How LLMs Work?

High level look at internal workings for the general audience

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The Fundamental Surprise

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- Emergent capabilities

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- Built from >1 trillion word patterns

The best thing about AI is its ability to

learn	4.5%
predict	3.5%
make	3.2%
understand	3.1%
do	2.9%

What Makes Text "Reasonable"?

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- Not rule-based - pure probability

Example: Predicting the Next Word

- Input: "The best thing about AI is its ability to..."

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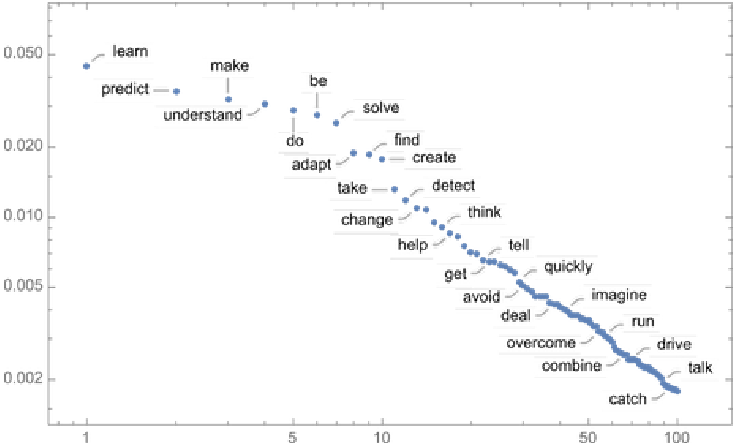
Probability Distribution in Action



- High-probability choices: "learn", "adapt"

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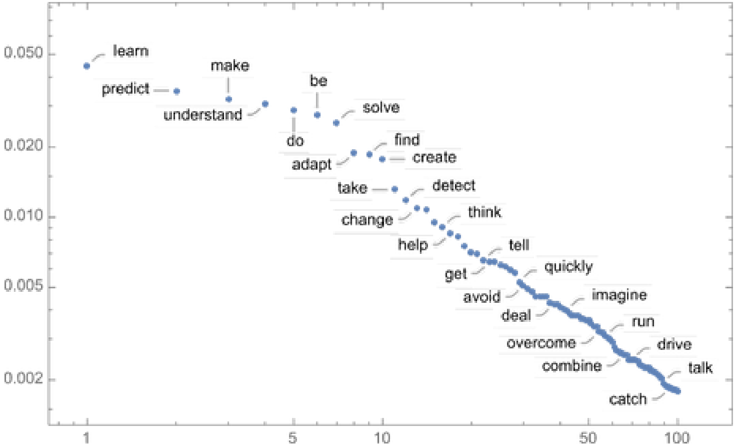

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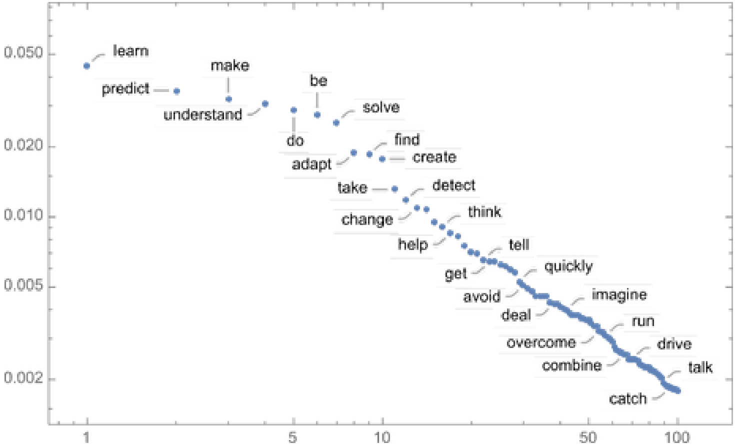

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- Long-tail distribution pattern

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- Fundamental operation: ”What’s the next word given previous text?”
- Trained on >1 trillion words from web pages/books

Controlled Randomness

- Pure max-probability leads to flat text:

  The best thing about AI is its ability to see through, and make sense of, the world around us, rather than panicking and ignoring. This is known as AI "doing its job" or AI "run-of-the-mill." Indeed,

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- Beam Search

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- Chatbot Arena Explanation

Token Generation Process

- Text is chunked into tokens (words/subwords)
- Model estimates probability distribution over possible next tokens
- Selection involves randomness (temperature parameter)

Example of tokens: Deepseek

antidisestablishmentarianism

noun

The doctrine or political position that opposes the withdrawal of state recognition of an established church; -- used especially concerning the Anglican Church in England. Opposed to disestablishmentarianism.

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Deepseek

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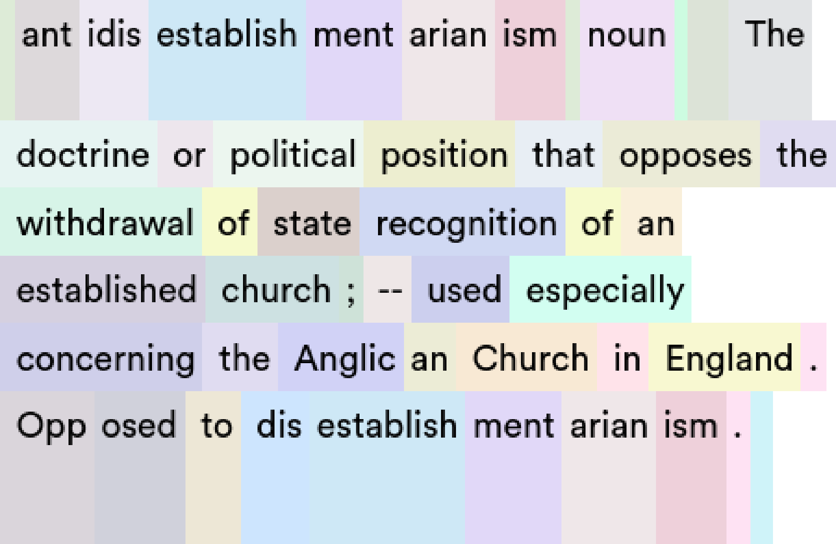
Example of tokens: ChatGPT

