



CMPT 413/713: Natural Language Processing

Conclusion

Spring 2026
2026-04-01

What is natural language?

- Way for humans to **communicate** with each other
 - Use it to express feelings, transmit information, and store **knowledge**
- **Discrete**, combinations of symbols
- **Learnable** by all humans

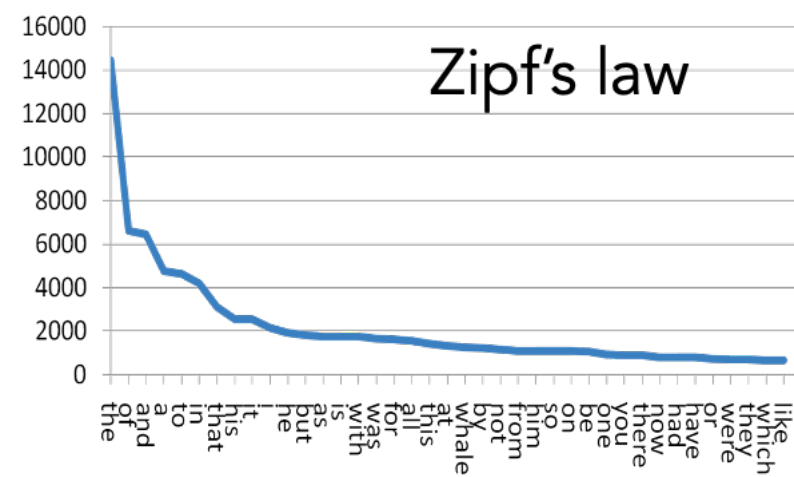
Key challenges of understanding language

- Ambiguity (at multiple levels)

I saw her duck



- Scale
- Sparsity (Long tail)
- Variation
- Expressivity
- Unmodeled Variables (Implicit knowledge / Context)
- Unknown representation (representation)



What has this course covered?

Representations

- Embeddings
- Compositional
- Structured

Methods

- Language Models
- Statistical Methods
- Neural Models
- Dynamic programming

LLMs

- Prompting
- Efficient fine-tuning
- Pre-training
- Post-training

Applications and tasks

- Machine translation, text generation, question answering, grounding

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Key Questions

- How to **represent** language?
- How to **compose** meaning?
- How do we **parse** the “surface form” of language to a representation that a computer can process?
- How do we take an encoded representation and **generate** text from it?
- What are the key methods / algorithms for **learning** these representations?

Methods we covered

Rule-based methods

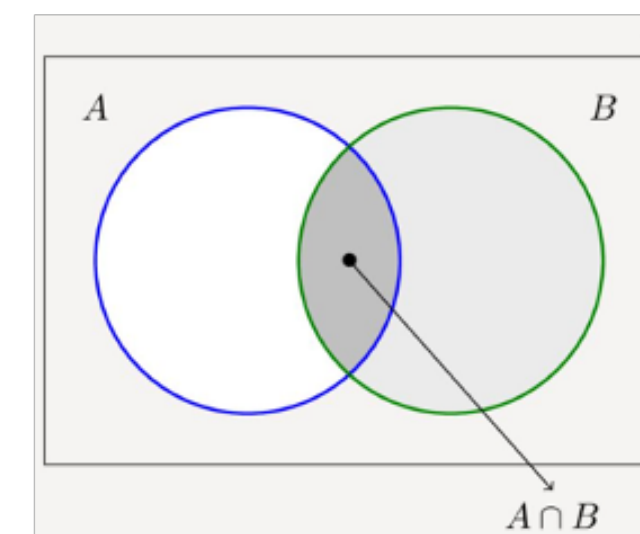
(0 YOU 0 ME) [pattern]
→
(WHAT MAKES YOU THINK I 3 YOU) [transform]

You hate me

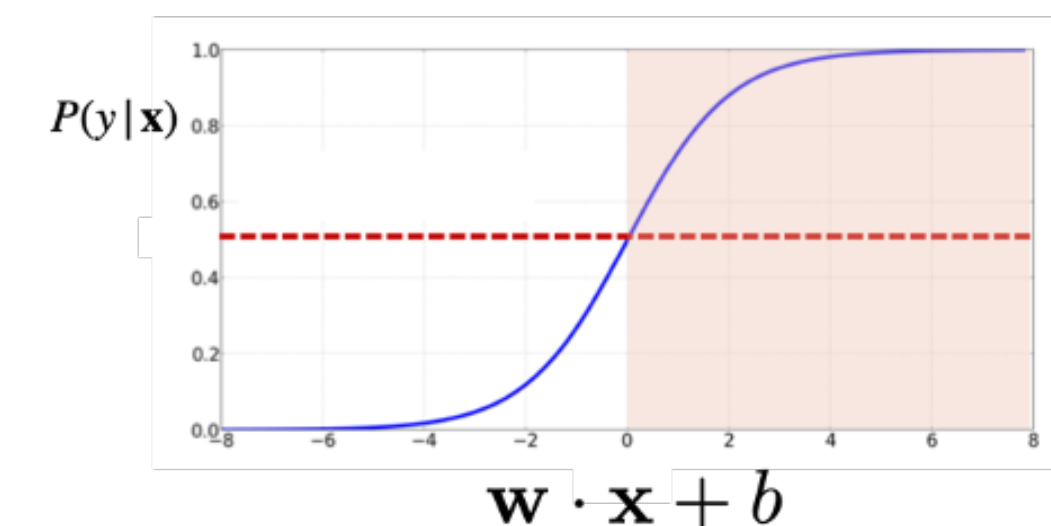
WHAT MAKES YOU THINK I HATE YOU

Use when you have no data
Good way to have something to bootstrap from

Statistical methods



Naive Bayes

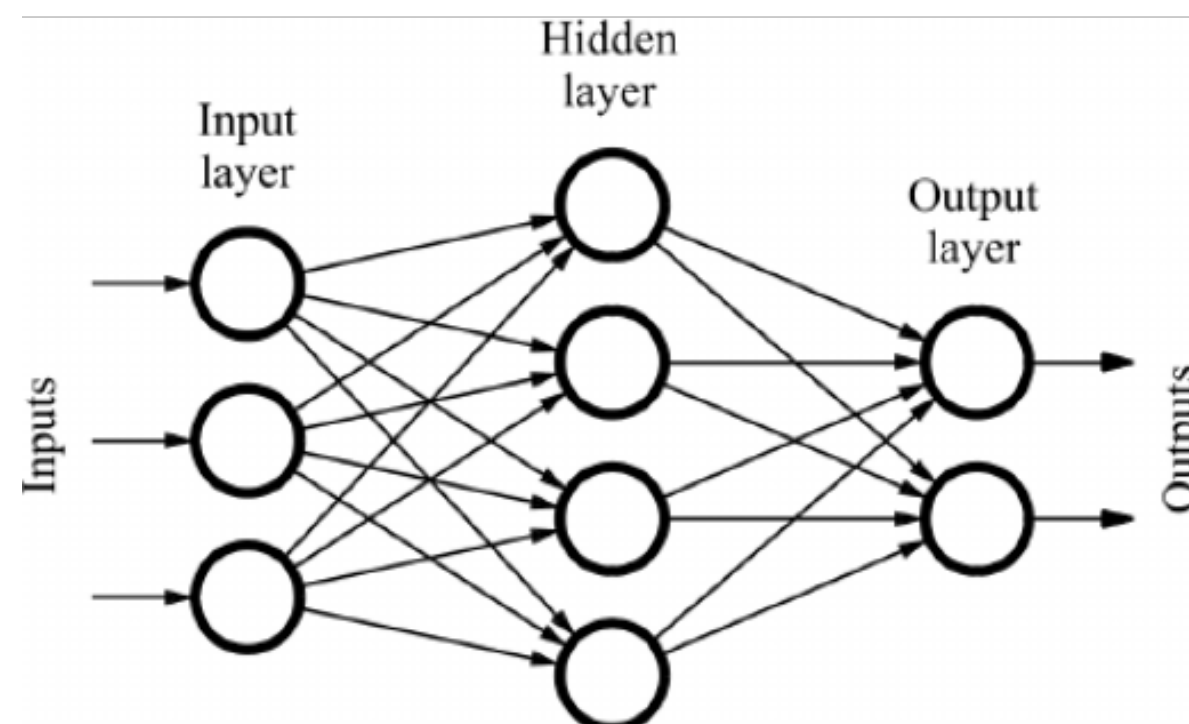


Logistic regression

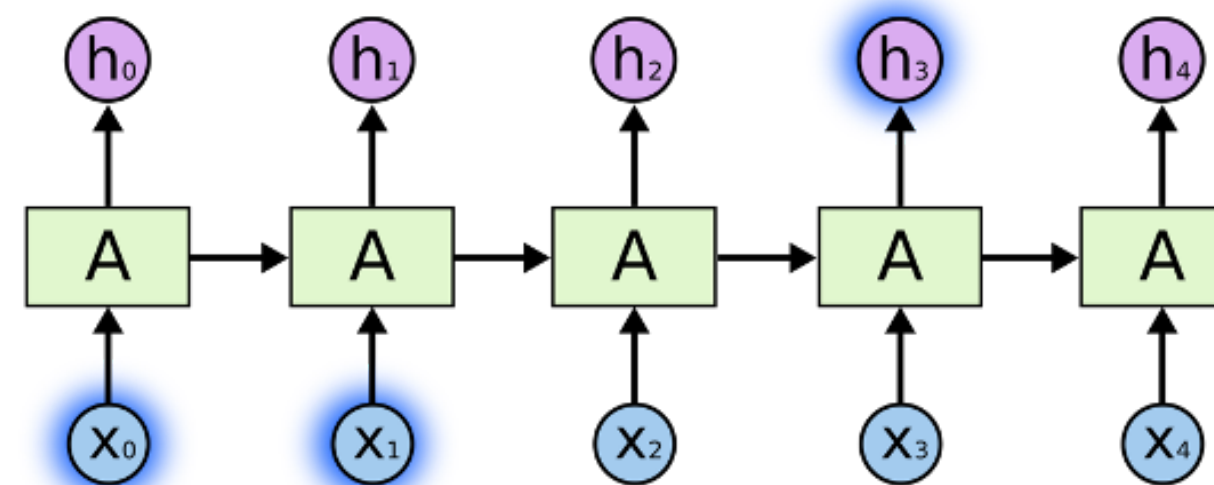
Simple baselines for text classification
Solid understanding helps understand NNs

Neural networks for NLP

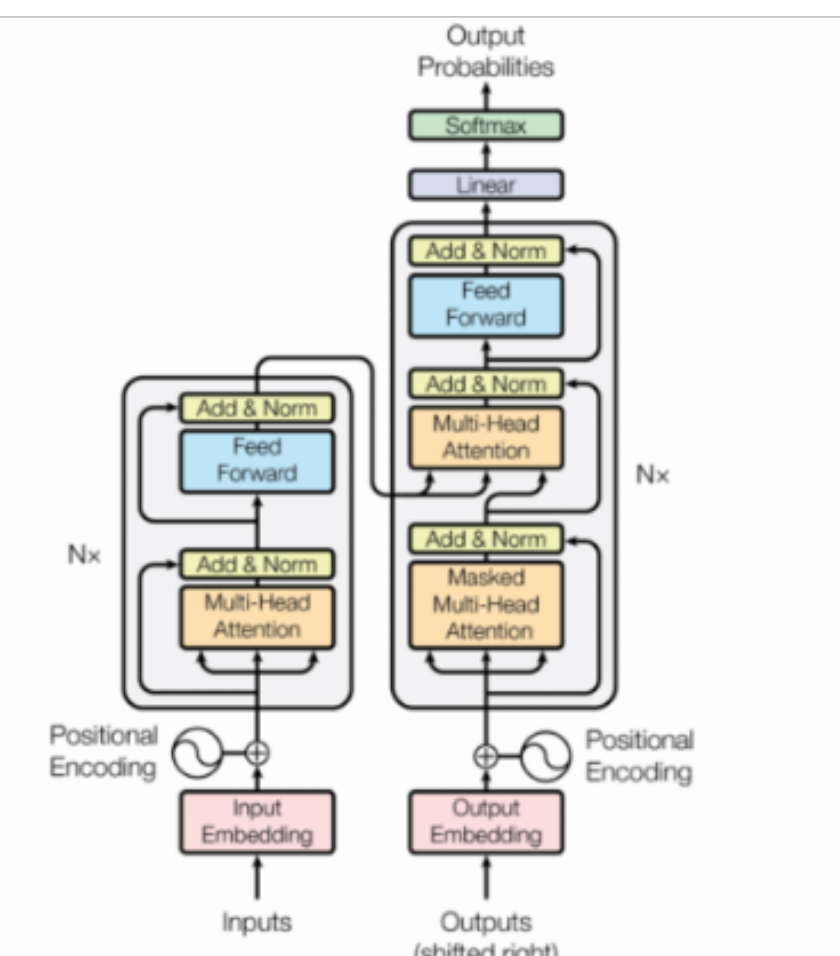
Feed-forward NNs



Recurrent networks (RNNs)

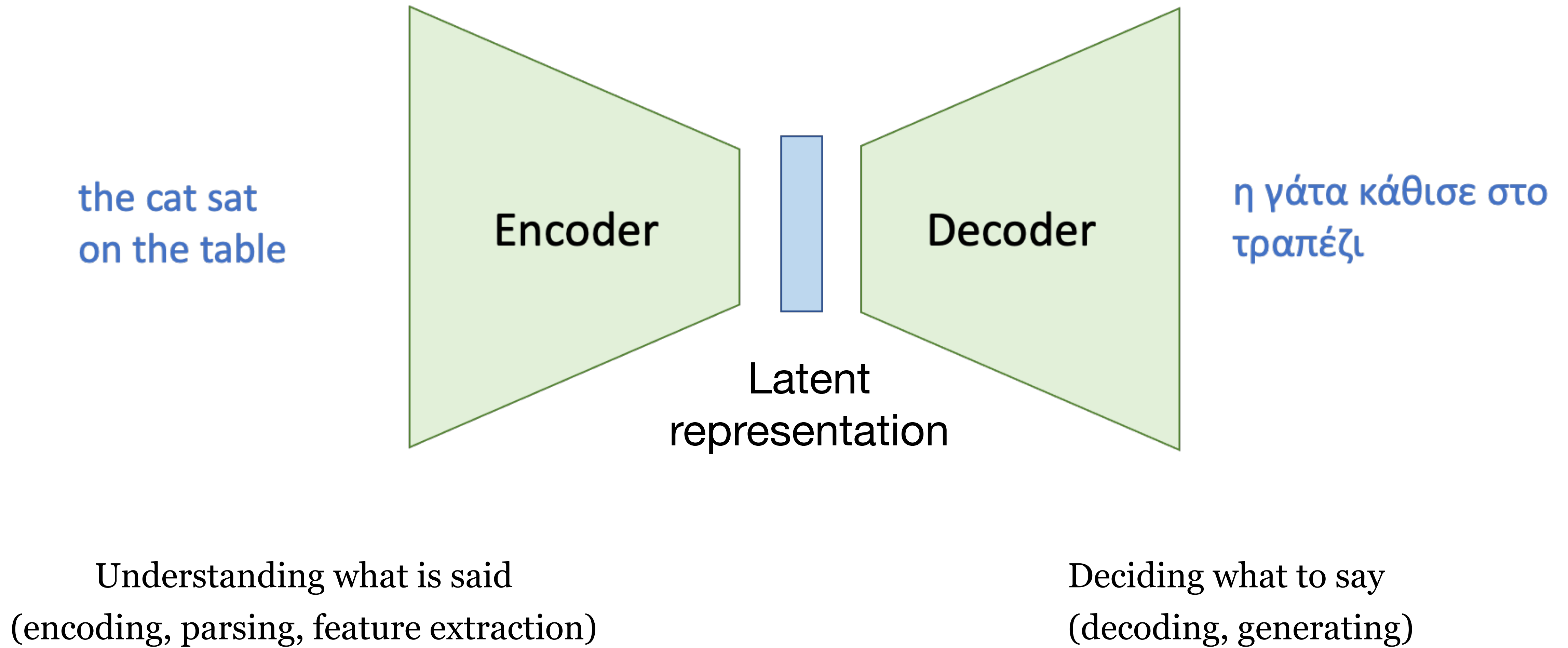


Transformers



Data hungry, compute intensive → Use pretrained models and then fine-tune on limited data

