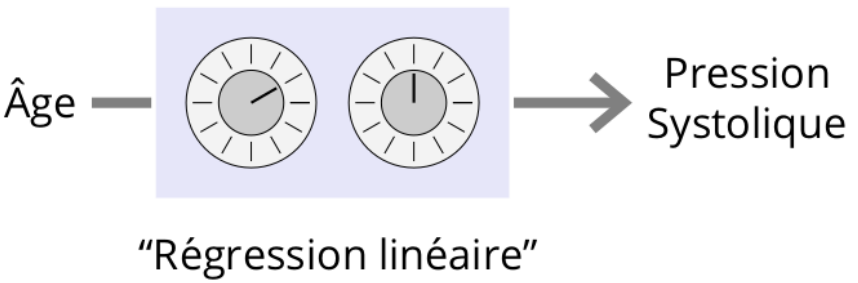

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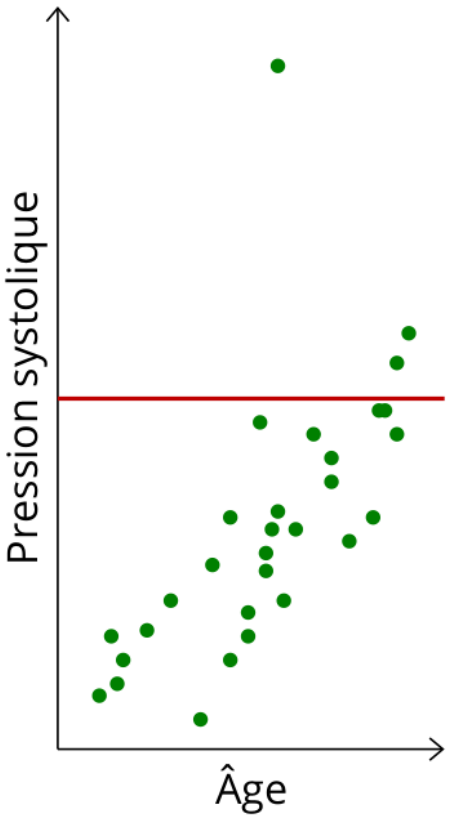

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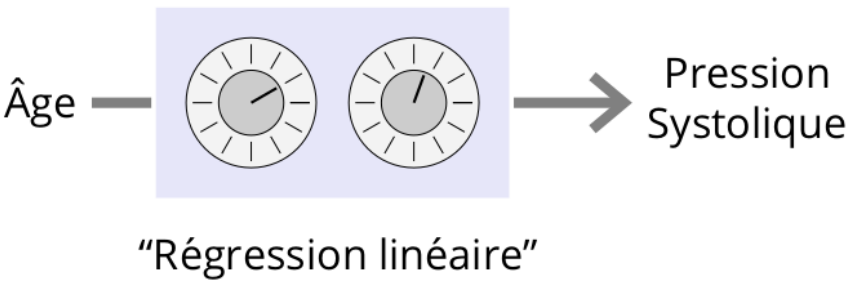

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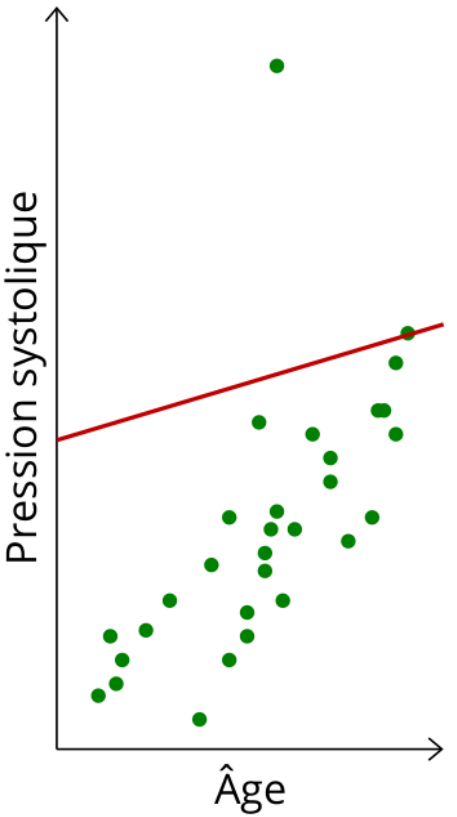

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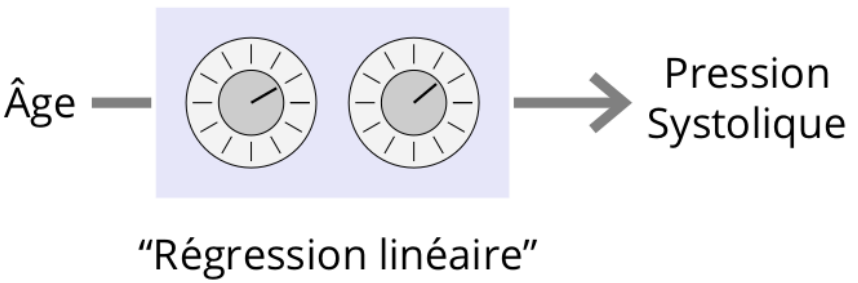
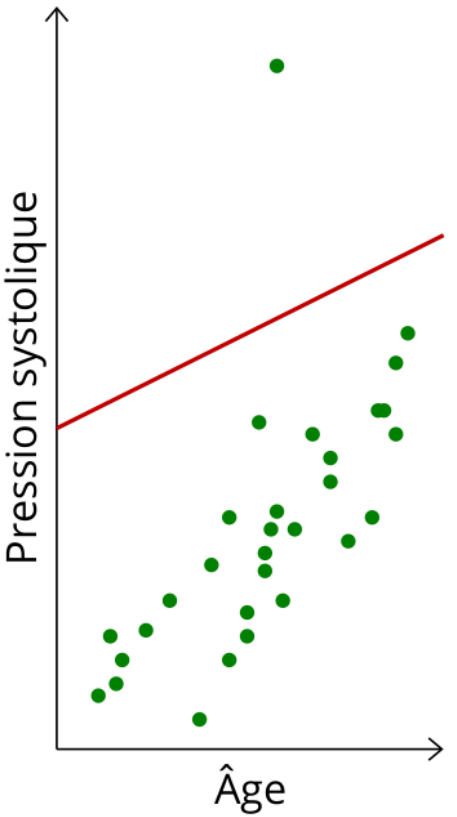


"Régression linéaire"



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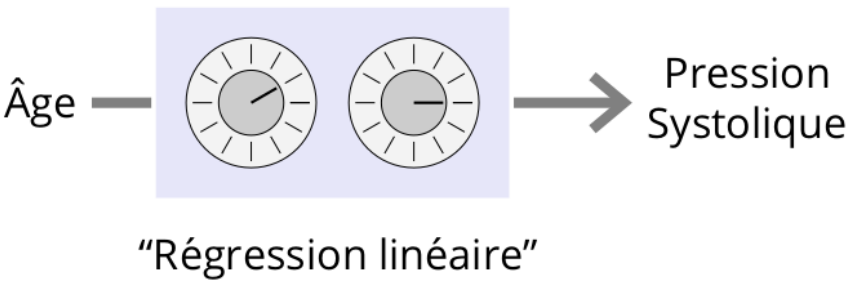
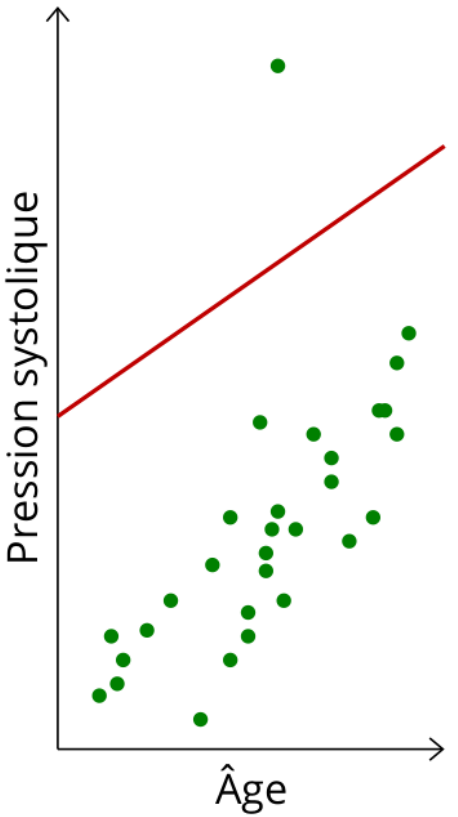


