GPT-NeoX-20B

An Open-Source Autoregressive Language Model

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EleutherAI is a decentralized grassroots collective of researchers focused on AI alignment, scaling, and open source AI research.

How did this all start?

One day, Connor Leahy posted in the TPU Podcast Discord:

Daj 2020-07-02
https://arxiv.org/abs/2006.16668

Hey guys lets give OpenAI a run for their money like the good ol' days

To which Leo Gao replied:

bmk 2020-07-02
@Daj this but unironically

And so it began.

Our Community

- Organized via **Discord**
- Transparent research
- Community driven
- Anyone can join:
  - Research projects
  - Discussion of state-of-the-art
  - Interpretability reading group

Language Modeling

Why Train a(nother) Large Language Model?

- Access to large language models is essential for doing research on them.

- How does repeated exposure to the same data influence the probability that the language model will memorize that data?
  - Deduplicating Training Data Makes Language Models Better
  - Quantifying Memorization Across Neural Language Models

- To what extent do language models learn to generalize notions found in the training data to the testing data?
  - Impact of Pretraining Term Frequencies on Few-Shot Reasoning

What is a Transformer?

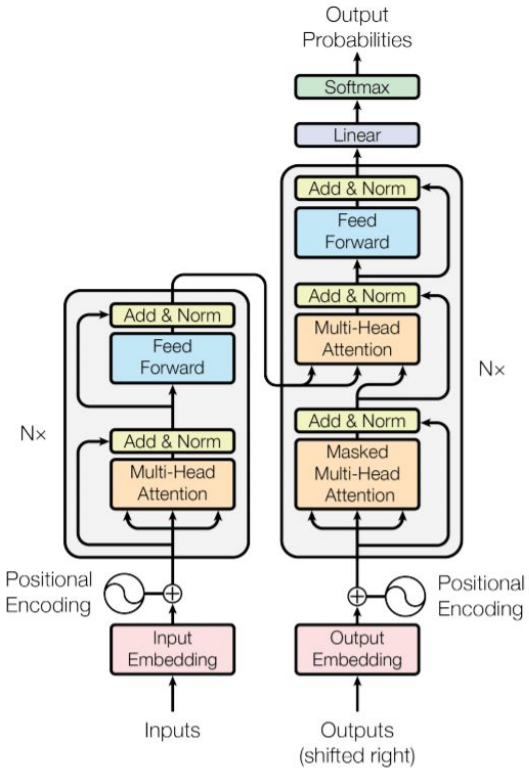
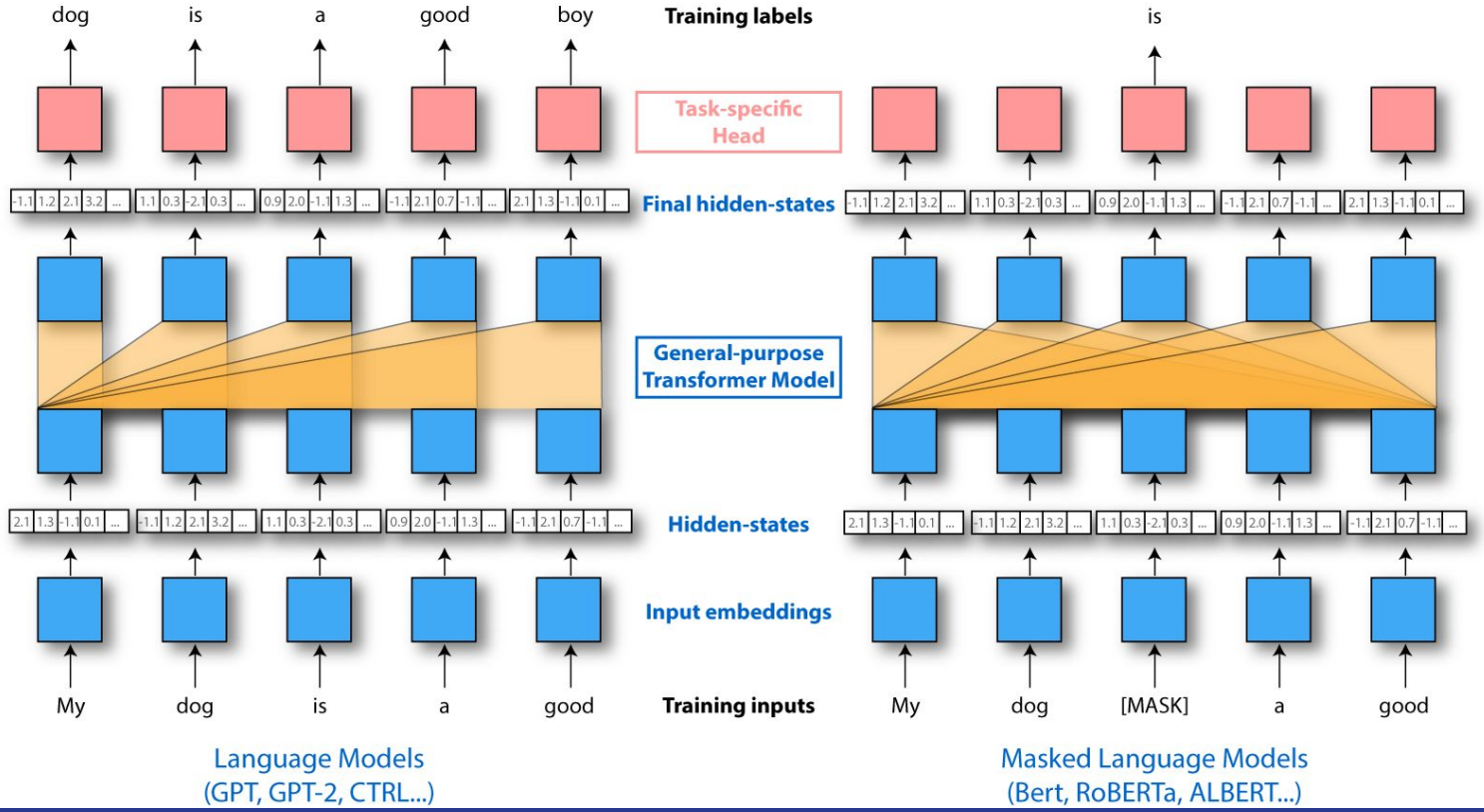


Figure 1: The Transformer - model architecture.