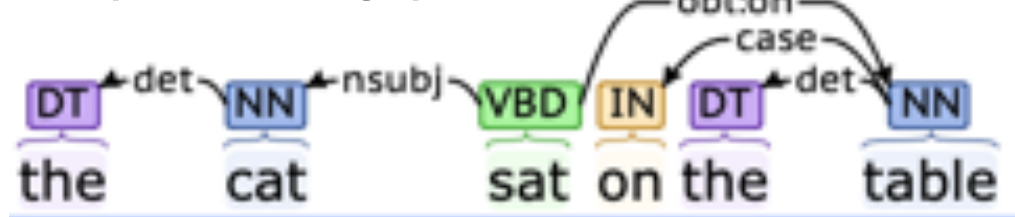
Encoder-Decoder Model



How to **represent** language?

the cat sat
on the table

Dependency parse



Encoder

Latent
representation

Decoder

η γάτα κάθισε στο
τραπέζι

Image

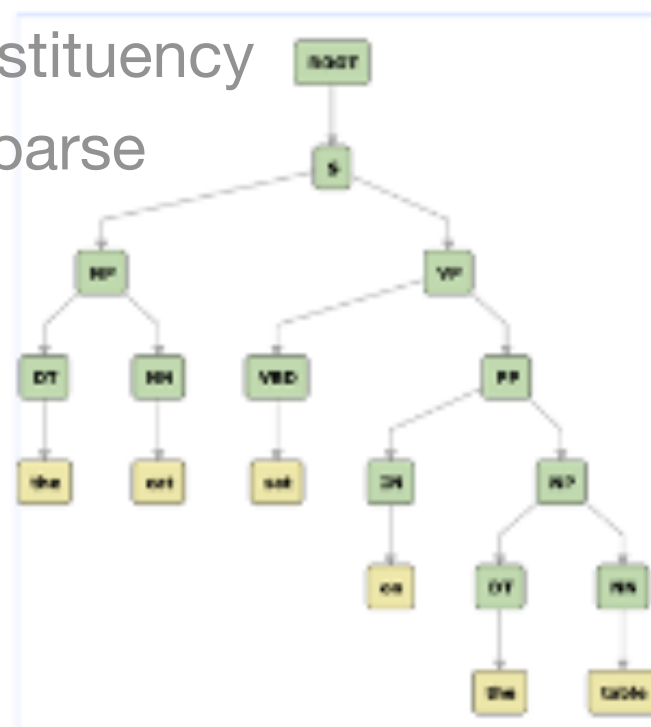


What kind of representation should go here?
Structured? Unstructured? Grounded?

$$L = \begin{bmatrix} \vdots & \vdots & \vdots & \dots & \vdots & \vdots \end{bmatrix}_n \quad \text{Tensor}$$

the cat mat ...

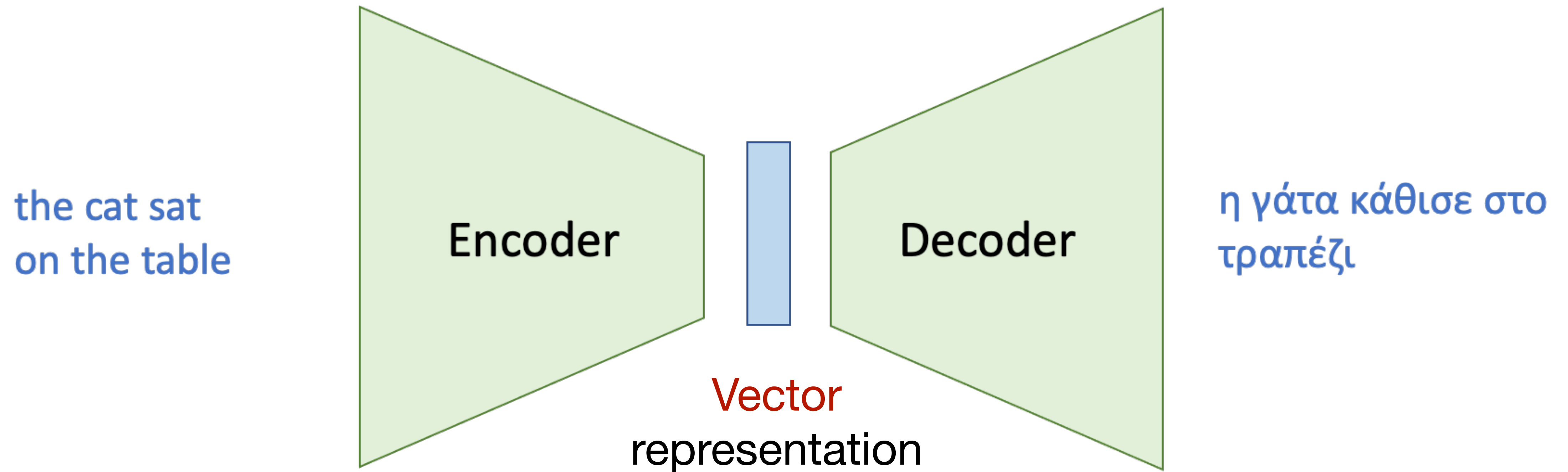
Constituency
parse



Lambda expression:

$((\lambda x . (\lambda y . x)) (\lambda z . z)) (\lambda a . a)$

Vector based representation



Common choice: flat unstructured vector of real numbers

- easy to work with
- well defined mathematical operations
- can be used to measure if two things are similar or not

How to **encode** language?

What is this function that takes the sentence and converts it into a vector?

the cat sat
on the table

Encoder

Vector
representation

Properties we want

- Be able to represent a single word
- Be able to represent the meaning of a sentence as a composition of the meaning of each word

Understanding what is said
(encoding, parsing, feature extraction)

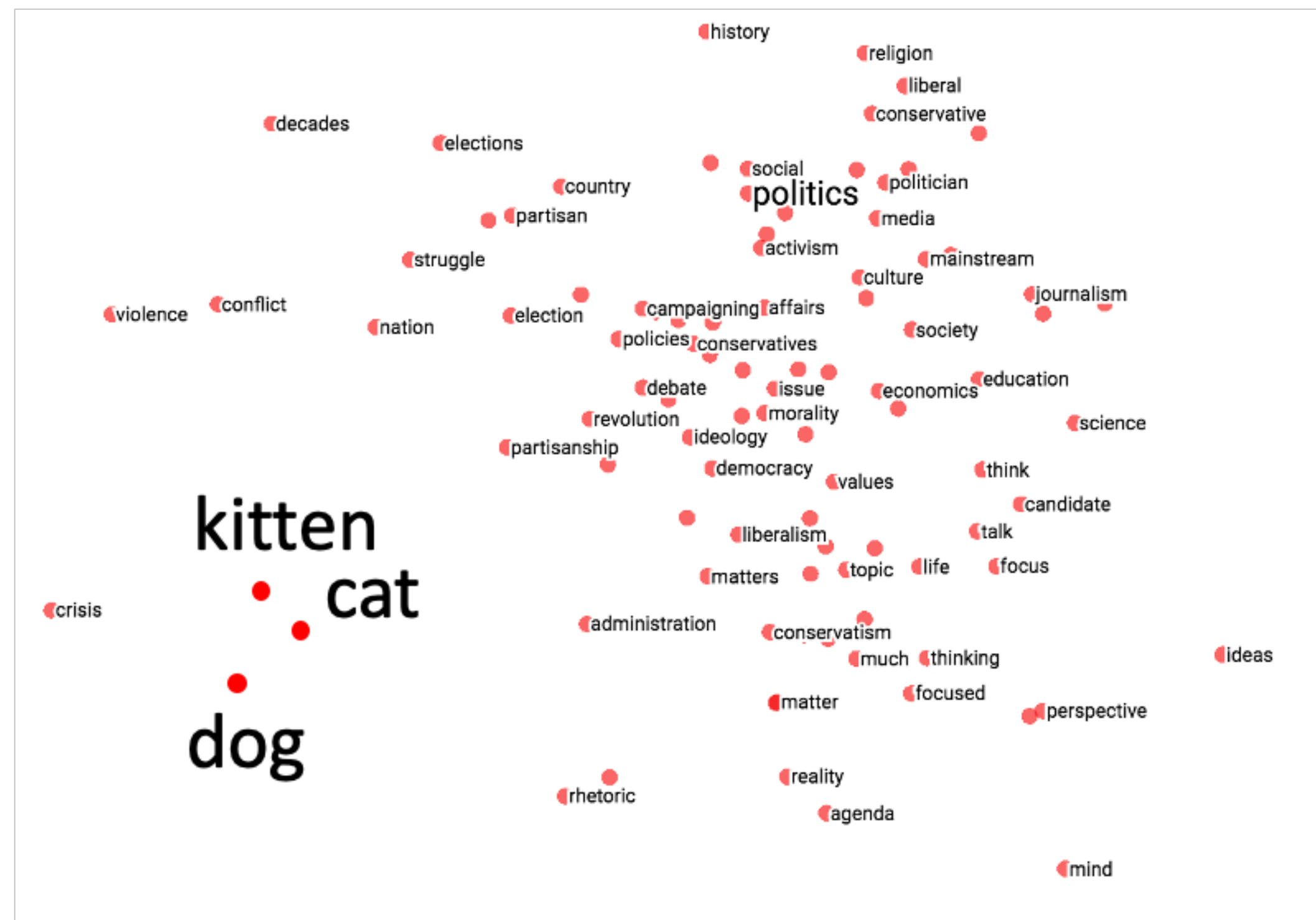
How to learn representations for words?



“cat”



“dog”



Use context to represent words

...government debt problems turning into **banking** crises as happened in 2009...

...saying that Europe needs unified **banking** regulation to replace the hodgepodge...

...India has just given its **banking** system a shot in the arm...

These **context words** will represent **banking**

how to learn a dense vector representation that can be used to **predict** words from their context

- Predict what goes next

The cat sat on the

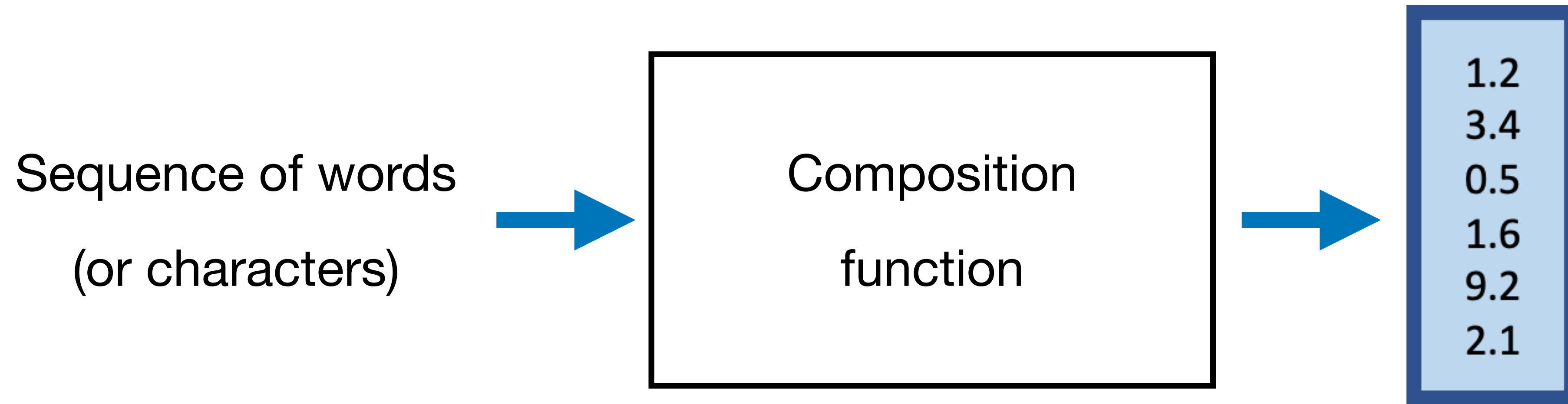
LM

- Fill in the blank

A bottle of _____ is on the table.

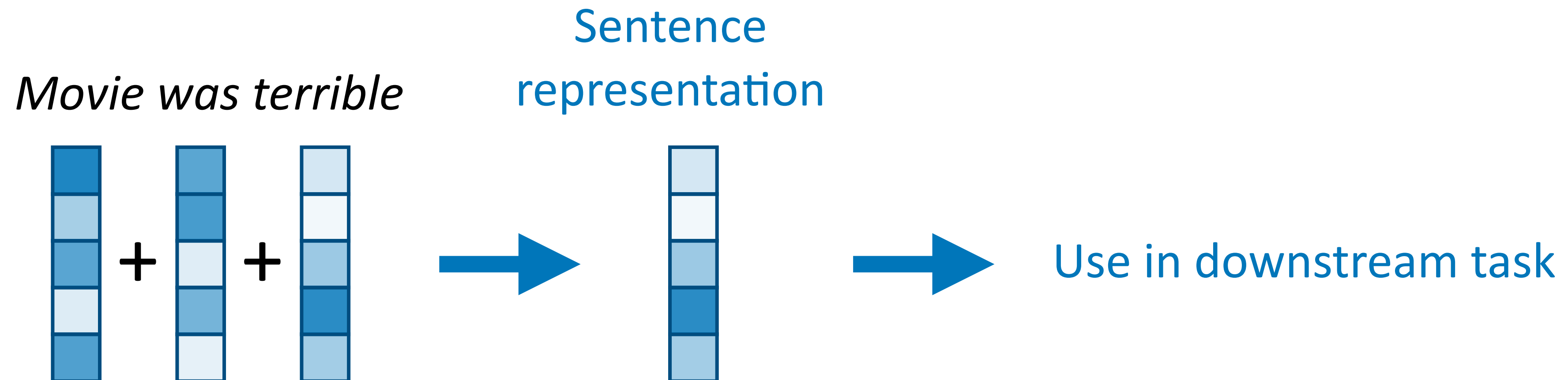
MLM

How to **compose** language?