"Régression linéaire"



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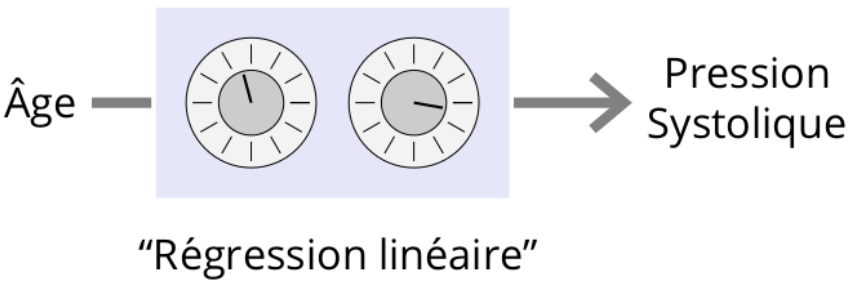
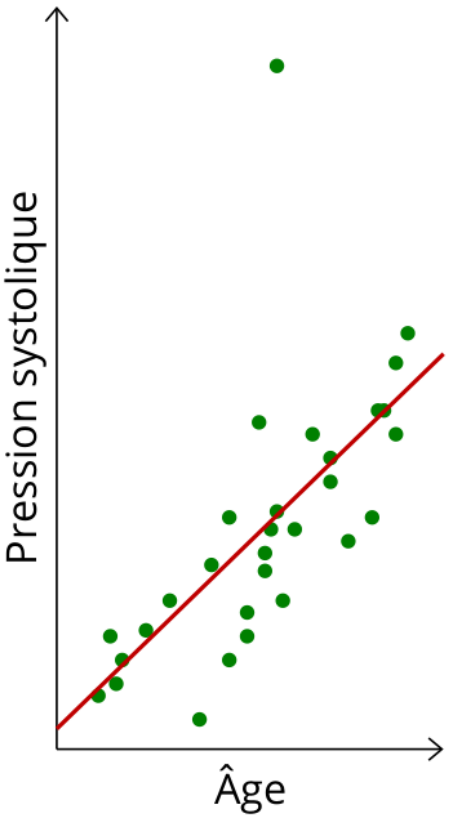


"Régression linéaire"



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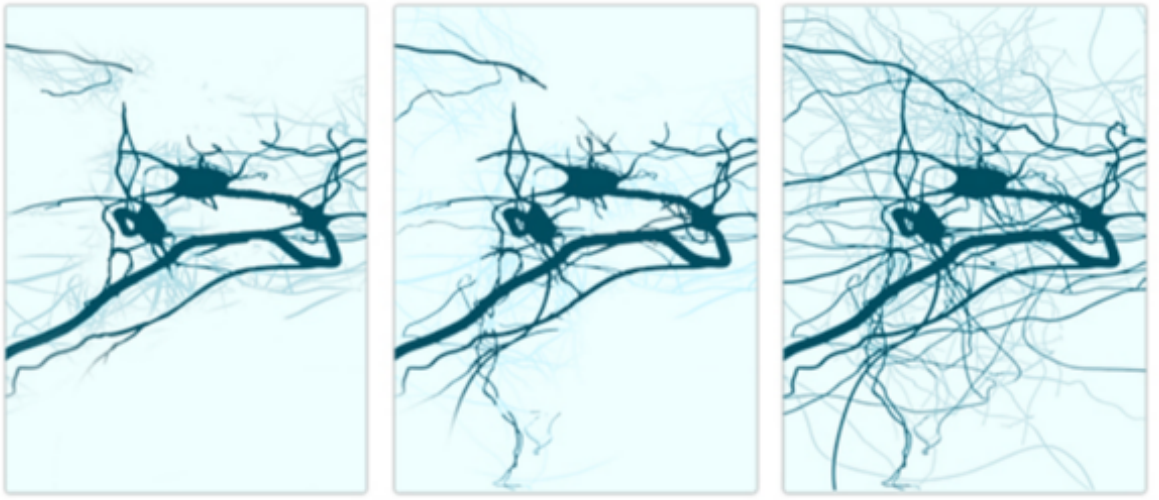
Les réseaux de neurones

Cette stratégie rappelle la plasticité des réseaux de neurones naturels permettant au cerveau de créer, renforcer ou défaire les connexions entre les neurones pour apprendre.



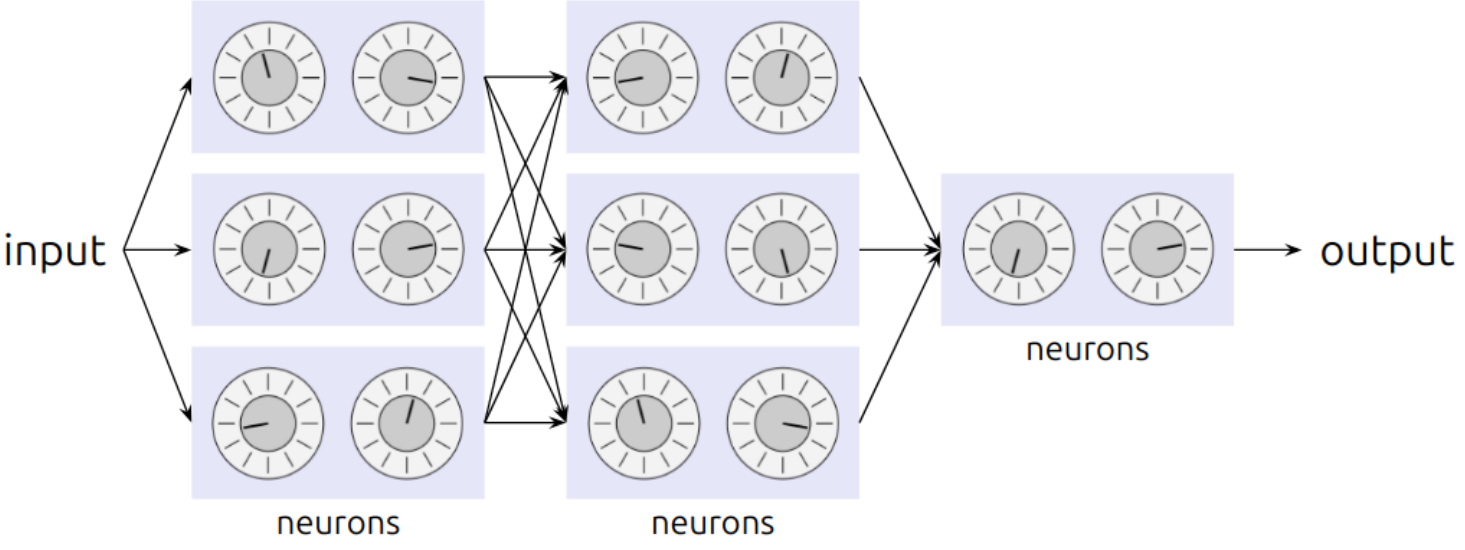
Les réseaux de neurones **avant** l'entraînement

