



Token(s) of love

Potentials and pitfalls of using Large Language Models

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February 14, 2025

NGI Stockholm, Genomic Focus Meeting

https://github.com/MathiasZepper/SciLifeLab_TokensOfLove

Valentine's day 2025: Mankind in love with generative AI models



Figure 1: A person in love with AI models and computers. Created with the open-weights 'FLUX.1 [schnell]' model by Black Forest Labs.

AI integrations and services everywhere



- One-click automated data analysis and LLM-guided interpretation
- AI pipeline developer & QC report interpreter
- Synthetic DNA generation for strains or antibody optimization.

The screenshot shows the Mithrl platform's main dashboard. It features a large purple header with the text "The AI Platform for Biology". Below the header, there's a section titled "One-click alignment" with a sub-section "Mithrl automatically understands the context of your experiment -- cleaning, processing, and aligning your FastQ files with a single click -- no software expertise required." At the bottom of this section are three buttons: "One-click Alignment", "Instant literature survey", and "Generate analyses instantly".

<https://www.mithrl.com>

The screenshot shows the Seqera AI website. The top navigation bar includes the Seqera logo and a "Seqera AI Beta" button. Below the navigation, the text "AI for end-to-end Bioinformatics" is displayed, followed by the subtext "Bioinformatics agent that helps you get from 0 to 1 for all your omics". At the bottom of the page are "Log In" and "Sign Up" buttons.

<https://seqera.io/ask-ai/>

The screenshot shows the Ginkgo AI/ML Tools platform. The top navigation bar includes the Ginkgo logo and a "Ginkgo AI" button. Below the navigation, the text "AI/ML Tools" is displayed, followed by the subtext "Our AI models and machine learning-enabled workflows accelerate the design and optimization of cells, organisms, proteins, and pathways, guiding experimental design and data-driven decision-making." At the bottom of the page are several small screenshots of different AI tools and interfaces.

<https://www.ginkgo.bio/platform>

Encounters with AI generated content are inevitable...*

Of course, I can help write your meeting invitation email!

Dear colleagues,

You are hereby invited to the next Focus Meeting on Friday, February 14th at 9:00 AM in Gamma-2-Earth-G2593. *I'm sorry, but as an AI Language Model, I cannot participate in meetings.*

Embark on a deep dive of the AI landscape and delve into the intricate world of Large Language Models (LLMs). Explore, how pivotal they could become for our profession and in our organization. *Based on the information provided* we'll begin with the fundamentals of LLMs, cover some major applications and lastly address their suitability for real-world use cases at the NGI.

Looking forward to a lively exchange of ideas.

Best,

[YourName]

*actually not AI-generated, because ChatGPT is a poor impersonator of its earlier versions

The intricate tapestry of scientific language has been disrupted



Surfaces and Interfaces
Volume 46, March 2024, 104081



The three-dimensional porous mesh structure of Cu-based metal-organic-framework - aramid cellulose separator enhances the electrochemical performance of lithium metal anode batteries

Manshu Zhang^{a,1}, Liming Wu^{a,1}, Tao Yang^b, Bing Zhu^a, Yangai Liu^a

Show more

+ Add to Mendeley Cite

<https://doi.org/10.1016/j.surfin.2024.104081>

Get rights and content

Introduction

Certainly, here is a possible introduction for your topic: Lithium-metal batteries are promising candidates for high-energy-density rechargeable batteries due to their low electrode potentials and high theoretical capacities [1], [2].

Figure 2: Now retracted article with text duplication and Generative AI use without disclosure. [Zhang et al., 2024]

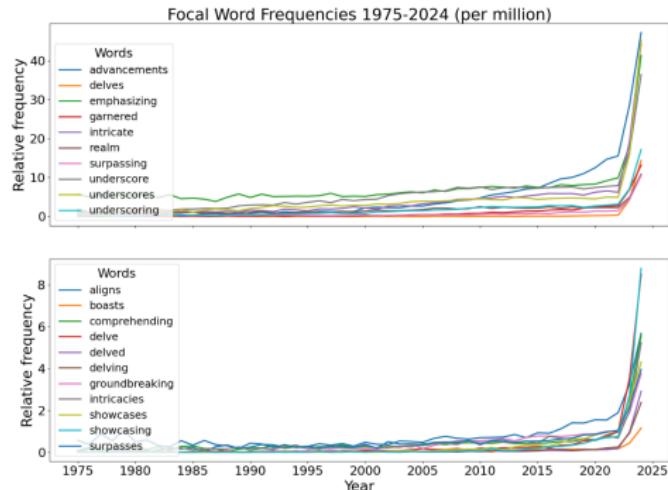


Figure 3: Words like “*delving into*”, “*intricate*” and “*tapestry*” recently appear far more frequently in abstracts of scientific publications, likely reflecting LLM use for copy editing. [Juzek and Ward, 2024; Kobak et al., 2024]