Language Modeling?



https://twitter.com/thom_wolf/status/1186225108282757120?s=21

LLM Leaderboards

1		Announcement	Organizaton	Author Location	Language	Parameters	Model Accessibility	Data Accessibility
2	**PaLM**	2022-04-04	Google	USA	English	**540.0B**	**Closed**	**Closed**
3	**Megatron-Turing**	2021-10-11	Microsoft, NVIDIA	USA	English	**530.0B**	**Closed**	**Closed + Pile**
4	**Gopher**	2021-12-08	DeepMind	USA	English	**280.0B**	**Closed**	**Closed + Pile**
5	**ERNIE 3.0**	2021-12-08	Baidu	China	Chinese, English	**260.0B**	**Closed**	**Closed**
6	**Yuan 1.0**	2021-10-10	Inspur AI Research	China	Chinese	**245.0B**	**Limited**	**Limited**
7	**HyperCLOVA**	2021-09-10	NAVER	Korea	Korean	**204.0B**	**Closed**	**Closed**
8	**PanGu-α**	2021-04-26	Huawei	China	Chinese	**200.0B**	**Closed**	**Closed**
9	**Jurassic-1**	2021-08-11	AI21 Labs	Israel	English	**178.0B**	**Closed**	**Open (Pile)**
10	**GPT-3**	2020-05-28	OpenAI	USA	English	**175.0B**	**Commercial**	**Closed**
11	**OPT**	2021-05-03	Meta AI	USA	English	**175.0B**	**Open (NC)**	**Closed (roBERTa) + Pile**
12	**LaMDA**	2022-01-20	Google	USA	English	**137.0B**	**Closed**	**Closed**
13	**Chinchilla**	2022-03-29	DeepMind	USA	English	70.0B	**Closed**	**Closed**
14	**Anthropic LM**	2021-12-01	Anthropic	USA	English	52.0B	**Closed**	**Closed**
15	**GPT-NeoX-20B**	2022-02-02	EleutherAI	Germany, USA, India, Canada, UK, Australia, Austria	English	20.0B	**Open**	**Open (Pile)**
16	**Turing NLG**	2020-02-13	Microsoft	USA	English	17.2B	**Closed**	**Closed**
17	**FairSeq Dense**	2021-12-20	Meta AI	USA, UK, Germany	English	13.0B	**Open**	**Closed**
18	**Big Science Model**		Big Science	Multinational	Multilingual	13.0B	**Closed**	**Open (OSCAR)**
19	**mT5**	2020-10-22	Google	USA	Multilingual	13.0B	**Open**	**Open (mC4)**
20	**ByT5**	2021-05-28	Google	USA	Multilingual	13.0B	**Open**	**Open (C4)**
21	**T5**	2019-10-23	Google	USA	English	11.0B	**Open**	**Open (C4)**
22	**CPM-2.1**	2021-06-20	Tsinghua University	China	Chinese	11.0B	**Open**	**???**
23	**Megatron 11B**	2020-04-03	NVIDIA	USA	English	11.0B	**Theoretically Open**	**???**
24	**WuDao-GLM-XXL**		Beijing Academy of A	China	Chinese	10.0B	**Limited**	**???**
25	**WuDao-GLM-XXL**		Beijing Academy of A	China	English	10.0B	**Limited**	**???**

What Does it Take to Run?

- Slim checkpoint is 39 GB, 43 GB at runtime
- Full checkpoint 268 GB
- On an A6000 you can generate ~11 tokens per second
- Better performance on two RTX 3090 Tis, but less cost efficient

Model Training Details

The Pile: 800GB of Diverse Text for LLMs

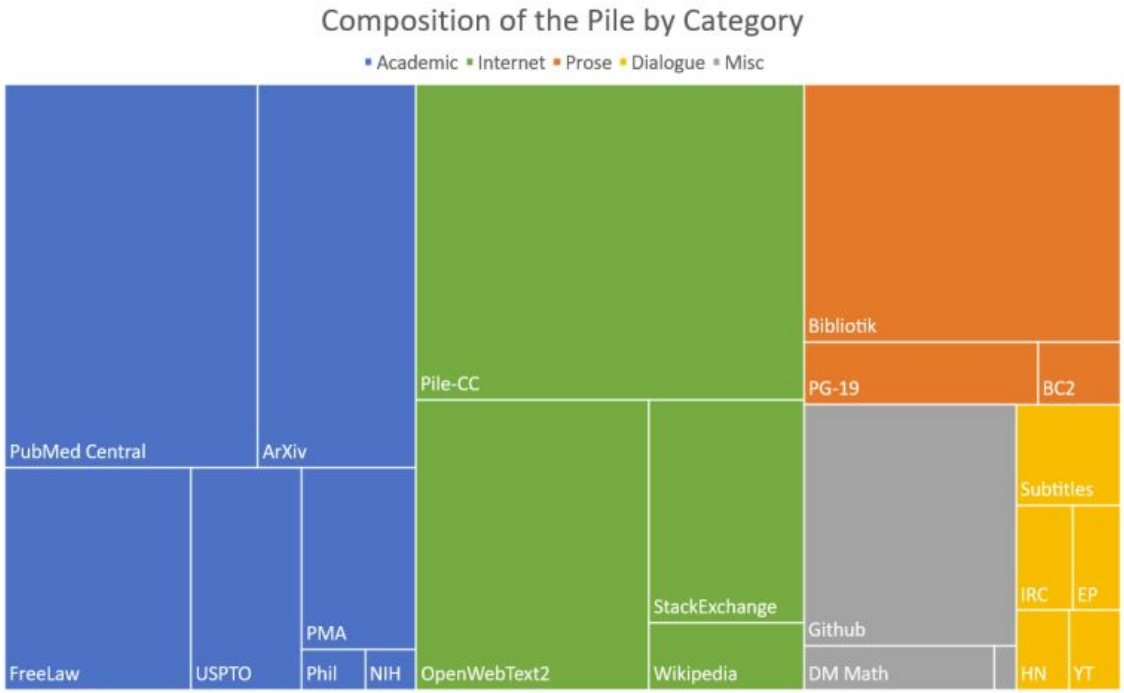


Figure 1: Treemap of Pile components by effective size.