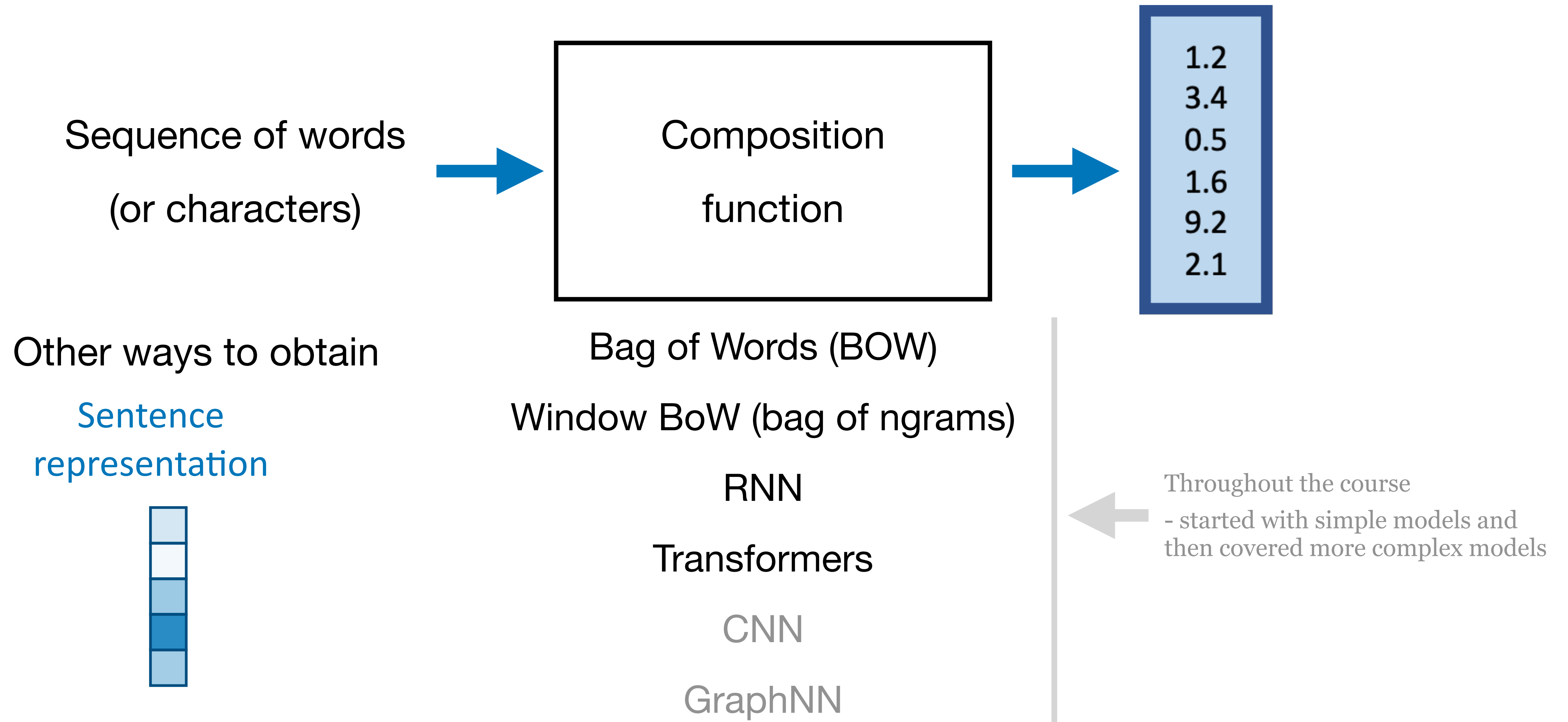


Simplest: take weighted average

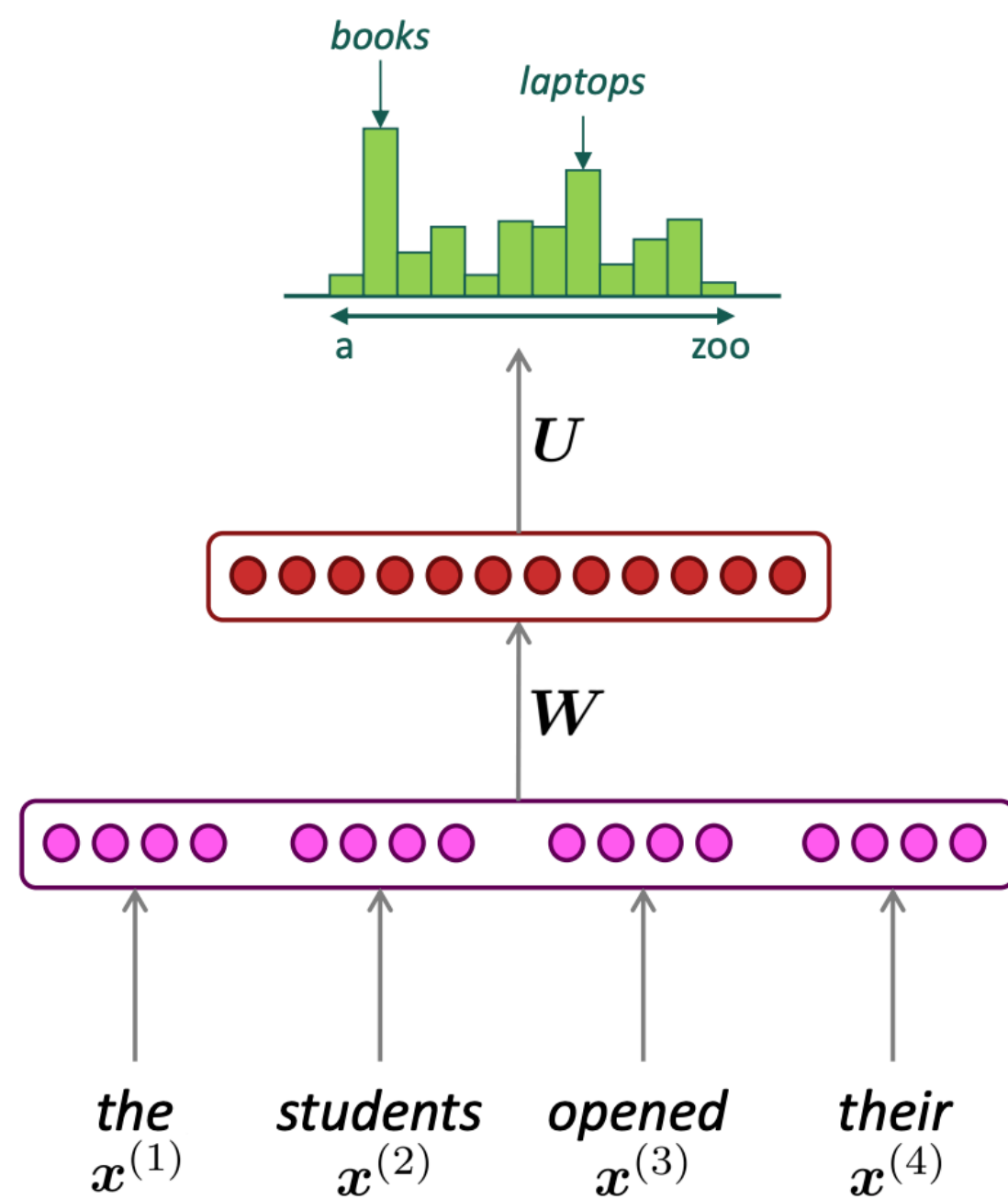
Example:



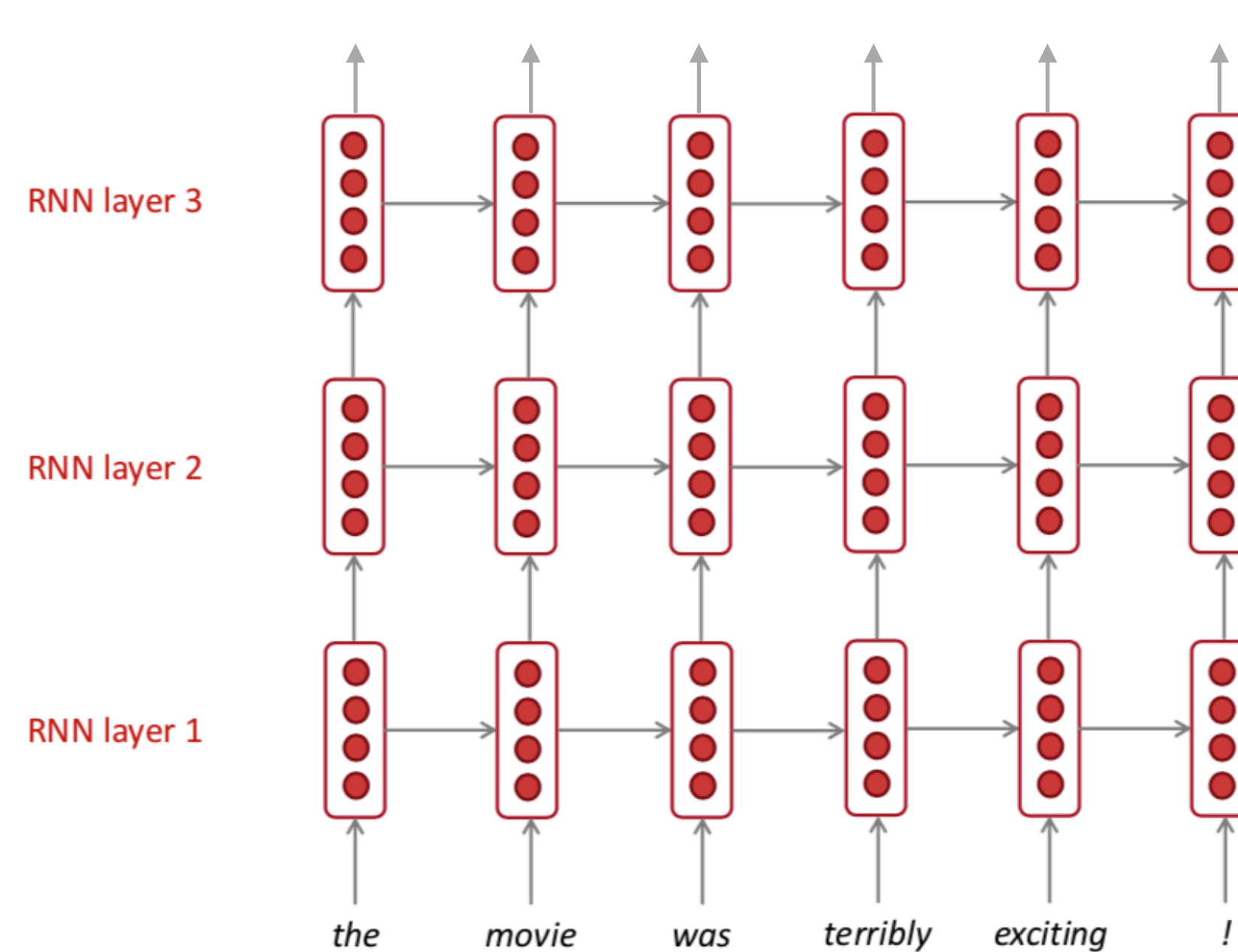
How to **compose** language?



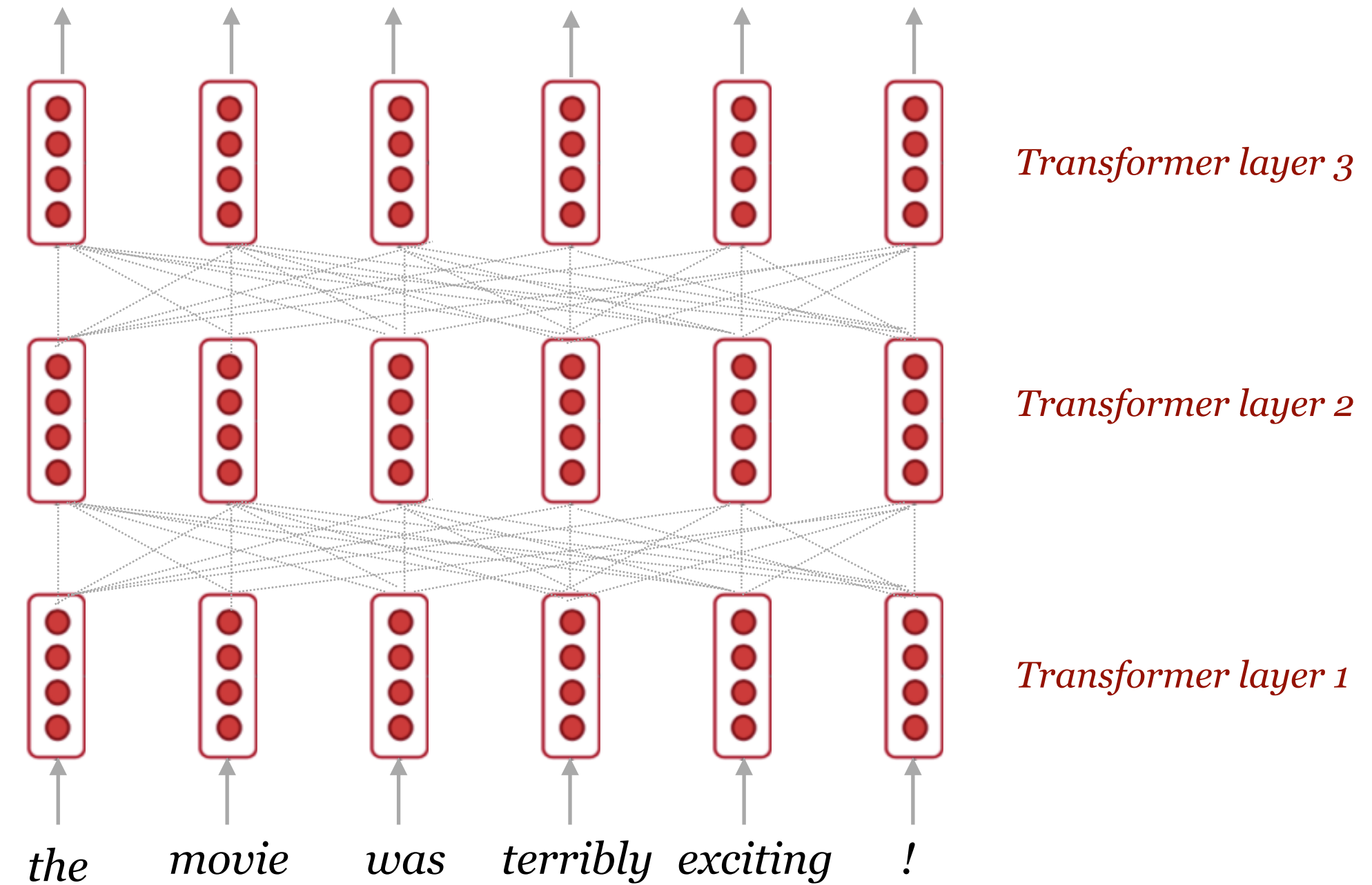
FFN vs RNNs vs Transformers



FFN



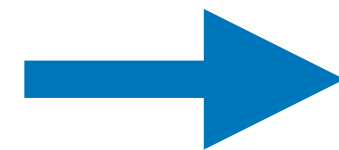
RNN



Transformer

How to use the learned **representation**?

What do we do with this vector representation after we get it?



Use in downstream task

Vector
representation

Do prediction: classify as spam/not spam

Use to generate text (also known as **decoding**)

Can also be used to generate other stuff (like images!)

How to **decode** language?

How do we generate text from this?

