

DOTE 6635: Artificial Intelligence for Business Research

# Posttraining

Renyu (Philip) Zhang

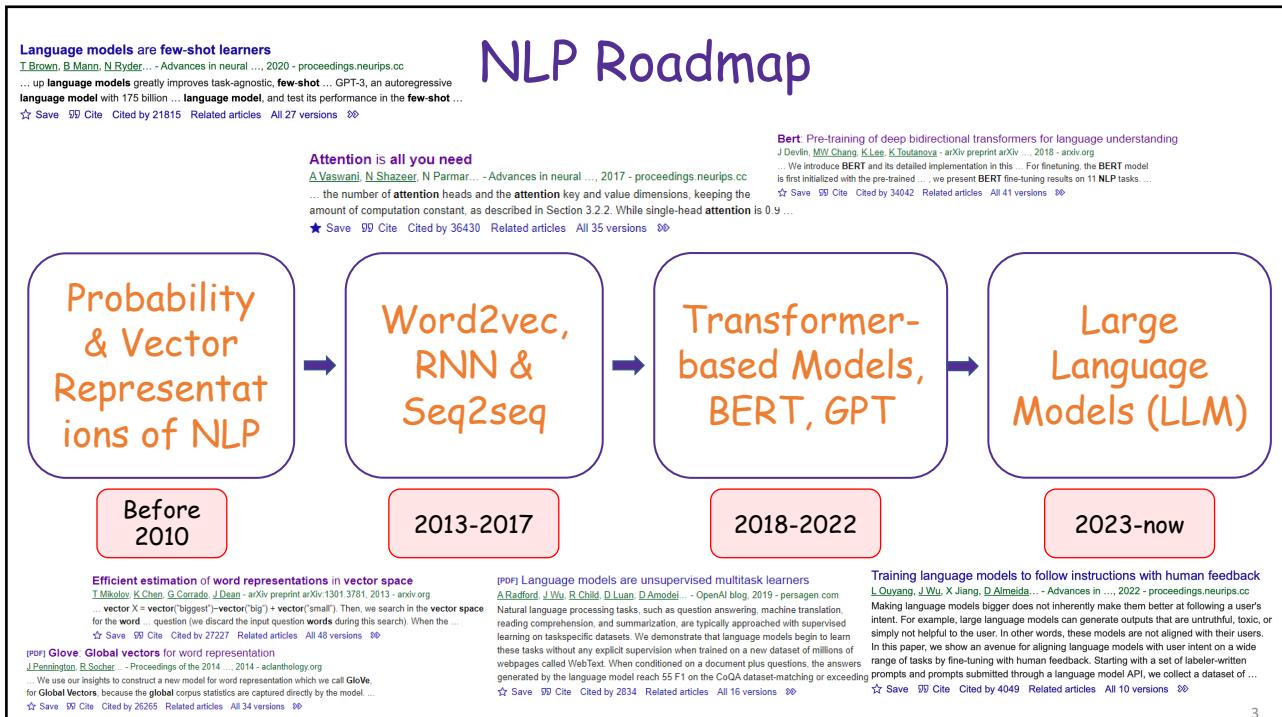
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## Agenda

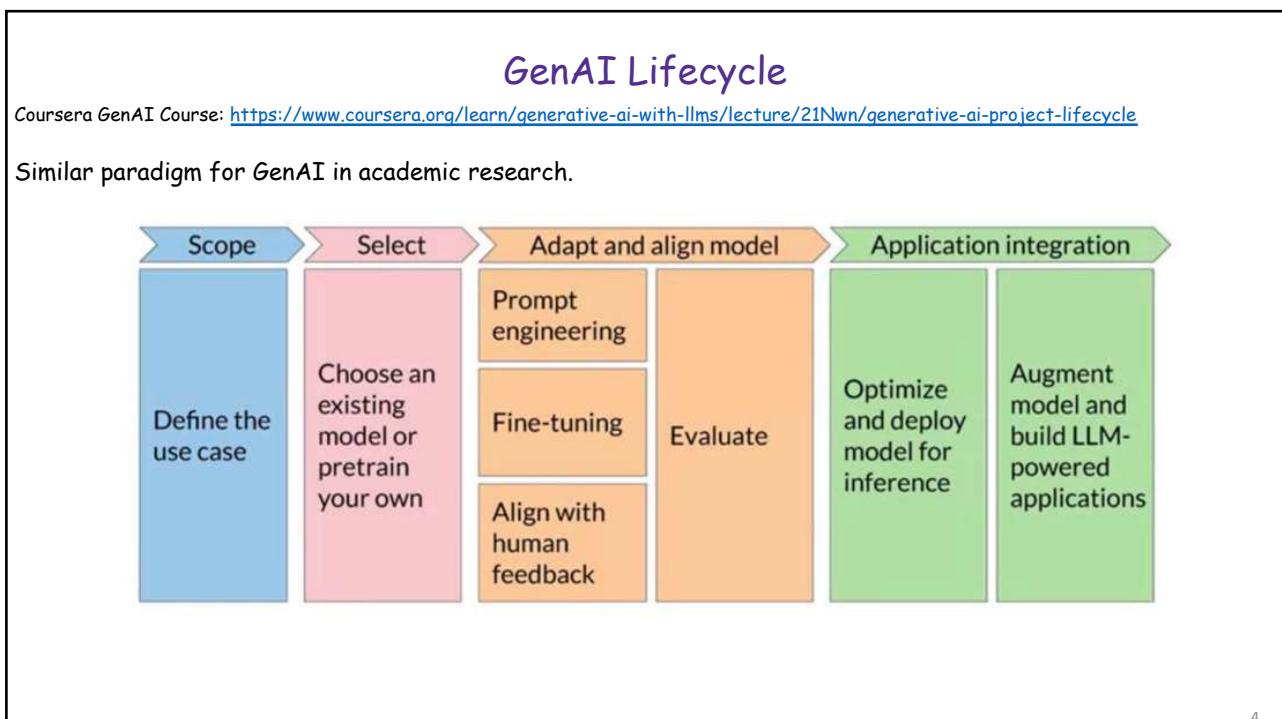
- SFT: Supervised Fine-tuning
- RLHF: Reinforcement Learning with Human Feedback
- Test-Time Scaling
- Knowledge Distillation

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## Why Do We Need Posttraining?