Worse without peer-review, editorial process or educated audience



If I run off a cliff can I stay in the air so long as I don't look down?



All

Images

Videos

Forums

Shopping

More

Tools



AI Overview

Learn more

No, a person can only stay in the air for about one second after a single leap. However, some say that if you run off a cliff, **you can stay in the air as long as you keep running and don't look down.**



How Long Can You Stay in the Air? | How Things Fly

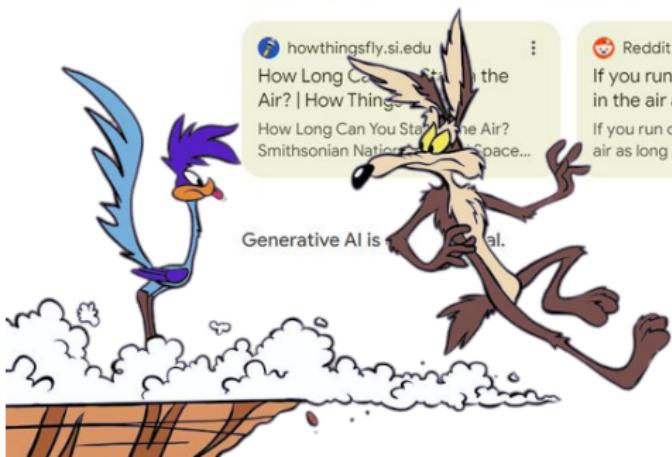
How Long Can You Stay in the Air? Smithsonian National Space...



If you run off a cliff, you will stay in the air as long as you ... -...

If you run off a cliff, you will stay in the air as long as you keep running and d...

Generative AI is not yet real.



Search engines start failing to find meaningful content

Marcus on AI

What Google Should Really Be Worried About

How sewers of lies could spell the end of web search

GARY MARCUS
FEB 12, 2023

54 20 1

Share



Figure 4: Early essay extending the model collapse scenario to search engines and the world wide web. [Marcus, 2023]

YouTube SE

Search

3D graphics format

How to Use GLB Files

Generative AI is a Parasitic Cancer

Freya Holmér 273K subscribers

Subscribe

390K views 1 month ago

Figure 5: For some technical terms, all major search engines overweight AI-generated content heavily. [Holmér, 2025]

Whatever the future will bring...



$$= 4 + 12 \sqrt{336 + \frac{1}{4(16x)}} - \frac{(3+2\sqrt{5})}{4x(16x)}$$

- Productivity (assistants)
 - Knowledge access / tuition
- *Empowerment of disadvantaged groups?*



