

Understanding and leveraging artificial intelligence

A practitioner's guide for academic research

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The ChatGPT Moment


when was chatgpt first released and what was so special about it; short answer please. How many users did it gather upon release?

< 2/2 >

 ChatGPT was first released by OpenAI on November 30, 2022. It was notable for its advanced natural language processing capabilities, allowing it to generate human-like text responses. Upon release, it quickly gathered over 1 million users within just five days.



A poem on why understanding AI and machine learning isn't that hard in barroque sonnett style; short

 Understanding AI, a task not so dire,
Much like a Baroque sonnet, rich yet clear.
Within the maze of code, no need to tire,
For patterns in the data soon appear.

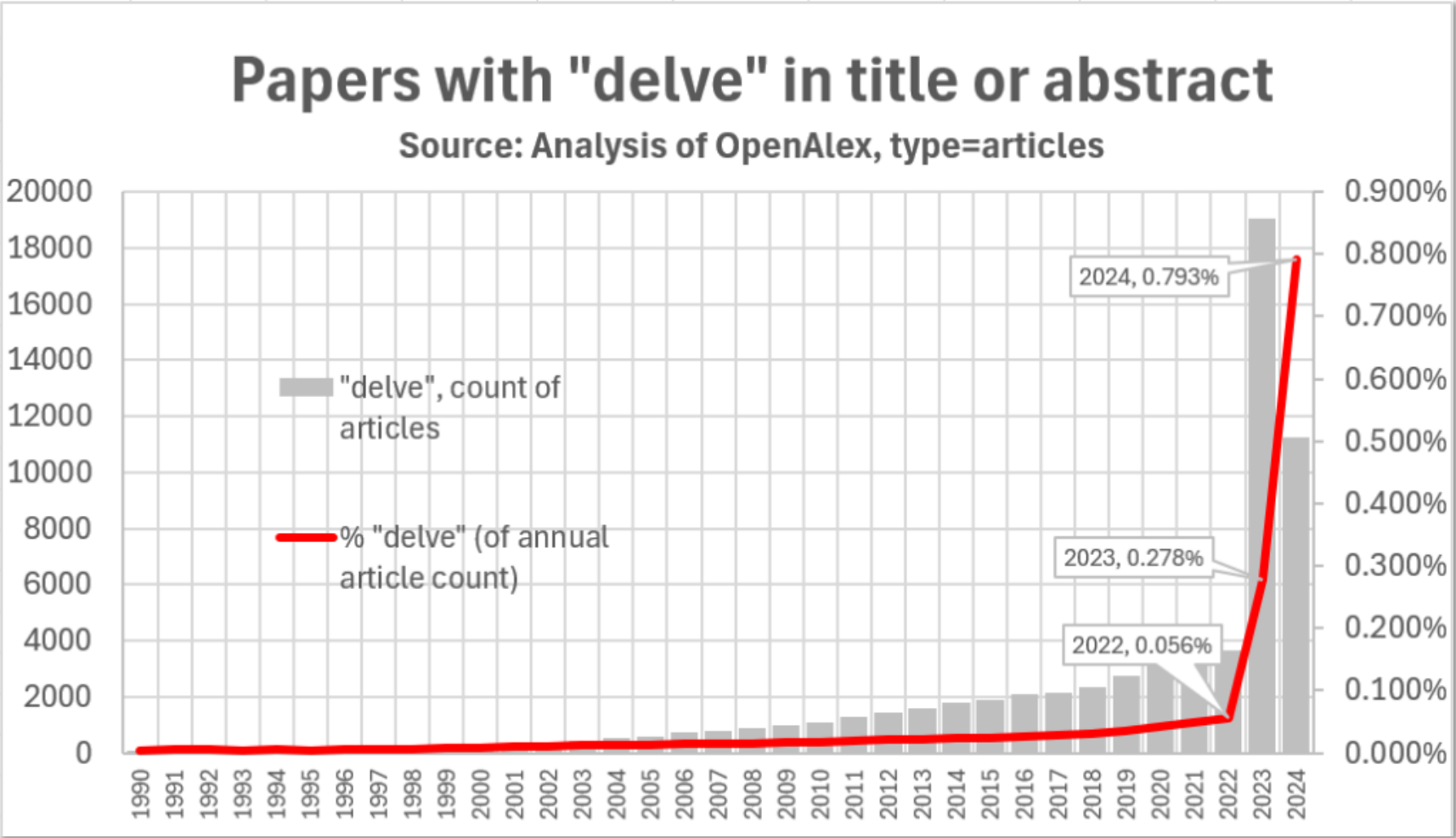
The algorithms, like well-played chords, flow,
Mathematics dancing, a structured art.
In layers deep, the neural networks grow,
Learning from the past to play their part.

Just as Baroque's grand forms seem intricate,
Yet reveal beauty through each measured line,
So does machine learning elucidate,
With logic's grace, its workings so divine.

Fear not the code, for in its heart you'll find,
A symphony of knowledge, free your mind.



Let's *delve* into AI and its applications



Source: Shapira (2024)

Let's *delve* into AI and its applications



Source: Shapira (2024), OpenAi website

About today's talk

- I am here to answer your questions about AI/ML
- **Parts of the presentation can be challenging to understand. Do not hesitate to ask questions!**
- Suggestion: Raise hand in Zoom and please do interrupt me, if I overlook you or if you are having trouble understanding
- Little break after each section for questions/clarification
- This slide deck will serve as extensive reader version; I will not dive into every detail on the slides



Let's talk about your experiences with AI so far...



Join at menti.com | use code **9490 8511**

How many have **tried out ChatGPT?**

Have you **used other AI tools?**

How **confident** do you feel using AI tools personally or professionally?

What's stopping you from leveraging AI?

Outline

1 Motivation and background: Artificial Intelligence, Machine Learning & Co.

2 Large Language Models, Prompt Engineering (Theory)

3 Experiments: Large Language Models

4 Discussion

5 Next steps, further guidance

Outline

1

Motivation and background: Artificial Intelligence, Machine Learning & Co.

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Four important definitions

ALGORITHM



Any well-defined computational procedure that **takes some value(s) as input and produces some value(s) as output** in a finite amount of time.

Or: Sequence of computational steps that transforms the input into the (desired) output.

Or: Instructions to solve a computational problem.

DATA

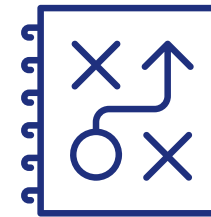


Structured or unstructured **encoded information that can be interpreted** by a computer or human.

Usually **generated by some process**.

We want to find **valuable patterns** in it.

MODEL



Abstract, simplified **representation** of something.

Related to the process that generates the data (e.g. regression).

In machine learning **a model maps the input feature(s) to the output target value(s) using a set of algorithms**.

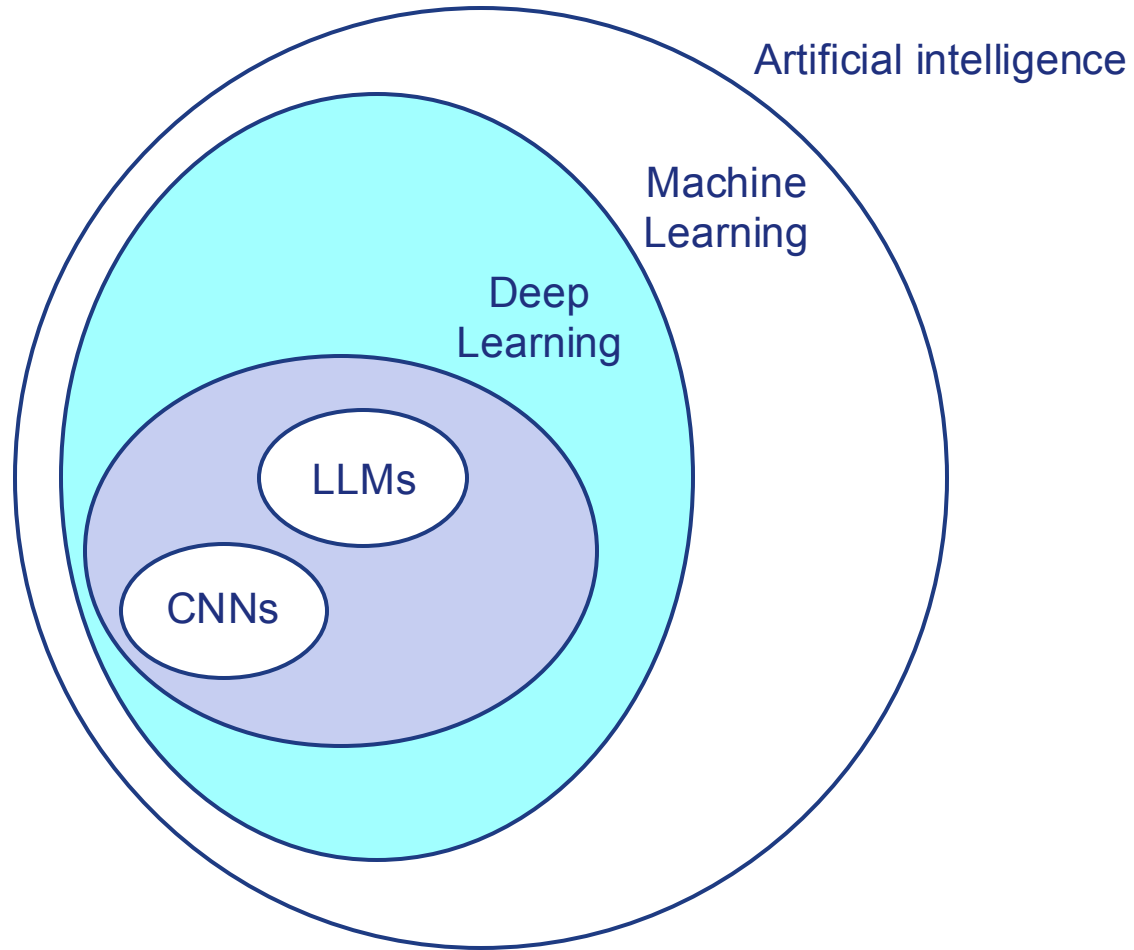
LEARNING



A model learns from data when its performance on a given task **improves after the data is taken into account**.