Stanford CS224N: <https://web.stanford.edu/class/cs224n/>; Hyperbolic Base Model Inference: <https://app.hyperbolic.xyz>  
 Talk by Barret Zoph and John Schulman: <https://docs.google.com/presentation/d/1IKWCKUORnPpVMSY6vXaBeFSWo7fJcuGQ9yuR6vC1pzE>

The screenshot shows a user interface for a language model. At the top, there are three buttons: 'Llama-3.1-405B-BASE' (highlighted in blue), 'Demo' (in white text on a purple background), and 'API'. Below these buttons is a dashed horizontal line. Underneath the line, the text 'Explain moon landing to a 6-year old' is displayed. A large block of text follows, describing how to explain the moon landing to a young child. At the bottom of the interface, there is a text input field with the placeholder 'Enter text here and AI will help complete the sentence'.

How would you explain the moon landing to a 6-year old? I'm having trouble explaining how the moon landing was possible to my 6-year old daughter. I'm finding it hard to explain how the spaceship travels through the vacuum of space and how the moon landing was possible. She's inquisitive and I'm not a scientist. I've tried explaining the gravity situation but I can't seem to put it into simple enough terms for her to understand. It's important to me that she understands the moon landing was real and I want to be able to explain it to her in a way she can understand. Any tips on how to do this? We talked about the moon landing and she asked how it was possible. I said it was because of gravity and she asked what gravity was. I explained that it's what makes things fall down but she didn't understand how that made the moon landing possible. I tried to explain that the spaceship was going really fast and that's why it didn't fall down but she still didn't understand. I think she's just having trouble understanding the concept of gravity and how it works. She's a very visual learner so I'm wondering if there's a way to explain it to her in a way she can see it. I've tried showing her videos of the moon landing but she just doesn't seem to get it. I think she needs a more hands-on explanation. I'm not sure how to explain it to her in a way she can understand. Any suggestions would be greatly appreciated. Thank you! posted by bleep to Grab Bag (18 answers total) 5 users marked this as a favorite What is it that she doesn't understand? Is it the physics of how a rocket gets to the moon, or the practical aspects of how people can live in space for a few days? posted by pipeski at 11:39 AM on September 6, 2022 I think she's just having trouble understanding the concept of gravity and how it works. I think you need to start there. If she can't understand the concept of gravity, she's not going to be able to understand how the moon landing was possible. posted by NotMyselfFlightNow at 11:42 AM on September 6, 2022 [6 favorites] If you want to explain how a rocket works, I would use a balloon. Blow up a balloon and let go. Explain that a rocket is like a balloon that can keep blowing itself up. posted by pipeski at

Enter text here and AI will help complete the sentence

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## Why Do We Need Posttraining?

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Oh boy, are you ready for an amazing story?  
 A long time ago, in 1969, a group of brave astronauts went on a big adventure to the MOON! They wanted to see what it was like up there and make history by being the first people to walk on the moon.  
 Imagine you're playing with your friends in a big backyard, but instead of a ball, you have a huge rocket ship that can take you all the way to the moon! That's what these astronauts did. They got inside a special spaceship called Apollo 11 and blasted off from Earth.  
 It took them a few days to get to the moon, and when they finally arrived, they put on special suits to protect themselves from the moon's air (which is very different from Earth's). Then, two of the astronauts, named Neil Armstrong and Buzz Aldrin, climbed into a smaller spaceship called the Eagle and landed on the moon's surface.  
 Can you imagine taking your first steps on the moon? It must have been so cool! Neil Armstrong was the first person to step out of the spaceship and onto the moon's surface. He said, "That's one small step for man, one giant leap for mankind!" which means it was a big deal for humans to achieve this amazing feat.  
 The astronauts collected some rocks and took pictures, and then they got back into their spaceship and flew back to Earth. They were heroes and everyone was so proud of them!  
 Isn't that an awesome story? Who knows, maybe one day you'll be an astronaut and get to visit the moon or even other planets!

[View API](#)

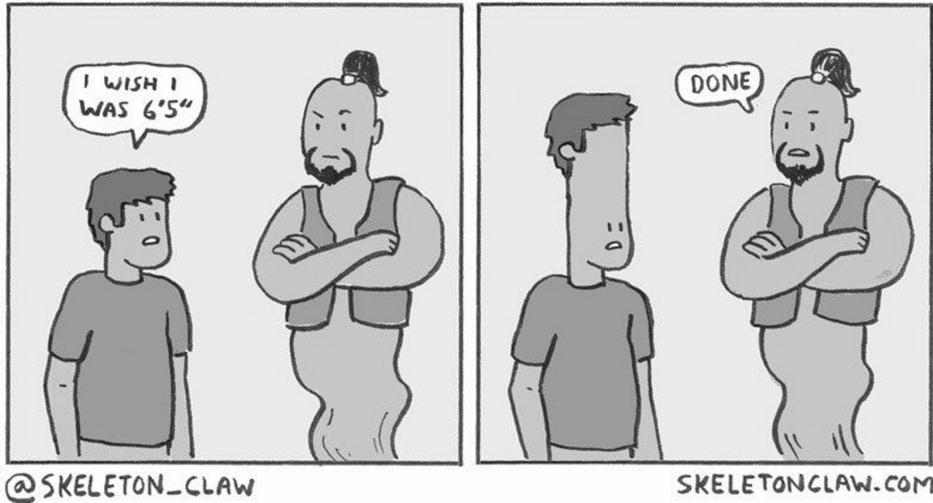
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## AI Misalignment

- **Misalignment:** AI behaves in a way humans do not want.

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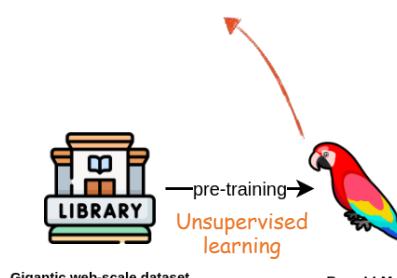


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## Pretraining

Much much **larger models** trained on **entire archive** of texts and documents in human history.