GPT-4(o, o-mini, o1-preview, o1-mini)



2nd Example of tokens

Kiyarash Fazeli

Apple

Sony

Joseph

Yousef

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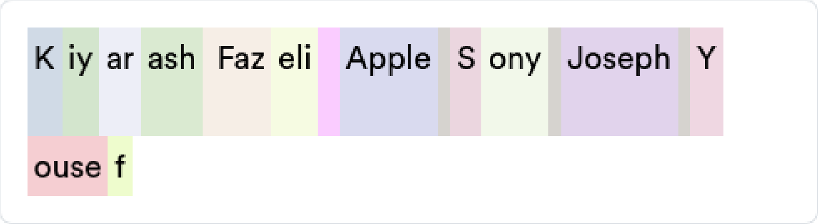


Deepseek

GPT

Probability in Action

At Each Step:

- Calculates probabilities for all possible next tokens
- Doesn't just pick highest probability
- Maintains creativity through probabilistic sampling

The Iterative Nature

- Each step feeds output back as input
- Context window grows with each iteration
- Surprisingly maintains coherence over long sequences

Why Does This Work?

- Emergent complexity from simple rules
- Massive neural network
- Captures linguistic patterns at multiple scales

Key Limitations

Important Caveats

- No true "understanding" of content
- Can't perform logical deductions
- Errors compound through iterations

Summary

- Statistical next-word prediction at scale
- Emergent complexity from simple iteration
- Combination of pattern recognition + controlled randomness

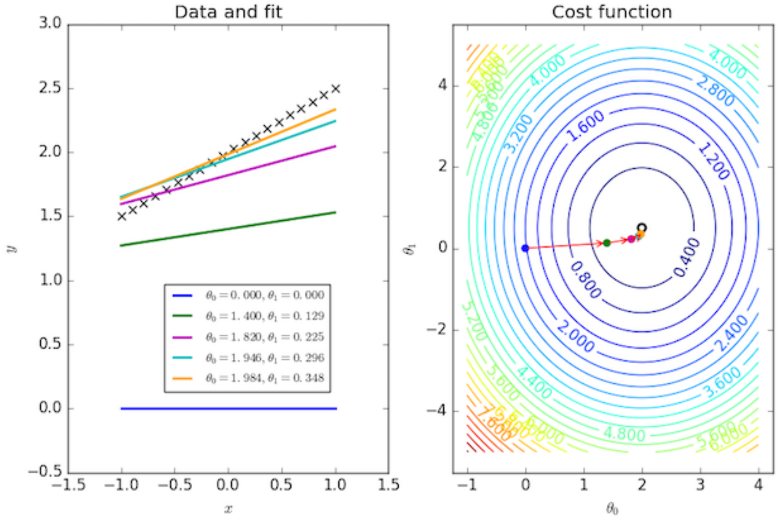
Goldberg IPython Notebook

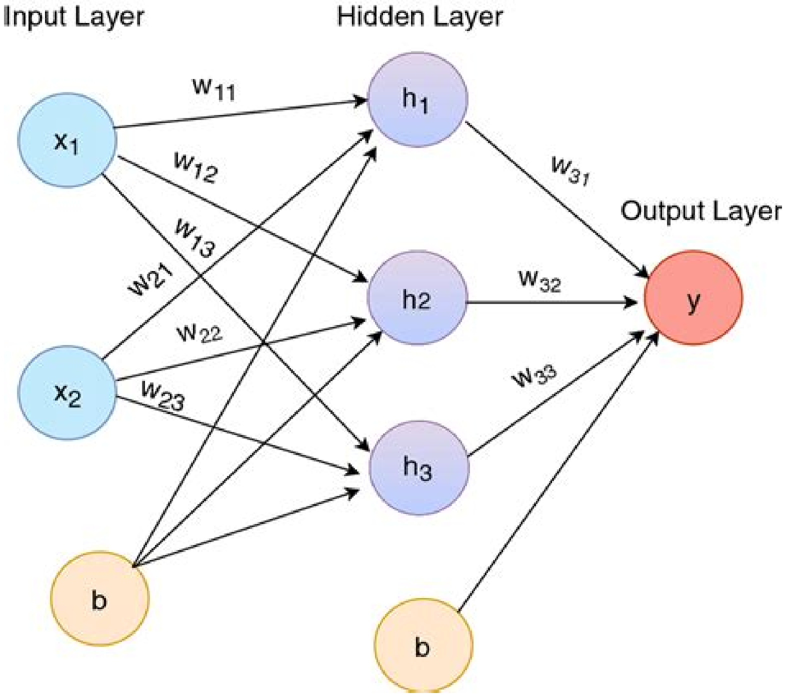
Differentiable Functions

Input→Output Pairs
Cost Minimisation

Random Start $\rightarrow$ $-$*Gradient* Steps

Example of Linear Regression




Input Layer
Hidden Layer
Output Layer
x_1
x_2
b
h_1
h2
h_3
b
y
w_{11}
w_{12}
w_{13}
w_{21}
w_{22}
w_{23}
w_{31}
w_{32}
w_{33}

3Blue1Brown Visual Intuition Series

Emdedding

My Thesis Examples

Attention as Enriching Embedding

...

Result of Attention: Context Length

...

MCP