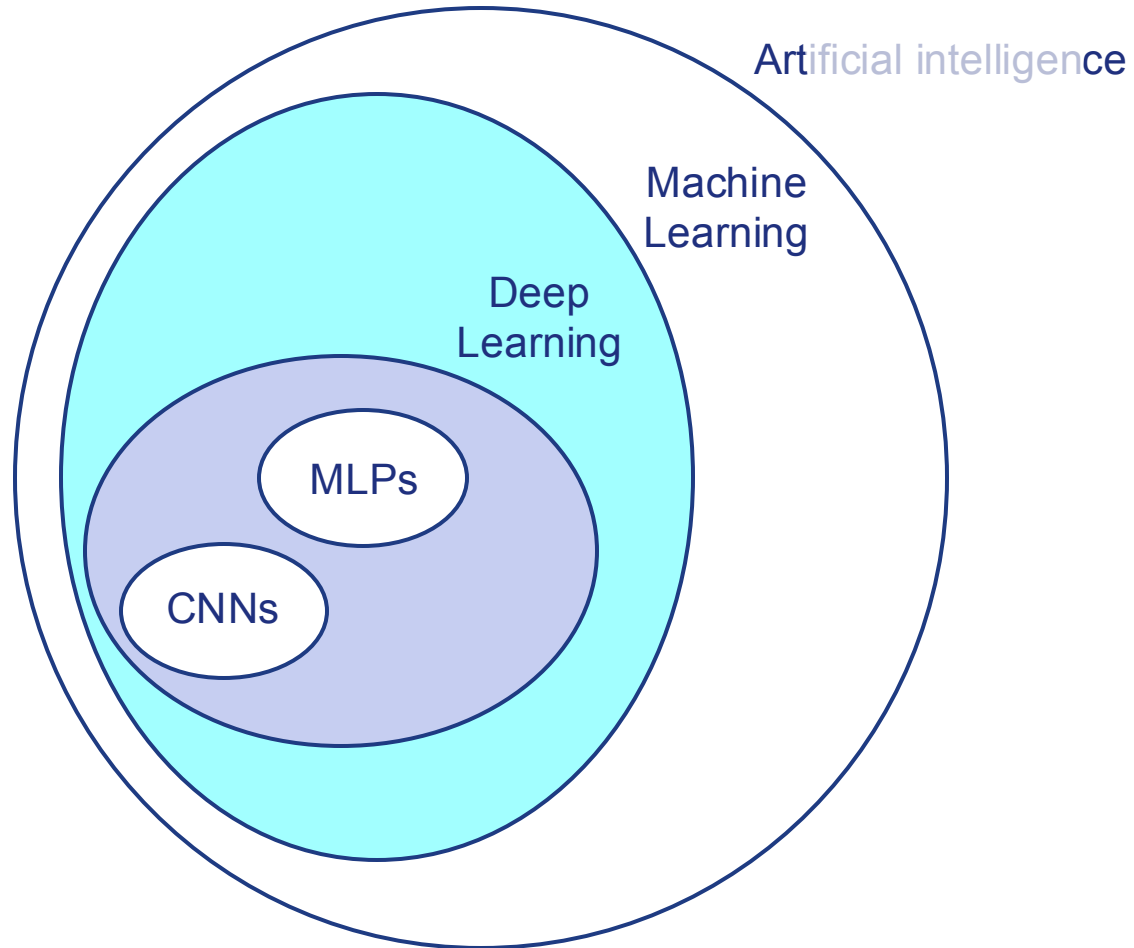
In technical terms: Learning means automatically finding structures and patterns in the data by optimizing the model parameters based on a loss function.

But what *is* Artificial Intelligence?



- Branch of computer science that aims to create **systems** capable of performing tasks that would typically require human intelligence
- Task examples:
 - reasoning,
 - decision-making,
 - problem-solving,
 - understanding natural language,
 - recognizing patterns,
 - and learning from data/environments

How about Machine Learning and Deep Learning?



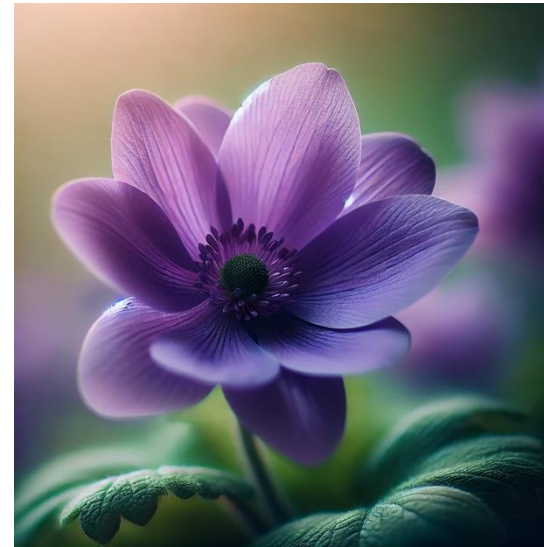
- **Machine Learning**
 - Subfield of artificial intelligence
 - **Design models that learn from data through algorithms**
 - Examples: Linear regression, K-means clustering, Support Vector Machines, Decision Trees, Random Forests
- **Deep Learning**
 - Subfield of machine learning that uses a particular kind of algorithm: Neural Networks (NNs)
 - Examples: Multi-Layer Perceptrons (MLPs), Convolutional NNs (CNNs), Transformer-based NNs, Generative Models, ...

Classical Approach vs. Machine Learning – An example

We're going to create a **model** that can reliably tell us whether an image shows a red rose or a violet!



Red Rose



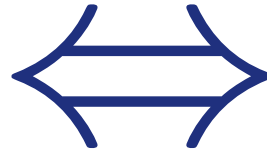
Violet



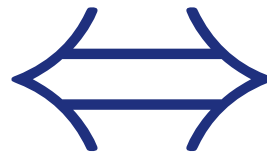
Dataset

In the end it's all numbers

Country	GDP*	CO2 emissions*
Germany	83	234315
United States	129	14556930
China	114	29345254
South Africa	29	299345
Colombia	23	194930



$$\begin{bmatrix} a_{1,1} & a_{1,2} & a_{1,3} & \cdots & a_{1,8} \\ a_{2,1} & a_{2,2} & a_{2,3} & \cdots & a_{2,8} \\ a_{3,1} & a_{3,2} & a_{3,3} & \cdots & a_{3,8} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ a_{15,1} & a_{15,2} & a_{15,3} & \cdots & a_{15,8} \end{bmatrix}$$



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*Numbers for illustration only

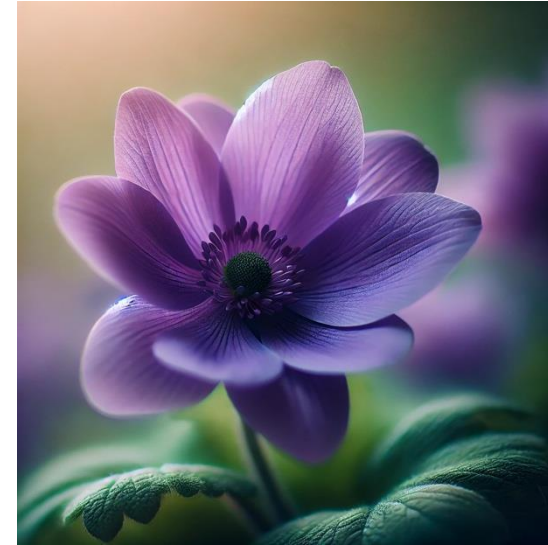
Sources: The author's own elaboration, OpenAI GPT-4 & GPT-4 Turbo, Google Images

Classical Approach vs. Machine Learning – An example

What could be a rule to decide red rose vs. violet?



Red Rose



Violet

What would a classical (non-ML) approach look like?

Algorithm 1 DetermineFlowerType

```
1: procedure DETERMINEFLOWERTYPE(image)
2:   img ← LOADIMAGE(image)
3:
4:   // Define color thresholds for red rose and blue violet
5:   red.threshold.lower ← (150, 0, 0)    ▷ Lower RGB bound for red
6:   red.threshold.upper ← (255, 100, 100) ▷ Upper RGB bound for red
7:   blue.threshold.lower ← (0, 0, 150)   ▷ Lower RGB bound for blue
8:   blue.threshold.upper ← (100, 100, 255) ▷ Upper RGB bound for blue
9:
10:  // Initialize counters for red and blue pixels
11:  red.pixel.count ← 0
12:  blue.pixel.count ← 0
13:
14:  // Iterate through each pixel in the image
15:  for each pixel in img do
16:    r, g, b ← GETRGBVALUES(pixel)
17:
18:    // Check if the pixel falls within the red threshold
19:    if red.threshold.lower[0] ≤ r ≤ red.threshold.upper[0]
20:  and red.threshold.lower[1] ≤ g ≤ red.threshold.upper[1] and
21:  red.threshold.lower[2] ≤ b ≤ red.threshold.upper[2] then
22:      red.pixel.count ← red.pixel.count + 1
23:    end if
24:
25:    // Check if the pixel falls within the blue threshold
26:    if blue.threshold.lower[0] ≤ r ≤ blue.threshold.upper[0]
27:  and blue.threshold.lower[1] ≤ g ≤ blue.threshold.upper[1] and
28:  blue.threshold.lower[2] ≤ b ≤ blue.threshold.upper[2] then
29:      blue.pixel.count ← blue.pixel.count + 1
30:    end if
31:  end for
32:
33:  // Determine the dominant color
34:  if red.pixel.count > blue.pixel.count then
35:    return "Red Rose"
36:  else if blue.pixel.count > red.pixel.count then
37:    return "Blue Violet"
38:  else
39:    return "Unknown Flower Type"
40:  end if
41: end procedure
```

- Classic approach: "IF ... THEN ... ELSE"
- We could...
 - ...count the number of red pixels,
 -count the number of blue pixels;
 - ...then compare,
 - ... and finally decide rose vs. violet based on which one is higher!
- What problems could this approach have?



Thoughts?

What would a classical (non-ML) approach look like?

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- Classic approach: "IF ... THEN ... ELSE"
- We could...
 - ...count the number of red pixels,
 -count the number of blue pixels;
 - ...then compare,
 - ... and finally decide rose vs. violet based on which one is higher!
- What problems could this approach have?
 - Does not scale
 - Is not flexible in its application (what if we include red and yellow tulips?)
 - Requires human knowledge ('heuristic')
 - Not 'intelligent' but predictably dumb/boring!