Auto-regressive text-generation

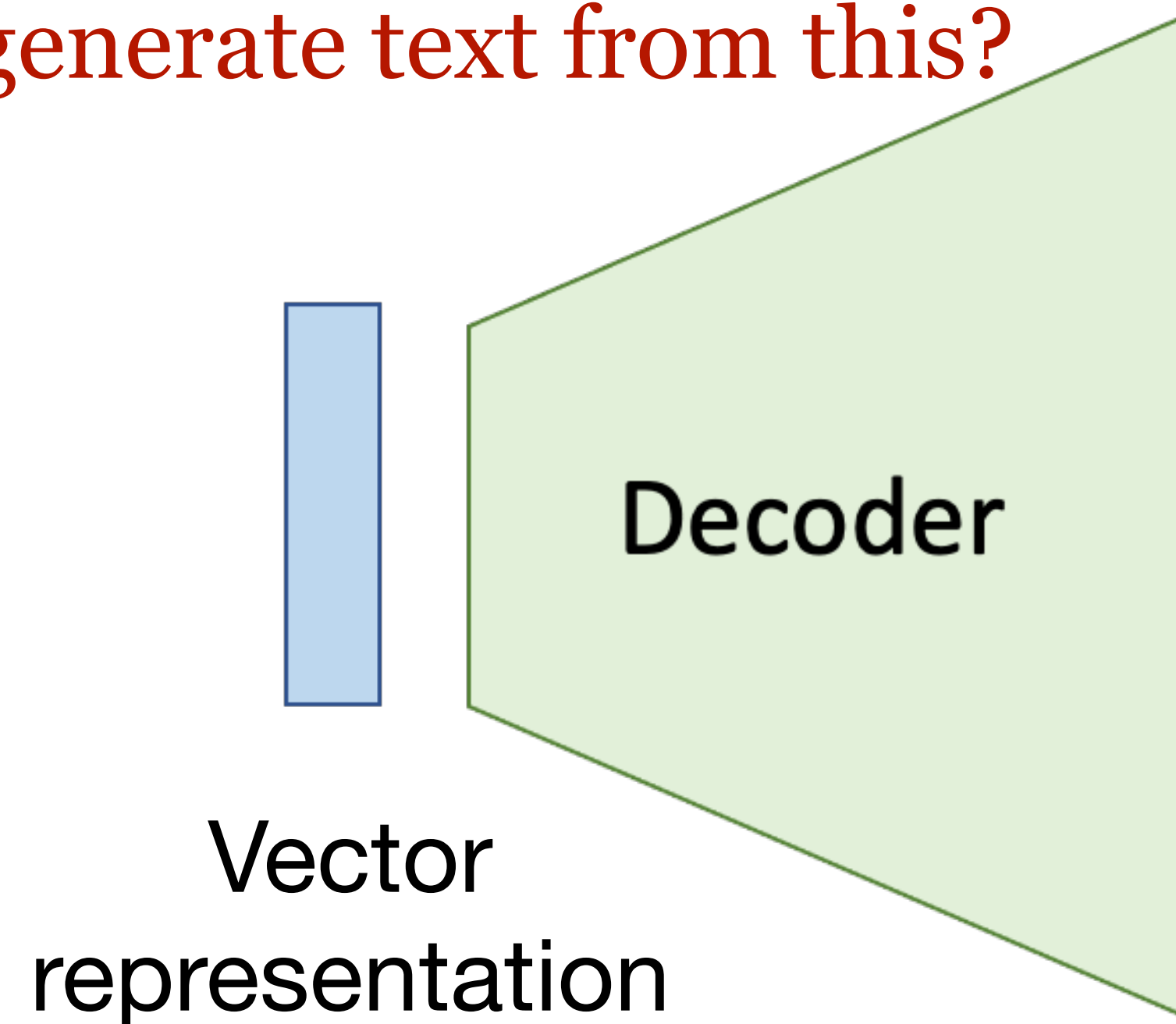
- Predict one word at time
- Big classification problem
- Can predict word from vocabulary or copy from somewhat else

Different training strategies

- Maximum likelihood estimation (cross-entropy loss for classification)

Different decoding strategies

- Greedy, Beam search, Sampling



Deciding what to say
(decoding, generating)

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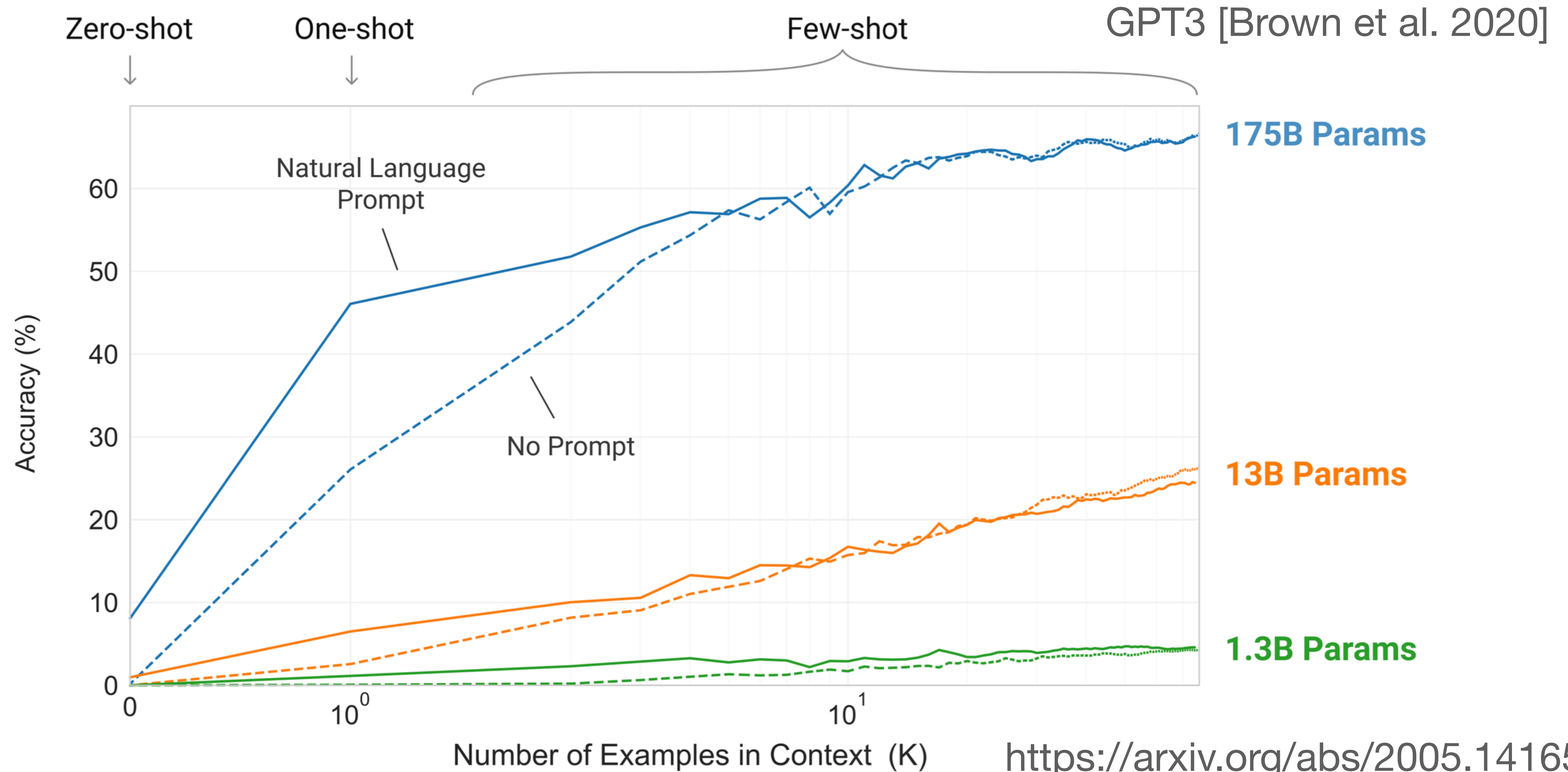
LLMs

- Prompting
- Efficient fine-tuning
- Pre-training
- Post-training

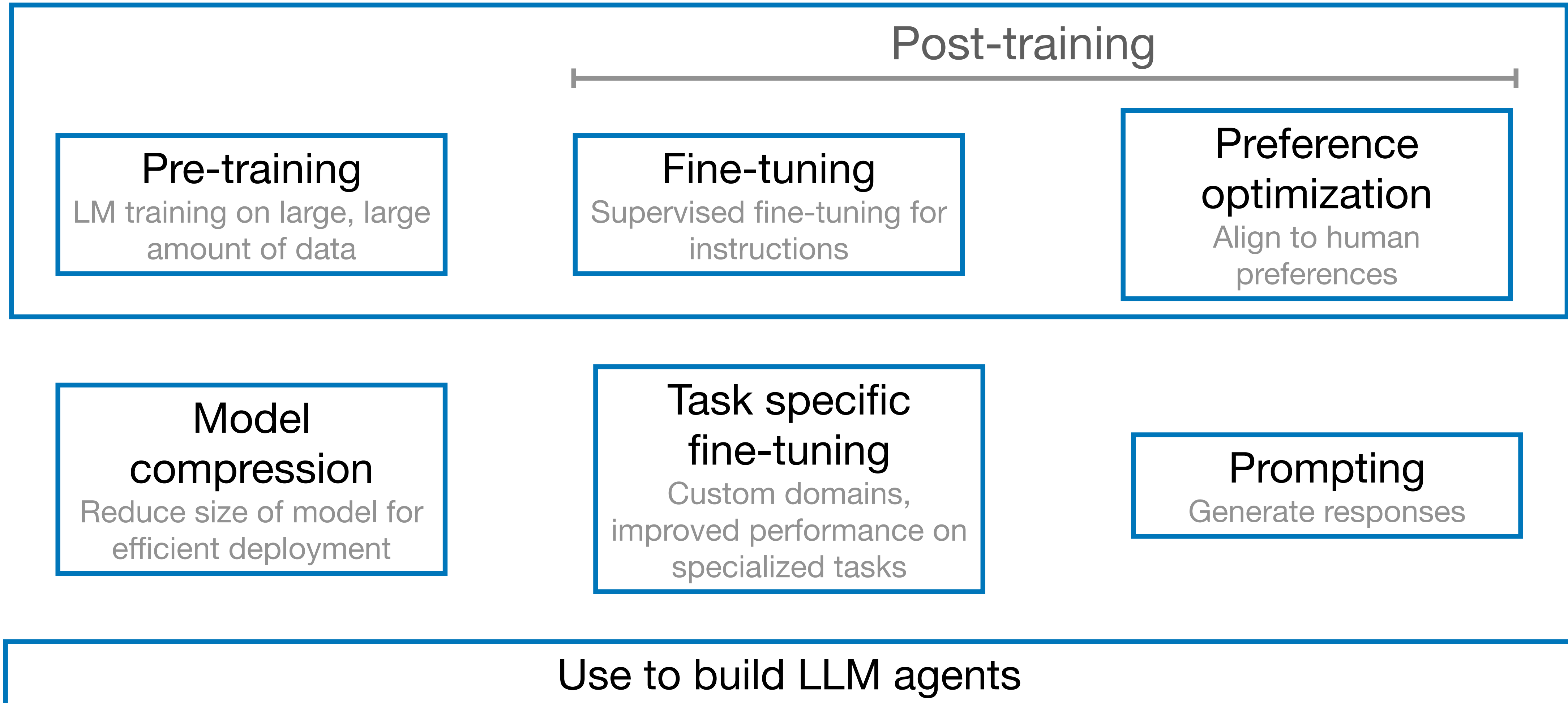
Applications and tasks

- Machine translation, text generation, question answering, grounding

Emergence of capabilities in LLMs

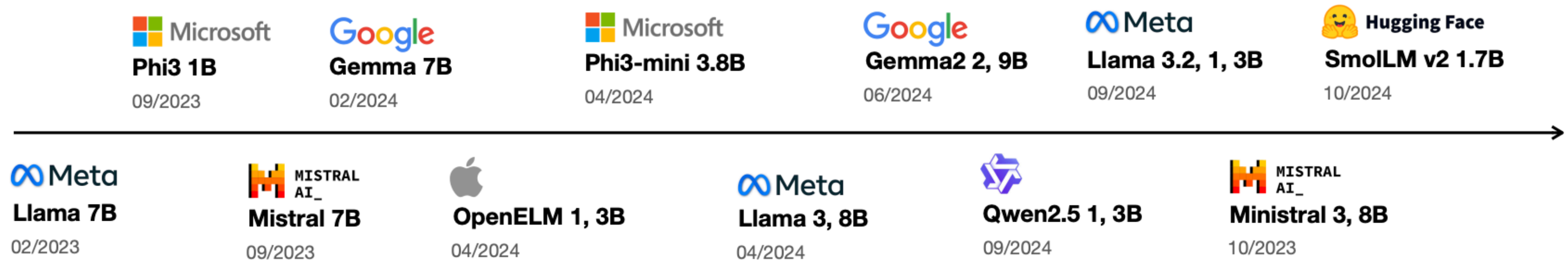


SoTA methods: can use zero-shot/few-shot prompting, or fine-tune



Small language models

- SLM: language models <10B



Reduce model parameters and size through

- Pruning
- Distillation
- Quantization

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LLMs

- Prompting
- Efficient fine-tuning
- Pre-training
- Post-training

Applications and tasks

Limited coverage of applications

- Machine translation, text generation, question answering, grounding

Guest Lectures



Issam Laradji

Agentic AI



Jialin Song

Jailbreaking LLMs



Mike Lu

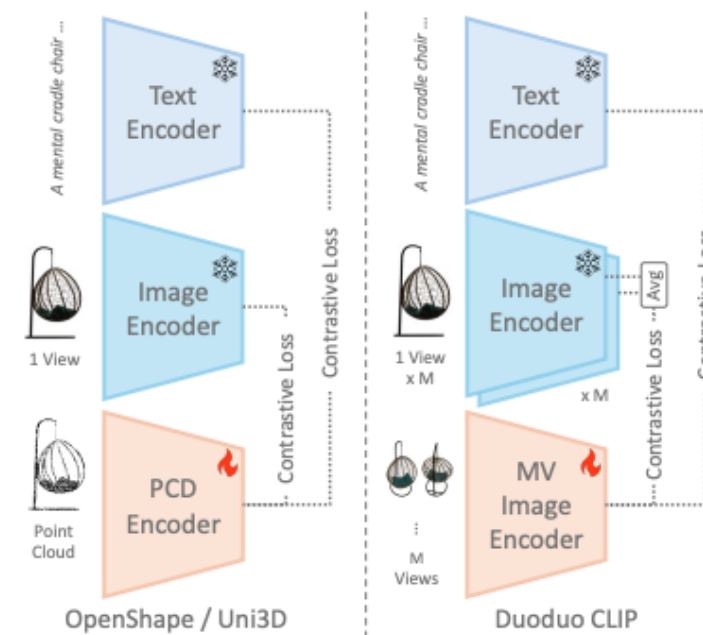
AI4Math

TA presentations

Text and 3D
Representation Learning



Qirui Wu



Semantic Representation
for Robots



Sonia Raychaudhuri



Text-to-Scene
Generation

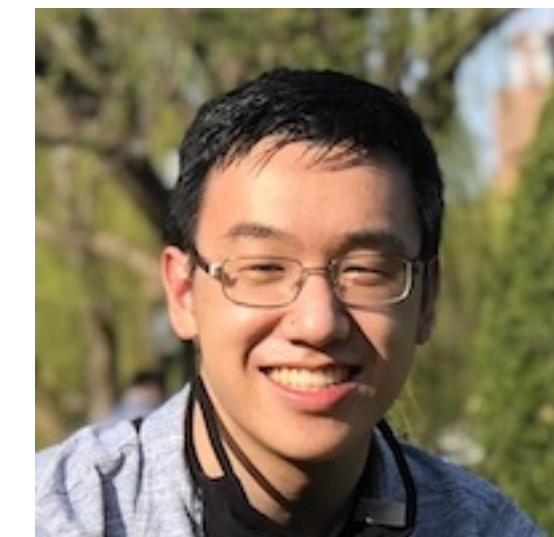


Xiaohao Sun

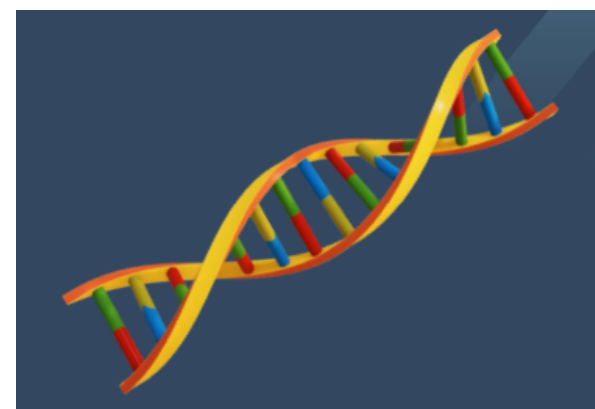
A 1b1b apartment of a researcher
who has a cat.