Les réseaux de neurones **après 2 semaines** de stimulation cognitive

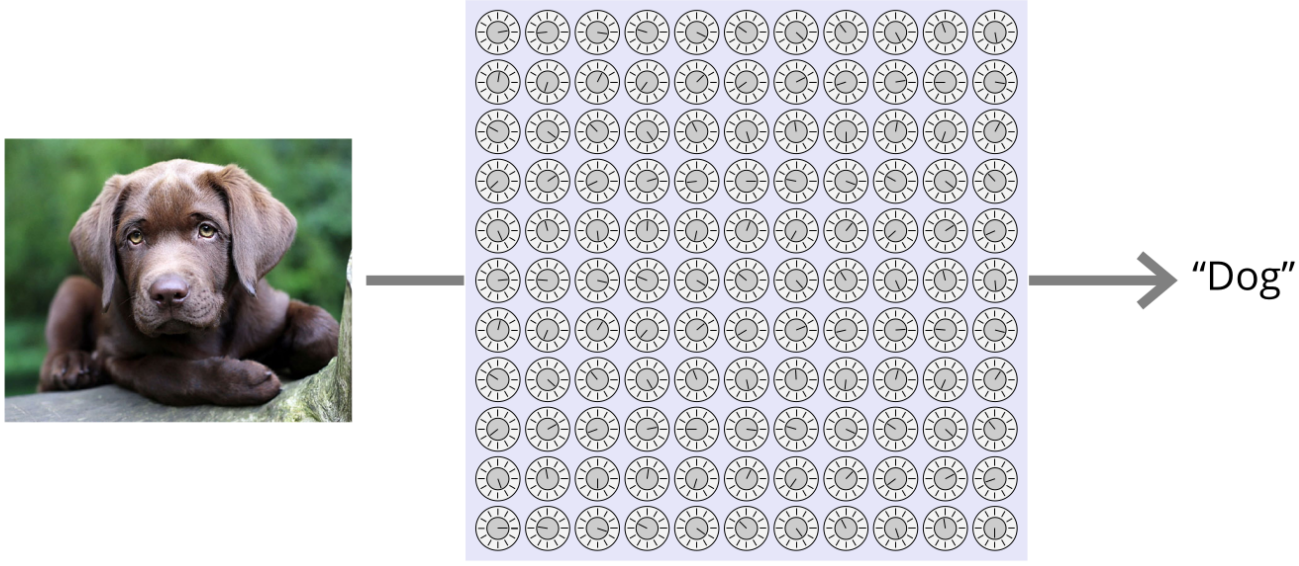
Les réseaux de neurones **après 2 mois** de stimulation cognitive

En poussant cette analogie, des neurones artificiels peuvent être définis comme des fonctions mathématiques qui prennent des entrées $\mathbf{x}$, les transforment, et retournent des sorties y.

Ces neurones peuvent ensuite être organisés en couches interconnectées, pour former des **réseaux de neurones artificiels**.



À grande échelle, ces modèles sont capables d'extraire de l'information à partir d'image, de son, ou de texte.



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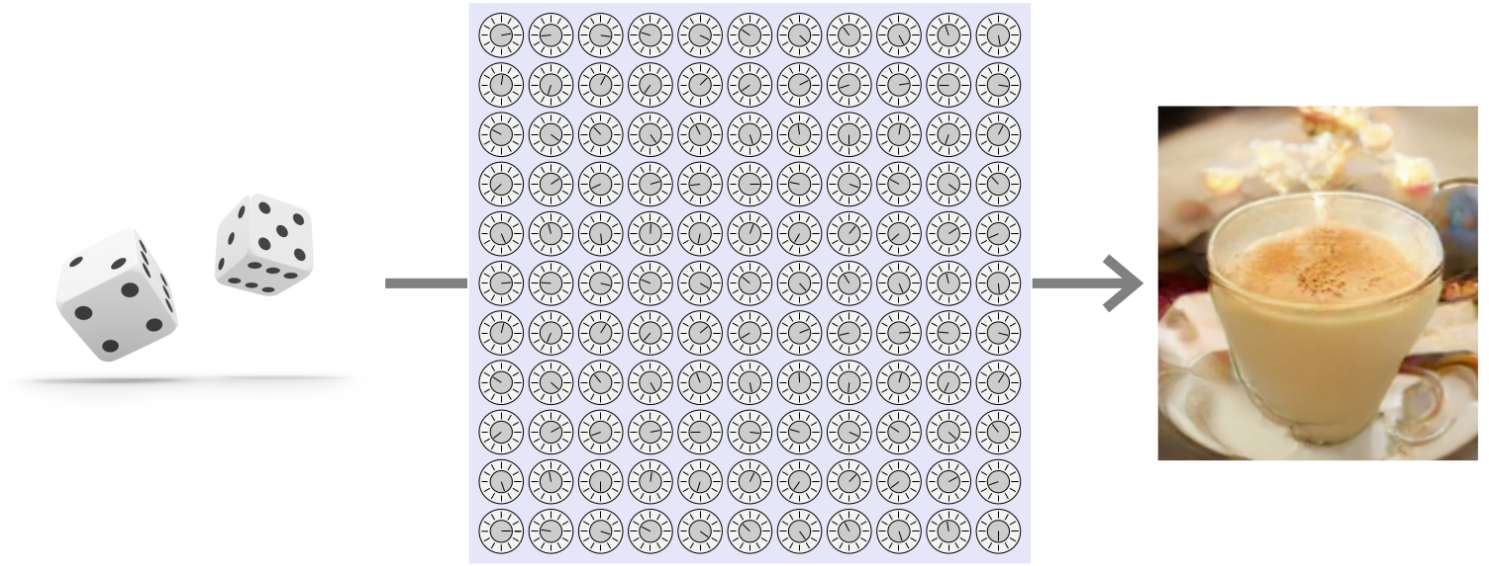
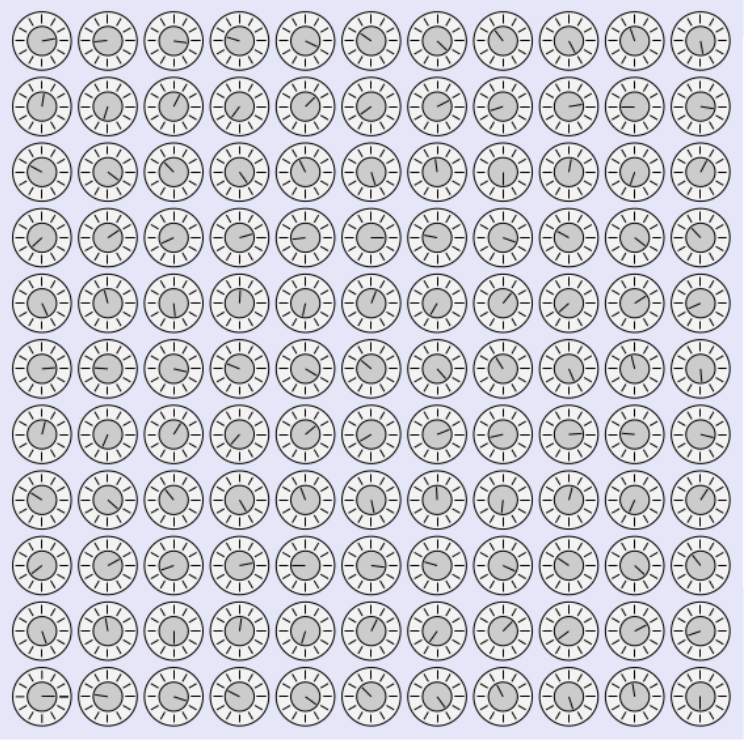
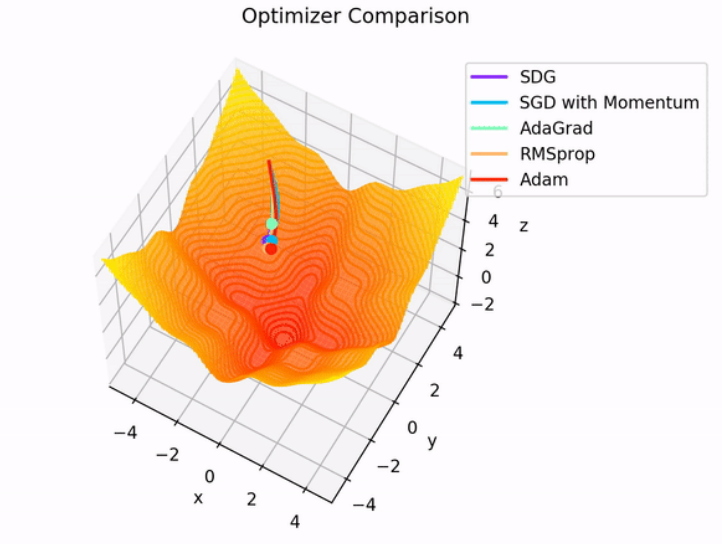
... ou de produire des images, du son, ou du texte.