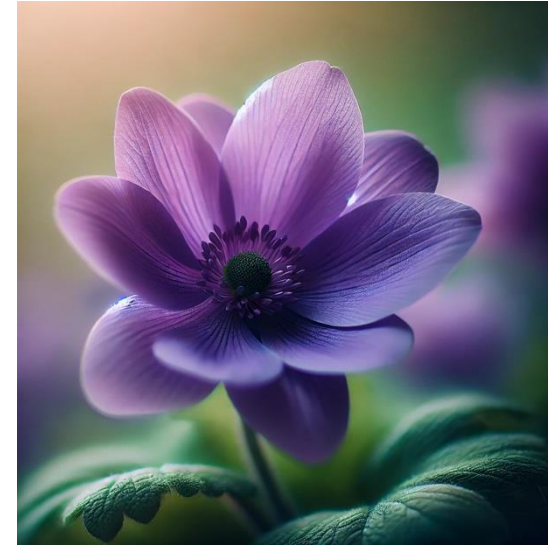
How do we *learn* from data?

We're going to create an algorithm that can reliably tell us whether an image shows a red rose or a violet!

FEATURE
TARGET



Red Rose



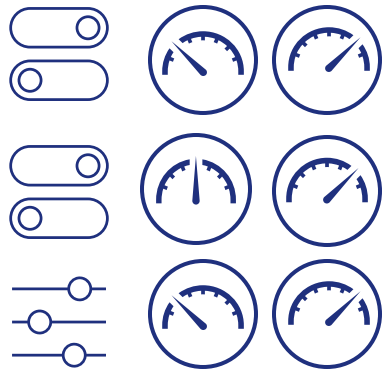
Violet



What would a machine learning approach look like?



A very flexible mathematical function



Optimize our function to minimize error

“Training”

Something that tells us how far off we are (error)



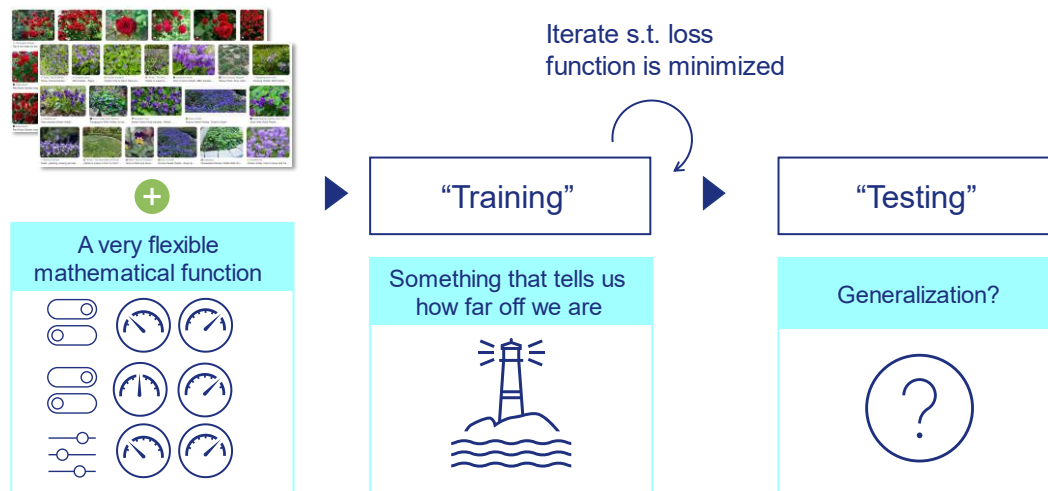
“Testing”

Generalization?





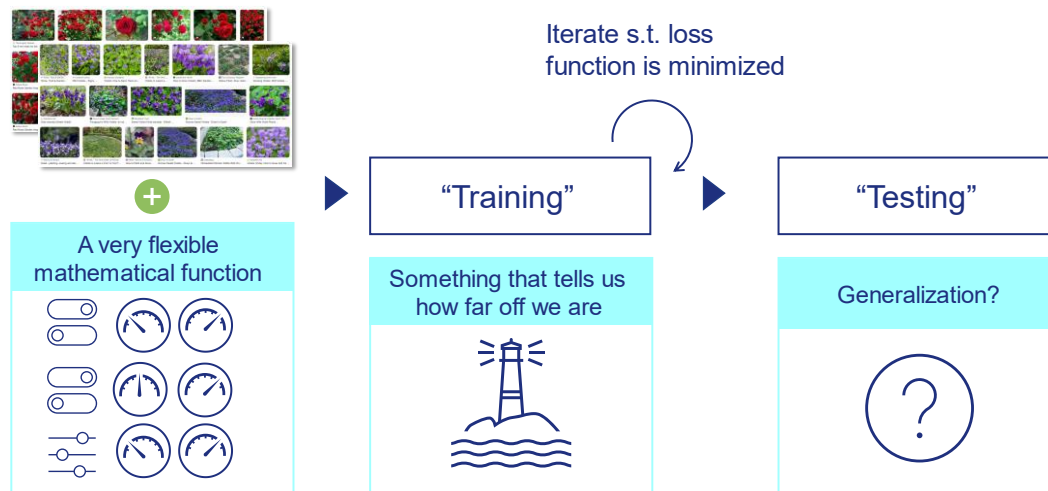
What would a machine learning approach look like?



- ML approach: Find patterns in the data that generalize
- We could...
 - ...use a very flexible, malleable function,
 -feed it a lot of our images;
 - ...let the function reflect differences that generalize,
 - ... and decide which flower it is.
- Advantages
 - scales to other images (same as classical approach)
 - Could flexibly integrate a new flower type without changing the algorithm
 - Does not require human input for decision making



What would a machine learning approach look like?

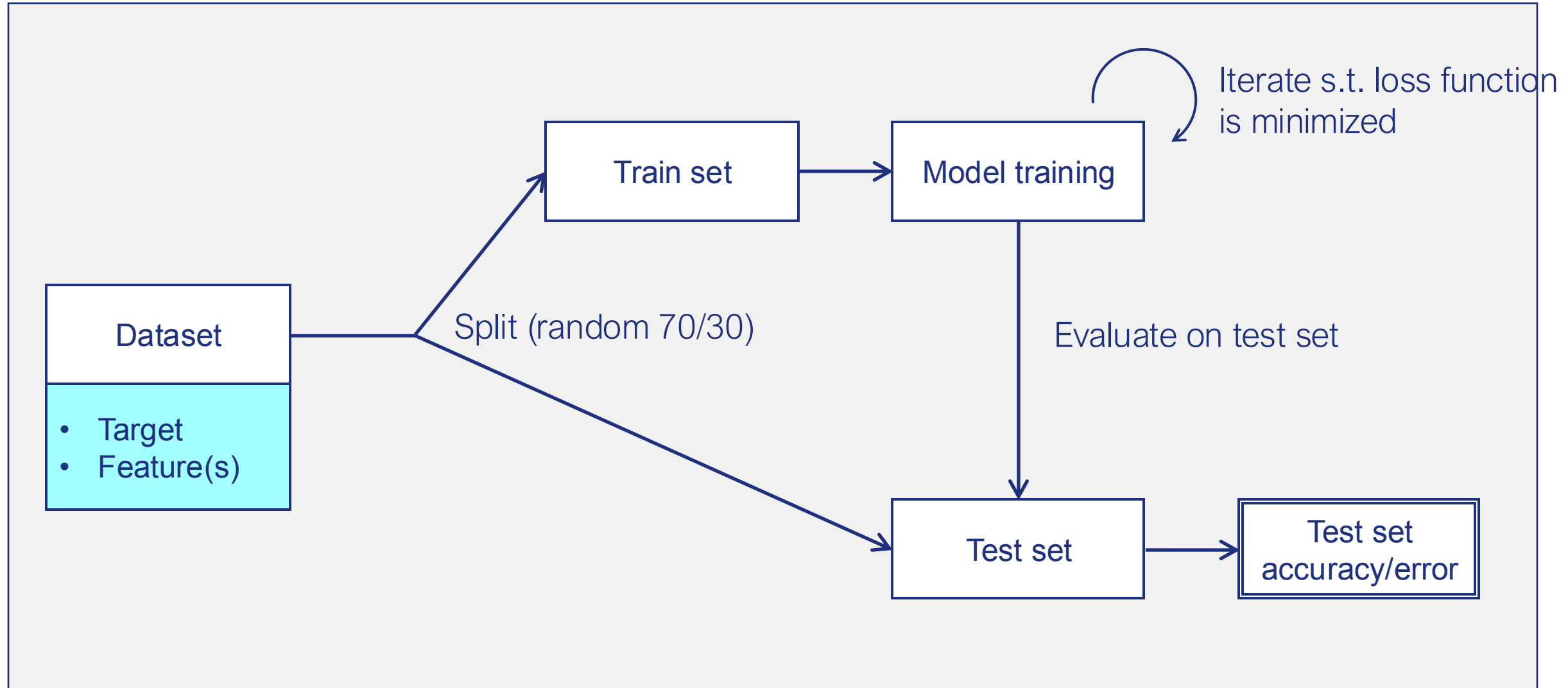


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- Advantages
 - scales to other images (even as classical approach)
 - Can identify new flower type without changing the algorithm
 - Does not require human input for decision making

Disadvantages?