LLMs for
modeling DNA



Austin Wang



Topics in NLP research

- Dialogue and Interactive Systems
- Discourse and Pragmatics
- **Generation** and Summarization
- Information Extraction
- Question Answering
- Information **Retrieval**
- Language Resources and **Evaluation**
- **Language and Vision**
- Linguistic and Psycholinguistic Aspects of CL
- **Machine Learning for NLP**
- **Machine Translation**
- NLP for Web, Social Media and Social Sciences
- NLP-enabled Technology
- Phonology, Morphology and **Word Segmentation**
- Semantics
- Sentiment Analysis and Opinion Mining
- Spoken Language Processing
- **Tagging, Chunking, Syntax and Parsing**
- **Text Categorization** and Topic Models

Remaining challenges and topics in NLP

- Understanding and interpreting these large data-driven models
- Compositional generalization
- Grounded natural language understanding
- Unsupervised and few-shot learning
- Language acquisition and emergence of language
- Integrating domain-specific knowledge into NLP models
- Improving evaluation
- Building practical systems
- Efficient models
- Bias, trust, and ethics

Long-form context evaluation

Can modern LLMs consistently answer questions that require reasoning over long-context (e.g. novels)?

TRUE

Despite her skills as an Apoth, Nuisis is unable to reverse engineer the type of portal opened by the reagents key found in Rona's wooden chest.

Gemini Pro 1.5

<explanation>

The statement is false because the reagents key found in Rona's wooden chest was not given to Nuisis. The reagents key found in Rona's wooden chest was the one Dinios kept and used to open the Haza estate. The key given to Nuisis was the one found in the empty house near Rona's residence.

</explanation>

<answer>FALSE</answer>

✗

FALSE

By using her skills as an Apoth, Nuisis is able to reverse engineer the type of portal opened by the reagents key found in Rona's wooden chest.

<explanation>

The text states that Nuisis is unable to determine the type of portal opened by the reagents key found in Rona's wooden chest. She runs it under tests, but they are inconclusive.

</explanation>

<answer>FALSE</answer>

✓

Marzena Karpinska

One Thousand and One Pairs: A “novel” challenge for long-context language models [Karpinska et al. EMNLP 2024]

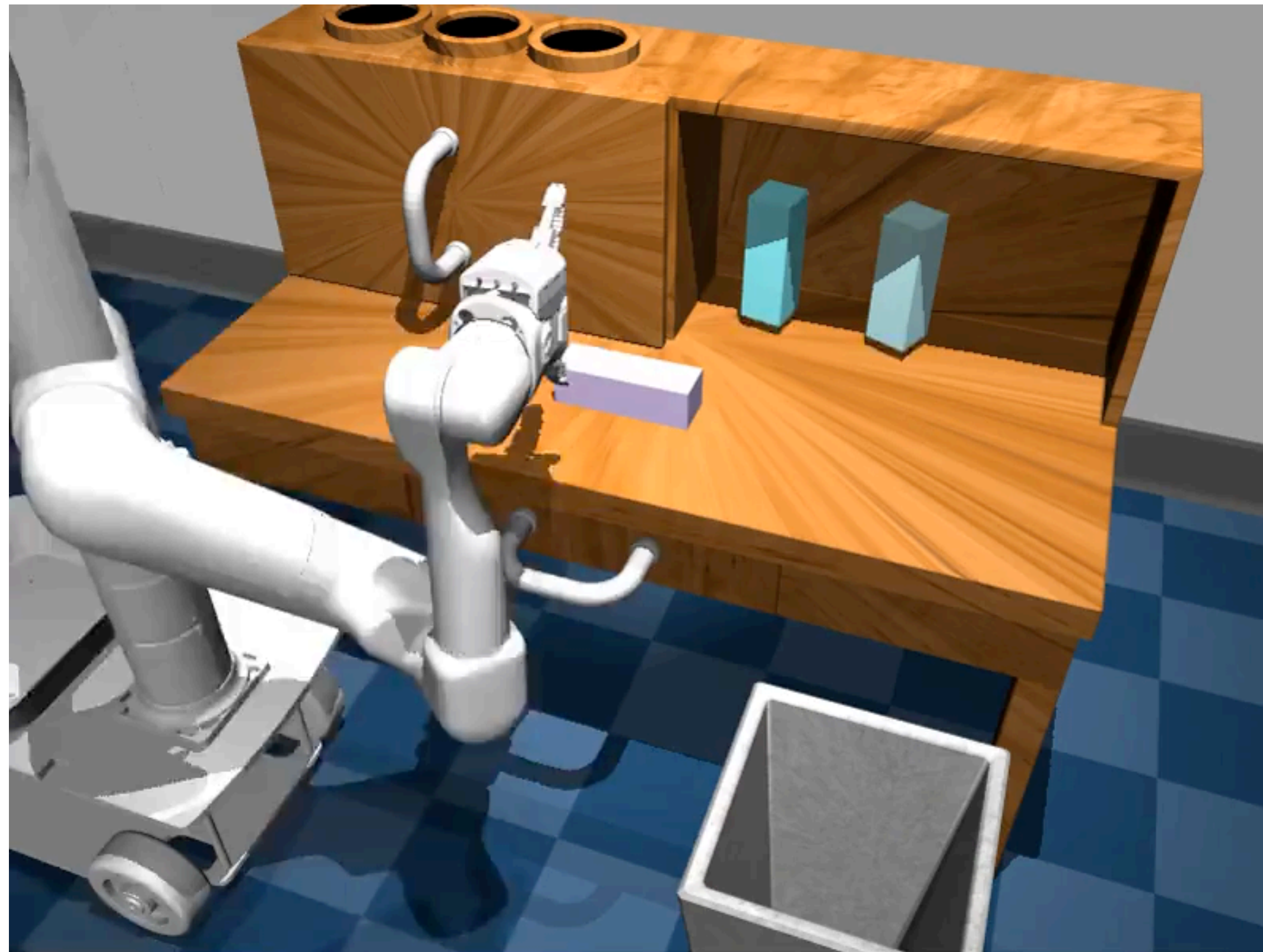
Culture specific questions

Governance and Society Tswana: Umbrella for Democratic Change (UDC) ke eng, e etelelswa pele ke mang mme e nale diparty tse kafe mo go yone? What is Umbrella for Democratic Change (UDC), who is its leader and how many parties fall under it?	Language and Literature Hebrew: למה יש אנשים שאומרים על רבים בלשון יחיד, למשל "המבצע" או "המבשר"? בניית תחביר: 100 נדרים? או "100 כדורים" או "100 כדורים"? Why do some people refer to plurals in singular form, for example, "go soldier" or "100 bullet were fired"? Is this proper Hebrew?	Food and Drinks Japanese: 仙台の牛タン弁当って 国産の牛タンですか? Is the beef tongue used in Sendai's beef tongue bento boxes sourced from domestic cattle?
Religion and Customs Fijian: Ni dua na lewe ni vanua daulesutale ki na nona vale ni sa buto na bogi, na cava e kilikili kina mo virika vakayawa sara na vatu sabera ni ko na curu taumada ki na nomu loma ni vale? When a person walks home late at night, why is it said that they should throw a stone as far as they can before entering their house?	History Kirundi: Mbega ko ata bimenyeshamakuru mu Burundi vyahahoze ku ntware ya camu, amatangazo y'i bwami bayamenyesha gute? Since there were no medias in Burundi during the Monarchy, how were the announcements from the palace widespread?	Economy and Industry Faroese: Hvi hava útróður og fiskivinna týðning i samfelagnum i dag? Why are boat fishing and the fishing industry important in today's society?
Education and Careers Korean: 경기외교 수원외교 어느 고등학교가 경쟁률이 높은가요? Which high school has a higher competition rate, Gyeonggi Foreign Language High School or Suwon Foreign Language High School?	Technology Kirundi: Nigam kuvira igurura ya mubura ikubashyamba imbi y'ikurusi? How do they traditionally treat malaria?	Media and Entertainment Arabic: ما هي قصة مسلسل "المنسي"؟ What is the story of the series "Al-Munsi"?
Geography, Tourism, and Climate Balochi: طینگ بولان کھلات و لڑو کرے منظرنامہ جون اثر انداز ہے۔ Where is Sleeping beauty mountain and how does it impact the tourism landscape?	Health Kirundi: Nigam kuvira igurura ya mubura ikubashyamba imbi y'ikurusi? How do they traditionally treat malaria?	Other Urdu: پشتانہ ویسی مٹوکی کی وجہ سے؟ Why do Pashtuns have light eyes?

CaLMQA: Exploring culturally specific long-form question answering across 23 languages [Arora et al. ACL 2025]

FUTURISM	Study: New York Times Has Published Extensive AI-Generated Articles	Mentions our paper
THE ATLANTIC	How AI Is Creeping Into The New York Times	Discusses our paper
WSJ	An AI Upheaval Is Coming for Media. This Journalist Is Already All In	Mentions our paper
PRESS GAZETTE	Study claims 9% of US newspaper articles at least partly AI generated	Discusses our paper
FORBES	Study Shows Experienced Humans Can Spot Text Created By AI	Discusses our paper
THE ECONOMIST	GPT, Claude, Llama? How to tell which AI model is best	Mentions our paper
TECH CRUNCH	Gemini's data-analyzing abilities aren't as good as Google claims	Discusses our paper
SLATOR	In Literary Translation, Humans Prefer Humans and Machines Prefer Machines	Discusses our paper

Grounded NLP / RoboNLP



now: **do not do anything**

next:

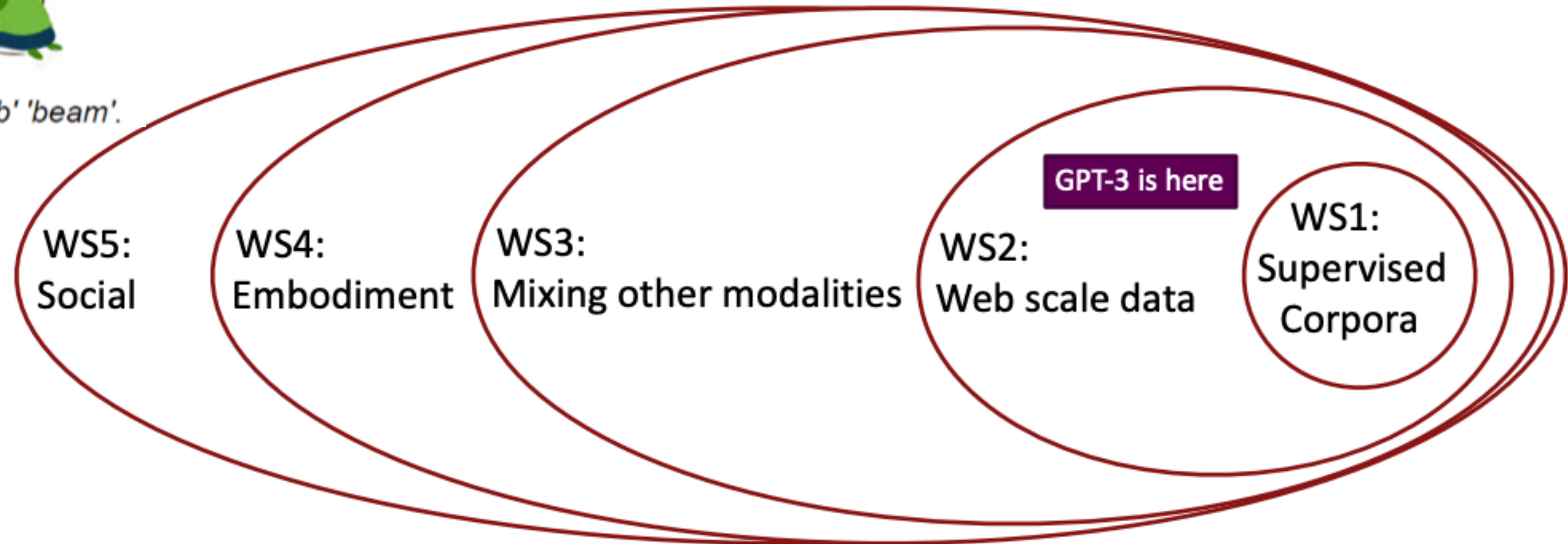
Language Conditioned Imitation Learning over Unstructured Data (<https://language-play.github.io/>)

Lynch and Sermanet, RSS 2021

Going beyond passive, supervised NLP



'block' 'pillar' 'slab' 'beam'.



Experience Grounds Language (https://www.youtube.com/watch?v=cQasYLUC_00)
Bisk et al, EMNLP 2020

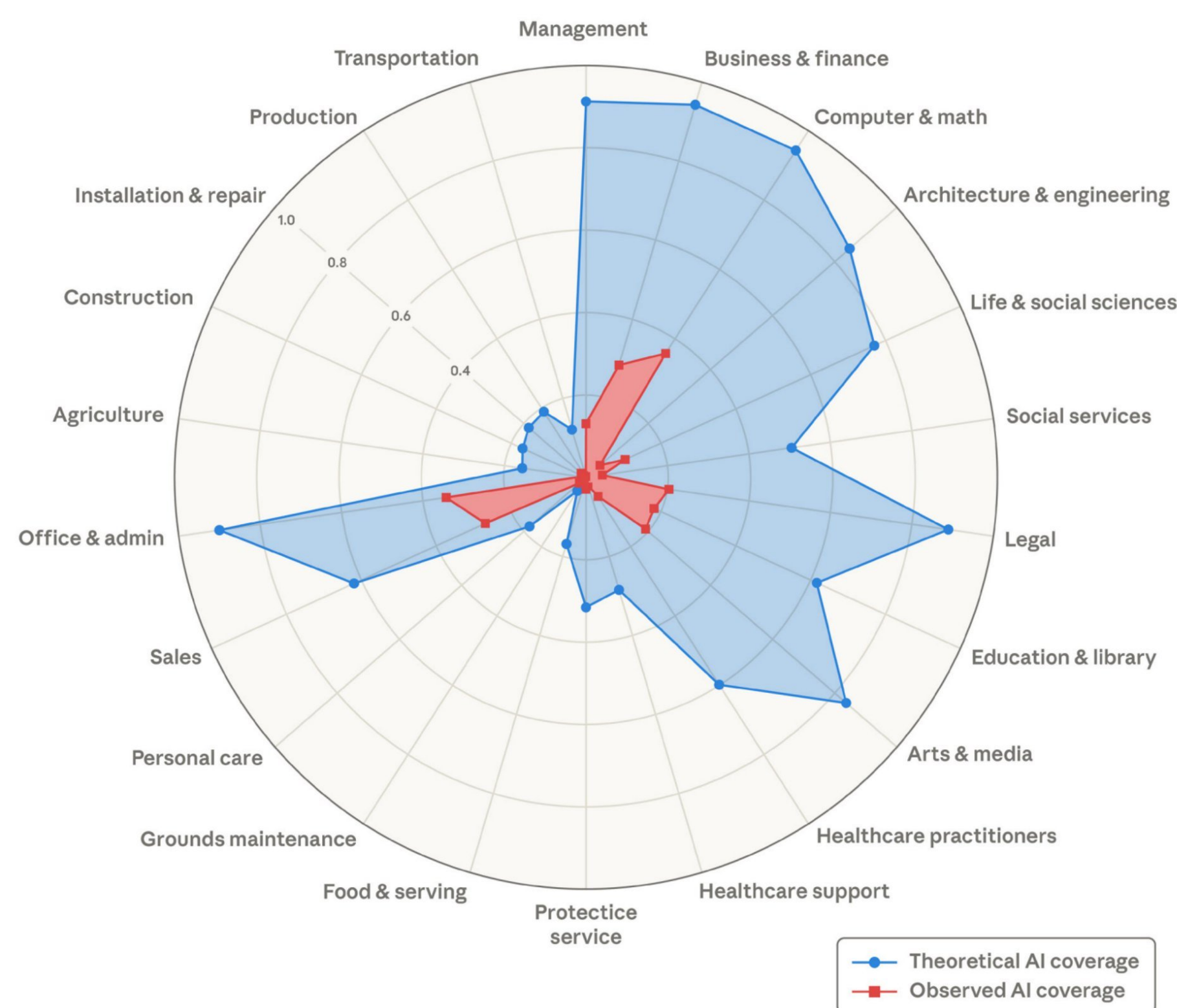
AI and society

Big topics, not just ML researchers

- How does LLMs and AI impact society?
 - How will it change society?
 - How will jobs be affected? How will education be affected?
 - Who are the stakeholders that are affected?
 - Can you trust what the LLMs are generating?
 - What about power consumption and energy requirements?