Comme précédemment, les réseaux de neurones sont **entraînés** en ajustant leurs paramètres pour minimiser l'erreur entre leurs prédictions et les vraies valeurs.

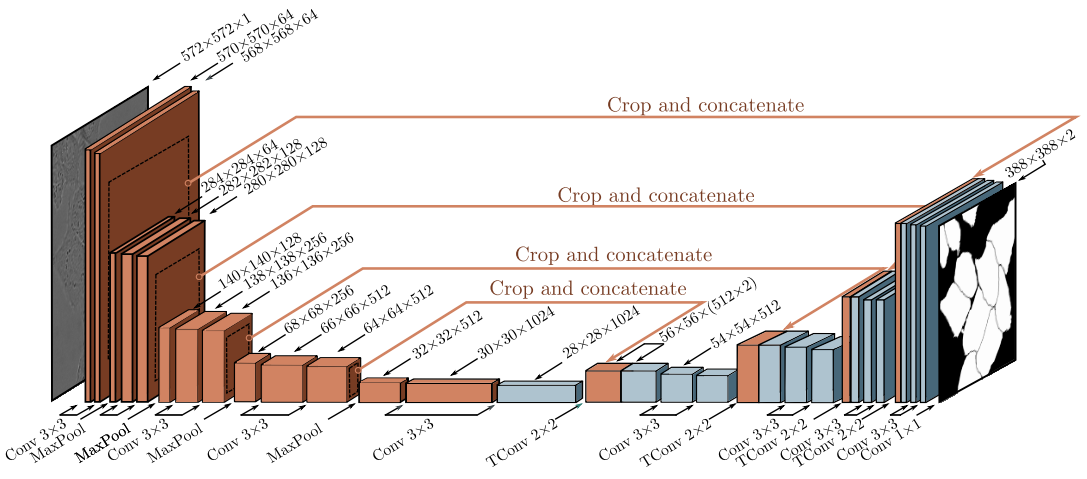


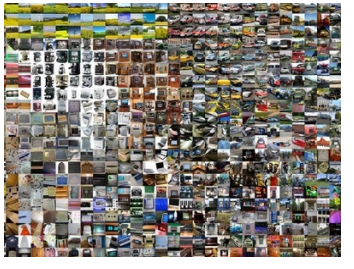


$$\theta_{t+1} = \theta_t - \gamma \nabla \mathcal{L}(\theta_t)$$

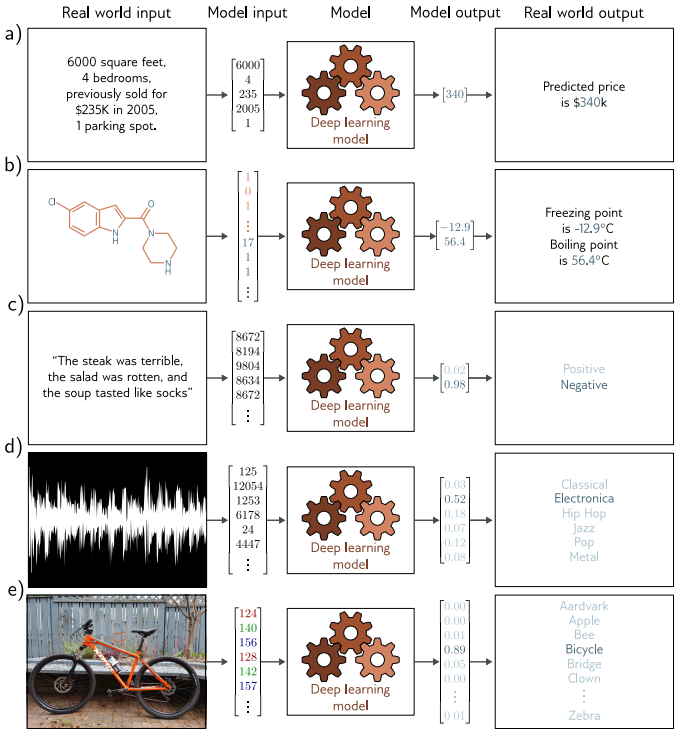
Le **deep learning** (ou **apprentissage profond**) applique la même stratégie, mais à une échelle beaucoup plus grande encore:

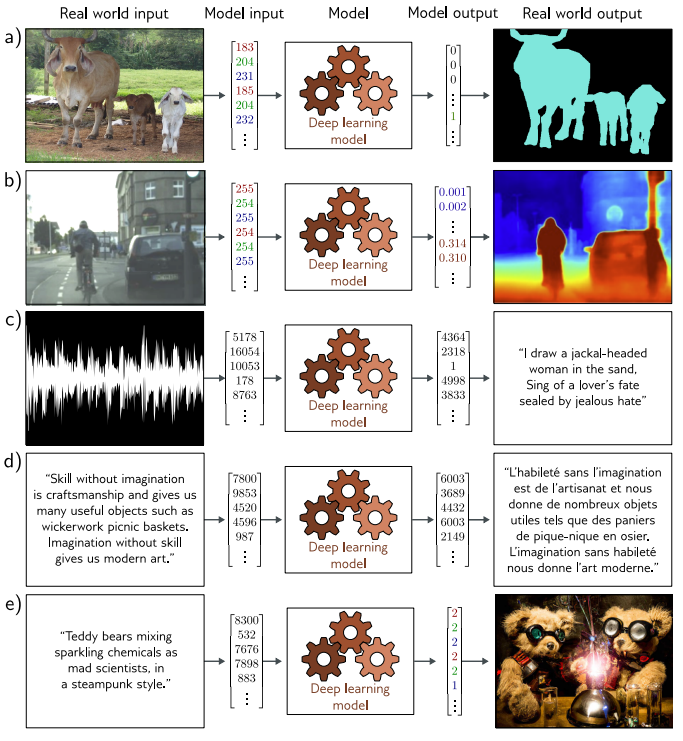
- en utilisant des réseaux de neurones gigantesques (jusqu'à 10^{11} paramètres),
- en s'entraînant sur des données les plus larges possibles (TBs ou PBs),
- en utilisant des ressources de calcul dédiées (des data centers entiers).





L'IA résoud des problèmes



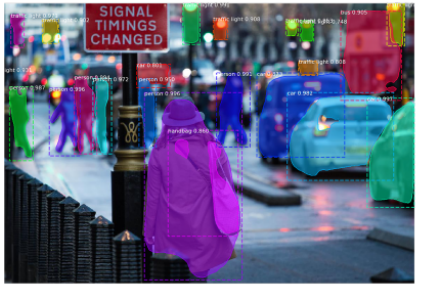


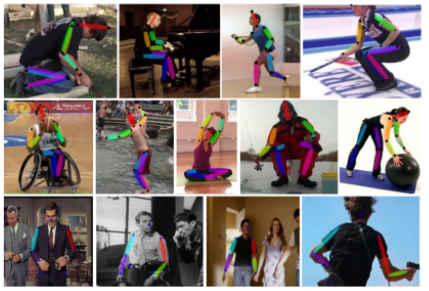
La plupart des problèmes d'IA peuvent être formulés comme des tâches de **prédiction** où l'objectif est de prédire une sortie y à partir d'une entrée x.

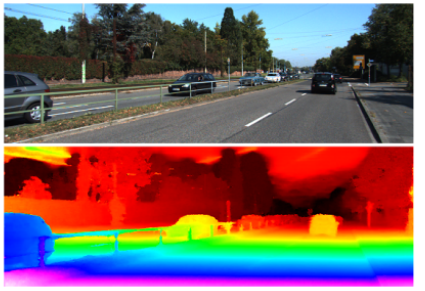
—

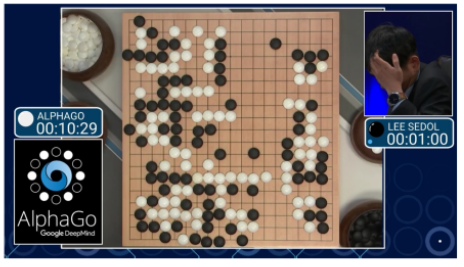
Credits: Simon J.D. Prince, 2023.