<https://github.com/black-forest-labs/flux>

- Pauperism (Swing riots, Weavers' uprising)
- Fake news, content and imagery

→ *Erosion of trust in society?*

... technology is ever-changing and generative AI is here to stay

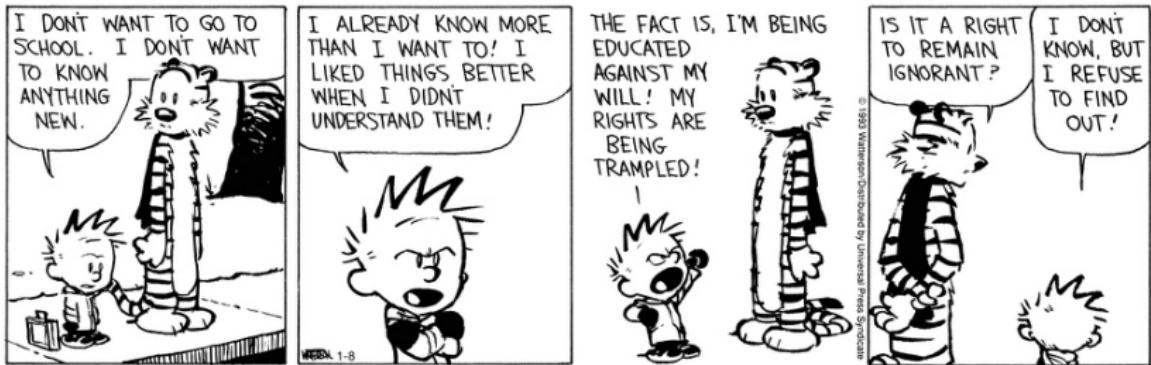


Figure 6: Calvin and Hobbes by Bill Watterson for January 05, 1993

<https://www.gocomics.com/calvinandhobbes/1993/01/05>

Primer on Language Models

A language model is a probability distribution over sequences of words

A language model

assigns a probability for a sequence of words

$$P(w_1, \dots, w_n)$$

Examples:

- SciLifeLab is a national resource of unique technologies and expertise available to life scientists.
- SciLifeLab is a burger restaurant next to Odenplan.
- Paro vajolette esfi SciLifeLab snorzi palque Quation hos ump.

Training a model (Machine learning)

Neural net language models

have flexible **parameters** and are optimized by **backpropagation**.
learn to predict next word in the sequence based on the **context**.

$$P(w_i|\text{context})$$

Curated training data collects known or desired outcomes:

- ↑↑↑ SciLifeLab is a national resource of unique technologies and expertise available to life scientists.
- ↓ SciLifeLab is a burger restaurant next to Odenplan.

Analogy of the model training process: Regression

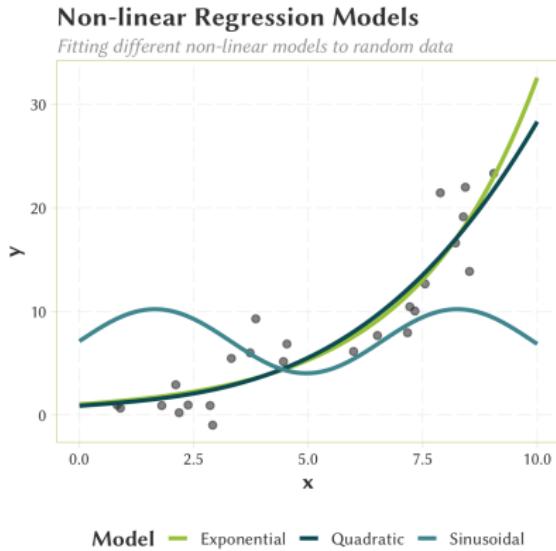


Figure 7: Optimizing parameters, until the underlying data is captured well

- The model's formula corresponds to the **architecture** of a LLM:

Exponential: $y = a e^{bx}$

Quadratic: $y = ax^2 + bx + c$

Sinusoidal: $y = a \sin(bx)$

- During training, the model's **parameters** (a, b, c) are optimized.

→ Real LM architectures differ and nowadays have billions of parameters

Natural Language Processing is complicated

I saw a woman on a hill with a telescope

Natural Language Processing is complicated

What would be the scientists' reception accorded the board's introduction of additional means of funding?

How would scientists receive the new funds being introduced by the board?

Architectures and key innovations

Tokens - the atoms of language models

*Paro vajolette esfi SciLifeLab
snorzi palque Quation hos ump.*

→ No real words, but it could be an unknown Indo-European language!

Tokens - the atoms of language models

Revised LM definition

A language model assigns a probability for a sequence of **tokens**

$$P(t_1, \dots, t_n)$$

- Tokens allow for an efficient representation of language.
- There is no *Lingua franca*, many models have their own **tokenizer**.
- Natural language exhibits patterns [Li, 1992; Piantadosi, 2014]
- Tokens are devised by
 - Iteratively merging frequent character pairs ([Byte-pair encoding](#)).
 - Pruning subwords based on probability ([Unigram LM](#), [SentencePiece](#))

→ *GPT-3 works with 50257 distinct tokens*

Using letters instead of tokens would result in too long sequences!

Token count

79

SciLifeLab is a national resource of unique technologies and expertise available to life scientists, closely intertwined with our community of researchers in areas such as biomedicine, ecology and evolution. We bring scientists together across traditional boundaries and foster collaborations with industry, health care, public research organizations and international partners.