How LLMs and AI changing jobs?

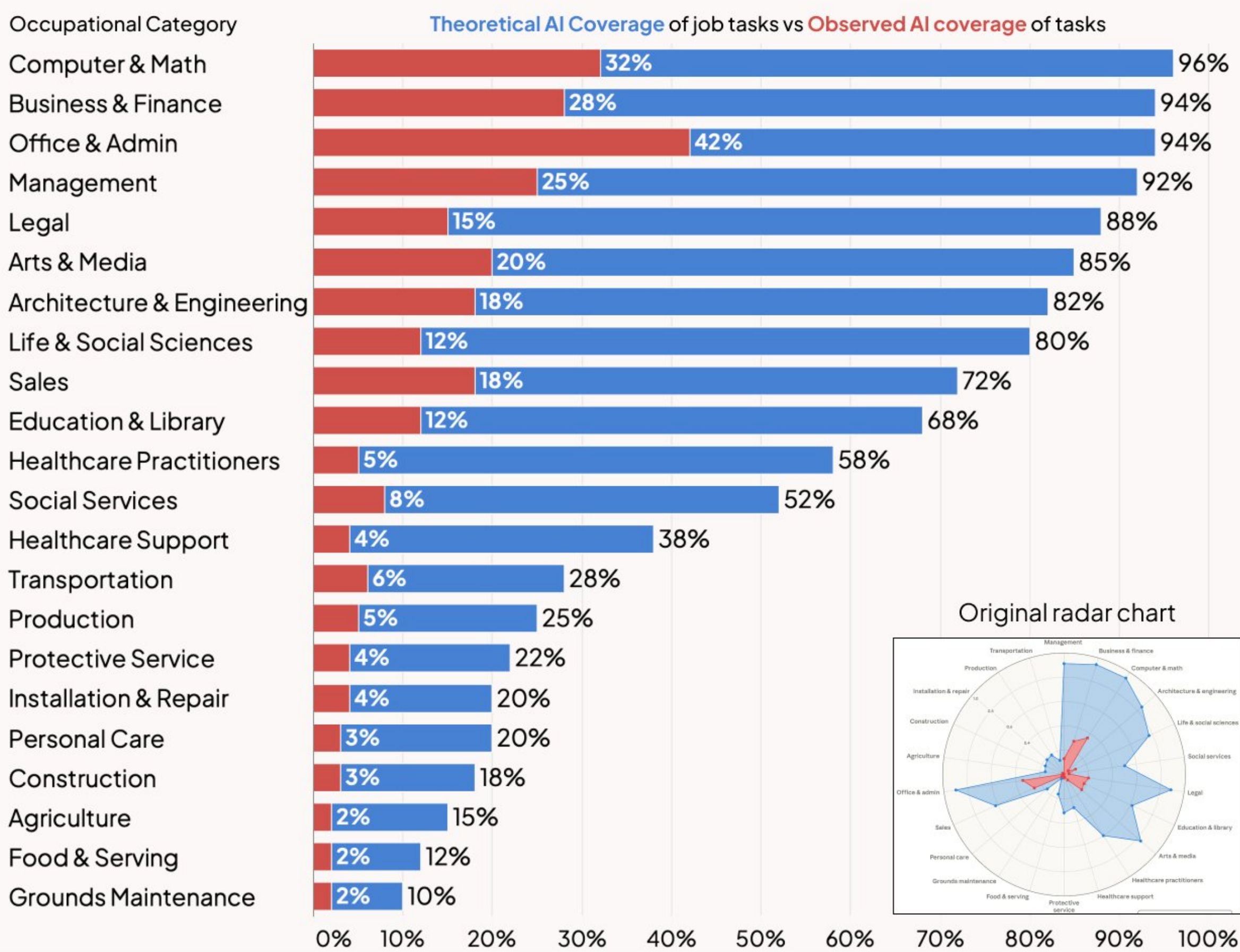
- AI can be used for tasks in many sectors



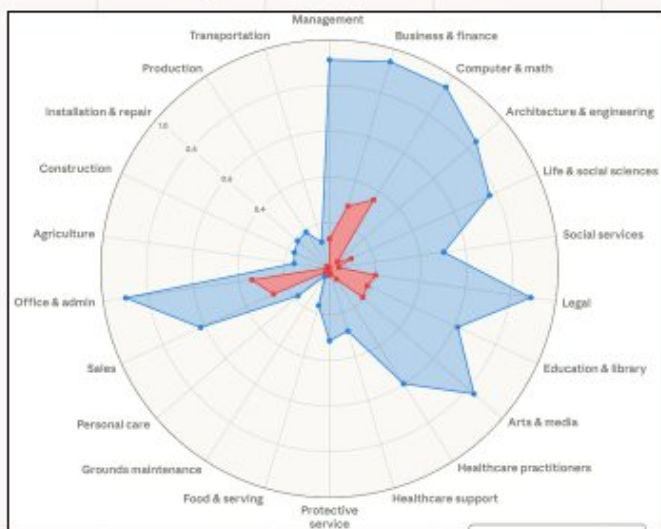
Theoretical capability and observed exposure by occupational category

Share of job tasks that LLMs could theoretically perform = **blue bars**

Anthropic's own job coverage measure derived from usage data = **red bars**



Original radar chart



<https://www.anthropic.com/research/labor-market-impacts>

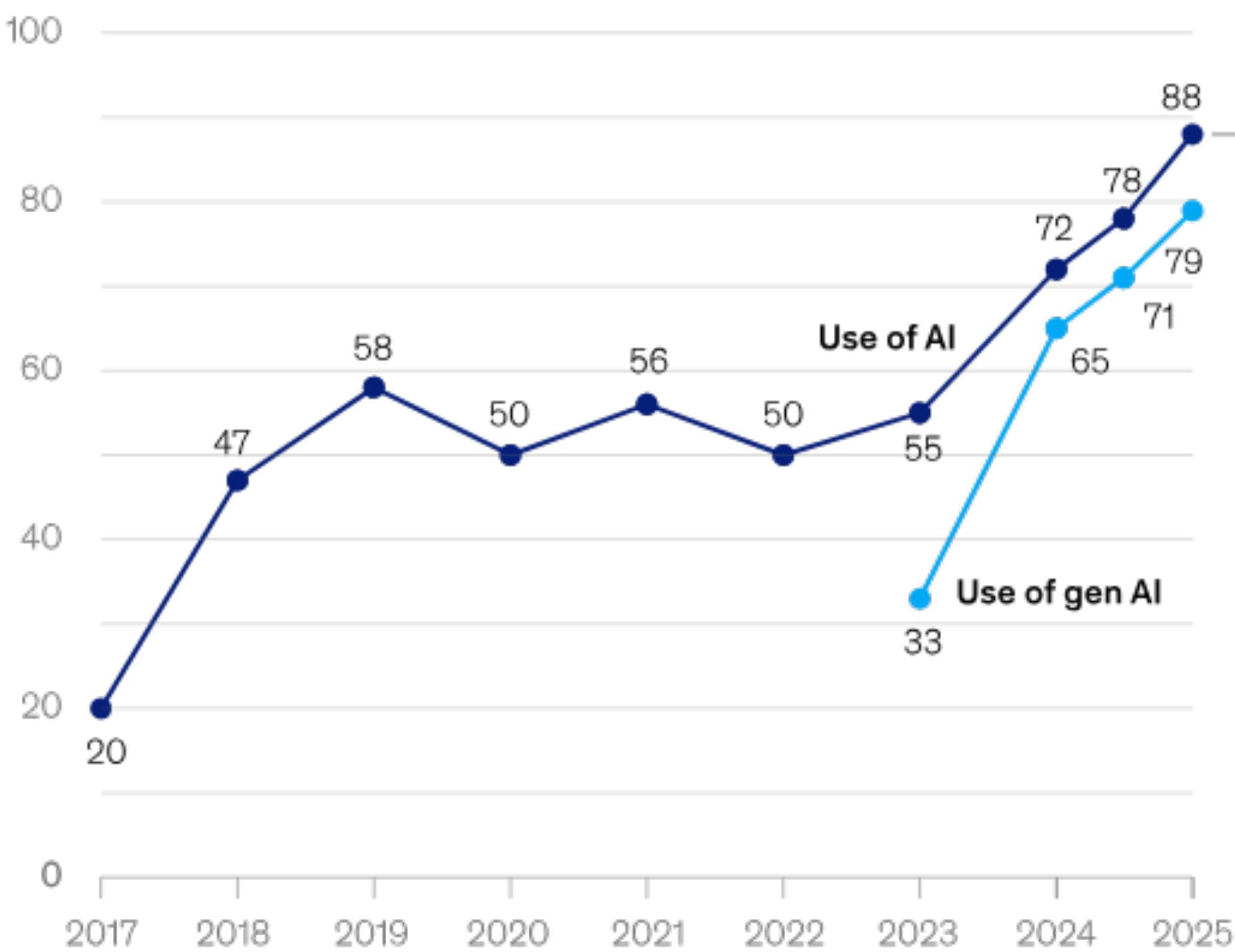
Data: <https://www.anthropic.com/research/labor-market-impacts> | Chart: Peter Walker

Companies are using AI

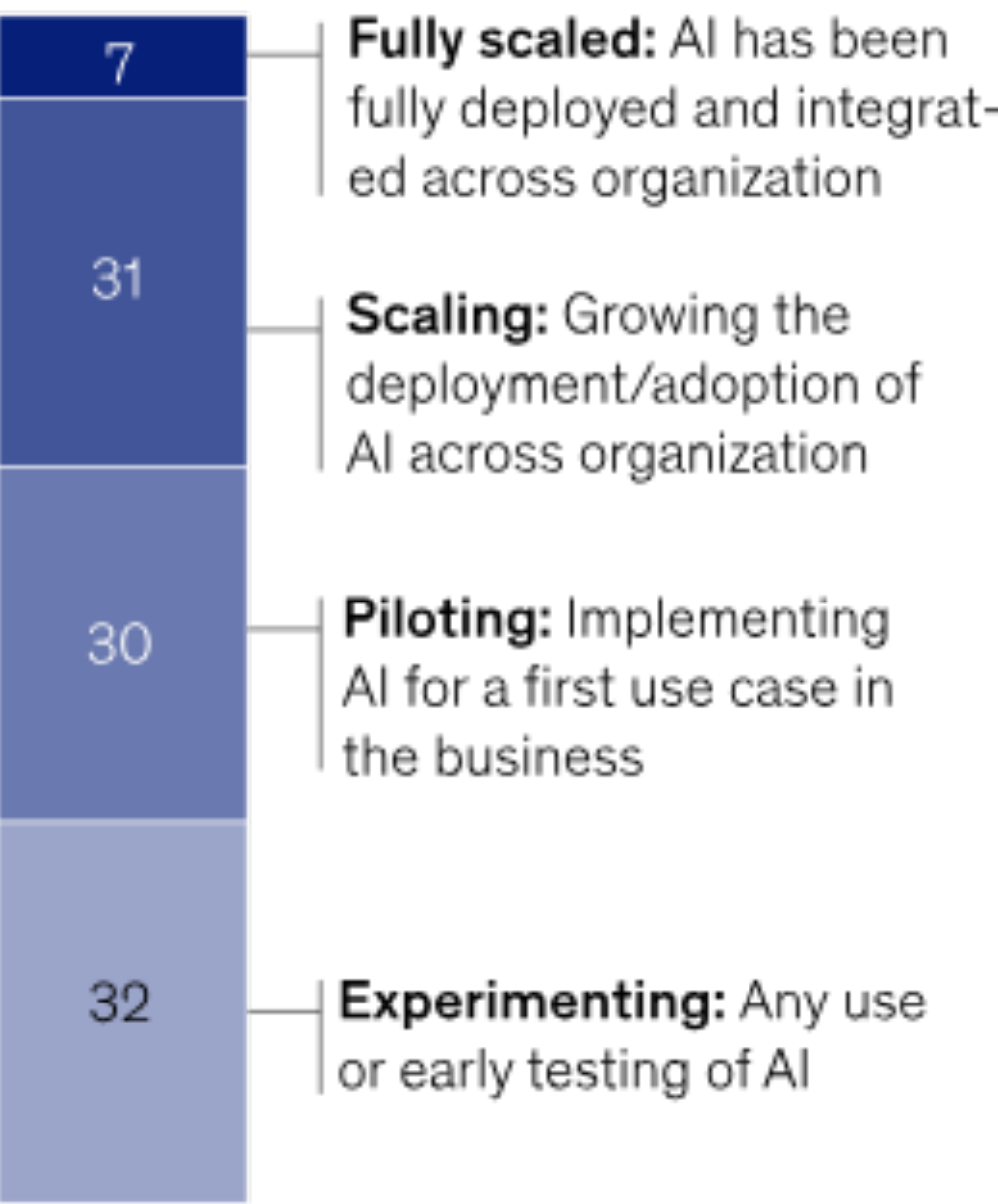
Reported use of AI in at least one business function continues to increase.