New Tokenizer

- Variant on standard BPE tokenizer
- Adds special tokens for spaces to handle code data better
- 15% fewer tokens on arXiv
- 23% fewer tokens on GitHub
- 0.001% more tokens on C4

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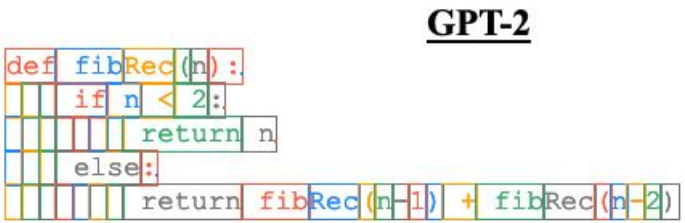
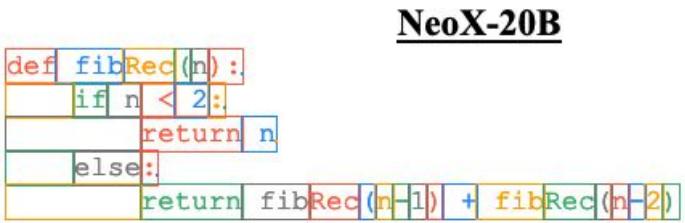


Number of tokens=55



Number of tokens=39

Model architecture

- Mostly the same as GPT-3, but all dense layers
- Pretty different from GPT-Neo
- Almost exactly the same as GPT-J
- 44 layers, hidden dimension size of 6144, and 64 heads

Parallel Attention and Feedforward Layers

Standard: $x + \mathrm{FF}(\mathrm{LN}_2(x + \mathrm{Attn}(\mathrm{LN}_1(x))$

GPT-J: $x + \mathrm{Attn}(\mathrm{LN}_1(x)) + \mathrm{FF}(\mathrm{LN}_2(x))$

Rotary Embeddings

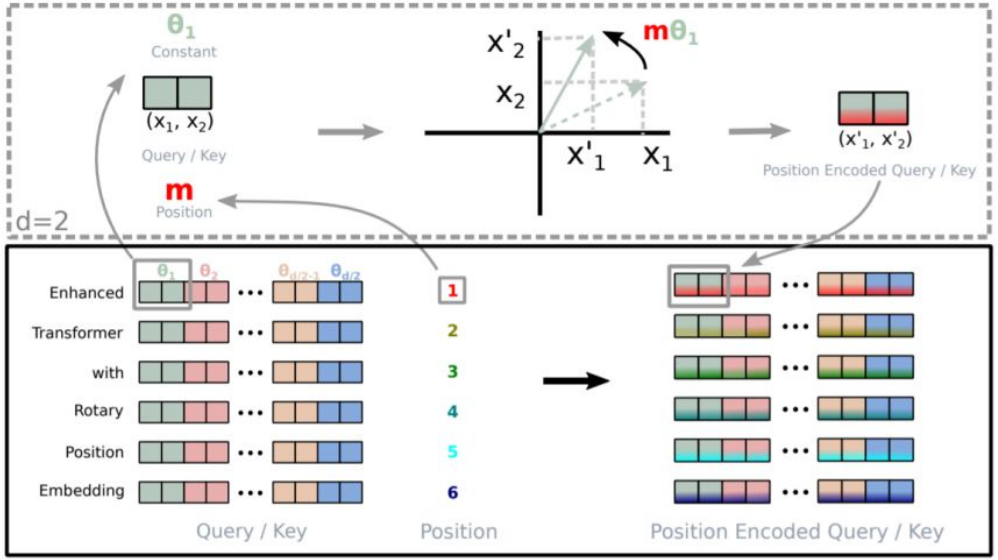


Figure 1: A pictorial representation of rotary embeddings, from Su et al. [2021].

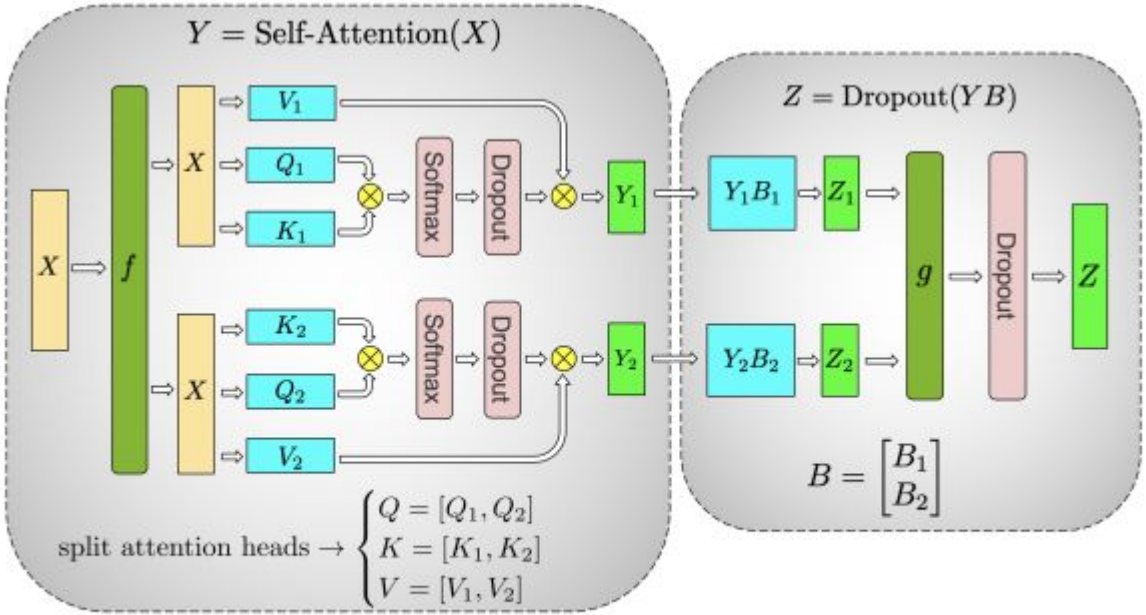
$$\text{softmax}\left(\frac{1}{\sqrt{d}}\sum_{n,m}\mathbf{x}_m^T\mathbf{W}_q^T\mathbf{W}_k\mathbf{x}_n\right)$$

$$\text{softmax}\left(\frac{1}{\sqrt{d}}\sum_{n,m}\mathbf{x}_m^T\mathbf{W}_q^T R^d_{\Theta,(n-m)}\mathbf{W}_k\mathbf{x}_n\right)$$