Des **réseaux des neurones spécialisés** peuvent ainsi être entraînés et atteindre des performances supérieures à celles de l'homme sur des tâches complexes.









I: Jane went to the hallway.
I: Mary walked to the bathroom.
I: Sandra went to the garden.
I: Daniel went back to the garden.
I: Sandra took the milk there.
Q: Where is the milk?
A: garden

(Haut) Compréhension de scène, estimation de pose, raisonnement géométrique.
(Bas) Planification, annotation d'images, compréhension à la lecture.

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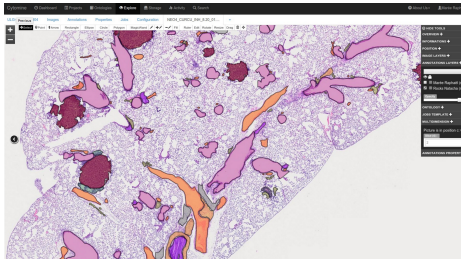
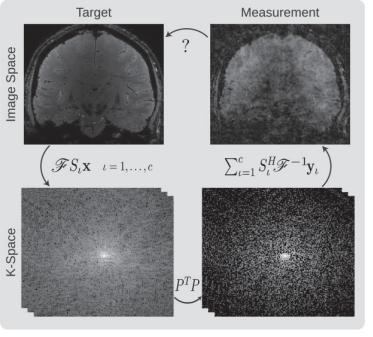
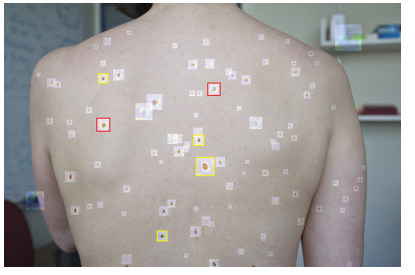
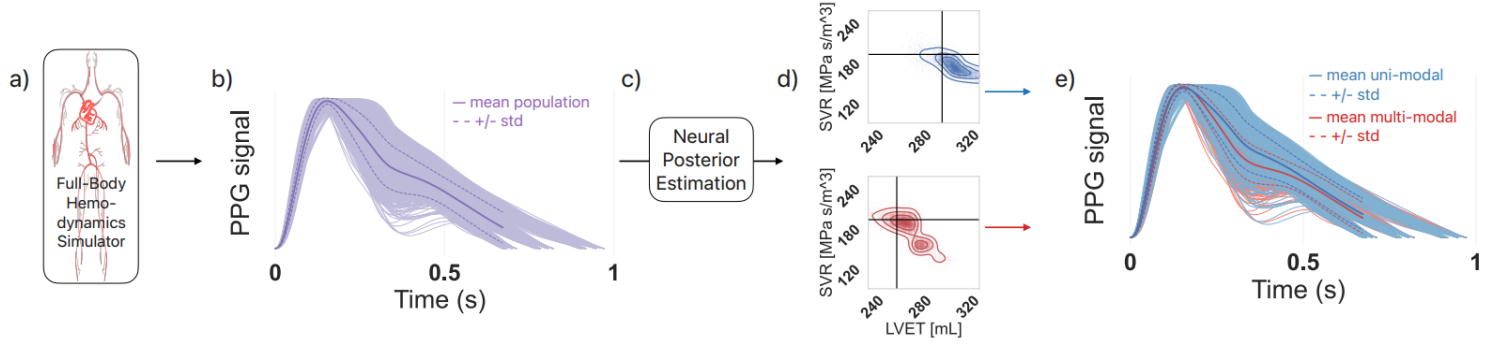
Les réseaux de neurones forment des **primitives** qui peuvent être transférées à de nombreux domaines.







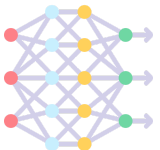


(Haut) Analyse des lames histologiques, débruitage des images IRM, détection des nævus. (Bas) Reconstruction de l'hémodynamique corporelle à partir de PPGs.

Autonomous cars (Waymo, 2022)

Powering the future of clean energy (NVIDIA, 2023)

How AI is advancing medicine (Google, 2018)



Le deep learning peut également **résoudre des problèmes que personne ne pouvait résoudre auparavant**.

AlphaFold: D'une séquence d'acides aminés à une structure 3D

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Highly accurate protein structure prediction with AlphaFold

John Jumper, Richard Evans, Alexander Pritzel, Tim Green, Michael Figurnov, Olaf Ronneberger, Kathryn Tunyasuvunakool, Russ Bates, Augustin Žídek, Anna Potapenko, Alex Bridgland, Clemens Meyer, Simon A. A. Kohl, Andrew J. Ballard, Andrew Cowie, Bernardino Romera-Paredes, Stanislav Nikolov, Rishub Jain, Jonas Adler, Trevor Back, Stig Petersen, David Reiman, Ellen Clancy, Michal Zielinski, … Demis Hassabis

+ Show authors

Nature **596**, 583–589 (2021) | Cite this article

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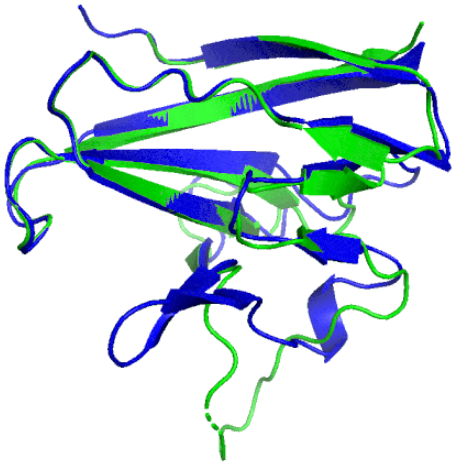


Abstract

Proteins are essential to life, and understanding their structure can facilitate a mechanistic understanding of their function. Through an enormous experimental effort[1,2,3,4], the structures of around 100,000 unique proteins have been determined[5], but this represents a small fraction of the billions of known protein sequences[6,7]. Structural coverage is bottlenecked by the months to years of painstaking effort required to determine a single protein structure. Accurate computational approaches are needed to address this gap and to enable large-scale structural bioinformatics. Predicting the three-dimensional structure that a protein will adopt based solely on its amino acid sequence—the structure prediction component of the 'protein folding problem'[8]—has been an important open research problem for more than 50 years[9]. Despite recent progress[10,11,12,13,14], existing methods fall far short of

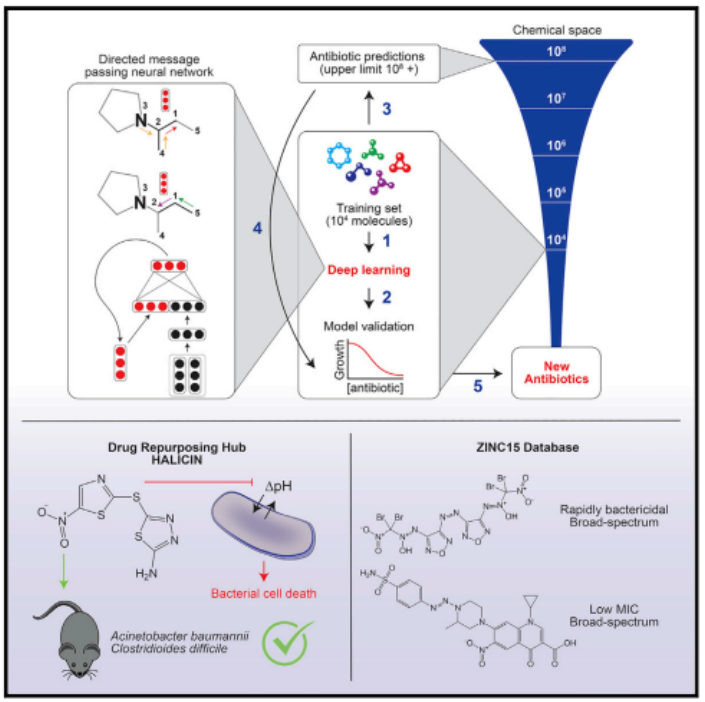
AI for Science (Deepmind, AlphaFold, 2020)

Découverte de médicaments avec des graph neural networks

Cell

A Deep Learning Approach to Antibiotic Discovery

Graphical Abstract



Authors

Jonathan M. Stokes, Kevin Yang, Kyle Swanson, ..., Tommi S. Jaakkola, Regina Barzilay, James J. Collins