Use of AI by respondents' organizations, % of respondents

Organizations that use AI in at least 1 business function¹

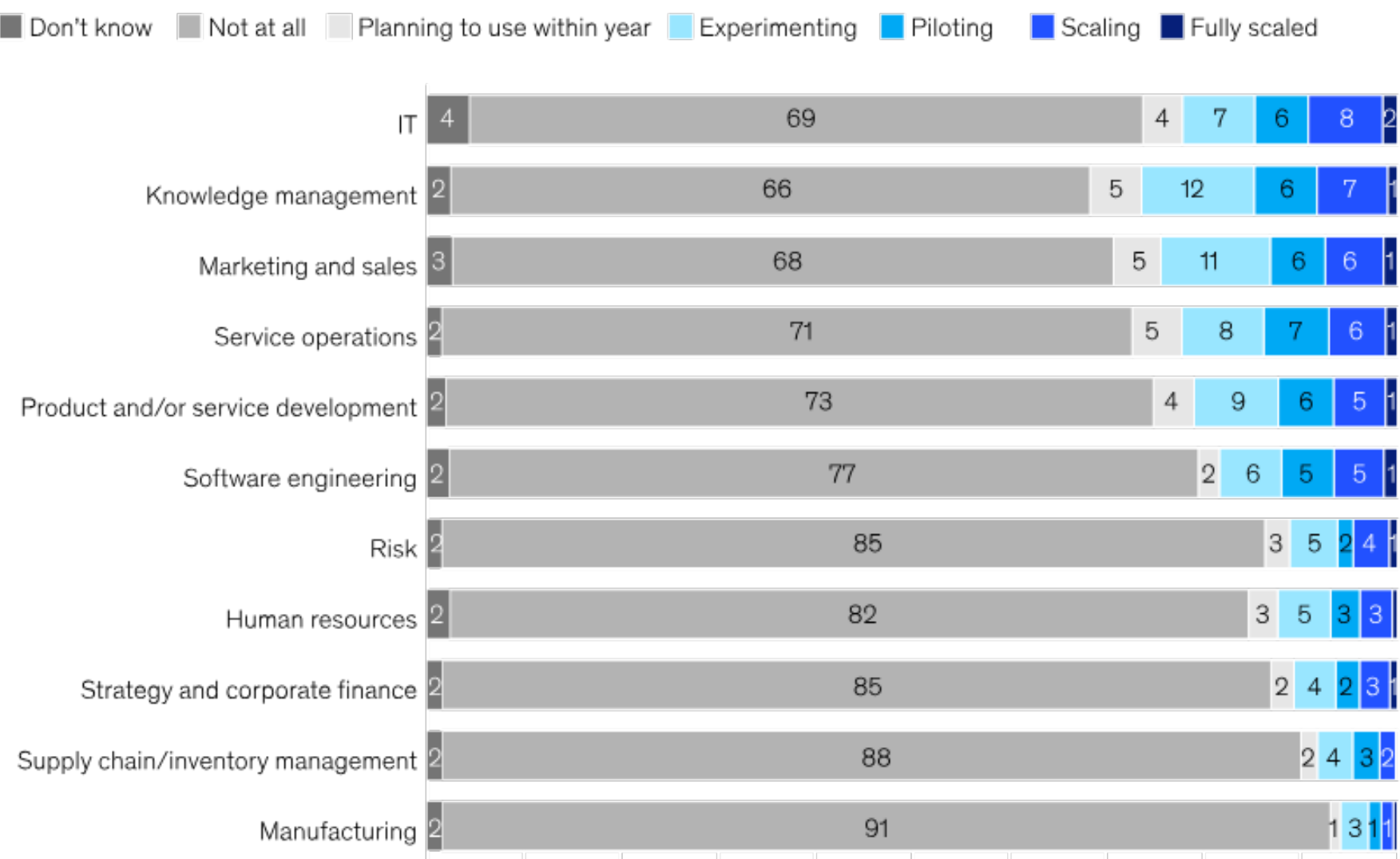


Phase of AI use among organizations using AI in 2025



No more than 10 percent of respondents report scaling AI agents in any individual function.

Phase of AI agent use at respondents' organizations, by business function,¹ % of respondents (n = 1,933)



Note: Figures may not sum to 100%, because of rounding.
¹Question was asked only of respondents who reported regular use of AI in the respective functions and was rebased to reflect the total sample.
Source: McKinsey Global Survey on the state of AI, 1,993 participants at all levels of the organization, June 25–July 29, 2025

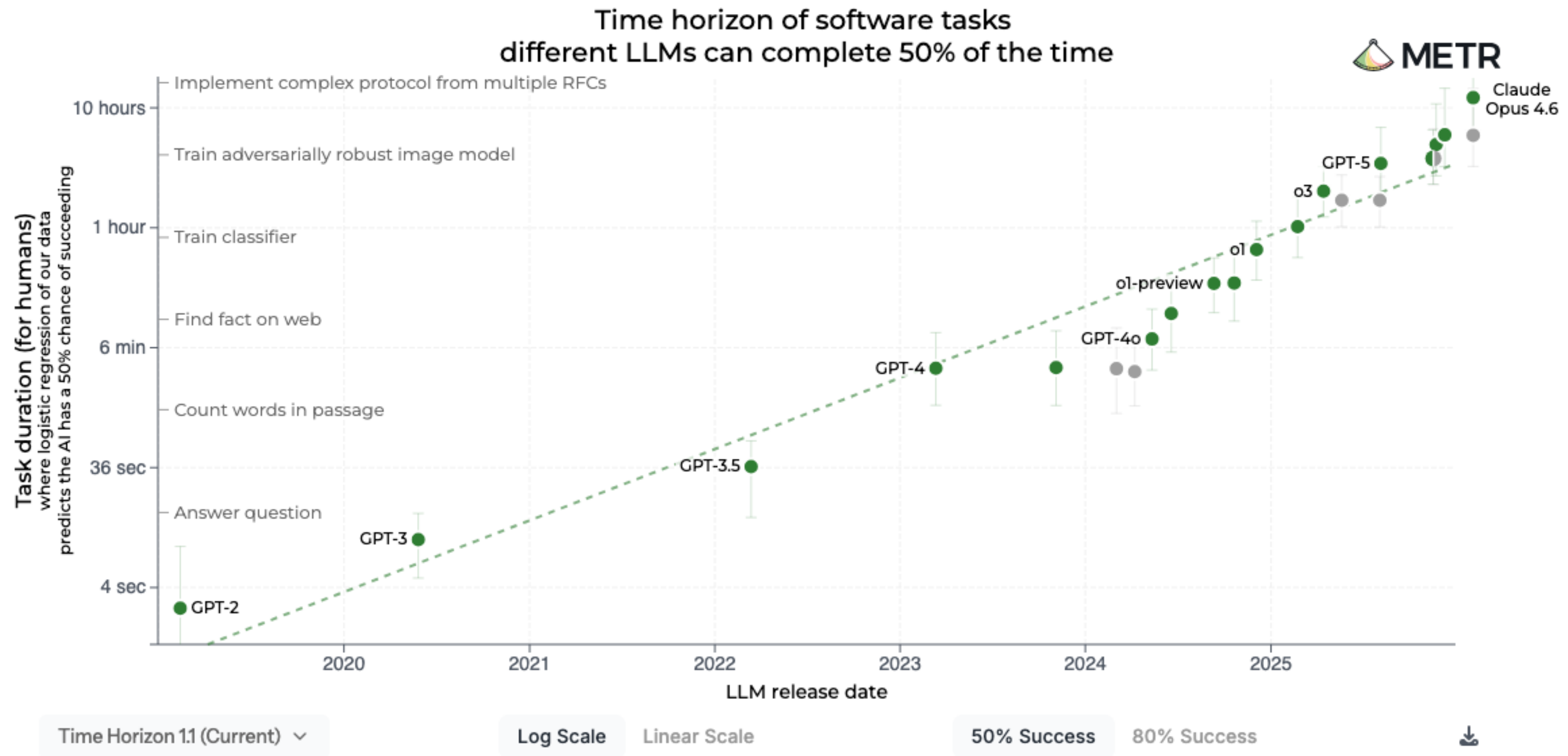
McKinsey & Company

- LLMs to write reports
- AI agents to automate tasks and workflow

¹In 2017, the definition for AI use was using AI in a core part of the organization's business or at scale. In 2018–19, the definition was embedding at least 1 AI capability in business processes or products. From 2020, the definition was that the organization has adopted AI in at least 1 function, and in 2025, the definition was regular use of AI in at least 1 function.
Source: McKinsey Global Surveys on the state of AI, 2017–25

AI for software

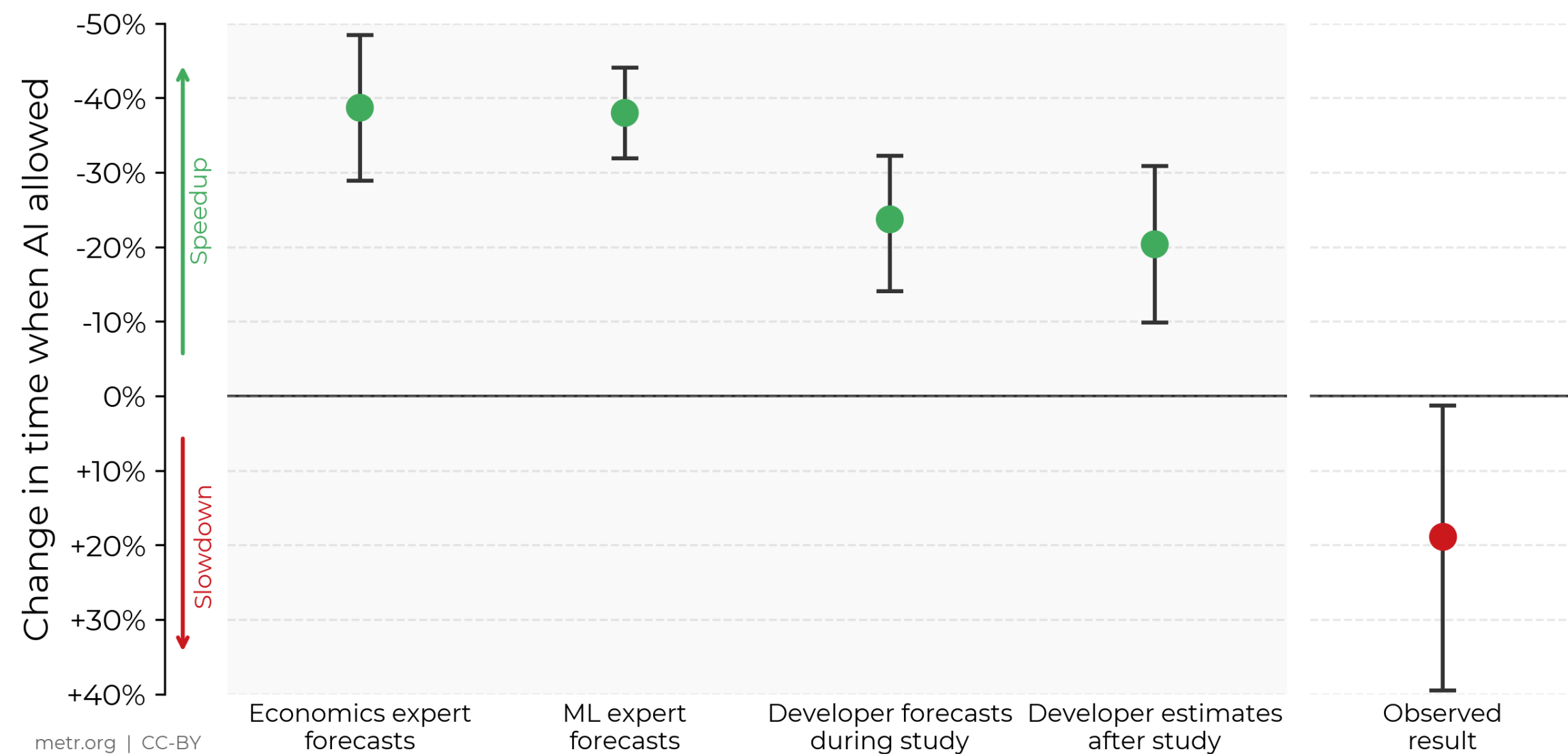
AI output quality vs. human experts: **12% → 83%** in under two years



<https://metr.org/blog/2025-03-19-measuring-ai-ability-to-complete-long-tasks/>

AI for software

2025: Developers over estimated the amount of time AI agents will help them save



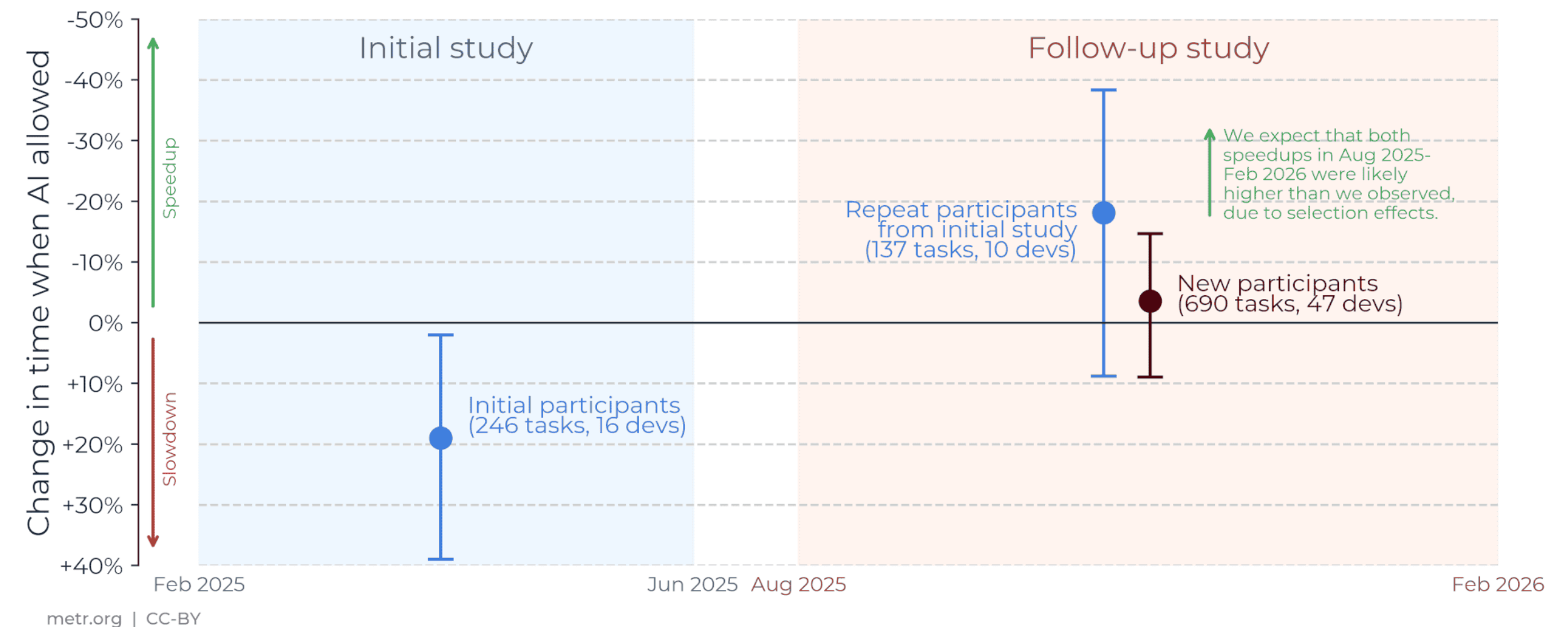
<https://metr.org/blog/2025-07-10-early-2025-ai-experienced-os-dev-study/>

2026: Developers don't want to code without AI assistance. AI is also better.