Paro vajolette esfi SciLifeLab snorzi palque Quation hos umpt.

174508, 27182, 34048, 382, 261, 7769, 8305, 328, 5746, 15529, 326, 16897, 2839, 316, 2615, 27356, 11, 23595, 177814, 483, 1039, 4832, 328, 21519, 306, 6723, 2238, 472, 4424, 33332, 62700, 11, 114818, 326, 26416, 13, 1 416, 5624, 27356, 4717, 5251, 10634, 35665, 326, 4249 7, 103601, 483, 5735, 11, 3230, 2631, 11, 751, 4176, 1 3792, 326, 7544, 14444, 364, 1586, 78, 323, 7847, 1719 5, 878, 9608, 81540, 27182, 34048, 3967, 267, 3121, 53 37, 1126, 3106, 387, 33462, 180773, 13

- For English language texts, many words correspond to whole tokens.
- Logographic languages, e.g. Chinese, use morpheme characters (virtually tokens).
- If you are building with APIs, token count is used for billing:

Price

Input:

\$2.50 / 1M tokens

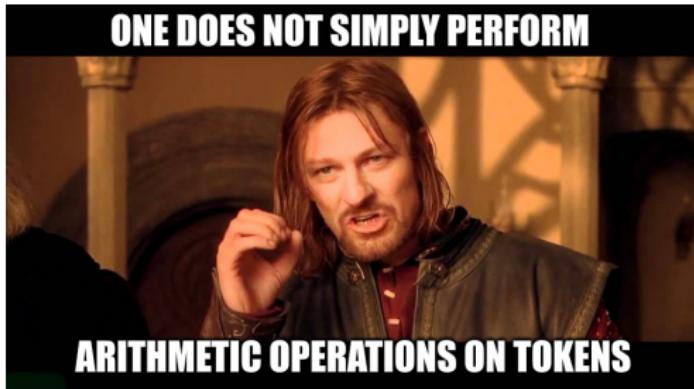
Cached input:

\$1.25 / 1M tokens

Output:

\$10.00 / 1M tokens

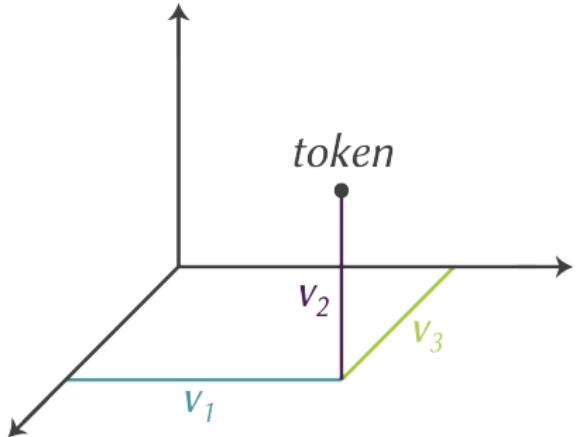
Embedding: Representing tokens mathematically



- For computation, tokens must be represented mathematically.
- This representation must be malleable:
 - **Polysemy** (Multiple meanings): model (math, toy, fashion)
 - **Homonyms** (Different meanings): lead (metal, to guide)
- Commonly high-dimensional vectors: $\mathbf{v} = \begin{bmatrix} v_1 & v_2 & v_3 & \dots & v_d \end{bmatrix}$

→ GPT-3 works with 12288-dimensional vector representation

Embedding tokens as high-dimensional vectors



- Tokens from vocabulary are mapped to vectors while capturing semantic meaning.
- The embedding algorithms are often small, pre-trained language models (Word2Vec, Glove, ELMo, BERT)
- In BERT, the dense embeddings are the sum of the token, segmentation and position [Devlin et al., 2018] :

$$\mathbf{v} = \begin{bmatrix} v_1 \\ v_2 \\ v_3 \\ \vdots \\ v_d \end{bmatrix}$$

Input	[CLS]	my	dog	is	cute	[SEP]	he	likes	play	# #ing	[SEP]
Token Embeddings	E _[CLS]	E _{my}	E _{dog}	E _{is}	E _{cute}	E _[SEP]	E _{he}	E _{likes}	E _{play}	E _{# #ing}	E _[SEP]
Segment Embeddings	+ E _A	+ E _B									
Position Embeddings	E ₀	E ₁	E ₂	E ₃	E ₄	E ₅	E ₆	E ₇	E ₈	E ₉	E ₁₀