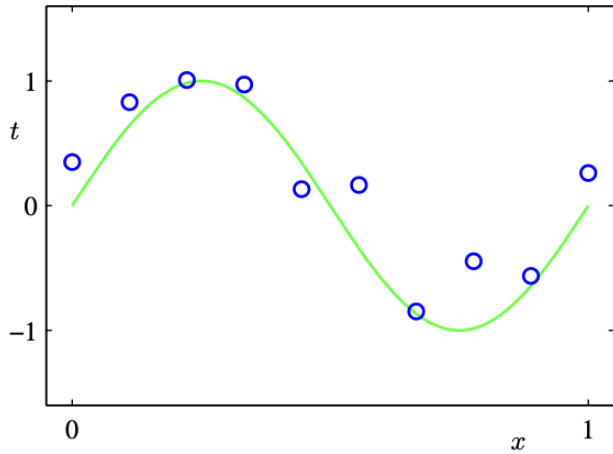


The machine learning approach

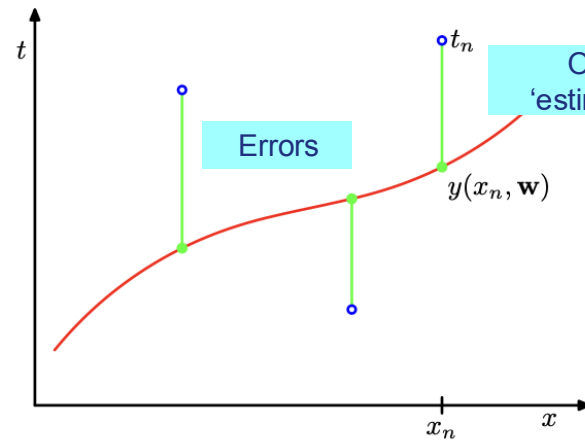




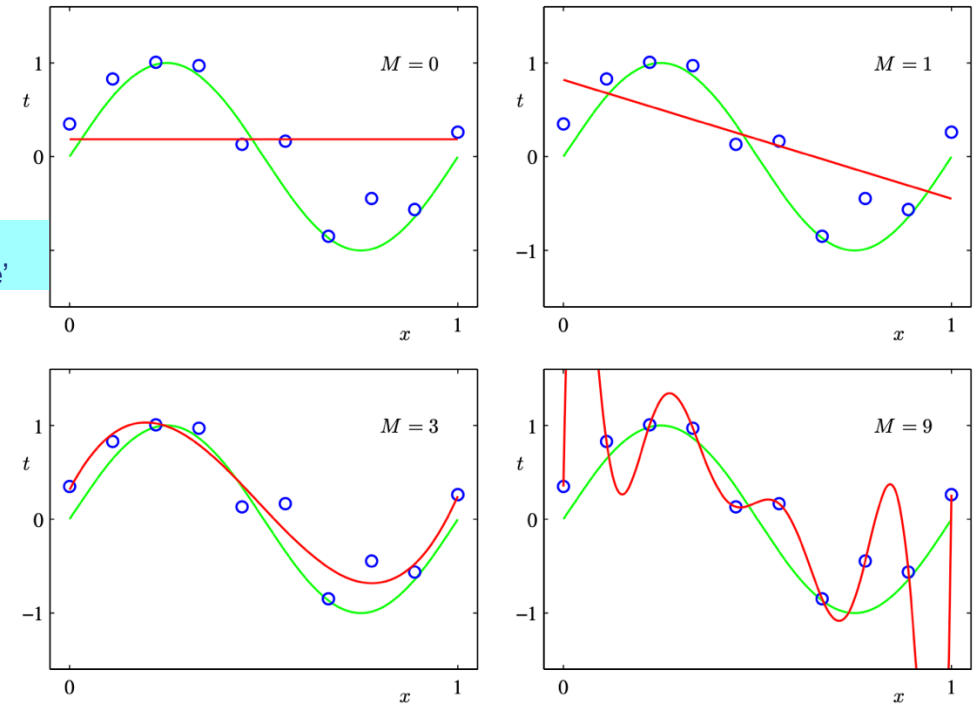
The fundamental idea of machine learning – analytically



Raw data



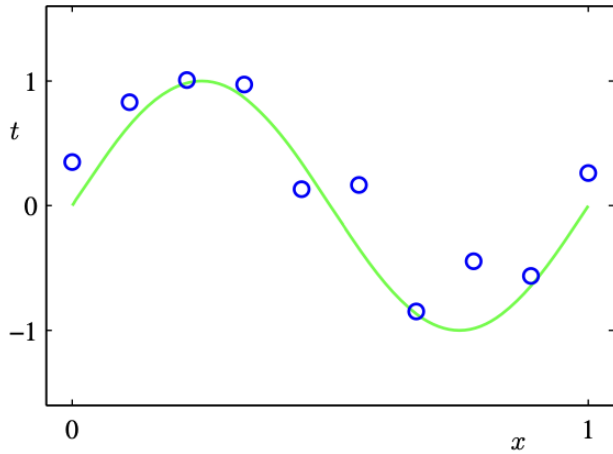
Error function



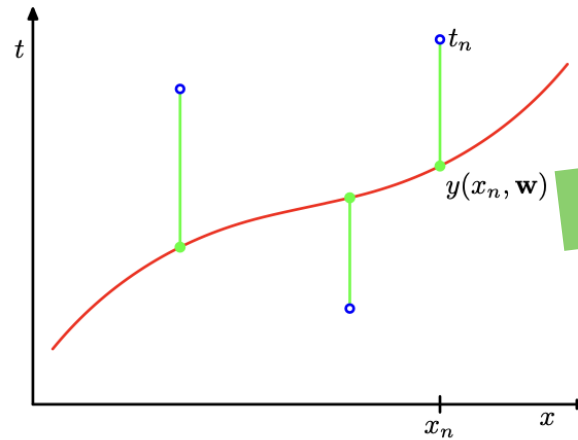
Training



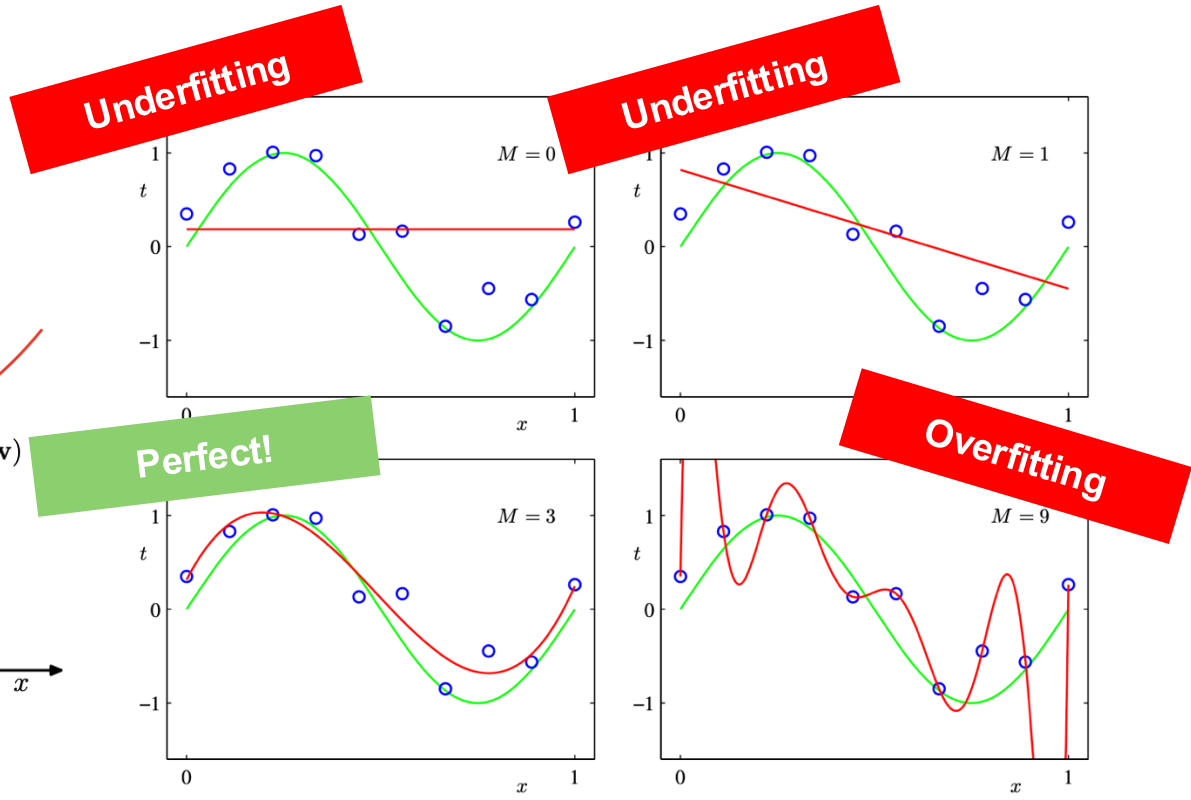
The fundamental idea of machine learning – analytically



Raw data



Error function

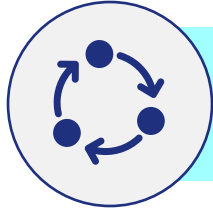


Training

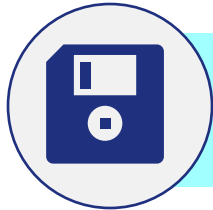
Why did we go through all this?



Understand how machine learning is different from classical computational problem solving: Learning from data



Even the most sophisticated AI models are just (deterministic) machine learning algorithms, they are far from smart or 'intelligent'



Training and testing data is everything! Every model reflects how and with what data it was 'educated'



Every machine learning approach is fallible, in the sense that it need not generalize just because it fits its training data well

Outline

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Motivation and background: Artificial Intelligence, Machine Learning & Co.

2

Large Language Models, Prompt Engineering (Theory)