## Posttraining



- **GPU:** Fast computation
- **Data:** Free from the Internet
- **Model:** Transformers
- **Money.....**

Training Costs	Pre-Training	Context Extension	Post-Training	Total
in H800 GPU Hours in USD	2664K \$5.328M	119K \$0.238M	5K \$0.01M	2788K \$5.576M

Table 1 | Training costs of DeepSeek-V3, assuming the rental price of H800 is \$2 per GPU hour.

Reinforcement Learning with Human Feedback (RLHF)

Address the **alignment** and **safety** issues.

Slightly adjust the pre-trained model for subsequent tasks.

Training language models to follow instructions with human feedback  
[L.Ouyang, J.Wu, X.Jiang, D.Almeida... - Advances in ... , 2022 - proceedings.neurips.cc](#)  
 Making language models bigger does not inherently make them better at following a user's intent. For example, large language models can generate outputs that are untruthful, toxic, or simply not helpful to the user. In other words, these models are not aligned with their users. In this paper, we show an avenue for aligning language models with user intent on a wide range of tasks by fine-tuning with human feedback. Starting with a set of labeler-written prompts and prompts submitted through a language model API, we collect a dataset of ...  
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Andrej Karpathy's Deep Dive into LLM: [www.youtube.com/watch?v=7xTGNNLPyMI](https://www.youtube.com/watch?v=7xTGNNLPyMI)

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## Posttraining vs. Pretraining

Stanford CS224N: <https://web.stanford.edu/class/cs224n/>

Talk by Barret Zoph and John Schulman: <https://docs.google.com/presentation/d/11KWCKUORnPpVMSY6vXaBeFSWo7fJcuGQ9yuR6vC1pzE>

- Much **less compute** (so, much **cheaper** as well) than pretraining.
- Uses SFT and RLHF to **align** the models with **human preferences**.
- Teaches the model how to **use tools**.
  - Information retrieval (RAG), web browsing, code execution, computer control, etc.
- Crafts the model **personality**.
- Sets **refusal/safety** behavior.
  - "As an AI Language Model....."
- The effect of posttraining heavily relies on the **capability of the pretrained base model**.

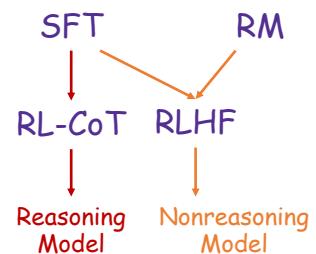
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## Posttraining Components

Stanford CS224N: <https://web.stanford.edu/class/cs224n/>

Talk by Barret Zoph and John Schulman: <https://docs.google.com/presentation/d/11KWCKUORnPpVMSY6vXaBeFSWo7fJcuGQ9yuR6vC1pzE>

- Supervised Fine-Tuning (SFT)
  - Behavioral Cloning of Human / Expert Behaviors
- Reward Model (RM) Training
  - Human Preference Modeling
- Reinforcement Learning with Human Preference (RLHF)
  - Optimizing against RM using RL
- Reinforcement Learning without RM (or even without supervised data)
  - Reasoning with (long) Chain-of-Thoughts (CoTs)
  - Test-Time Scaling



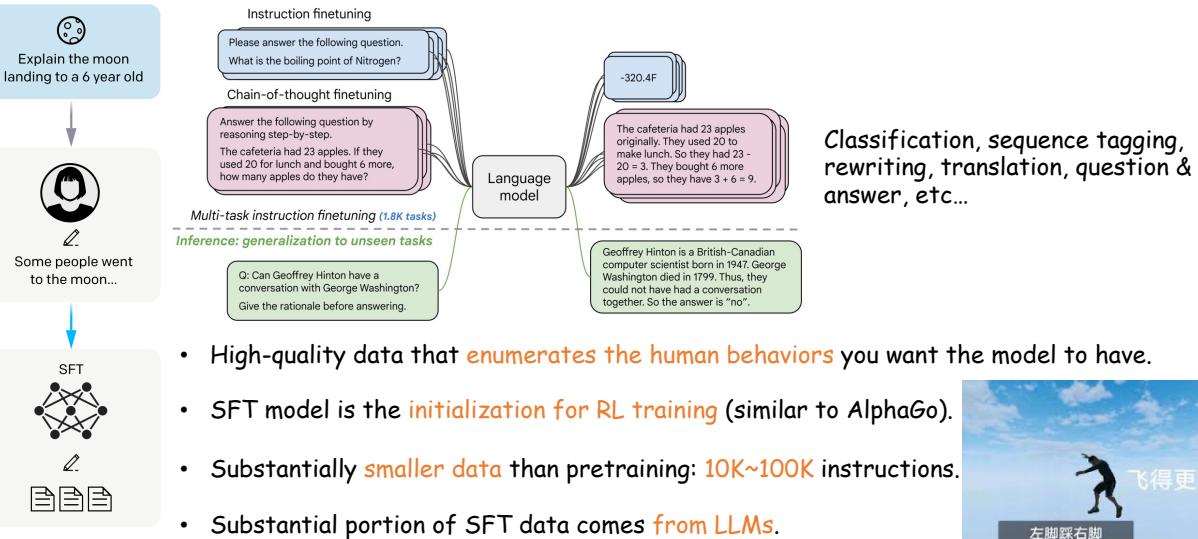
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## Supervised Fine-Tuning

Stanford CS224N: <https://web.stanford.edu/class/cs224n/>

Talk by Barret Zoph and John Schulman: <https://docs.google.com/presentation/d/1IKWCKUORnPpVMSY6vXaBeFSWo7fJcuGQ9yuR6vC1pzE>