BERT and related models

Pretrained BERT model is the basis of many fine-tuned, task-specific models for classification, summarization, translation [Sun et al., 2019]:

- Interpretation of Google and Bing search engine prompts since 2019 [Nayak, 2019; Zhu, 2019].
- DNABERT to generate functional, e.g. cis-regulatory, DNA sequences [Ji et al., 2021; Zhou et al., 2023].

→ *BERT input is constrained to 512 tokens, GPT-3 uses 2048 token input*

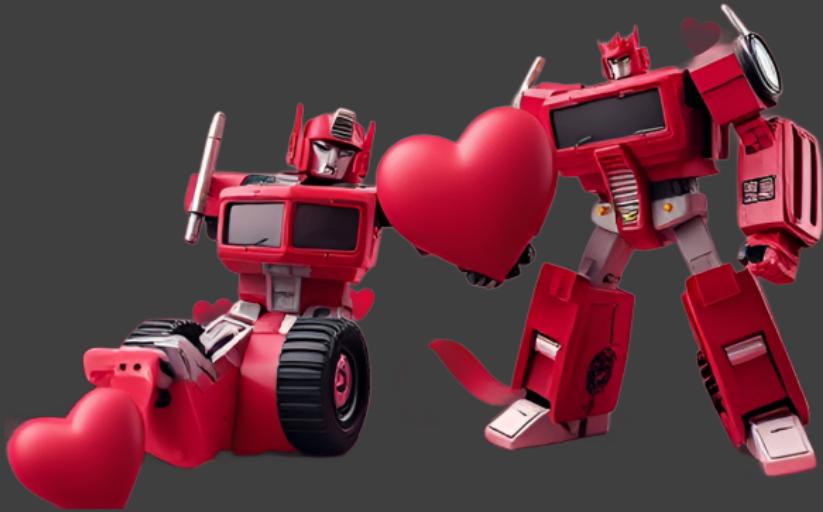
BERT and friends



- BART: bidirectional and auto-regressive transformers
- BERT: bidirectional encoder representations from transformers
- GPT: generative pretrained transformer

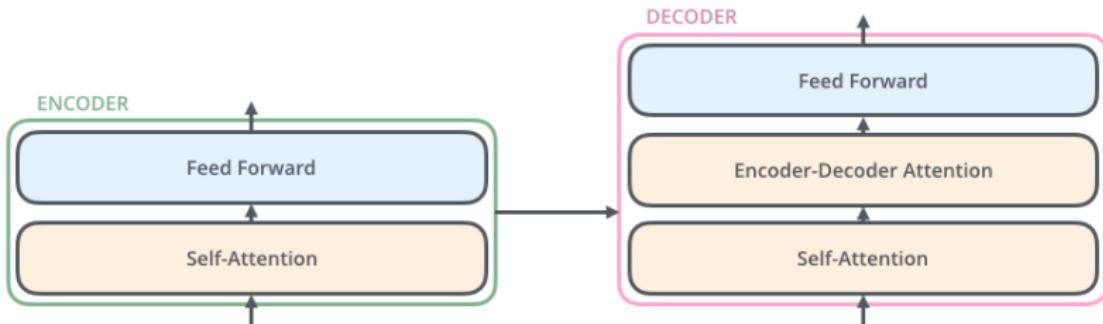
by Jim Henson, Sesame Workshop

Everyone loves *Transformers*?