3

Experiments: Large Language Models

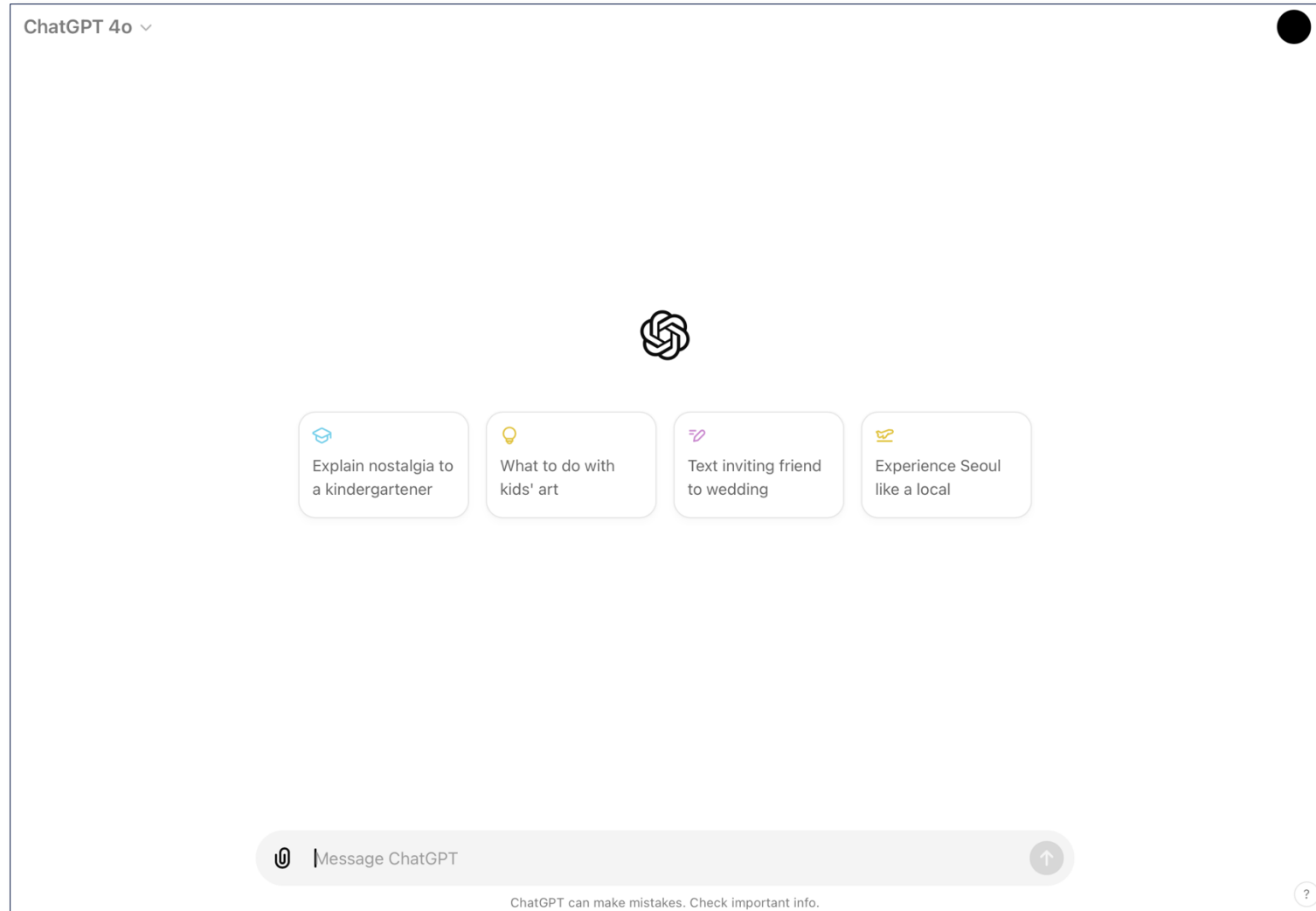
4

Discussion

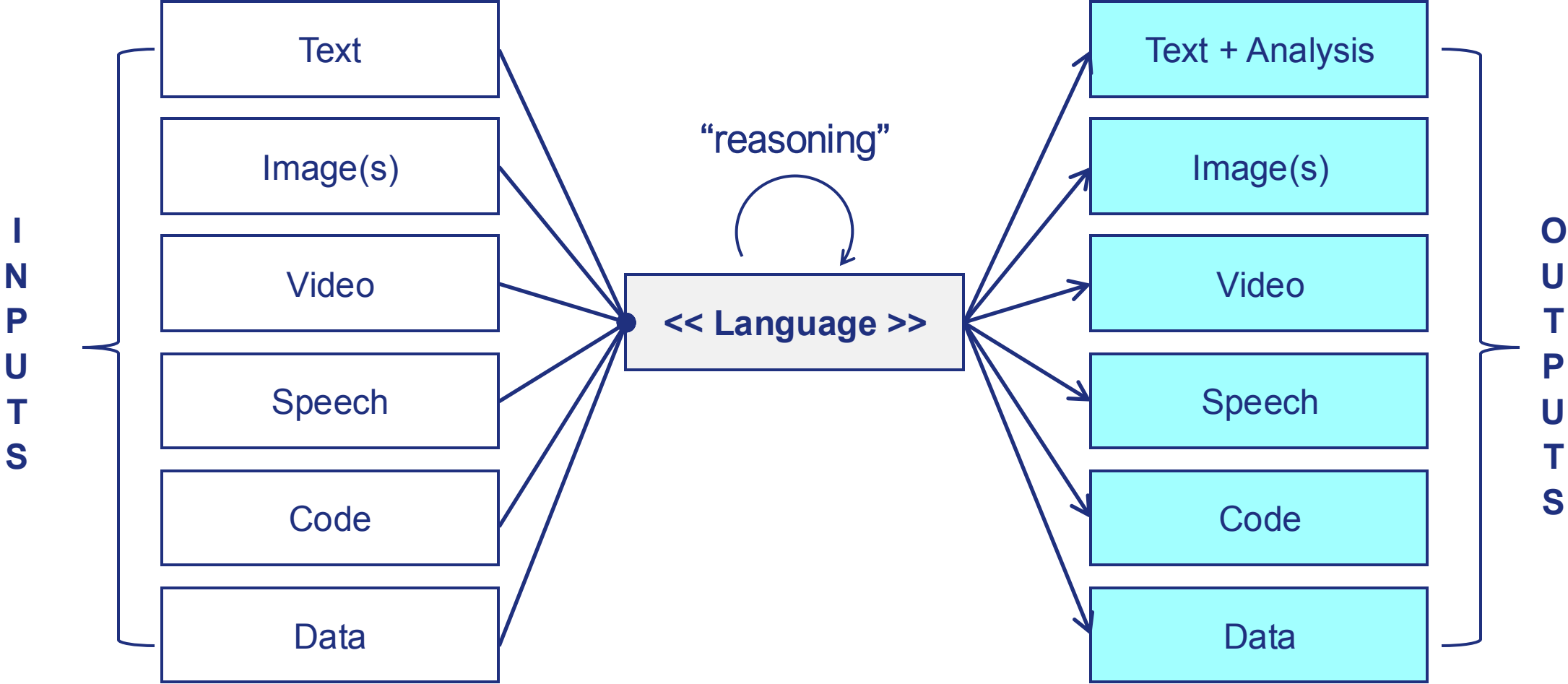
5

Next steps, further guidance

Large Language Models



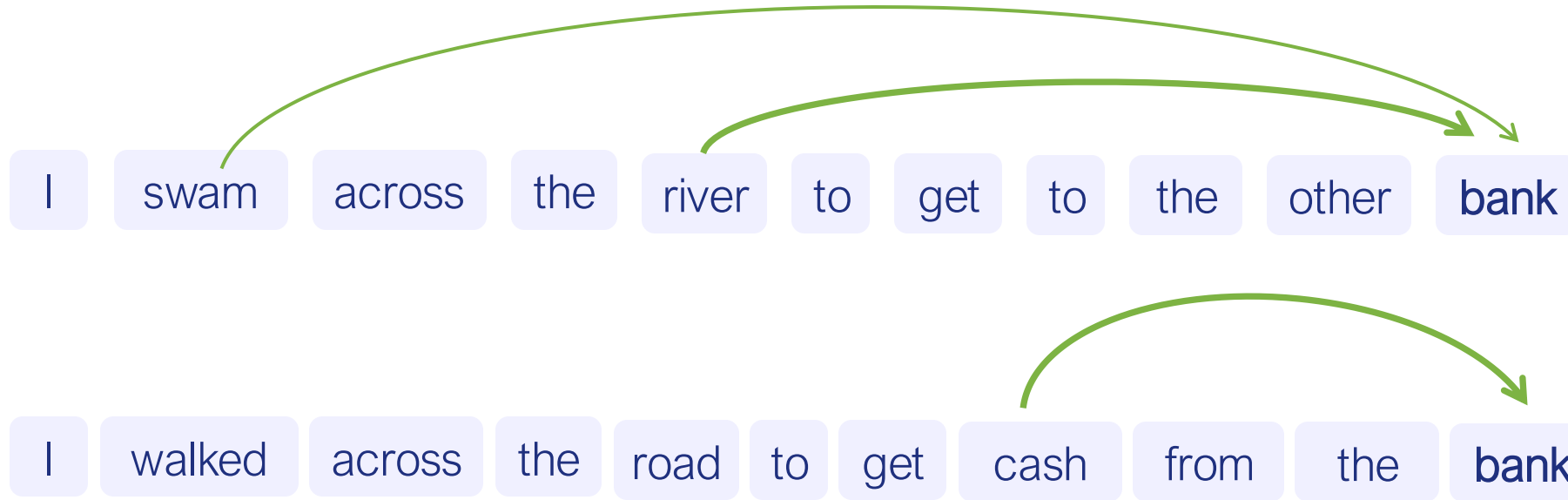
Leveraging LLMs: Natural Language as Interface



Sources: The author's own elaboration, OpenAI



The cornerstones of Large Language Models (LLMs)



- **'bank' has different meanings**, and this can **only be detected by looking at the context**
- Some words are more important than others in determining which 'bank' we are referring to
- The mathematical implementation of this concept in deep learning is called **Attention**
- Attention forms the basis of the **Transformer** (T in GPT)
- Attention made the 'LLM revolution' possible
- ...paired with an extreme expansion of computational power



The cornerstones of Large Language Models (LLMs)

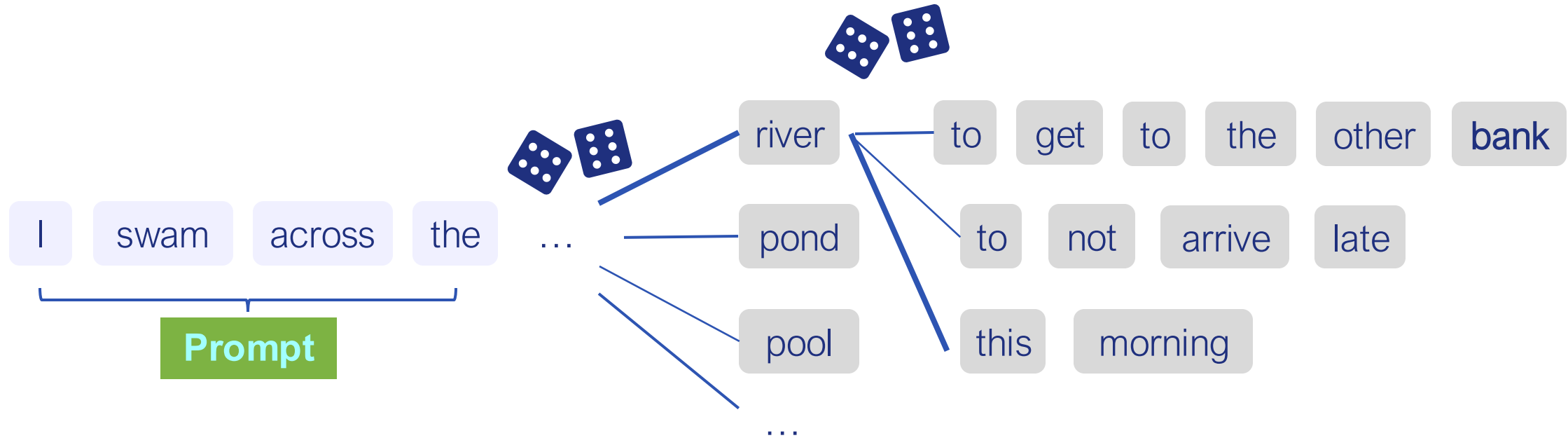
I swam across the river to get to the other bank