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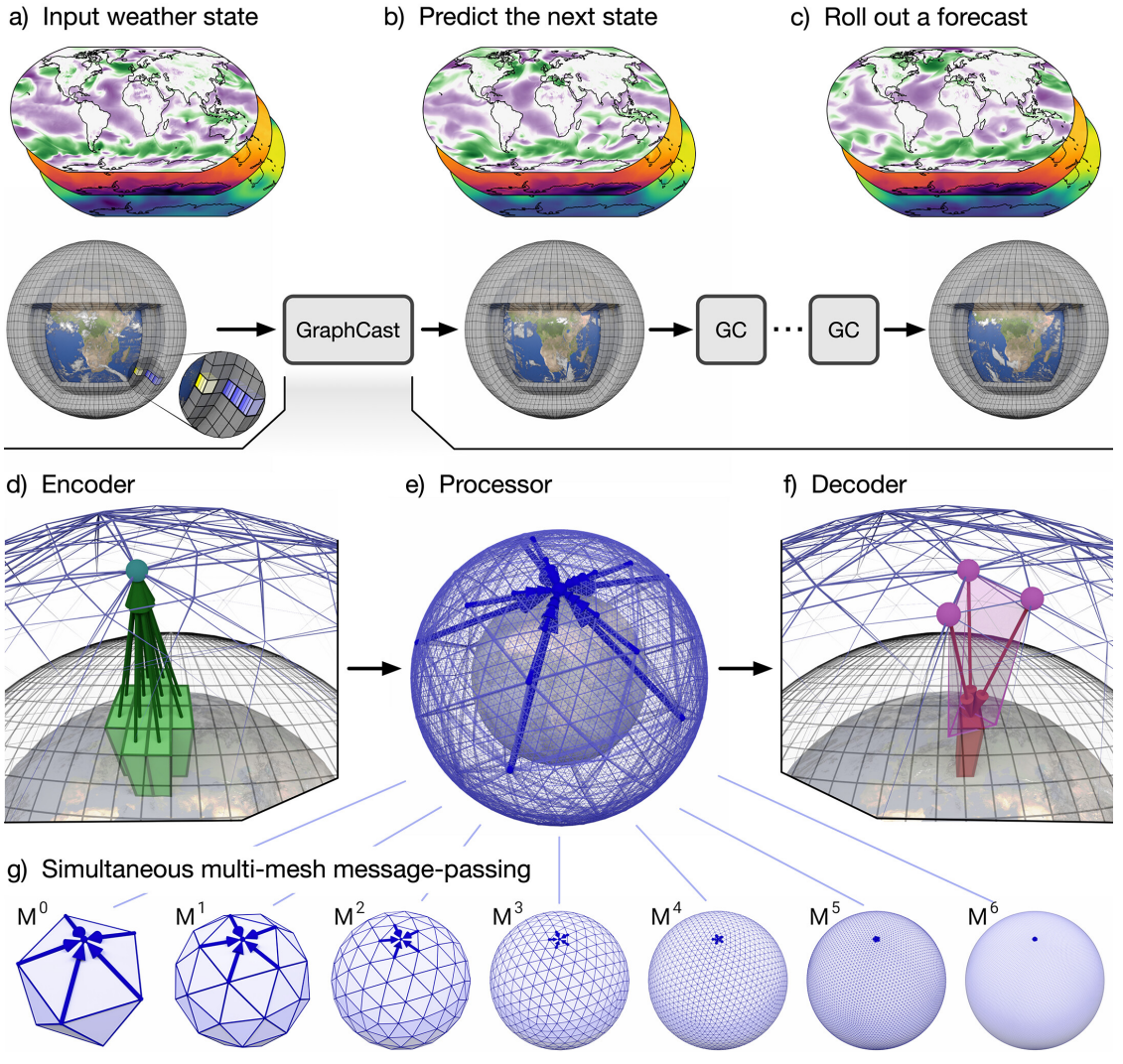
regina@csail.mit.edu (R.B.), jimjc@mit.edu (J.J.C.)

In Brief

A trained deep neural network predicts antibiotic activity in molecules that are structurally different from known antibiotics, among which Halicin exhibits efficacy against broad-spectrum bacterial infections in mice.

GraphCast: des prédictions météorologiques rapides et précises



L'IA lit, écrit, entend, parle et voit

The breakthrough

Attention Is All You Need

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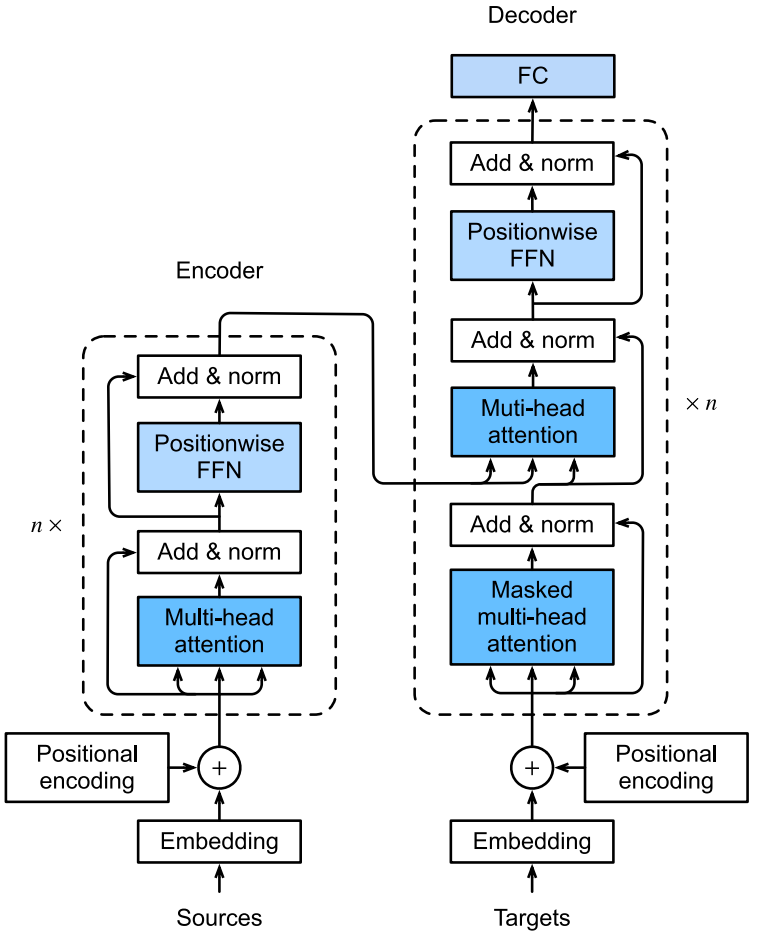
Illia Polosukhin* ‡ illia.polosukhin@gmail.com