Training

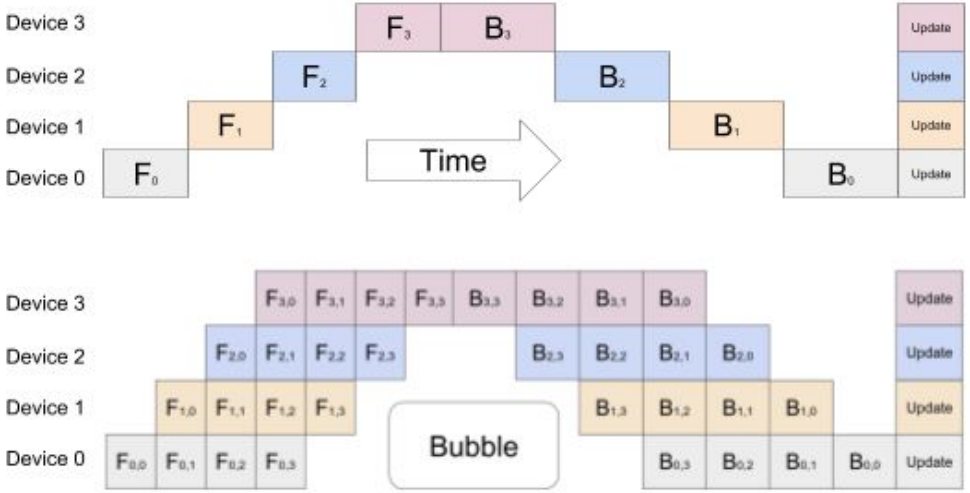
- Hyperparameters based on GPT-3
- Batch size of 3.15M tokens = 1538 contexts of 2048 tokens each
- 150,000 steps
- AdamW optimizer with beta values of 0.9 and 0.95 with ZeRO optimizer
- Tensor and pipeline parallelism