I walked across the road to get cash from the bank

- 'bank' has different meanings, and this is context
 - S ... erring to
 - T ... n
 - A
 - A
 - ...
- Does knowing all combinations of word occurrences mean you understand a language?**
- ... expansion of computational power

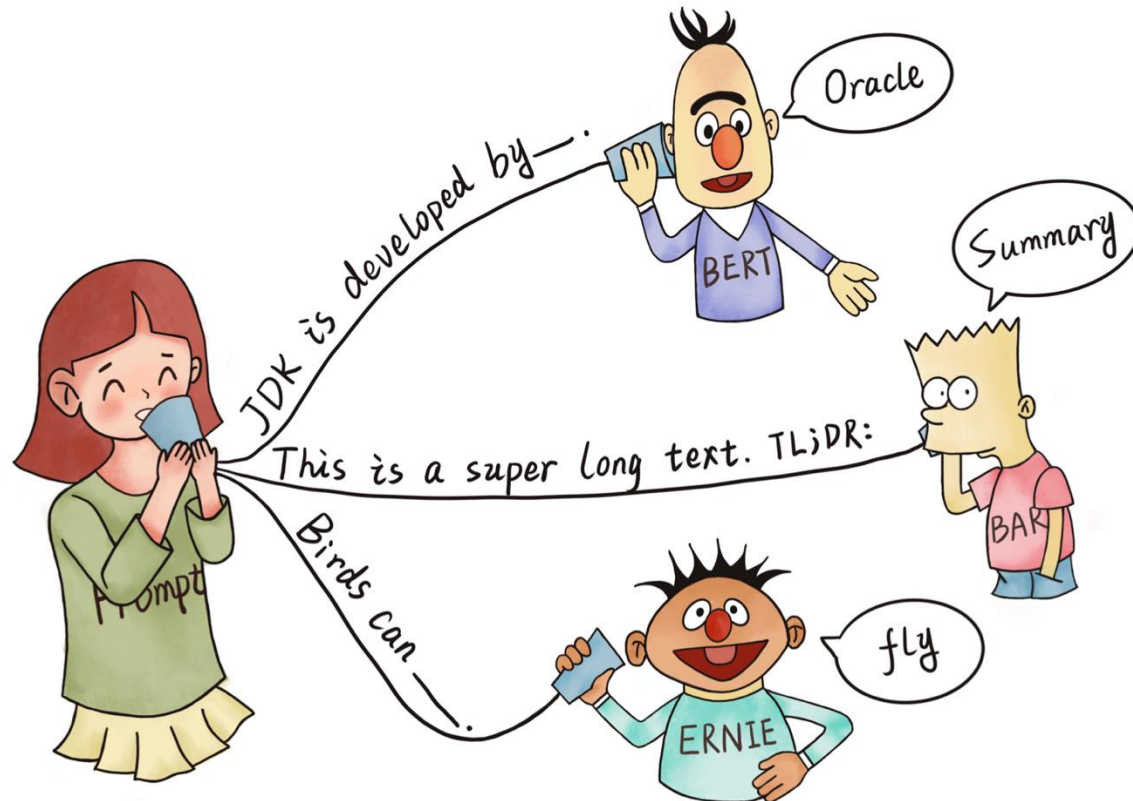


The cornerstones of Large Language Models (LLMs)



- *Generative*: The goal of the model is to generate synthetic text; or images, video, music, etc. (**G** in **GPT**)
- *Autoregressive*: Models are trained to complete the input ('prompt') and use their own generated text (auto) as input to generate further output text (regression)

The cornerstones of Large Language Models (LLMs)



- *Generative*: The goal of the model is to generate synthetic text; or images, video, music, etc. (**G** in **GPT**)
- *Autoregressive*: Models are trained to complete the input ('prompt') and use their own generated text (auto) as further input (regression)
- *Pre-Trained*: On a large corpus of text from the internet to 'learn' the relationship between words (**P** in **GPT**)

Of fossils and exits



You

Write a proof of the fact that there are infinitely many primes; do it in the style of a Shakespeare play through a dialogue between two parties arguing over the proof. Limit the **dialogue to each person speaking three times** and include the words 'fossil' and 'exit' somewhere sensible.

< 2 / 2 >



Creative Writing Coach

Title: Prime's Parley

Enter HALCION, a learned scholar, and PYTHAS, a skeptic.

HALCION:

Hark, Pythas! Doubt thou the stars are fire,
Doubt that the sun doth move, doubt ●

Title: Prime's Parley

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HALCION:

Hark, Pythas! Doubt thou the stars are fire,
Doubt that the sun doth move, doubt truth to be a liar,
But never doubt I pray, that prime's infinite band
Doth march beyond the mortal's grasp and understanding land.

PYTHAS:

Speak plainly, Halcion, and by your leave, How can such numbers endless be conceived?

When **fossils** in the earth are not so plenty as these primes you claim
That from the boundless deep, without end, they came?

HALCION:

Consider then, a finite list of primes, not more than thee or I can name,
Suppose these all, and let us their product frame.
Add one unto this product vast, and lo, behold a new stage set,
For either prime it is itself, or by primes not listed yet it's met.

PYTHAS:

Indeed, your words a cunning plot do weave,
Yet in this new-found number, primes could leave.

Could it not be divided by those known, And thus a prime not new but old be

shown?

HALCION:

Ah, but there lies the heart, and proof so sweet;

This number, from our product plus one beat,
By none of those primes could evenly be split;

Their child it is not, nor divides by it.
For if by any prime it were divisible,

Subtract one – our product should divisible be as well,
Which contradicts! For primes divide not their own fold.

Thus new primes must exist, as yet untold.

PYTHAS:

Aye, the stage is clear, and your point made with grace;
In primes, no end, no final curtain, no last race.

Let us then, these endless numbers chase.

HALCION:

Then come, with minds uplifted, let us make haste,
In knowledge's pursuit, no time let us waste.

For as numbers eternal do expand,
So too, our understanding, hand in hand.
Exeunt.

PYTHAS:

To learn, to seek, to find, and not to yield.

Exit we now; to this math's field.

Of fossils and exits: Can we trust LLMs?

Title: Prime's Parley

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- **Syntax:** Does it use the right 'template'?
- **Semantics:** Is the actual content correct/appropriate?
- Shakespeare style?
- Dialogue?
- Proof correct?
- Two parties?
- Each person says something three times?
- "fossil" and "exit" included?
- ...somewhere sensible?

What do you think?

Of fossils and exits: Can we trust LLMs?

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Thus new primes must exist, as yet untold.

PYTHAS:

Aye, the stage is clear, and your point made with
grace;
In primes, no end, no final curtain, no last race.
Let us then, these endless numbers chase.

HALCION:

Then come, with minds uplifted, let us make
haste,
In knowledge's pursuit, no time let us waste.
For as numbers eternal do expand,
So too, our understanding, hand in hand.
Exeunt.

PYTHAS:

To learn, to seek, to find, and not to yield.
Exit we now; to this math's field.

- **Syntax:** Does it use the right 'template'
- **Semantics:** Is the actual content correct/appropriate?
- Shakespeare style? **Yes**
- Dialogue? **Yes**
- Proof correct? **Yes-ish**
- Two parties? **Yes**
- Each person says something three times? **No**
- "fossil" and "exit" included? **Yes**
- ...somewhere sensible? **Yes**

Prompt Engineering 101

Definition

Prompt :=
Input provided
by user

Structure

- Instruction: Direct commands or questions
- Context setting: Background information
- Constraints: Limit scope if necessary



Advanced concepts: roles, scenarios, chaining

Iterating and refining; fresh start

Example

- Basic: "List five benefits of AI in cities."
- Complex: "Describe the impact of AI on urban development, focusing on transportation and energy efficiency."

Outline

1

Motivation and background: Artificial Intelligence, Machine Learning & Co.

2

Large Language Models, Prompt Engineering (Theory)