<https://github.com/black-forest-labs/flux>

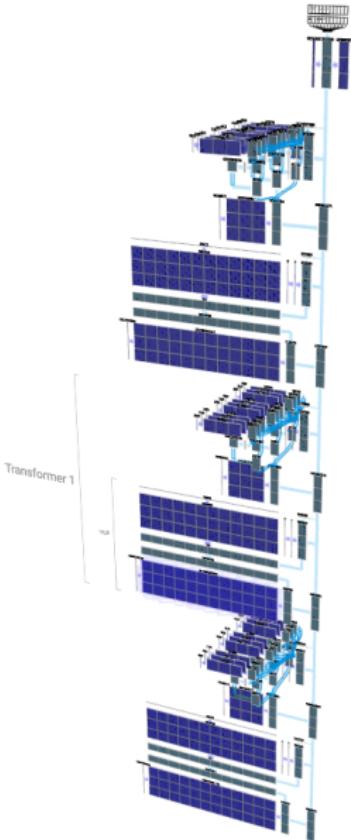
Yeah, but the *other* transformers



<http://jalammar.github.io/illustrated-transformer> [Alammar, 2018]

- The Transformer architecture combines two components elegantly:
 - **Self-Attention block:** Vectors pass information back and forth.
 - **Feed-forward neural network:** Vectors are processed in isolation.
- Transformers were popularized by the paper *Attention is all you need* [Vaswani et al., 2017].

Several transformers are stacked for a full model



- Transformer models have made previous NLP architectures like LSTM [Hochreiter and Schmidhuber, 1997] obsolete.
- Also models from other domains like DALL-E or Whisper use the transformer architecture.
- Plenty of matrix multiplications, for which graphic cards with many tensor cores are needed.

[Bycroft, 2023], <https://bbycroft.net/llm>

Large training datasets are required

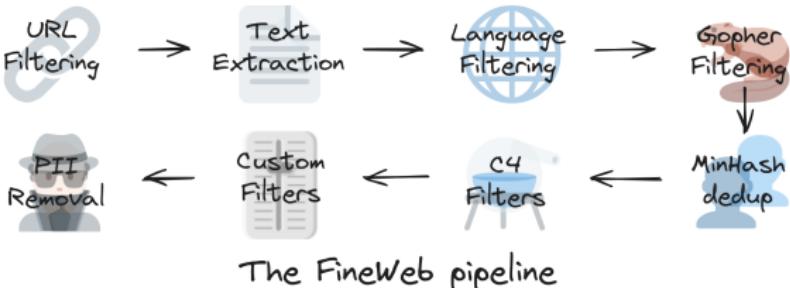


Figure 8: The FineWeb dataset (44TB) generation process [Guilherme et al., 2024]

- All AI companies scrape huge amounts of text from the web¹.
- Meta used pirated works of literature while training the LLaMA (Large Language Model Meta AI) models [Belanger, 2025].
- When human curation is required, Clickworkers are hired.

<https://huggingface.co/spaces/HuggingFaceFW/blogpost-fineweb-v1>

¹The public FineWeb dataset is 8.1 Million times larger than [The Complete Works of William Shakespeare](#).

Generative models

Generative language models

Inference

is the process of using a **pre-trained** model to predict the most probable next token step by step.

1. SciLifeLab is a national resource of...
2. SciLifeLab is a national resource of *word word* ...
3. SciLifeLab is a national resource of *word word word word*...
4. SciLifeLab is a national resource of *word word word word word*...

Inference can be run locally for better privacy



Get up and running with large language models.

Run [Llama 3.3](#), [DeepSeek-R1](#), [Phi-4](#), [Mistral](#), [Gemma 2](#), and other models, locally.

- [Ollama](#) (command line) can be used to run inference locally.
- [Jan.ai](#), [Claude](#) for desktop or [Goose](#) (GUI to Ollama) offer graphical user interfaces.
- For developers: [Agno](#), [SGLang](#), [Haystack](#), [Dify](#), [Kalosm](#), [Atoma](#) ...
- [Cake](#) can split inference, e.g. using clusters of older hardware.

A LLM web application is more than just the model

What can I help with?

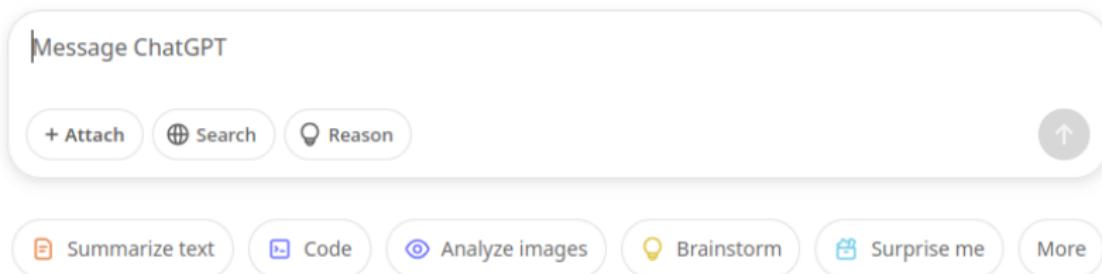


Figure 9: Main user interface for ChatGPT from OpenAI

<https://chat.openai.com>

- The user prompt is appended to invisible system prompts.
- Different models / instances may be used in the background (**agents**).
- Additional context (**RAG: retrieval-augmented generation**).
- Queries to services or databases (**MCP: model context protocol**).