Tensor Parallelism



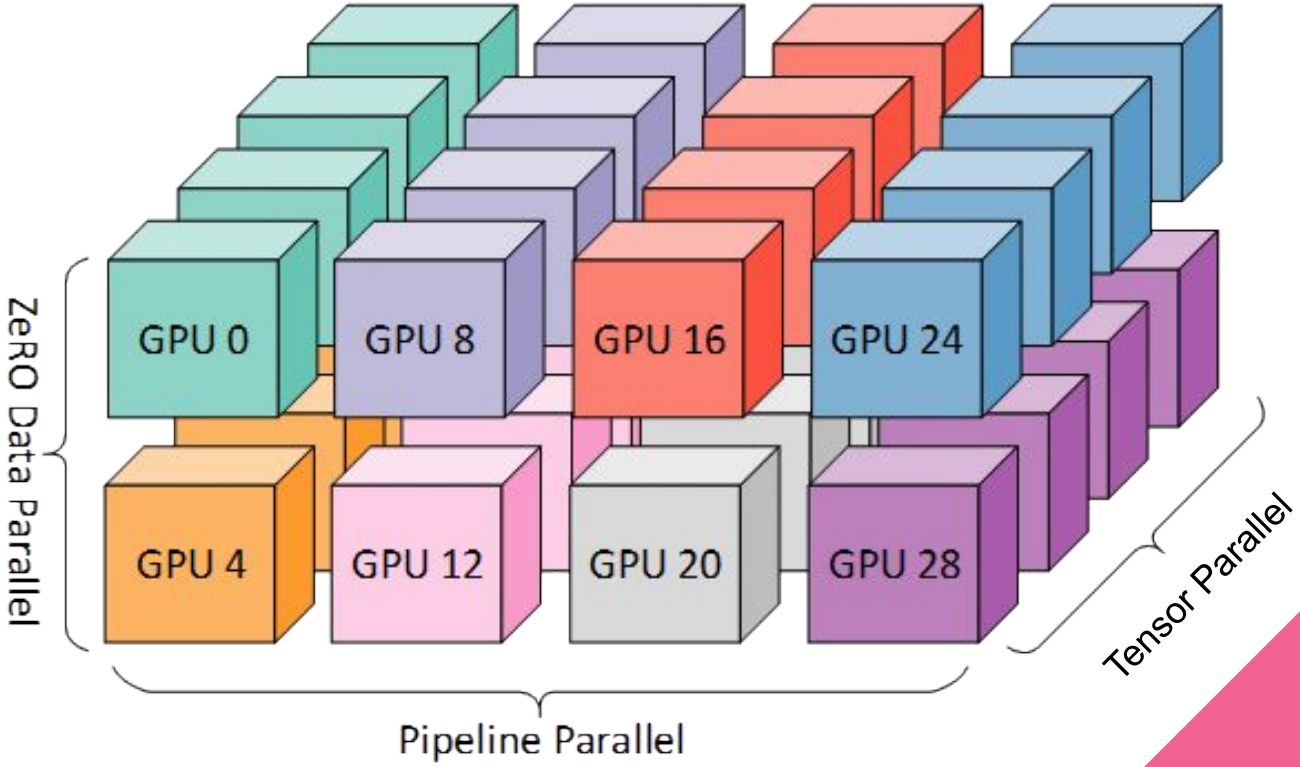
(b) Self-Attention

Pipeline Parallelism

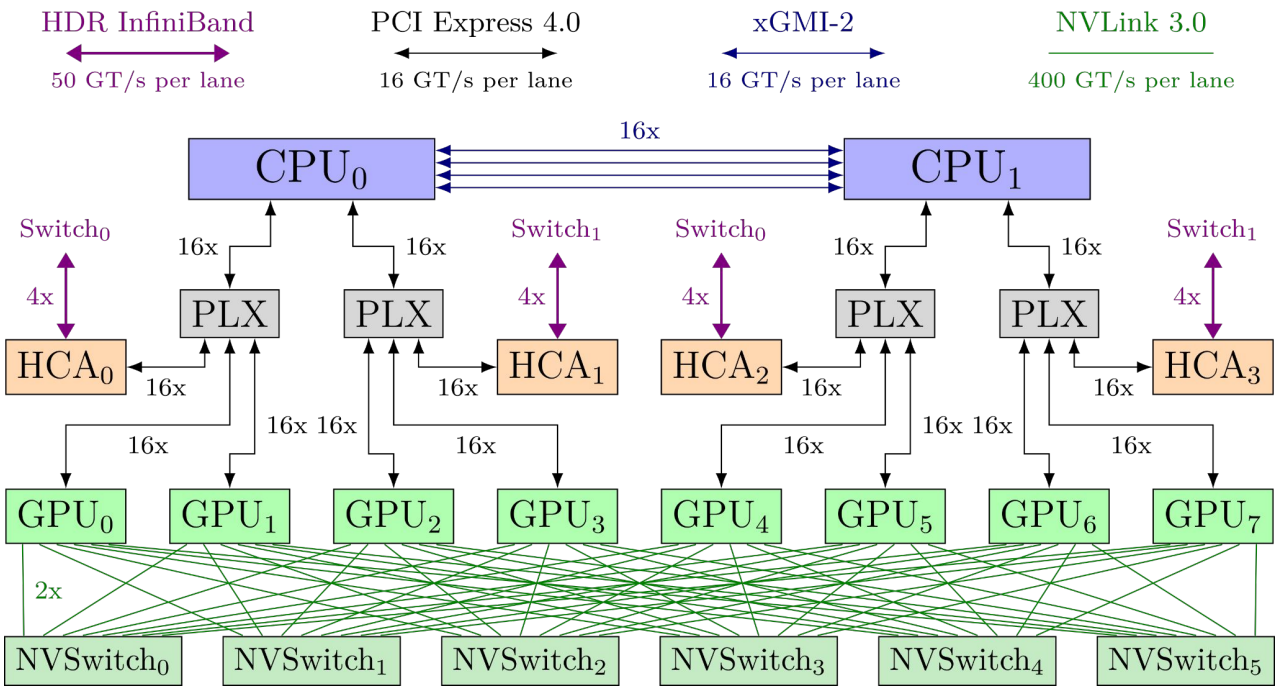


*Top: The naive model parallelism strategy leads to severe underutilization due to the sequential nature of the network. Only one accelerator is active at a time. **Bottom:** GPipe divides the input mini-batch into smaller micro-batches, enabling different accelerators to work on separate micro-batches at the same time.*