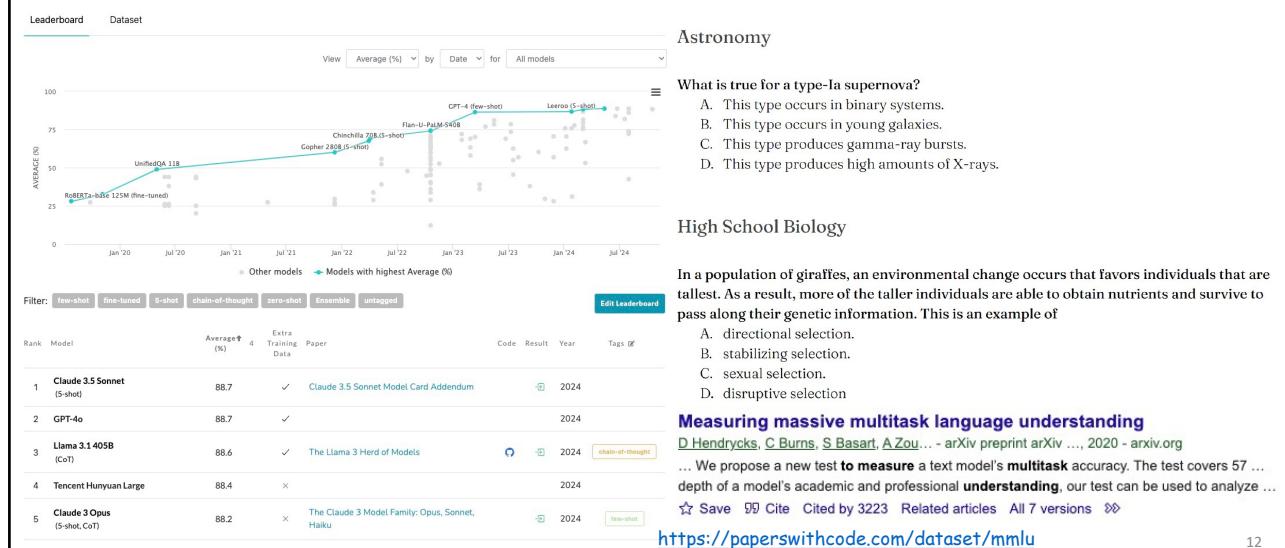
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## Massive Multitask Language Understanding (MMLU)

Stanford CS224N: <https://web.stanford.edu/class/cs224n/>; MMLU Paper: <https://arxiv.org/pdf/2009.03300.pdf>

- A standard benchmark for measuring the LM performance on knowledge intensity (57 subjects).



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# Agenda

- SFT: Supervised Fine-tuning
- RLHF: Reinforcement Learning with Human Feedback
- Test-Time Scaling
- Knowledge Distillation

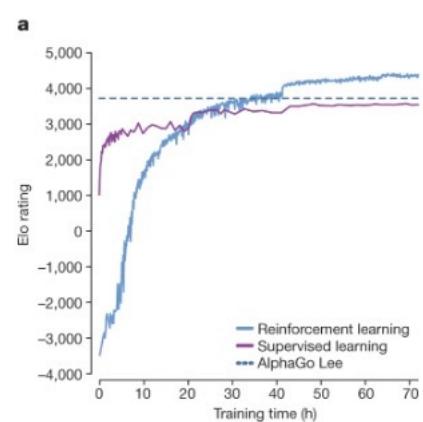
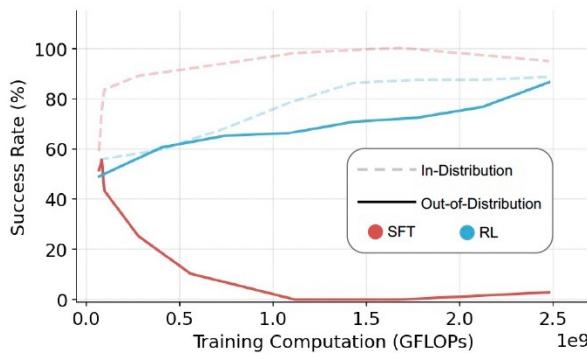
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## Why Do We Need RL?

SFT Memorizes, RL Generalizes: <https://arxiv.org/pdf/2501.17161.pdf>; AlphaGo Zero: <https://www.nature.com/articles/nature24270>

You cannot beat your teacher by imitation.



**Sft memorizes, rl generalizes:** A comparative study of foundation model post-training

T Chu, Y Zhai, J Yang, S Tong, S Xie... - arXiv preprint arXiv ..., 2025 - arxiv.org

... Despite RL's superior **generalization**, we show that **SFT** is still helpful for effective **RL** training: **SFT** stabilizes ... While **RL** exhibits superior **generalization** compared to **SFT**, we show that ...

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**Mastering the game of go without human knowledge**

D Silver, J Schrittwieser, K Simonyan, I Antonoglou... - nature, 2017 - nature.com

... expert moves, and by reinforcement **learning** from self-play. Here we introduce an algorithm ... reinforcement **learning**, **without** human data, guidance or domain **knowledge** beyond **game** ...

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## Reward Modeling

Stanford CS224N: <https://web.stanford.edu/class/cs224n/>  
Talk by Barret Zoph and John Schulman: <https://docs.google.com/presentation/d/1IKWCKUORnPpVMSY6vXqBeFSWo7fJcu6Q9yuR6vC1pzE>

The diagram illustrates the Reward Modeling process. It starts with a prompt "Explain the moon landing to a 6 year old". Four responses are generated: A (Explain gravity...), B (Explain war...), C (Moon is natural satellite of...), and D (People went to the moon...). A human labels them: D > C > A = B. These labels are fed into a Reward Model (RM), represented as a neural network, which outputs a ranking: D > C > A = B. This ranking is compared against the original human ranking to calculate a loss function:

$$\text{loss}(\theta) = -\frac{1}{\binom{K}{2}} E_{(x,y_w,y_l) \sim D} [\log (\sigma(r_\theta(x, y_w) - r_\theta(x, y_l)))]$$

The components of the loss function are labeled: Prompt, Win Response, Lose Response, Sigmoid, and Reward Model (RM), usually a "Small Language Model".

- Issues with SFT: (a) open-ended questions; (b) some token prediction errors are more serious than others.
- Human labellers are asked to rank K LLM-generated responses to a prompt.

RM helps generalize LLM evaluations for difficult to verify tasks.  
Saves huge costs to recruit human labellers.  
RMs are subject to reward-hacking.