Late-2025 AI likely accelerates open-source developers, but selection effects make our follow-up results unreliable

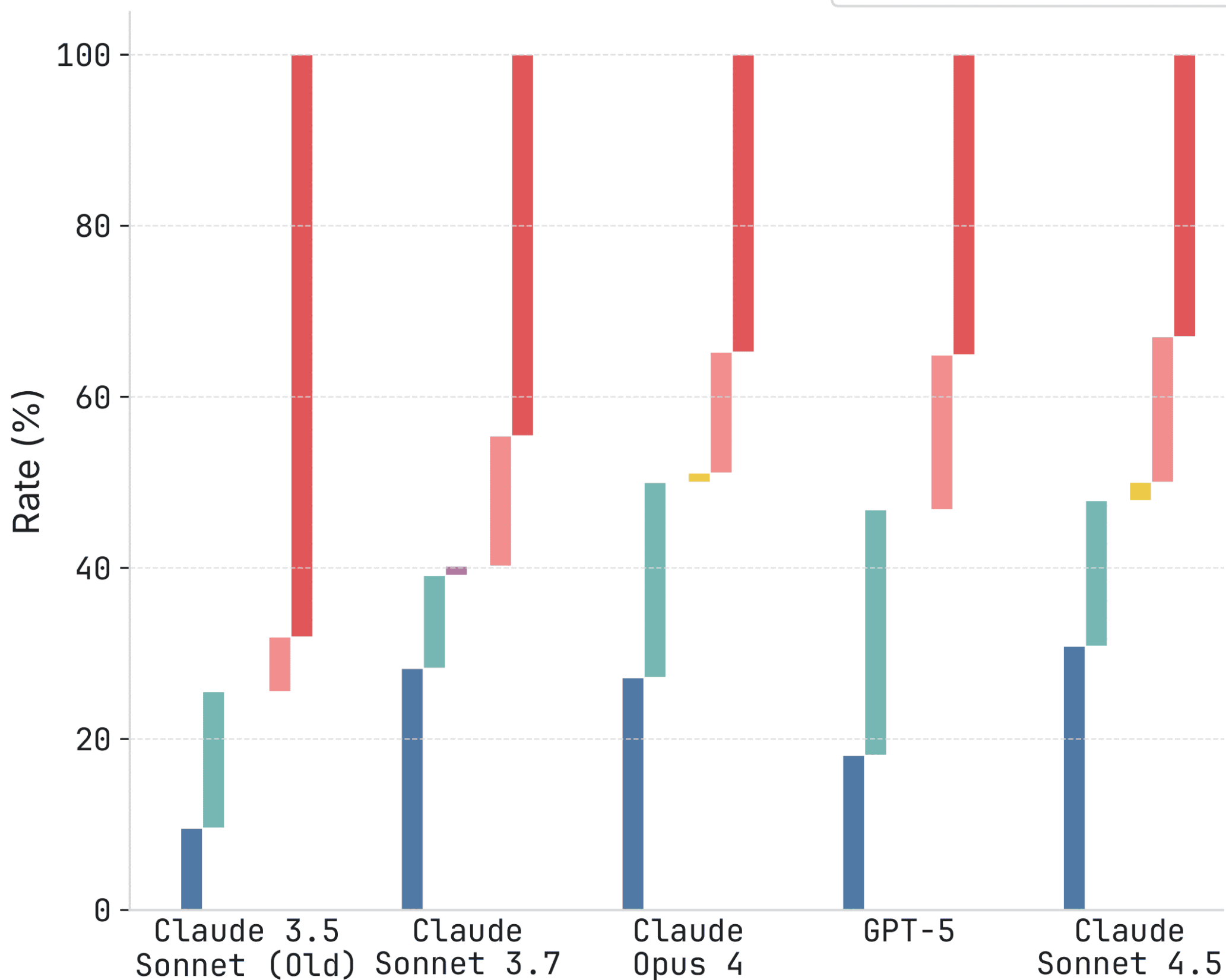
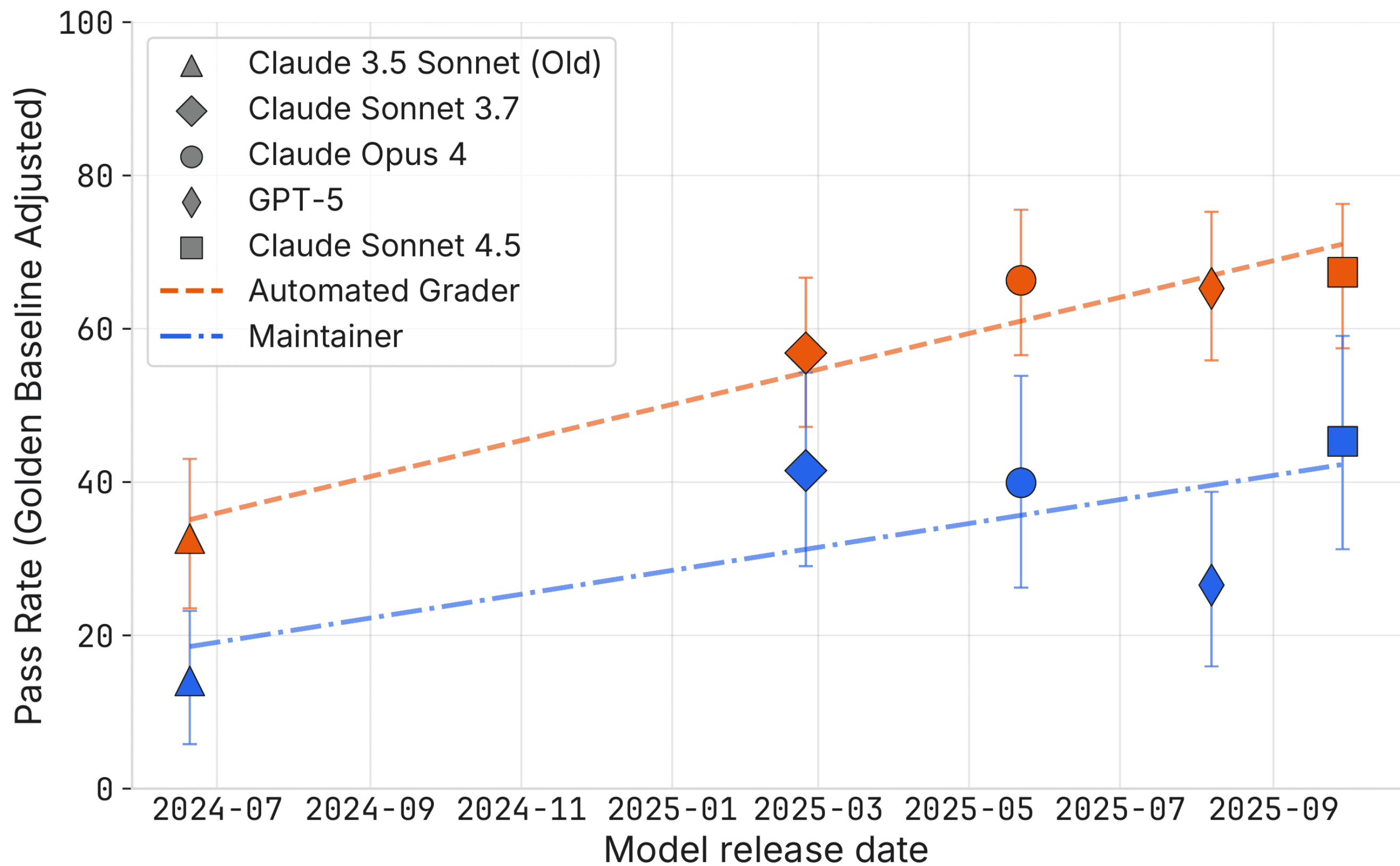


Developers in our follow-up RCT increasingly declined to work without AI, mostly due to anticipated productivity loss and to a lesser extent reduced pay. The resulting selection effect likely leads our new results to underestimate speedup.



<https://metr.org/blog/2026-02-24-uplift-update/>

Pass rate of Claude on PR fixes



Difference (Automated Grader - Maintainer Merge):

Average Difference: 24.2 pp (SE: 2.7)

Difference in pp/yr: 9.6 pp/yr (SE: 5.5)

How LLMs and AI changing jobs?

- Current software developers
 - Excited to be working with agents

**AI Doesn't Reduce Work—
It Intensifies It**

Harvard Business Review (Feb 6, 2026)

- Compared to other fields, agents takes the repetitive part, software developments focus on creative aspects

- Students

- Where are my jobs?

***Did A.I. Take Your Job? Or Was Your
Employer 'A.I.-Washing'?***

As companies blame artificial intelligence for layoffs, skeptics wonder whether that explanation captures the full picture.

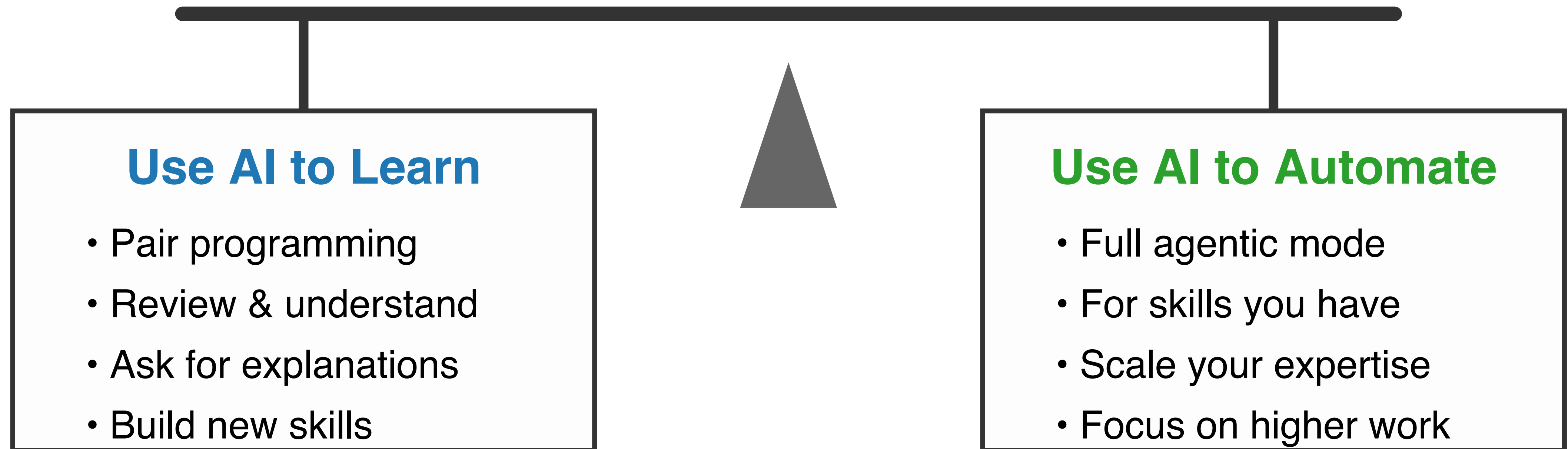
NYTimes (Feb 1, 2026)

How LLMs and AI changing jobs?

- How to adapt? Keep learning!
- Learn to use AI and use AI to learn

Don't blindly copy what AI gives you

Sweet Spot



AI is changing society

Both positive and negative aspects

Health Advice

Health Advice From A.I.
Chatbots Is Frequently Wrong,
Study Shows

In part, the problem has to do with how users are asking their questions.

NYTimes (Feb 9, 2026)

**Take It From a Doctor: It's OK if Your
Medical Advice Comes From A.I.**

NYTimes (Feb 17, 2026)

Therapist

Your Chatbot Isn't a Therapist

NYTimes (March 29, 2026)

ChatGPT as a therapist? New study reveals serious ethical risks

ScienceDaily (March 2, 2026)

Education

The risks of AI in schools outweigh the benefits, report says

NPR (Jan 14, 2026)

<https://www.npr.org/2026/01/14/nx-s1-5674741/ai-schools-education>

**I'm a High Schooler. AI Is
Demolishing My Education.**

The end of critical thinking in the classroom

The Atlantic (Sept 3, 2025)

***Teachers Worry About Students Using
A.I. But They Love It for Themselves.***

Educators are increasingly using generative A.I. in their own work, even as they express profound hesitation about the ethics of student use.

NYTimes (April 14, 2025)

**Students Are Skipping the
Hardest Part of Growing Up**

NYTimes (Jan 30, 2026)

**I'm a Professor. A.I. Has
Changed My Classroom,
but Not for the Worse.**

My students' easy access to chatbots forced me to make humanities instruction even more human.

NYTimes (Nov 25, 2025)

AI is changing society

Both positive and negative aspects

Work

AI Doesn't Reduce Work— It Intensifies It

[Harvard Business Review](#) (Feb 6, 2026)

**Gen AI Boosts Productivity, But Can't
Turn Novices Into Experts**

[HBS Working Knowledge](#) (Mar 16, 2026)

**AI Use at Work Is Causing “Brain Fry,” Researchers
Find, Especially Among High Performers**

"My thinking wasn't broken, just noisy — like mental static."

[Futurism](#) (Mar 6, 2026)

Companionship

Meet My A.I. Friends

Our columnist spent the past month hanging out with 18 A.I. companions. They critiqued his clothes, chatted among themselves and hinted at a very different future.

[NYTimes](#) (May 7, 2024)

To Stay in Her Home, She Let In an A.I. Robot

At 85, Jan Worrell lived alone on a remote corner of the Washington coast. Could ElliQ become her companion?

[NYTimes](#) (Feb 12, 2026)

Could Dementia Patients Benefit from an A.I. Companion?

New products are being developed in an attempt to reduce loneliness and bolster cognition.

[NYTimes](#) (July 31, 2025)

Dating

The Way We Live Now

They Fell in Love With A.I. Chatbots — and Found Something Real

[NYTimes Magazine](#) (Nov 5, 2025)

Women Are Falling in Love With A.I. It's a Problem for Beijing.

As China grapples with a shrinking population and historically low birthrate, people are finding romance with chatbots instead.

[NYTimes](#) (Feb 26, 2026)

AI harms

Hallucinations

Canadian man fined for submitting AI hallucinations as part of legal defense

Jean Laprade ordered to pay \$3,500 in legal saga of ‘hijacked planes’, Interpol red alerts and ‘inappropriate use’ of AI

[The Guardian](#) (Oct 15, 2025)

Psychosis

The Emerging Problem of "AI Psychosis"

Amplifications of delusions by AI chatbots may be worsening breaks with reality.

[Psychology Today](#) (Nov 27, 2025)

Toxic praise

Even when users mentioned manipulation, deception, or harmful actions, the AI defended them.



Science (Mar 6, 2026)

Suicide and killings

Character.ai Google and AI startup to settle lawsuits alleging chatbots led to teen suicide

Lawsuit accuses AI chatbots of harming minors and includes case of Sewell Setzer III, who killed himself in 2024



📷 Megan Garcia with her son Sewell Setzer III. Photograph: Megan Garcia/AP

[The Guardian](#) (Jan 8, 2026)

Father claims Google's AI product fuelled son's delusional spiral

4 March 2026

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Lily Jamali

North America Technology correspondent, San Francisco

Warning - this story contains distressing content and discussion of suicide

The father of a Florida man is suing Google in the first wrongful death case in the US against the tech giant over alleged harms caused by its artificial intelligence (AI) tool Gemini.

Joel Gavalas says that Google's flagship AI product fuelled a delusional spiral that prompted his 36-year old son, Jonathan, to kill himself last year.

The lawsuit also alleges that Gemini, which exchanged romantic texts with Jonathan Gavalas, drove him to stage an armed mission that he came to believe could bring the chatbot into the real world.

[BBC](#) (March 6, 2026)

‘Happy (and safe) shooting!’: chatbots helped researchers plot deadly attacks

Users posing as would-be school shooters find AI tools offer detailed advice on how to perpetrate violence

[The Guardian](#) (Mar 11, 2026)

Real world cases (2025)

- [Stabbing of 3 students in Pirkkala, Finland](#)
- [Cybertruck blow up in Las Vegas](#)



Photograph: Alcides Antunes/Reuters

Regulating AI

When should AI companies alert police? What the Tumbler Ridge tragedy reveals about regulating AI

The Tumbler Ridge, B.C., tragedy is raising questions about conversations with chatbots

[CBC](#) (Mar 2, 2026)

AI is changing people

- People making their words and life accessible to AI
 - Writing for AI
 - Uploading journals and personal information to AI
- Companies
 - Putting code into databases for AI
 - Making sure conversations are documented and recorded for AI

Topics that people study

- Ethics and impact of AI models
 - Bias and fairness
 - Safety and trustworthy AI
- Data valuation and privacy
- Evaluating the capability and failures of LLMs and other AI models
- Making models that are explainable and interpretable



Nick Vincent



Linyi Li

Courses and reading groups at SFU

- AI and society reading group
 - <https://nickmvincent.github.io/sfu-aias-rg/>
- Trustworthy Deep Learning
 - <https://sfu-tai.github.io/tld-spring-2025/>

More courses at SFU

- Advanced NLP: CMPT 839
 - Efficient training and fine-tuning of LLMs
 - Advanced techniques for text generation (e.g. diffusion for text generation)
 - Modelling long-sequences, state-space models
 - Grounded natural language understanding
 - Other recent trends and topics in NLP
- Special topics classes: CMPT 419/983
 - Human and Data-Centric AI with Nick Vincent
 - Trustworthy Deep Learning with Linyi Li
- Reinforcement learning (CMPT 729) with Jason Peng