3D Parallelism



Components of a Computing Cluster



96 A100s

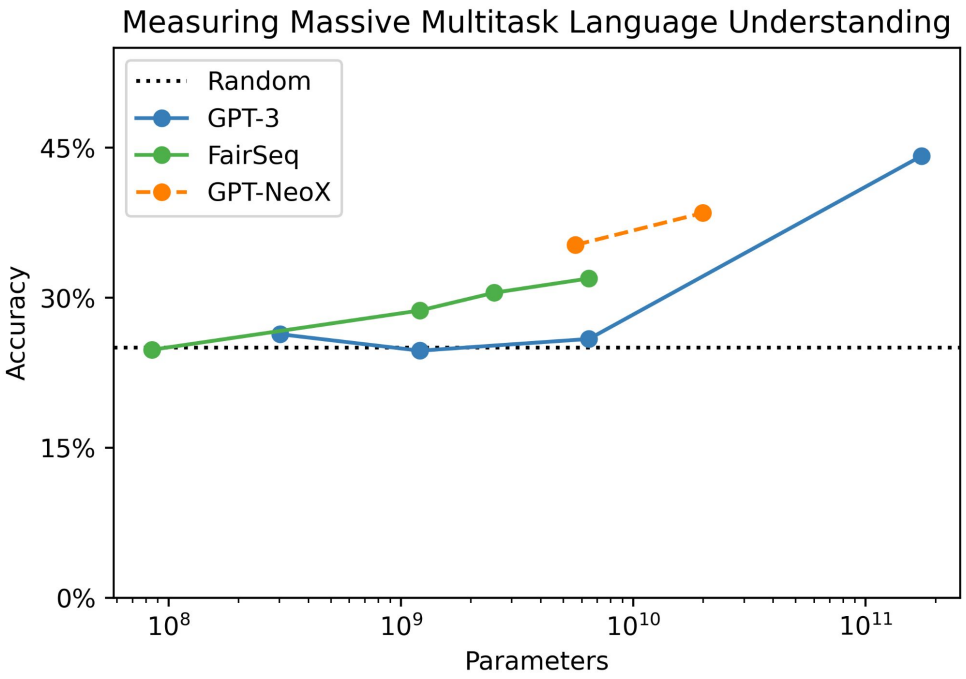
12 nodes of 8 A100s

Performance Metrics

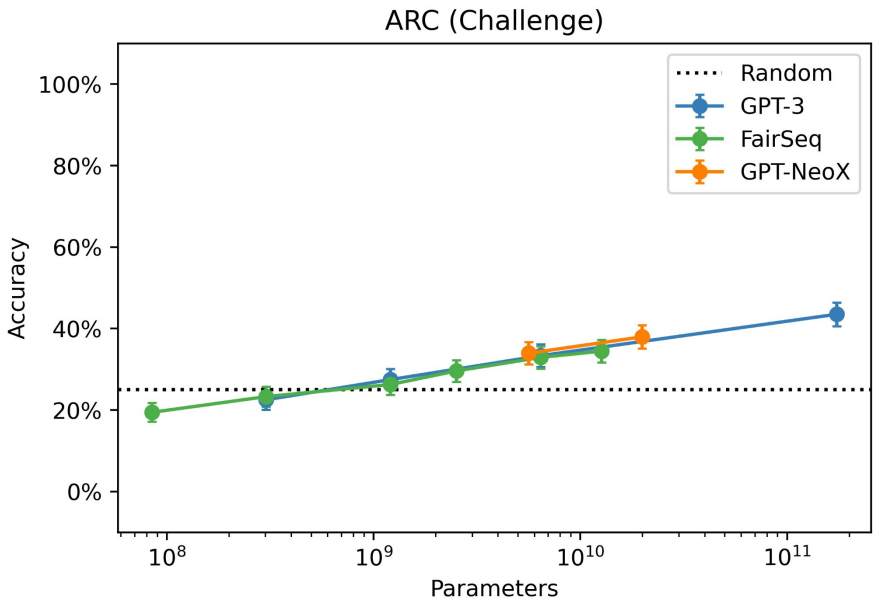
Knowledge-Intensive Tasks

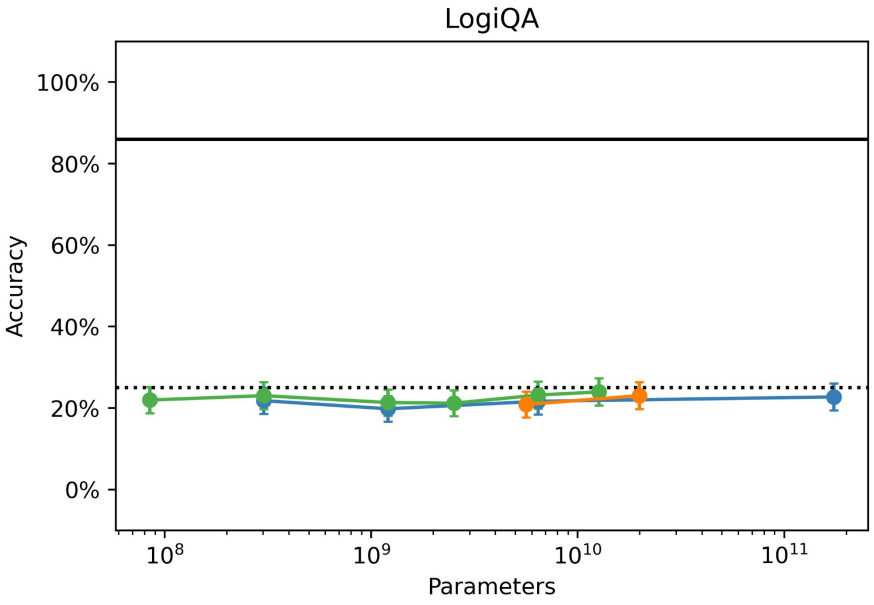
Data is primarily questions that require extremely advanced knowledge <u>in humans</u>

“Mere” intelligence is insufficient: substantial subject specific expertise is required <u>in humans</u>