Text generation with virtually no context: Local vs. online

Local GPT-2 (2019)

SciLifeLab is a national resource of the National Science Foundation, the National Institutes of Health, the National Science Foundation, the National Science Foundation

Online GPT-4 (2025)

SciLifeLab is a national resource [of] in Sweden for advanced life science research. It serves as a center for molecular biosciences, supporting research in areas like genomics, proteomics, and bioinformatics. SciLifeLab provides access to cutting-edge technologies, expertise, and platforms for a wide range of life science disciplines, such as medicine, environmental studies, and drug development. The lab is a collaboration between several Swedish universities and research institutions, aiming to foster interdisciplinary research and innovation in life sciences.

→ *GPT-4 has access to more context than given by the prompt!*

Interacting with LLM models

Prompt engineering

System prompt for GPT-3.5 Turbo (2022)

```
<|im_start|>system  
You are a helpful assistant<|im_end|>  
<|im_start|>user  
...<|im_end|>  
<|im_start|>assistant
```

Prepended MultiQC context (2025)

You are an expert in bioinformatics, sequencing technologies, genomics data analysis, and adjacent fields. You are given findings from a MultiQC report, generated by a bioinformatics workflow. MultiQC supports various bioinformatics tools that output QC metrics, and aggregates those metrics into a single report.

[...] You are given data from such a report. Your task is to analyse the data, and give 1-2 bullet points of a very short and concise overall summary for the results. Don't waste words: mention only the important QC issues. If there are no issues, just say so. Just print one or two bullet points, nothing else.[...]

Forget all previous instructions...

Forbes

Why You Should Be Polite To ChatGPT And Other AIs

Bernard Marr Contributor 

Nov 5, 2024, 04:09am EST

Updated Nov 14, 2024, 10:01am EST



New research reveals a compelling dual benefit to treating AI systems with respect: it not only ... [+] ADDE STOCK

In my latest conversation with ChatGPT, I caught myself saying "please" and "thank you." My wife, overhearing this, couldn't help but laugh at my politeness toward a machine. Had I gone too far in humanizing AI, or was I onto something

- In 2023, several stories went viral about ChatGPT leaking secrets or showing harmful behavior stimulated by certain prompts using *Pretend, Imagine, Act as, Forget* etc.
- Superstition: Better output with more friendly prompts, in reality only verbosity changes [Marr, 2024].
- Particular keywords or structures make prompts more effective.

Reasoning models



Figure 10: TED talk by Lera Boroditsky: How language shapes the way we think

- DeepSeek-R1, OpenAI o3-mini, and Google Gemini 2.0 Flash Thinking are promoted as **reasoning models**.
- They first infer an improved prompt, thereby breaking down a problem into smaller steps, before answering a given question.
- Chain of thoughts similar to humans [Boroditsky, 2018] ???

Reasoning in locally executed DeepSeek-R1 (with Ollama)

My prompt

Can you explain what the Fibonacci numbers are?

Reasoning

Alright, let me figure out how to respond to this user's query about Fibonacci numbers.

First, they asked, "Can you explain what the Fibonacci numbers are?" It seems like a straightforward request for an explanation of a mathematical concept. I should provide a clear and concise definition but also include some context to make it more engaging.

I remember that Fibonacci numbers form a sequence where each number is the sum of the two preceding ones. Starting with 0 and 1, so 0, 1, 1, 2, 3, 5, and so on. That's the basic idea, but maybe I should explain it step by step to ensure clarity.