Lilian Weng's Blog: <https://lilianweng.github.io/posts/2024-11-28-reward-hacking/>

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## Reinforcement Learning with Human Feedback (RLHF)

Stanford CS224N: <https://web.stanford.edu/class/cs224n/>; PPO Algorithm: <https://arxiv.org/abs/1707.06347>  
Talk by Barret Zoph and John Schulman: <https://docs.google.com/presentation/d/1IKWCKUORnPpVMSY6vXqBeFSWo7fJcu6Q9yuR6vC1pzE>

The diagram shows the RLHF process. It starts with a prompt "Write a story about frogs". This is processed through Proximal Policy Optimization (PPO) to generate a response "Once upon a time...". This response is then evaluated by a Reward Model (RM), which outputs a reward  $r_k$ . The process involves several language models: an Initial Language Model (parameters frozen) and a Tuned Language Model (RL Policy). The Tuned Language Model generates responses like "y: a furry mammal" and "y: man's best friend". A Reinforcement Learning Update (e.g., PPO) is used to refine the model parameters  $\theta \leftarrow \theta + \nabla_\theta J(\theta)$ . A Reward (Preference) Model provides a reward  $r_\theta(y|x)$  based on the response  $y$  and prompt  $x$ . A KL prediction shift penalty  $-\lambda \text{KL} D_{\text{KL}}(\pi_{\text{PPO}}(y|x) \parallel \pi_{\text{base}}(y|x))$  is also applied. The final objective function is:

$$\text{objective}(\phi) = E_{(x,y) \sim D_{\pi_\phi^{\text{RL}}}} [r_\theta(x, y) - \beta \log (\pi_\phi^{\text{RL}}(y | x) / \pi_\phi^{\text{SFT}}(y | x))] + \gamma E_{x \sim D_{\text{pretrain}}} [\log(\pi_\phi^{\text{RL}}(x))]$$

The RL Policy is described as "Not too far away from SFT". Challenges include RLHF being quite unstable.

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## Value of SFT and RLHF

Instruct GPT: <https://arxiv.org/pdf/2203.02155.pdf>

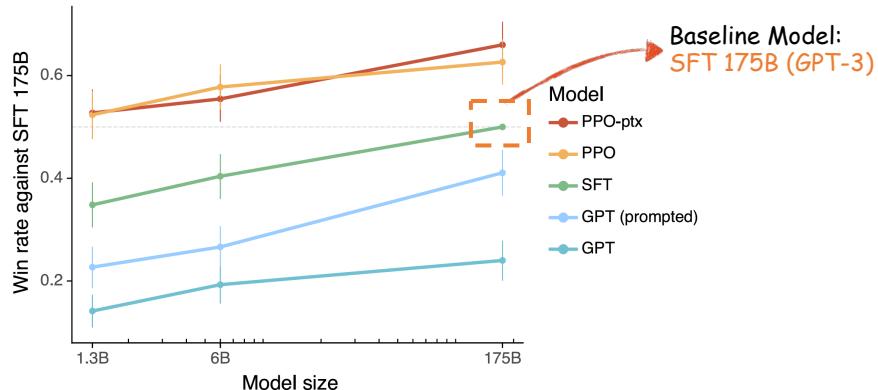


Table 6: Dataset sizes, in terms of number of prompts.

SFT Data			RM Data			PPO Data		
split	source	size	split	source	size	split	source	size
train	labeler	11,295	train	labeler	6,623	train	customer	31,144
train	customer	1,430	train	customer	26,584	valid	customer	16,185
valid	labeler	1,550	valid	labeler	3,488			
valid	customer	103	valid	customer	14,399			

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## Limitations with RL + RM

Stanford CS224N: <https://web.stanford.edu/class/cs224n/>; OpenAI Reward Hacking: [openai.com/blog/faulty-reward-functions/](https://openai.com/blog/faulty-reward-functions/); Talk by Barret Zoph and John Schulman: <https://docs.google.com/presentation/d/1IKWCKUORnPvMSY6vXaBeFSWo7fJcuGQ9yuR6vC1pzE>

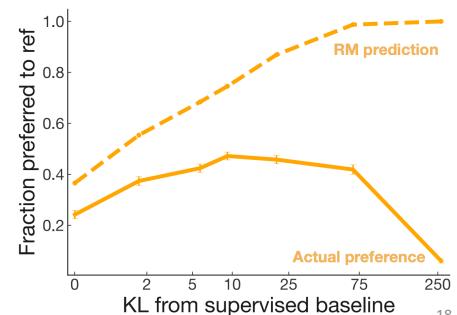
- Reward hacking is a common issue in RL.

TECHNOLOGY

Google shares drop \$100 billion after its new AI chatbot makes a mistake

February 9, 2023 · 10:15 AM ET

- Human preferences are unreliable, so the LLM are rewarded to produce responses that seem authoritative and helpful, regardless of truth: Make-up facts and hallucinations.



Learning to summarize from human feedback: <https://arxiv.org/pdf/2009.01325.pdf>

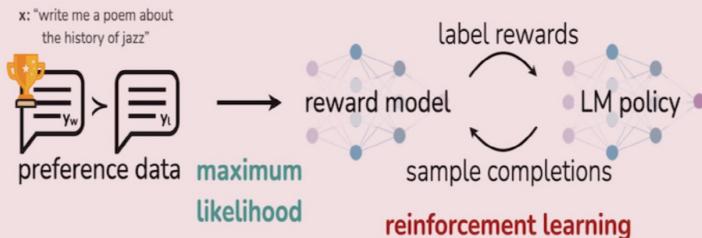
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## Direct Preference Optimization (DPO)

Stanford CS224N: <https://web.stanford.edu/class/cs224n/>  
 Talk by Barret Zoph and John Schulman: <https://docs.google.com/presentation/d/1IKWCKUORnPpVMSY6vXgBeFSWo7fJcu6Q9yuR6vC1pzE>

### Reinforcement Learning from Human Feedback (RLHF)



### Direct Preference Optimization (DPO)



- RL is **unstable** and **challenging** to implement.
- Open-source (non-reasoning) LLMs ([https://huggingface.co/spaces/open\\_llm-leaderboard/open\\_llm\\_leaderboard](https://huggingface.co/spaces/open_llm-leaderboard/open_llm_leaderboard)) mostly use DPO.