Abstract

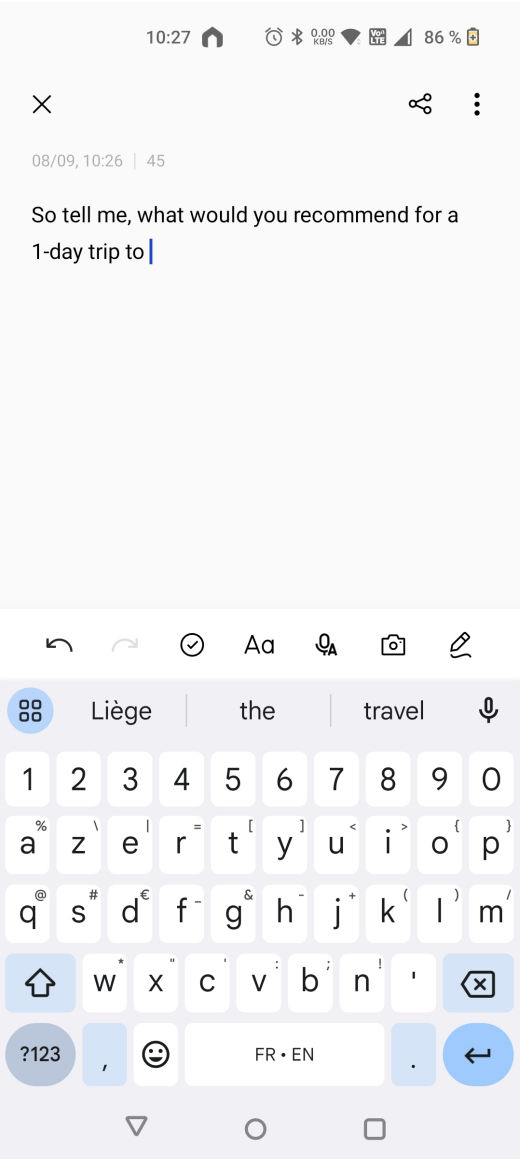
The dominant sequence transduction models are based on complex recurrent or convolutional neural networks that include an encoder and a decoder. The best performing models also connect the encoder and decoder through an attention mechanism. We propose a new simple network architecture, the Transformer, based solely on attention mechanisms, dispensing with recurrence and convolutions entirely. Experiments on two machine translation tasks show these models to be superior in quality while being more parallelizable and requiring significantly less time to train. Our model achieves 28.4 BLEU on the WMT 2014 English-to-German translation task, improving over the existing best results, including ensembles, by over 2 BLEU. On the WMT 2014 English-to-French translation task, our model establishes a new single-model state-of-the-art BLEU score of 41.8 after training for 3.5 days on eight GPUs, a small fraction of the training costs of the best models from the literature. We show that the Transformer generalizes well to other tasks by applying it successfully to English constituency parsing both with large and limited training data.

Vaswani et al., 2017.



Une idée simple:

Devinez le mot suivant



In the 1960s, Armstrong _____

In the 1960s, Armstrong performed ___

In the 1960s, Armstrong performed a moonwalk ___

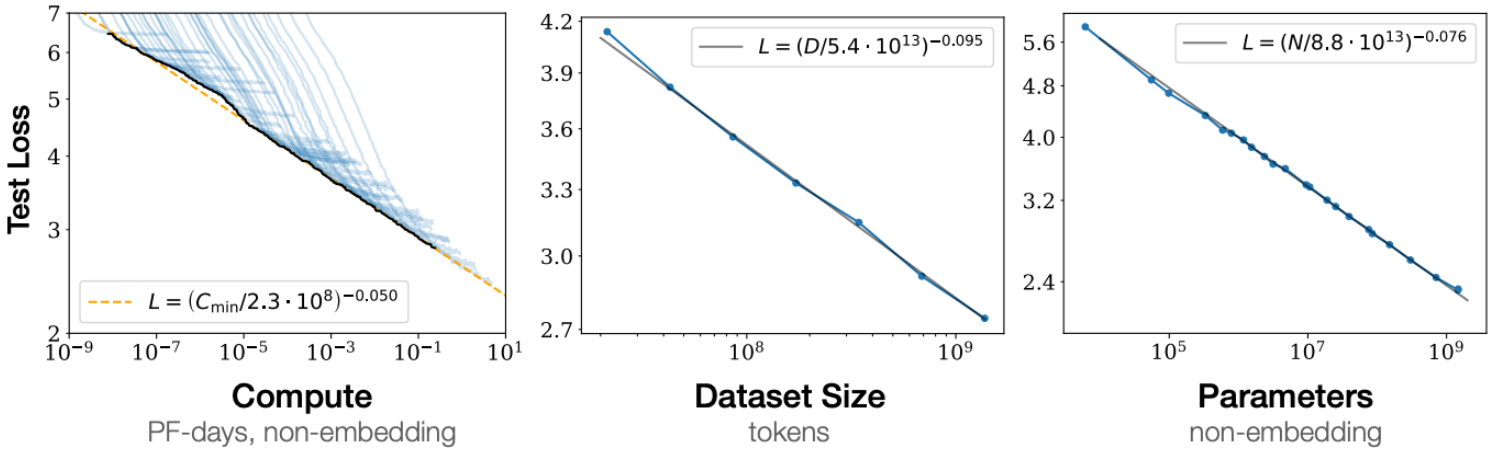
In the 1960s, Armstrong performed a moonwalk on the ___

In the 1960s, Armstrong performed a moonwalk on the lunar ___

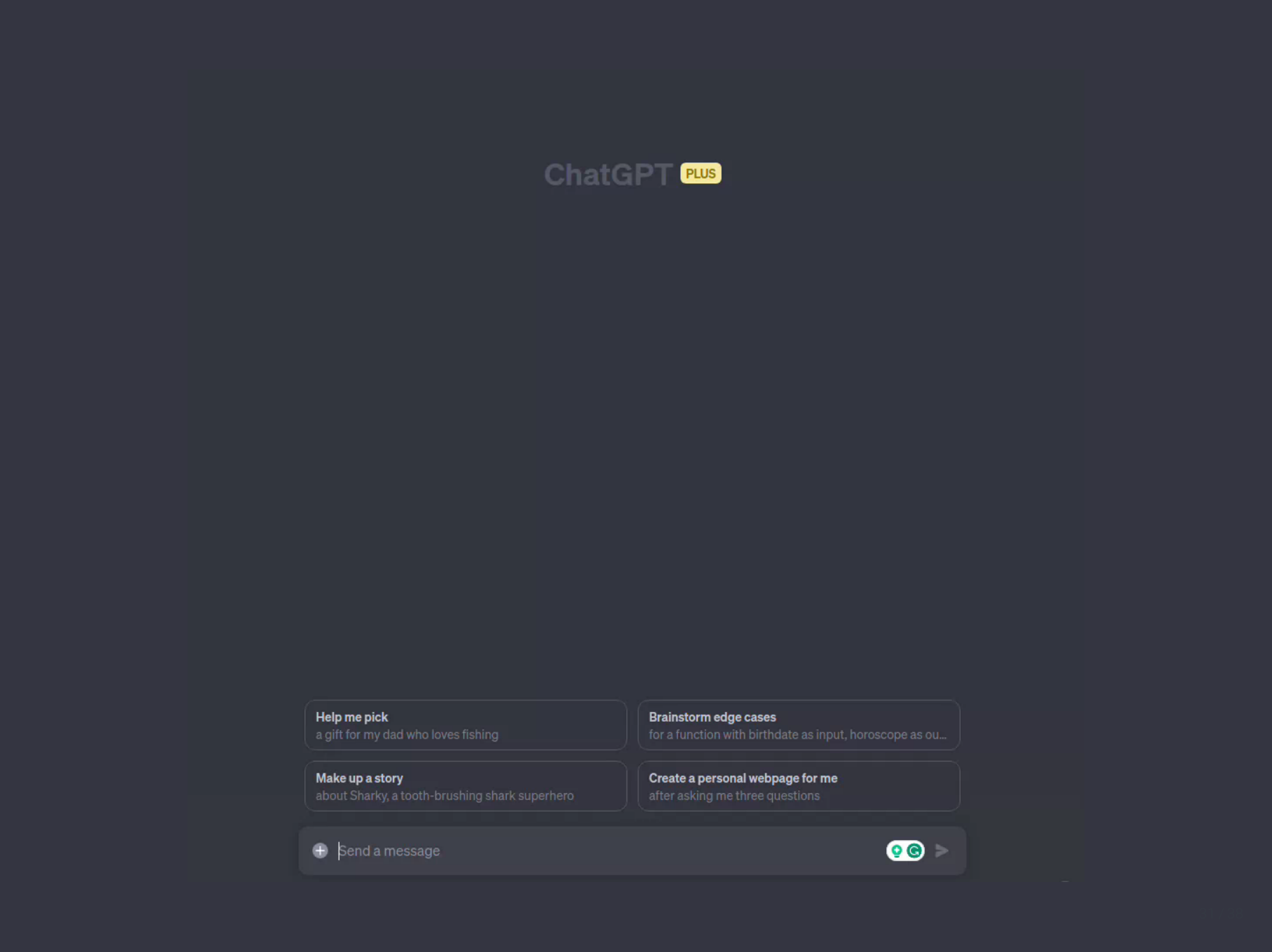
In the 1960s, Armstrong performed a moonwalk on the lunar surface and said ___