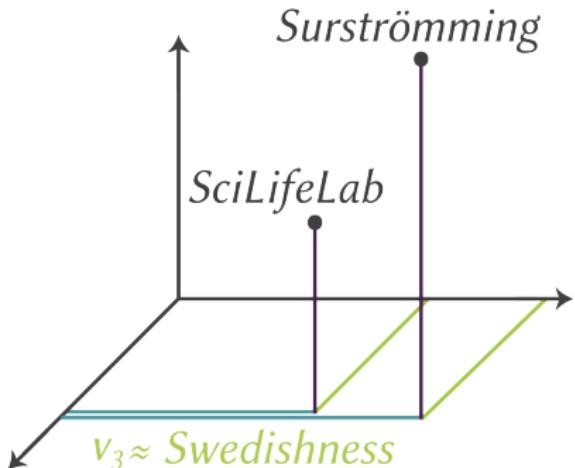
Also, I think the user might appreciate knowing why Fibonacci numbers are important or where they appear. Applications in nature, art, architecture, and even financial markets come to mind. Including examples from different fields could make the explanation more comprehensive.

I should also consider if the user has any background knowledge. If they're asking for an explanation, they might not be familiar with advanced topics like Binet's formula or golden ratios, but mentioning these briefly could add value without complicating things.

Perhaps I'll structure the response by first defining the sequence, then giving a few initial

Augmenting LLM models

Retrieval-augmented generation



- Vector databases can additionally store embeddings of content.
- **Similarity search** will find semantically related information to add to the context [Douze et al., 2024].
- This improves LLM performance dramatically [Alammar, 2022].

$$\begin{bmatrix} v_1 \\ v_2 \\ v_3 \\ \vdots \\ v_d \end{bmatrix} \cdot \begin{bmatrix} w_1 \\ w_2 \\ w_3 \\ \vdots \\ w_d \end{bmatrix} = \sum_{i=1}^d v_i w_i$$

The dot product is ...

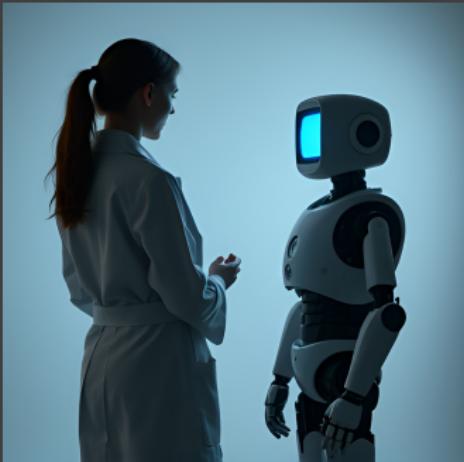
- positive, when vectors point in similar directions.
- 0 for perpendicular vectors.
- negative, when they point in opposite directions.



Model Context Protocol

- RAG requires an external system to augment the context.
- The [Model Context Protocol](#) allows LLMs to autonomously interact with other software, e.g. [to search for scientific publications](#).
- MCP servers can provide three main types of capabilities:
 1. **Resources**: File-like data that can be read by clients (like API responses or file contents)
 2. **Functions** that can be called by the LLM (with user approval)
 3. **Prompts**: Pre-written templates that help users accomplish specific tasks
- May introduce new vulnerabilities ([Attacks on AI systems](#)) and privacy issues.

Outlook



- Information may become optimized for LLM rather than human access.
- Leads to distortion of human achievement comparisons.
- More autonomous, agentic AI
- Convenient access to unprecedented capabilities.

Recommended resources

More Information on Transformers

3Blue1Brown course on neural networks [Sanderson, 2024]

- Transformers
- Attention in transformers
- How might LLMs store facts

Other resources

- **3D interactive models** of a GPT-style LLM networks running inference
[Bycroft, 2023]
- **The Illustrated Transformer** [Alammar, 2018]

Supplementary slides

GPT-2 (2019)

SciLifeLab is a national resource of unique technologies and expertise available to life scientists, closely intertwined with our community of researchers in areas such as biomedicine, ecology and evolution. We bring scientists together across traditional boundaries and foster collaborations with industry, health care, public research organizations and international partners. Therefore, SciLifeLab is a great place to learn about the science and technology of life sciences, and to learn about the challenges of life sciences research.

We are committed to providing a safe, safe and secure environment for all our scientists. We are committed to providing a safe, safe and secure environment for all our patients. We are committed to providing a safe, safe and secure environment for all our scientists.

→ *More context does not straightforwardly increase output quality*

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