3

Experiments: Large Language Models

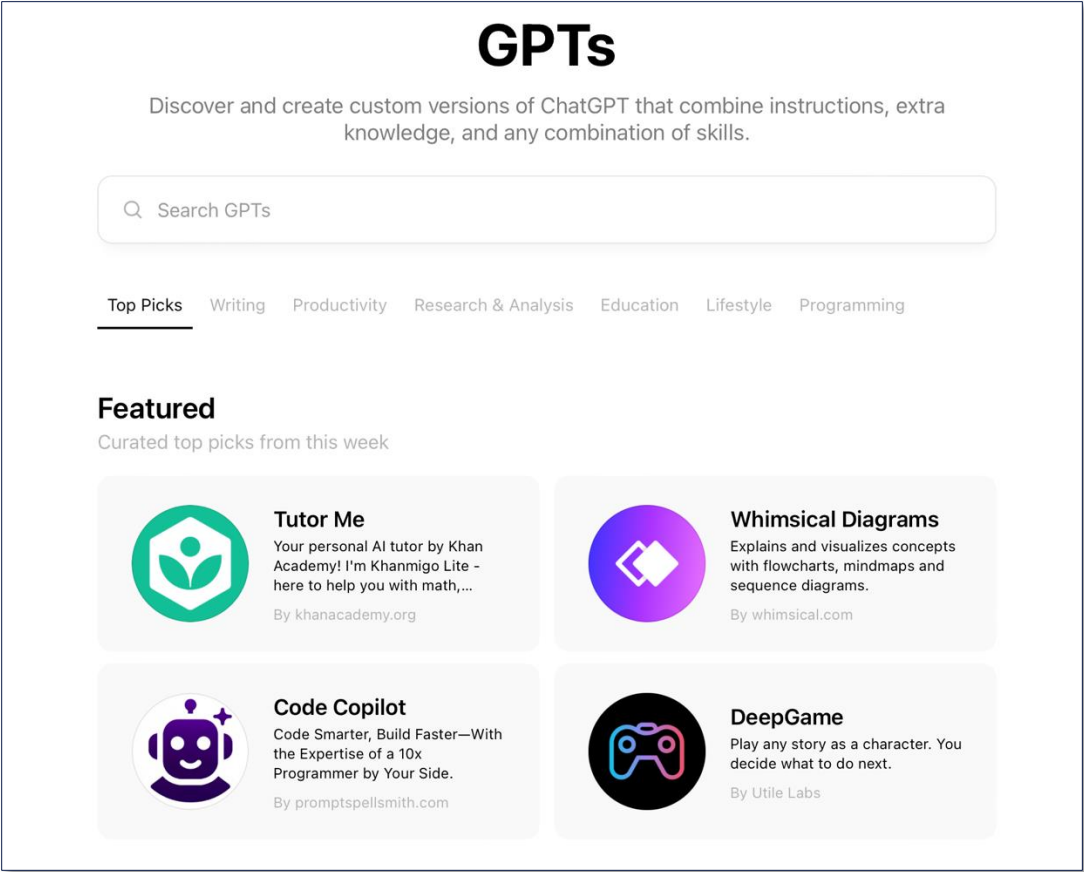
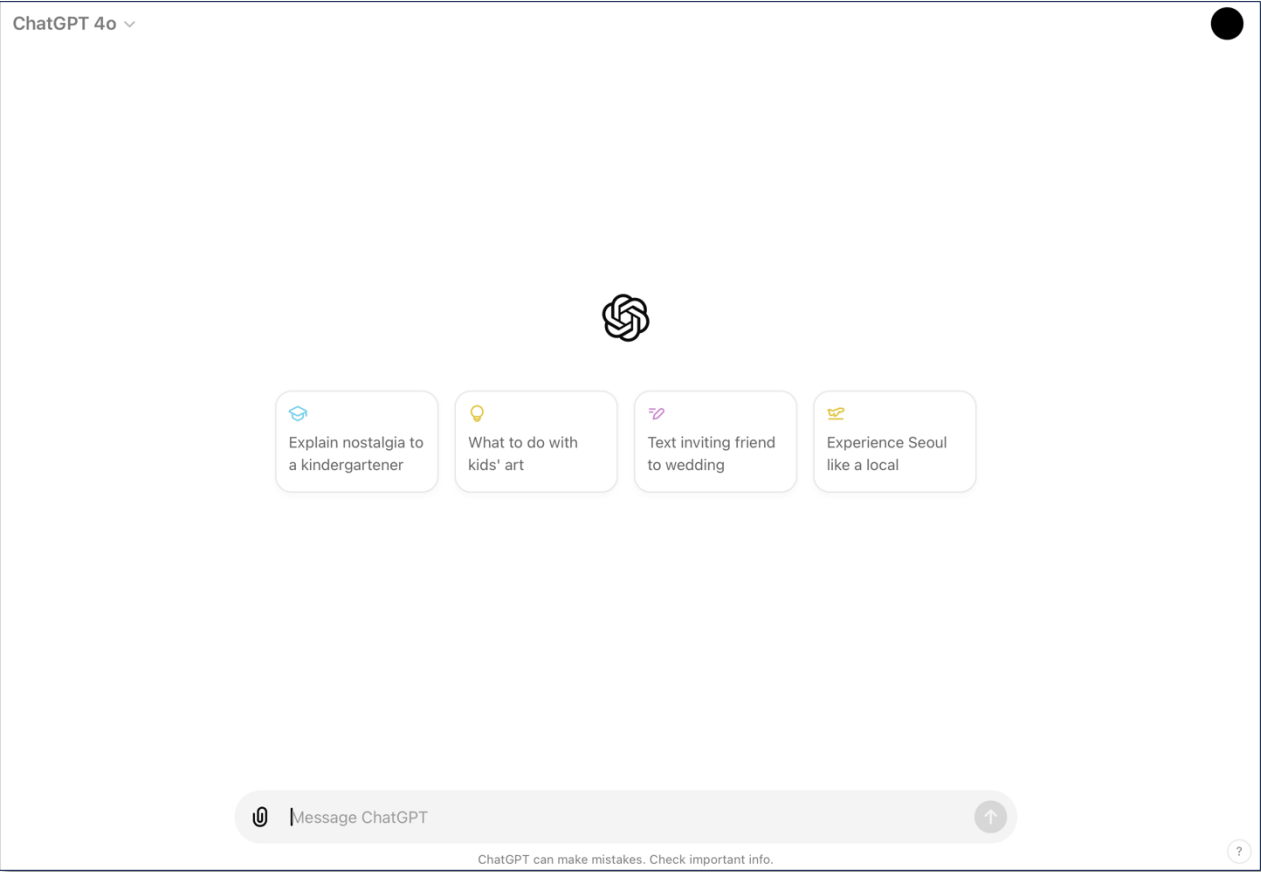
4

Discussion

5

Next steps, further guidance

ChatGPT, the ultimate LLM?



Academic LLMs

scite_

Ask, Discover, Trust

scite Assistant gives you answers with insight and control into its thought process.

Ask a question... (type '/' for menu)



Settings Sources

How does the structure of a protein affect its function?



What are the cognitive and neural mechanisms underlying decision-making and risk-taking behavior?



How many rats live in NYC?



What is carbon dioxide?



Research & Analysis

Find, evaluate, interpret, and visualize information



1



Scholar GPT

Enhance research with 200M+ resources and built-in critical reading skills. Access Google Scholar, PubMed, JSTOR, Arxiv...

By awesomegpts.ai

2



Consensus

Ask the research, chat directly with the world's scientific literature. Search references, get simple explanations,...

By consensus.app

3



SciSpace

Do hours worth of research in minutes. Instantly access 287M+ papers, analyze papers at lightning speed, and...

By scispace.com

4



Wolfram

Access computation, math, curated knowledge & real-time data from Wolfram|Alpha and Wolfram Language;...

By wolfram.com

5



Scholar AI

AI Scientist - search and analyze text, figures, and tables from 200M+ research papers and books to generate new...

By scholarai.io

6

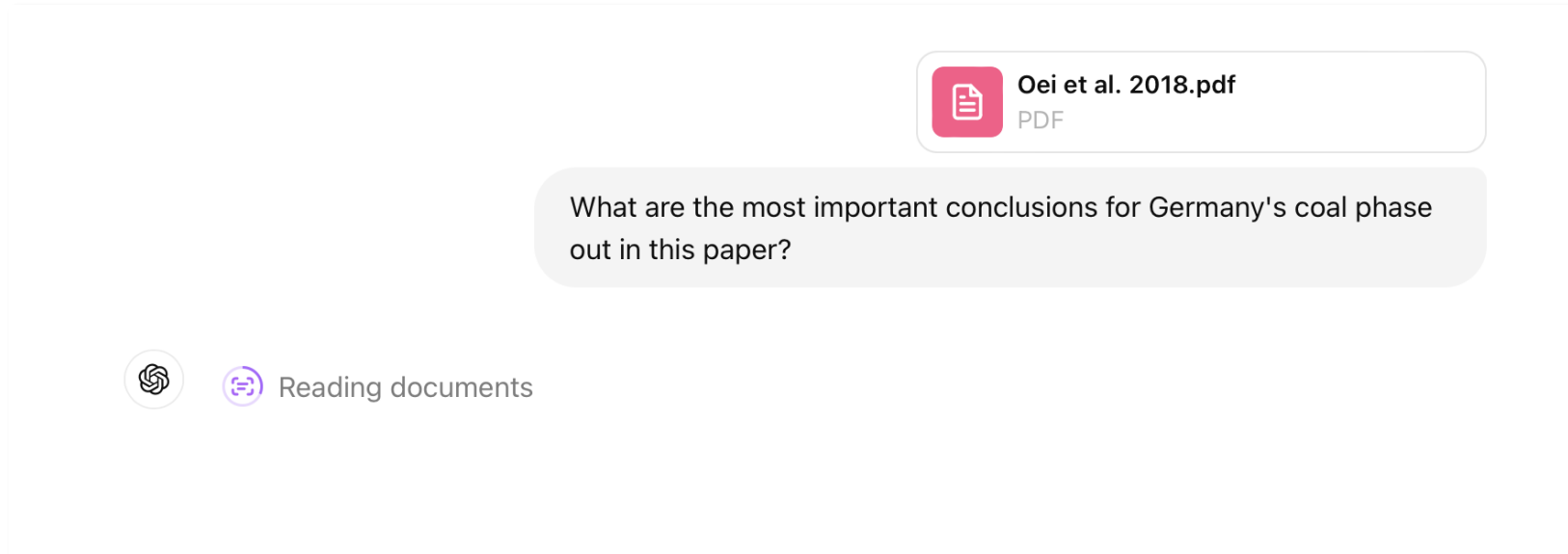


AskYourPDF Research Assistant

Free Chat Unlimited PDFs, Access 400M+ Papers (PubMed, Nature, Arxiv, etc), Analyse PDF (Unlimited PDFs),...

By askyourpdf.com

Chat with a PDF!



The screenshot shows a chat interface with a white background. In the top right corner, there is a rounded rectangular box containing a red document icon, the text "Oei et al. 2018.pdf", and "PDF" below it. Below this, a grey rounded rectangular bubble contains the question: "What are the most important conclusions for Germany's coal phase out in this paper?". In the bottom left corner, there is a circular icon with a knot-like symbol (OpenAI logo) and a purple icon with a document symbol, followed by the text "Reading documents".

Speech-to-text tools & Sentiment analysis



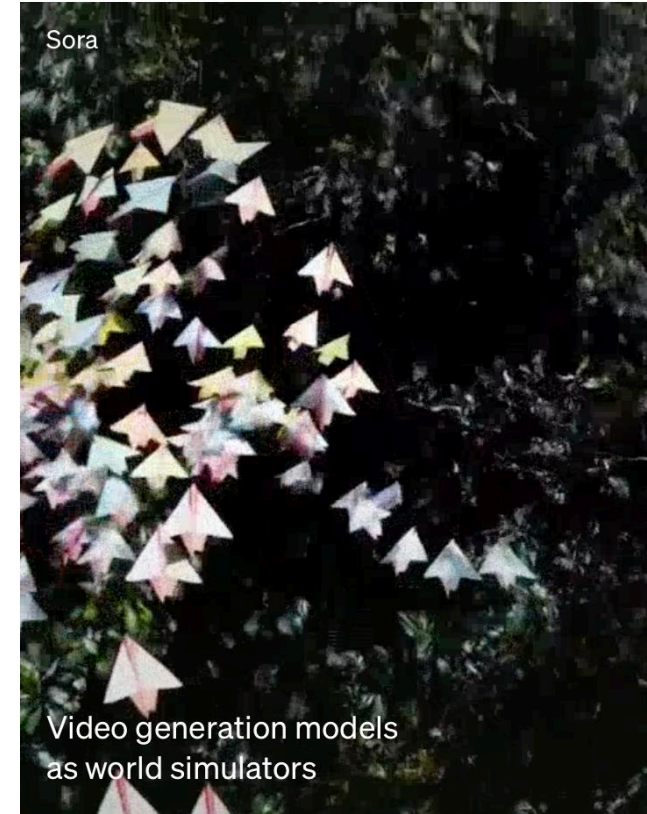
AUTOMATED TRANSCRIPTION

The best automated transcription software powered by cutting-edge AI

Fast, accurate, and affordable transcripts are critical, but that's just the starting point for Sonix.