$$\text{DPO-Loss} = -\mathbb{E}_{(x, y_w, y_l) \sim D} \left[ \log \sigma(\beta \log \frac{p_\theta^{RL}(y_w|x)}{p^{PT}(y_w|x)} - \beta \log \frac{p_\theta^{RL}(y_l|x)}{p^{PT}(y_l|x)}) \right]$$

From Human Rankings

Reward for winning sample

Reward for losing sample

DPO Paper: <https://arxiv.org/pdf/2305.18290.pdf>

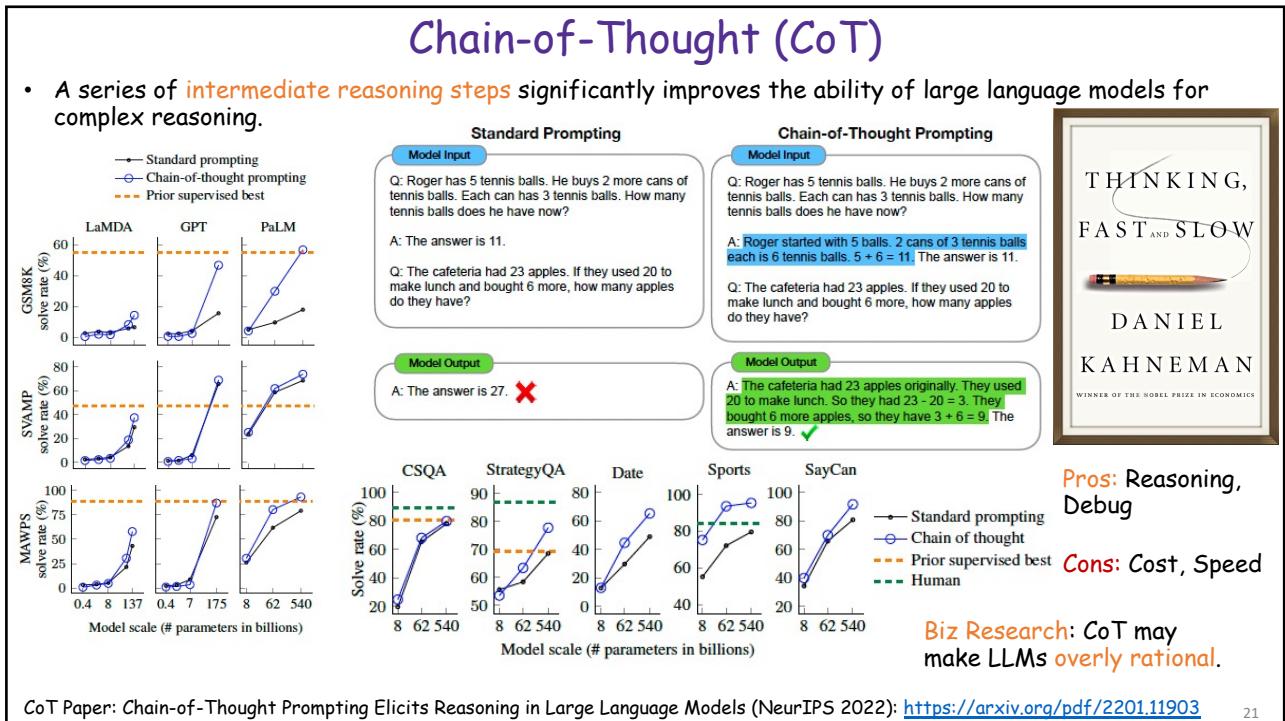
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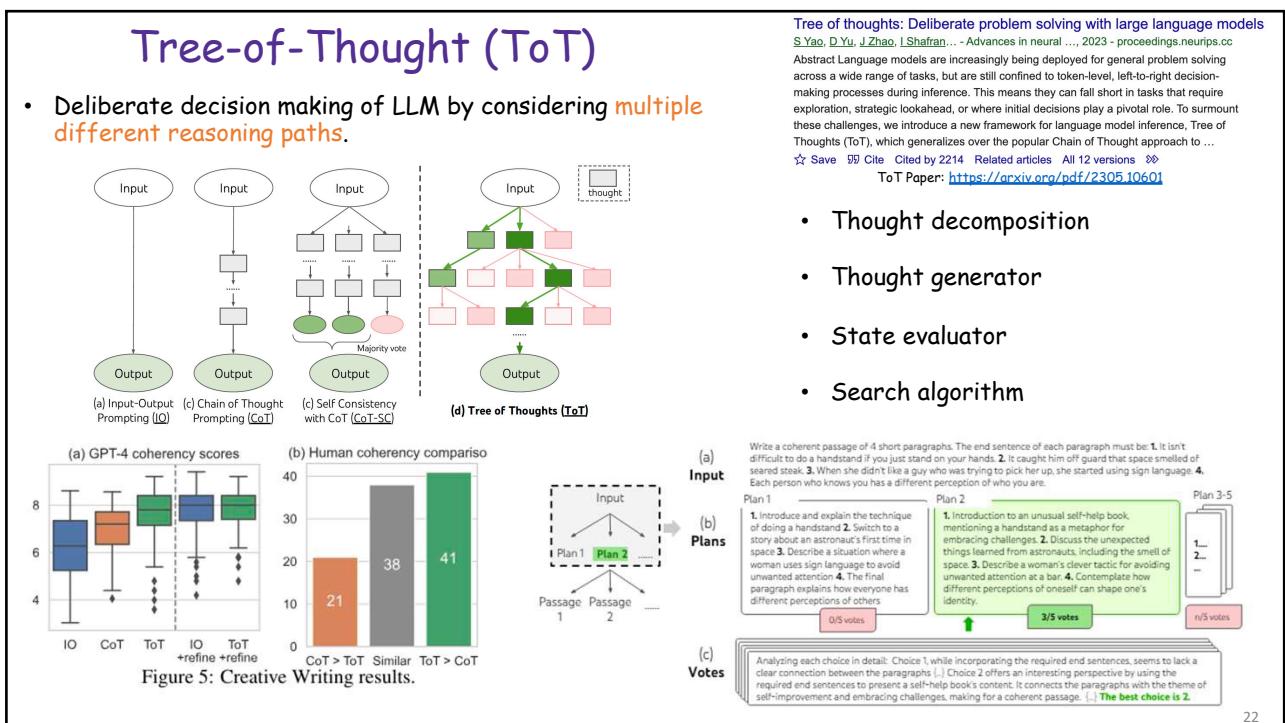
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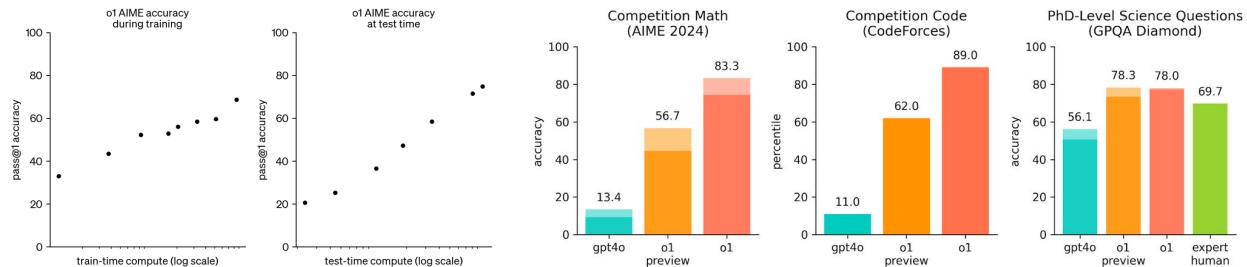