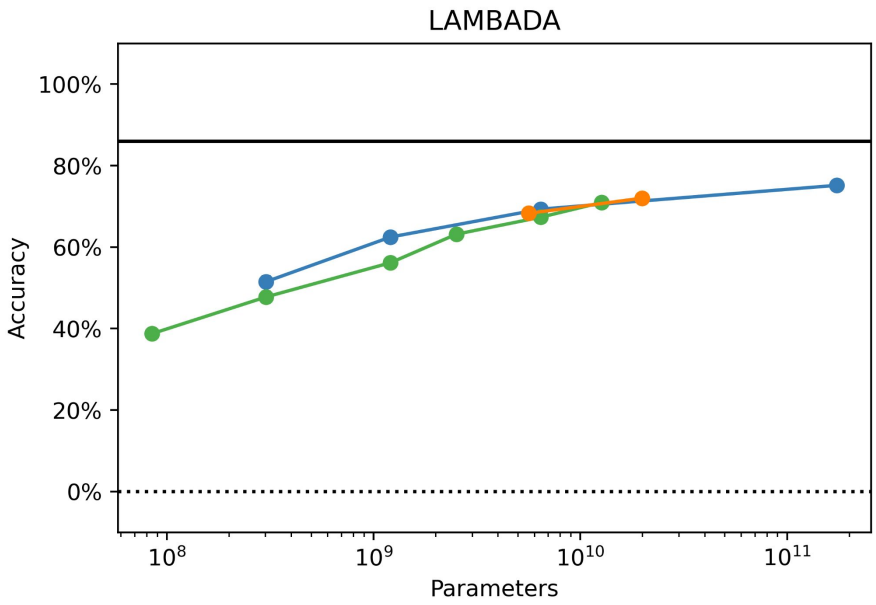


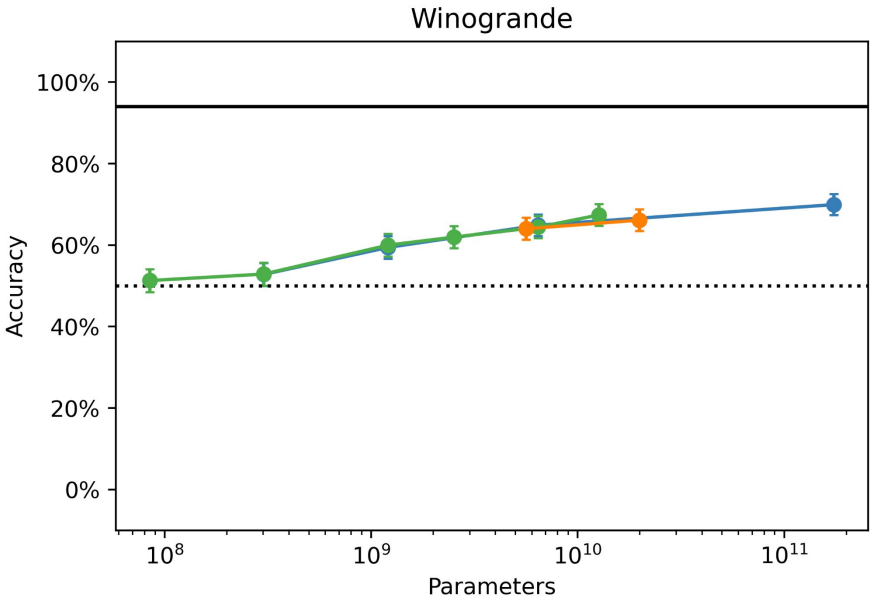
Standard Language Benchmarks



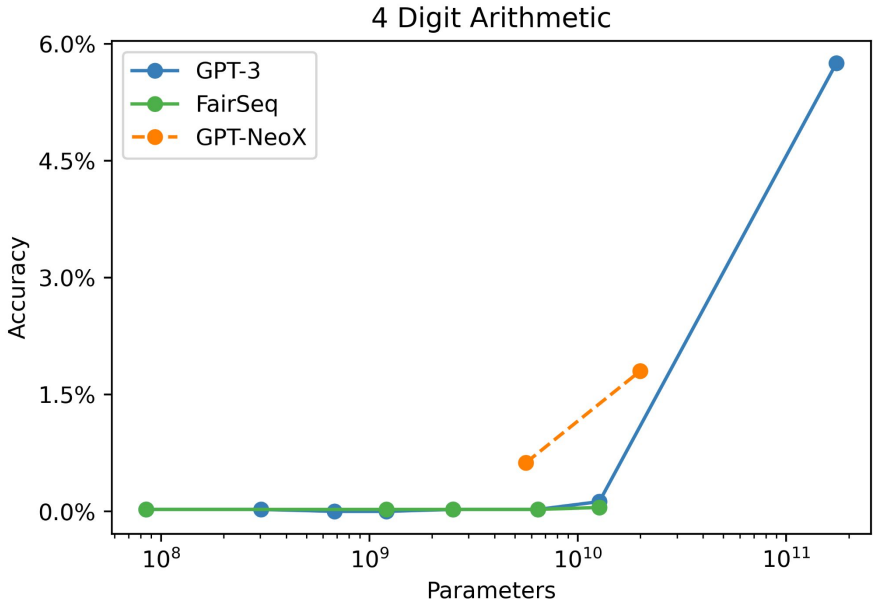


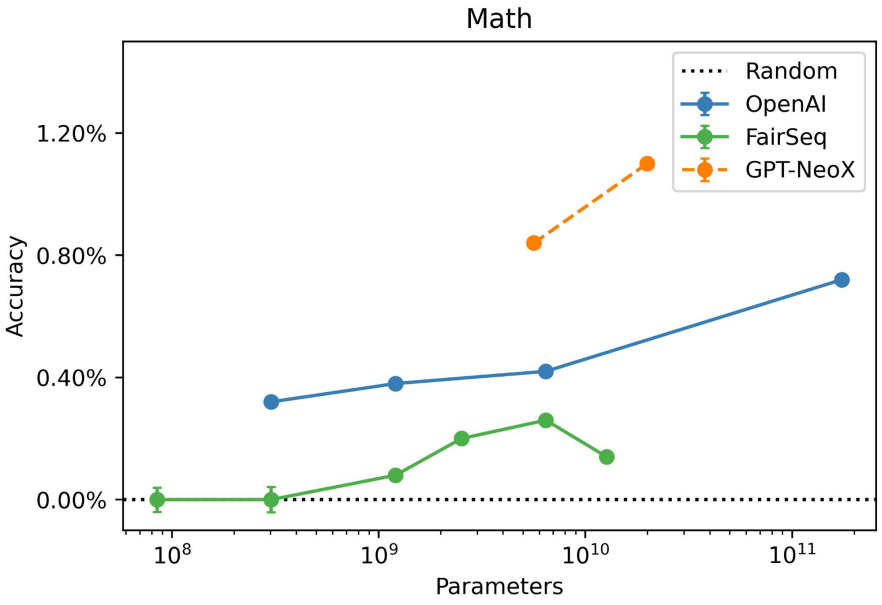
Standard Language Benchmarks





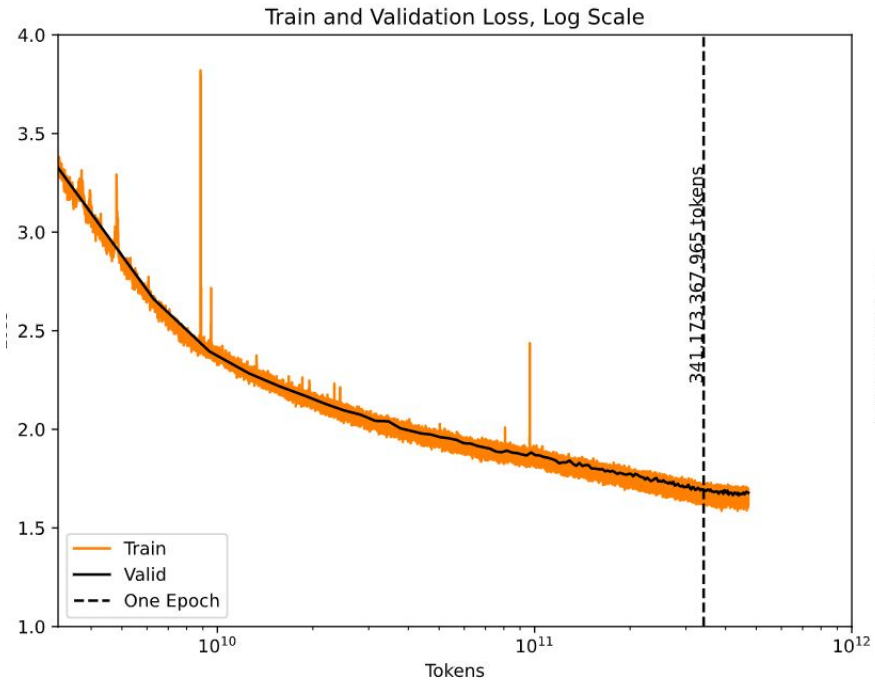
Mathematics

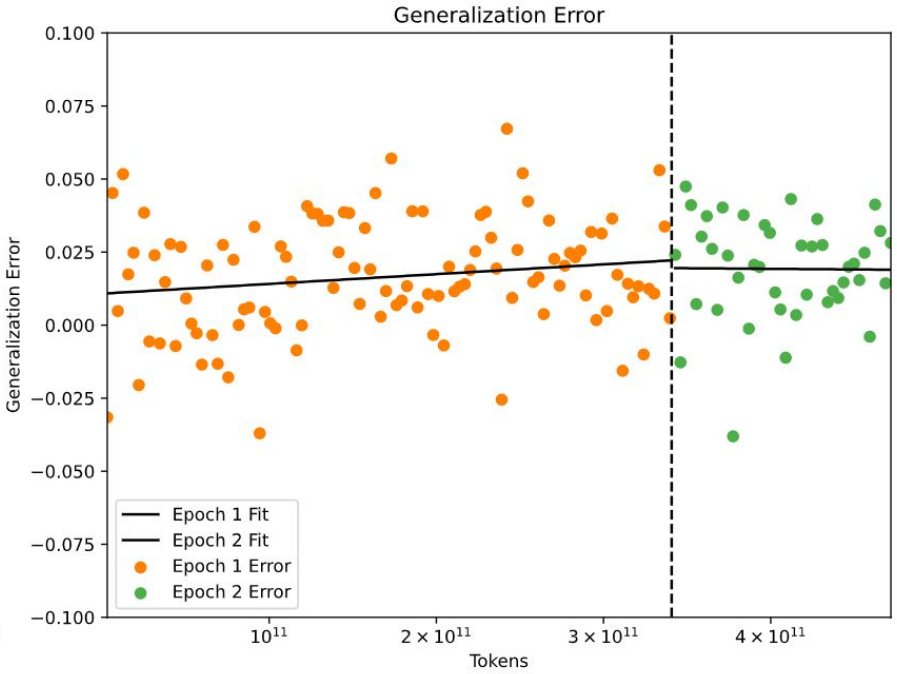




Scientific Observations

How Bad is a Second Epoch?

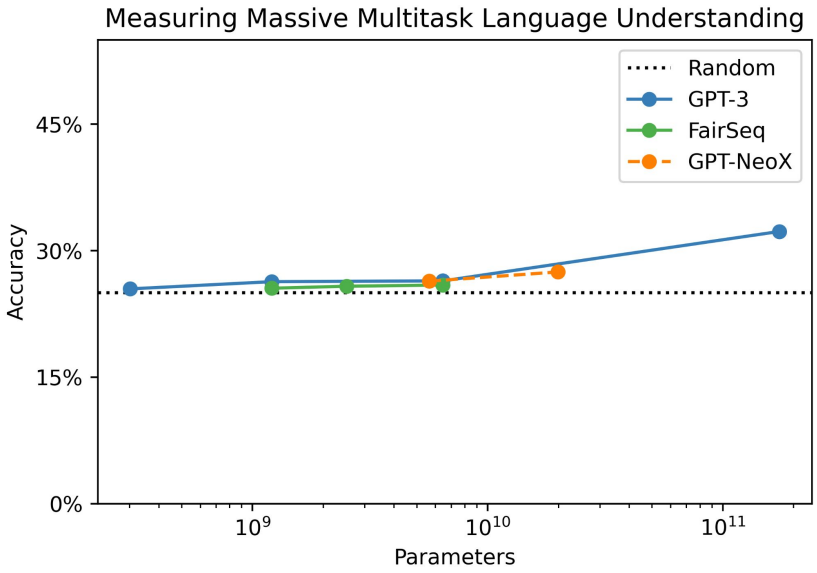




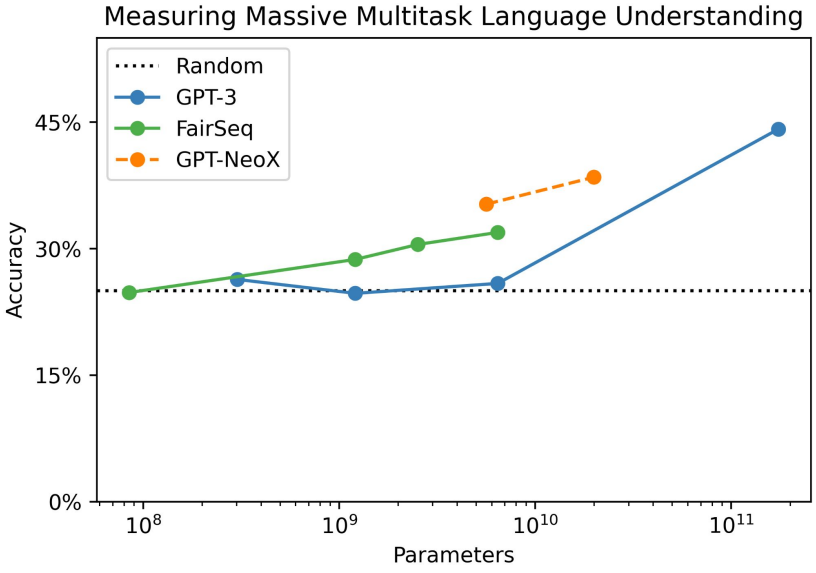
Improved Few-Shot Learning?

Perhaps due to “multitask” nature of the Pile

zero-shot



5-shot



Energy and Carbon

	Coal	Gas	Hydro	Nuclear	Solar	Wind	Other
% Electricity Mix	30.40%	31.30%	1.30%	17.40%	0.30%	18.10%	1.30%
t_{CO_2}/MWh	0.95	0.6078	0	0	0	0	0

1830 hours of training

920 hours of testing and evaluation

66.24 MWh -> 35 metric tons of CO2

Limitations

- Lack of coding evaluations
- Suboptimal training regime
- Further investigation of “multitask” training is needed
- Need for further improvement in democratizing access:
  If you want to use GPT-NeoX-20B in your research but do not have the computational resources to do so, email stella@eleuther.ai.

Questions?

Come join us!