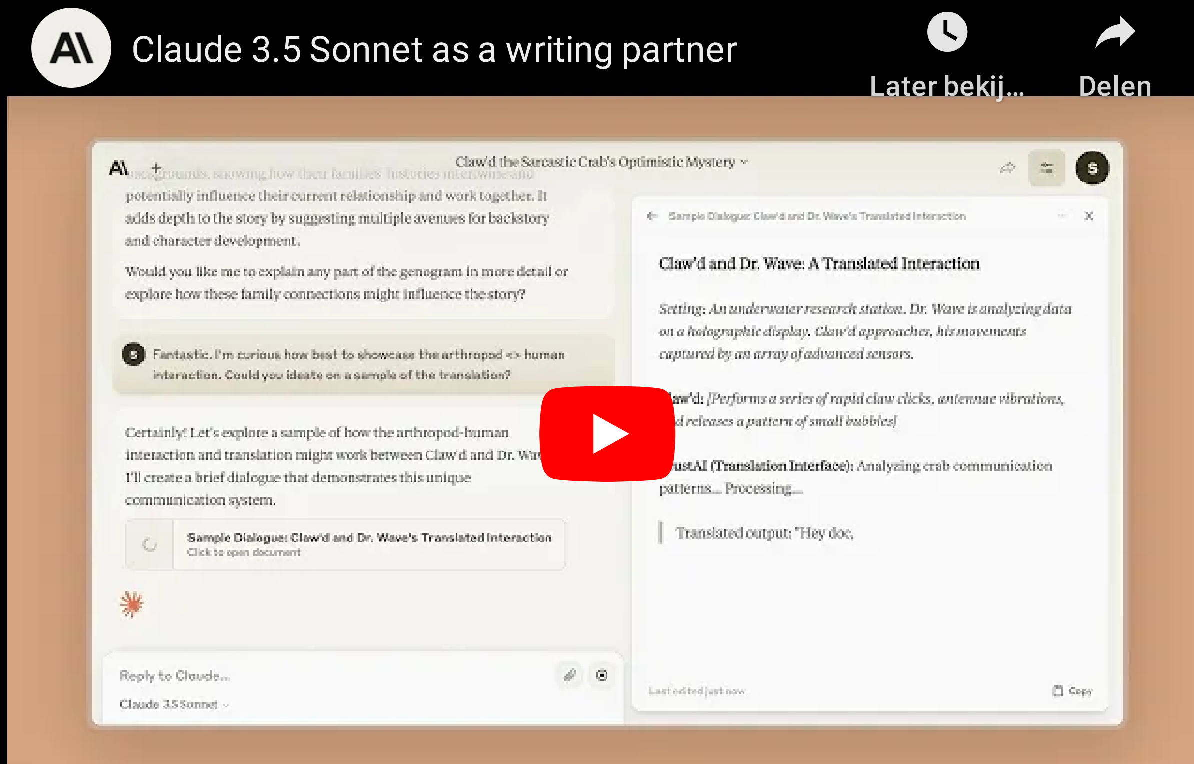
What does it mean to predict the next token well enough? It's actually [...] a deeper question than it seems. Predicting the next token well means that you understand the underlying reality that led to the creation of that token.

Ilya Sutskever, 2023.

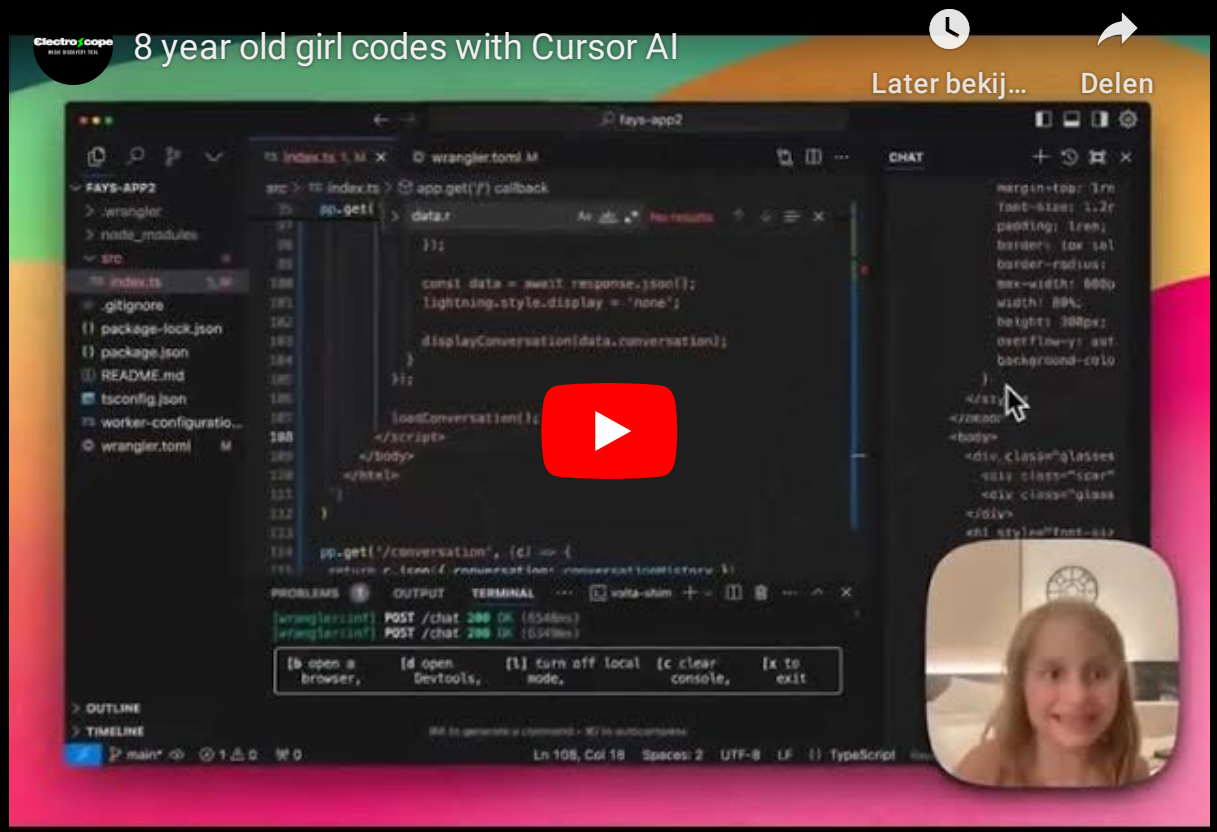


Une simplicité brutale: De plus grands modèles, entraînés sur plus de données, et plus de ressources de calcul continuent de repousser les limites de ce qui est possible, **sans signe de ralentissement**.


ChatGPT
PLUS
Help me pick
a gift for my dad who loves fishing
Brainstorm edge cases
for a function with birthdate as input, horoscope as ou...
Make up a story
about Sharky, a tooth-brushing shark superhero
Create a personal webpage for me
after asking me three questions
Send a message



Conversational AI assistants (Anthropic, 2024)



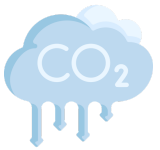
Code assistants (Cursor, 2024)

Not just text, but also images and sounds (OpenAI, 2024)

Et maintenant?

The good

- L'IA est devenue un outil capable de résoudre des problèmes complexes et de faire des découvertes.
- L'interface homme-machine est en train de changer radicalement, avec des assistants conversationnels facilitant l'utilisation du numérique.
- Les progrès continuent à un rythme effréné.



The bad

- Les modèles de deep learning sont souvent difficiles à interpréter et à expliquer.
- L'IA se trompe, et peut se tromper de manière catastrophique malgré les apparences de précision.
- Les modèles de deep learning sont devenus très gros et nécessitent des ressources de calcul importantes, avec des conséquences environnementales significatives.

The ugly

- Les modèles de deep learning sont biaisés et peuvent perpétuer des discriminations.
- Les utilisations malveillantes de l'IA sont de plus en plus fréquentes (deep fakes, bots, manipulation, etc).
- Dans tous les domaines de la société, une dépendance à l'IA s'installe, avec des risques de déshumanisation et de perte de contrôle.

The end.