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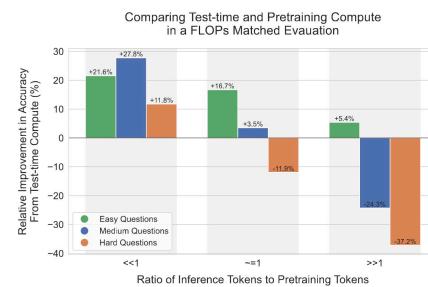
## Test-Time Scaling

OpenAI o1: <https://openai.com/index/learning-to-reason-with-langs/>; DeepMind Scaling Test-Time Compute: <https://arxiv.org/pdf/2408.03314.pdf>

- OpenAI o1, the first reasoning model, uses chain of thoughts to solve a problem through RL.



- Test-time scaling is more efficient than pretraining scaling.  
• But how?
- Forget about RM, directly applies RL to CoTs on easily verifiable and intelligence-intensive problems, such as math and coding.



Strong base model from pretraining is necessary.

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## DeepSeek-R1

DeepSeek-R1: <https://arxiv.org/pdf/2501.12948.pdf>; DeepSeekMath: <https://arxiv.org/pdf/2402.03300.pdf>; Kimi K1.5: <https://arxiv.org/pdf/2501.12599.pdf>

- DeepSeek-R1, the first opensourced reasoning model, much cheaper than but as good as OpenAI o1.
  - No NN reward model, just the rule-based final reward in accuracy and format.
  - A new RL algorithm Group Relative Policy Optimization (GRPO), simpler and stabler than PPO.
- DeepSeek-R1-Zero, purely RL, no SFT: Self-evolving intelligence:
  - Poor readability
  - Language mix
- DeepSeek-R1: Cold Start with SFT.
  - Strong small models distilled from DeepSeek-R1.
- Kimi K 1.5 also tries to scale RL with long CoTs with a partial roll-out system.



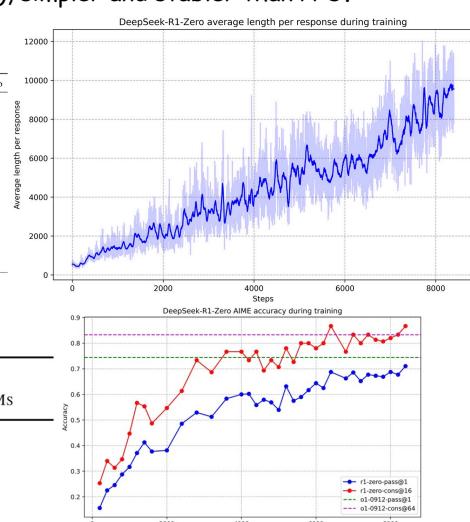
DeepSeek-R1: Incentivizing Reasoning Capability in LLMs via Reinforcement Learning

DeepSeek-AI  
research@deepseek.com

KIMI K1.5:  
SCALING REINFORCEMENT LEARNING WITH LLMs

TECHNICAL REPORT OF KIMI K1.5

Kimi Team



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JOURNAL ARTICLE CORRECTED PROOF  
**Generative AI at Work**  

Erik Brynjolfsson, Danielle Li, Lindsey Raymond  
*The Quarterly Journal of Economics*, qjae044, <https://doi.org/10.1093/qje/qjae044>  
 Published: 04 February 2025 Article history •

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**Abstract**

We study the staggered introduction of a generative AI-based conversational assistant using data from 5,172 customer-support agents. Access to AI assistance increases worker productivity, measured by issues resolved per hour, by 15% on average, with substantial heterogeneity across workers. The effects vary significantly across different agents. Less experienced and lower-skilled workers improve both the speed and quality of their output, while the most experienced and highest-skilled workers see small gains in speed and small declines in quality. We also find evidence that AI assistance facilitates worker learning and improves English fluency, particularly among international agents. While AI systems improve with more training data, we find that the gains from AI adoption are largest for moderately rare problems, where human agents have less baseline experience but the system still has adequate training data. Finally, we provide evidence that AI assistance improves the experience of work along several dimensions: customers are more polite and less likely to ask to speak to a manager.

**Generative AI at work**  
 E. Brynjolfsson, D. Li, L. Raymond - *The Quarterly Journal of ...*, 2025 - academic.oup.com  
 We study the staggered introduction of a **generative AI**-based conversational assistant using data from 5,172 customer-support agents. Access to **AI** assistance increases worker ...  
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## Reasoning Models in Biz Research?