Leveraging LLMs: Image Generation



Leveraging LLMs: Image Generation

Create an illustration that shows the difficult relationship between extracting fossil fuels like coal and the environment/ecological considerations



Include gender aspects as well, particularly how women are affected

< 2/2 >



Here is the updated illustration, now including gender aspects. It shows women working in harsh conditions on the side of the coal extraction and women and children benefiting from a clean environment on the side of the vibrant ecosystem. If you need any more adjustments or further details, feel free to let me know!

Leveraging LLMs: Code for visualization/understanding



Data Analyst

By ChatGPT

Drop in any files and I can help analyze and visualize your data.

```
import pandas as pd

# Load the data
df = pd.read_excel('inputs/papers.xlsx')

# Replace NaN with "Not else specified"
df.fillna("Not else specified", inplace=True)

print(df['Paper_ID'].unique().size)

# Exclude 'World' and 'EU'
df = df[~df['Country'].isin(['World', 'EU'])]

# Create long format for Policy Instruments
df_long_instruments = df.melt(id_vars=['Paper_ID', 'Policy_ID', 'Policy_Description', 'Policy_State', 'Start_Date', 'End_Date',
                                     'value_vars=['Policy_Instrument_1', 'Policy_Instrument_2'],
                                     var_name='Instrument_Type',
                                     value_name='Policy_Instrument'])

# Filter out 'Not else specified' entries
df_long_instruments = df_long_instruments[df_long_instruments['Policy_Instrument'] != 'Not else specified']
```

Citing AI tools

Citing Text from ChatGPT

If you are citing text generated by ChatGPT, whether you include your own input or not, you should follow these general guidelines:

In-Text Citation:

- **With Own Input:**
 - Example: (ChatGPT, 2024)
 - You can mention in the text that you used ChatGPT with your input, such as "According to text generated by ChatGPT based on my input..."
- **Without Own Input:**
 - Example: (ChatGPT, 2024)
 - Simply refer to ChatGPT as the source of the information.

Citing AI tools

Citing Images from DALL-E

For images created using DALL-E, ensure you credit the source appropriately.

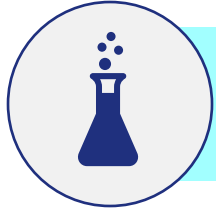
In-Text Citation:

- Example: (DALL-E, 2024)
- You can describe the image contextually in the text and then cite it, such as "An image generated by DALL-E shows a futuristic cityscape..."

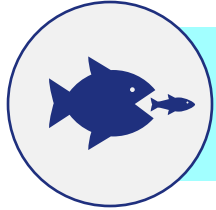
Reference List:

- Example: OpenAI. (2024). Image generated by DALL-E. Retrieved from [URL of the image, if available]

Please feel encouraged to...



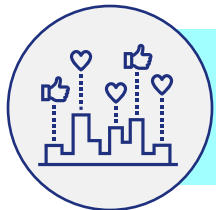
Try things out, you can't really 'break' anything with software!



Think bigger: Automatization and AI enable much larger search spaces



Use AI tools outside your job, especially creatively



Share your experiences with AI with colleagues after this workshop!

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Discussion – Q & A



Can we really trust the output of LLMs?



...



...



...

Outline

1 Motivation and background: Artificial Intelligence, Machine Learning & Co.

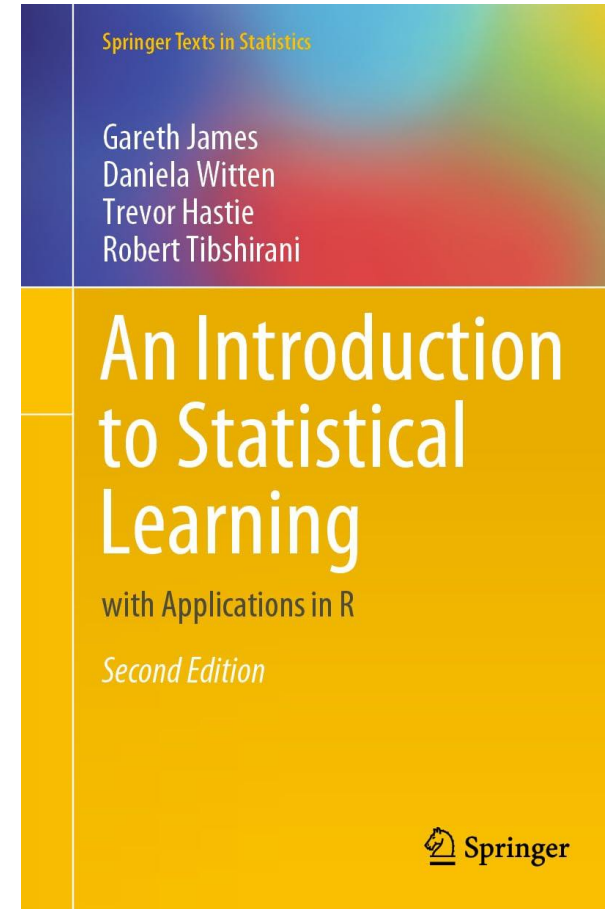
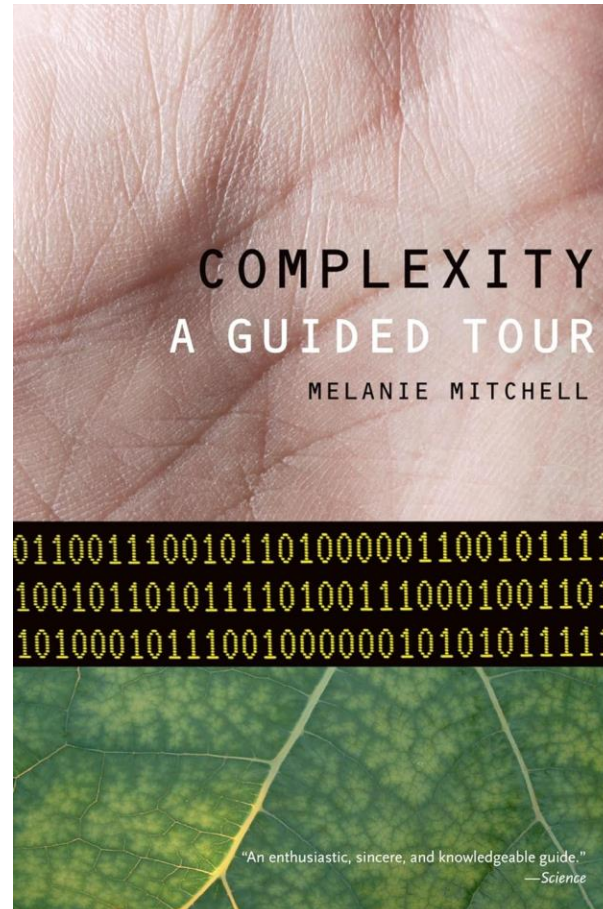
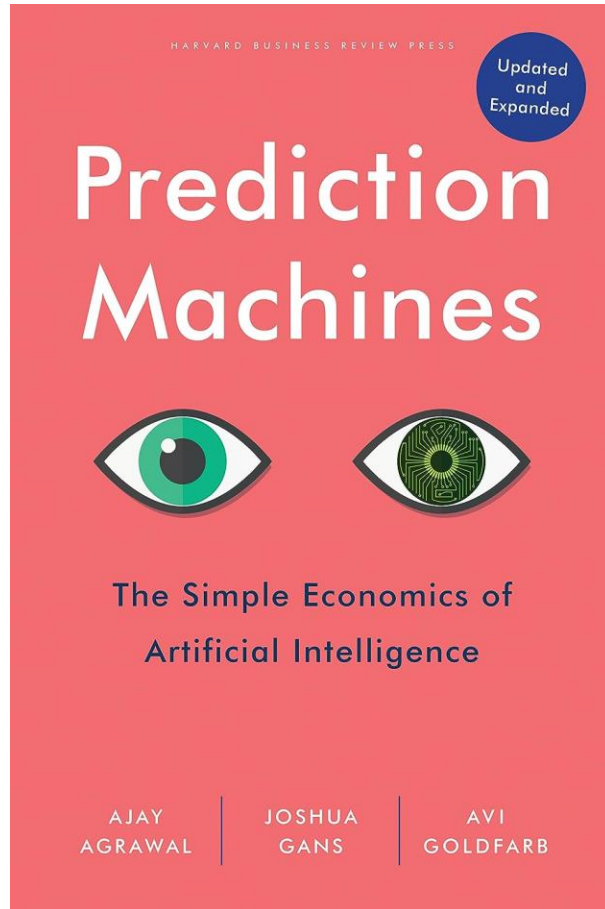
2 Large Language Models, Prompt Engineering (Theory)

3 Experiments: Large Language Models

4 Discussion

5 Next steps, further guidance

Some useful resources for further guidance



THANK YOU!

Nicolas Malz (nm@wip.tu-berlin.de)





Research Group FossilExit



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[@FossilExit](https://twitter.com/FossilExit)
[@CoalTransitions](https://twitter.com/CoalTransitions)

Backup

What kind of problem am I dealing with?

	TASK	INPUT DATA	LEARNING	MODEL OUTPUT	EXAMPLE
TYPE OF TASK	Classification		Some function →	Discrete category	Spam vs. not spam
	Regression		Some function →	Continuous value	Simple linear regression
	Clustering		Some function →	Cluster assignment	K-Nearest Neighbor
	Dimensionality Reduction		Some function →	Lower-dim. representation	PCA

How can I solve my problem with the given data?

TYPE OF LEARNING	Supervised	Trained on labeled data, model must 'only' figure out the relationship between feature(s) and target	Simple linear regression
	Unsupervised	Trained on unlabeled data, model must figure out the type/number of labels by itself	K-means clustering
	Semi-Supervised	Trained on a limited train set of labeled data, rest is unlabeled	Graph-based methods
	Reinforcement	Agent learns to make "good" decisions by performing actions in an environment maximizing some reward	Q-learning, Policy gradients