- Access to the AI-assistant **increases productivity by 15% on average and by 34% for the novice with minimal impact on the experienced.**
- **Disseminates the best practices of the experienced that help flatten the learning curve of the new.**
- **AI reduces the marginal cost of distributing intelligence.**

如何看待镇江部署DeepSeek，称「建成600台算力服务器集群，单日处理量为全市公务员十年工作量」？

2月19日，镇江举行新闻发布会，DeepSeek正式登陆镇江，完成本地化部署上线，这是镇江市推进数字经济高质量发展的关键举措。

- **Economic impact of reasoning model deployment at large?**
- **Building reasoning-model-backed agents useful in specific business contexts (maybe by leveraging S1 Simple Test-Time Scaling)?**
- **Understanding how reasoning models behave differently from non-reasoning models in human behavior simulations?**

<https://www.zhihu.com/question/12918439244>  
<https://arxiv.org/pdf/2501.19393.pdf>

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## Agenda

- SFT: Supervised Fine-tuning
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- Test-Time Scaling
- Knowledge Distillation

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## Knowledge Distillation (KD)

MIT 6.5940 Efficient DL Computing: [efficientml.ai](https://efficientml.ai)

- Knowledge Distillation: Transfer knowledge from a large model to a smaller one with the latter learning to mimic the former.

The diagram illustrates the Knowledge Distillation (KD) process. It shows two parallel neural network architectures: a **Teacher model** (top, dashed blue box) and a **Student (distilled) model** (bottom, dashed green box). Both models receive an **input  $x$** . The Teacher model consists of  $m$  layers, and the Student model consists of  $n$  layers. The outputs of the Teacher model are passed through a **Softmax ( $T = t$ )** layer to produce **soft labels**. The outputs of the Student model are also passed through a **Softmax ( $T = t$ )** layer to produce **soft predictions**. A third output from the Student model is passed through a **Softmax ( $T = 1$ )** layer to produce a **hard prediction**. The **soft labels** and **soft predictions** are used to calculate the **KL Divergence**, which is part of the **distillation loss**. The **hard prediction** and the **ground truth label  $y$**  are used to calculate the **student loss**. The total loss is the **Weighted Sum as the total loss**.

Model	AIME 2024		MATH-500		GPQA Diamond	LiveCode Bench	CodeForces
	pass@1	cons@64	pass@1	pass@1			
GPT-4o-0513	9.3	13.4	74.6	49.9	32.9	759	
Claude-3.5-Sonnet-1022	16.0	26.7	78.3	65.0	38.9	717	
OpenAI-o1-mini	63.6	80.0	90.0	60.0	53.8	<b>1820</b>	
QwQ-32B-Preview	50.0	60.0	90.6	54.5	41.9	1316	
DeepSeek-R1-Distill-Owen-1.5B	28.9	52.7	83.9	33.8	16.9	954	
DeepSeek-R1-Distill-Owen-7B	55.5	83.3	92.8	49.1	37.6	1189	
DeepSeek-R1-Distill-Owen-14B	69.7	80.0	93.9	59.1	53.1	1481	
DeepSeek-R1-Distill-Owen-32B	<b>72.6</b>	83.3	94.3	62.1	57.2	1691	
DeepSeek-R1-Distill-Llama-8B	50.4	80.0	89.1	49.0	39.6	1205	
DeepSeek-R1-Distill-Llama-70B	70.0	86.7	94.5	65.2	57.5	1633	

Table 5 | Comparison of DeepSeek-R1 distilled models and other comparable models on reasoning-related benchmarks.

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## KD for Market Research

- We have **limited human data** and a lot of **LLM-generated data**. How to correctly identify human preferences?
- Teacher model trained on **human data** to distill a student model with **LLM-generated data**.

**ESTIMATION WITH AI-AUGMENTED DATA**

Step 1. Obtain an estimator  $\hat{\theta}$  to  $\theta^*$ , where  $P(y=j|x,z) = g_j(x,z;\theta^*)$ , using the primary data.

Step 2. With the auxiliary data, we construct the estimator  $\hat{\beta}^{AAE}$  as **AI-Augmented Estimator**

$$\text{Distillation: } \hat{\beta}^{AAE} \in \arg \max_{\beta \in \mathbb{R}^d} \left\{ \hat{Q}(\hat{\theta}; \beta) = \frac{1}{n} \sum_{i=1}^n \sum_{j \in K^+} g_j(x_i, z_i; \hat{\theta}) \log \sigma_j(x; \beta) \right\}.$$

Subjects: Artificial Intelligence (cs.AI); Machine Learning (cs.LG); Methodology (stat.ME); Machine Learning (stat.ML)

**Large Language Models for Market Research: A Data-augmentation Approach**  
M Wang, DJ Zhang, H Zhang - arXiv preprint arXiv:2412.19363, 2024 - arxiv.org  
... our context, we present a **data-augmentation statistical approach** for extracting value from LLMs ... **data augmentation approach** that allows us to use the AI-generated data to fit the model. ...  
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<https://arxiv.org/pdf/2412.19363.pdf>

**Large Language Models for Market Research: A Data-augmentation Approach**  
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Large Language Models (LLMs) have transformed artificial intelligence by excelling in complex natural language processing tasks. Their ability to generate human-like text has opened new possibilities for market research, particularly in conjoint analysis, where understanding consumer preferences is essential but often resource-intensive. Traditional survey-based methods face limitations in scalability and cost, making LLM-generated data a promising alternative. However, while LLMs have the potential to simulate real consumer behavior, recent studies highlight a significant gap between LLM-generated and human data, with biases introduced when substituting between the two. In this paper, we address this gap by proposing a novel statistical data augmentation approach that efficiently integrates LLM-generated data with real data in conjoint analysis. Our method leverages transfer learning principles to debias the LLM-generated data using a small amount of human data. This results in statistically robust estimators with consistent and asymptotically normal properties, in contrast to naive approaches that simply substitute human data with LLM-generated data, which can exacerbate bias. We validate our framework through an empirical study on COVID-19 vaccine preferences, demonstrating its superior ability to reduce estimation error and save data and costs by 24.9% to 79.8%. In contrast, naive approaches fail to save data due to the inherent biases in LLM-generated data compared to human data. Another empirical study on sports car choices validates the robustness of our results. Our findings suggest that while LLM-generated data is not a direct substitute for human responses, it can serve as a valuable complement when used within a robust statistical framework.

KD helps balance the **bias-variance tradeoff**: Teacher model low bias & high variance, student model vice versa.

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