AI Box

大模型技术基础

《大语言模型》编写团队：赵鑫

大语言模型

AI Box

- 定义：通常是指具有超大规模参数的预训练语言模型
- 架构：主要为 Transformer解码器架构
- 训练：预训练（base model）、后训练（instruct model）

训练

预训练

数据：海量文本数据

优化：预测下一个词

建立模型的**基础能力**

base model

后训练

数据：大量指令数据

优化：SFT、RL等方法

增强模型的**任务能力**

instruct model

下游应用

测试（推理）

大语言模型

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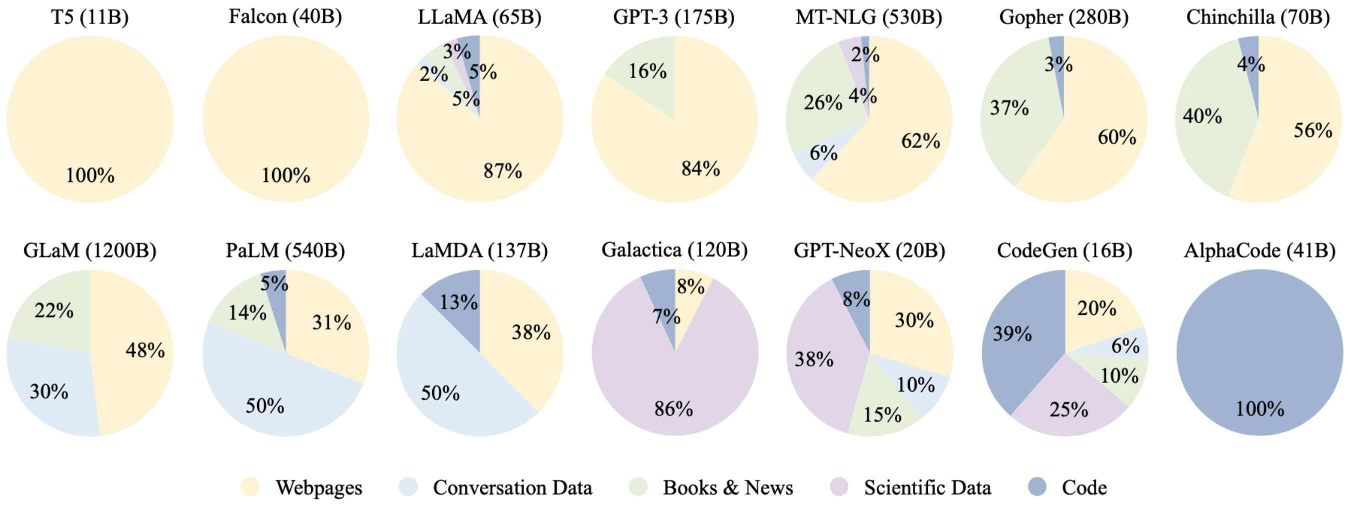
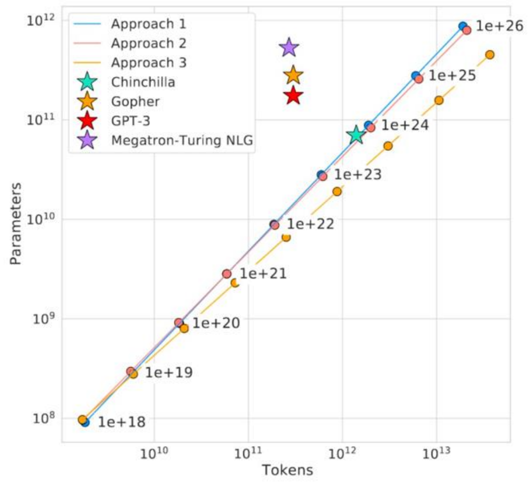
对比方面	预训练 (Pre-training)	后训练 (Post-training)
核心目标	建立模型基础能力	将基座模型适配到具体应用场景
数据资源	数万亿词元的自然语言文本	数十万、数百万到数千万指令数据
所需算力	耗费百卡、千卡甚至万卡算力数月时间	耗费数十卡、数百卡数天到数十天时间
使用方式	通常为few-shot提示	可以直接进行zero-shot使用

*此部分算力估计为一个大致估计，需要根据模型大小、数据数量、训练框架等多方面因素确定

大语言模型构建概览

- 大语言模型预训练（Pre-training）
  - 使用与下游任务无关的大规模模数据进行模型参数的初始训练
    - 基于Transformer解码器架构，进行下一个词预测
    - 数据数量、数据质量都非常关键

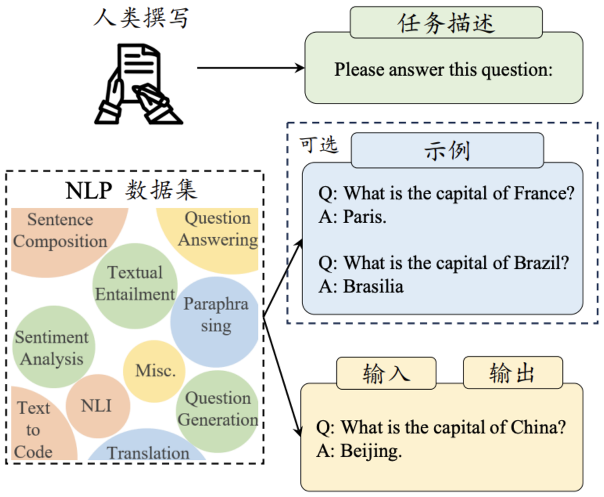


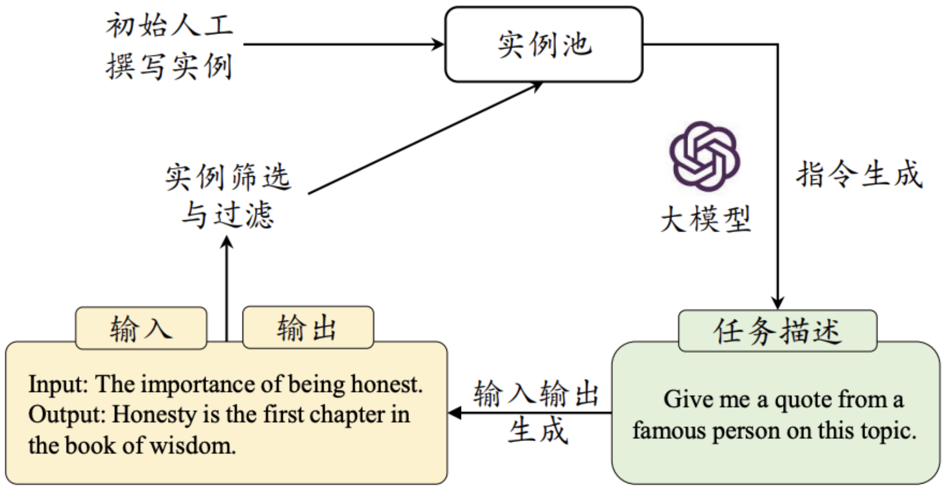


A Survey of Large Language Model, arXiv 2023

大语言模型构建概览

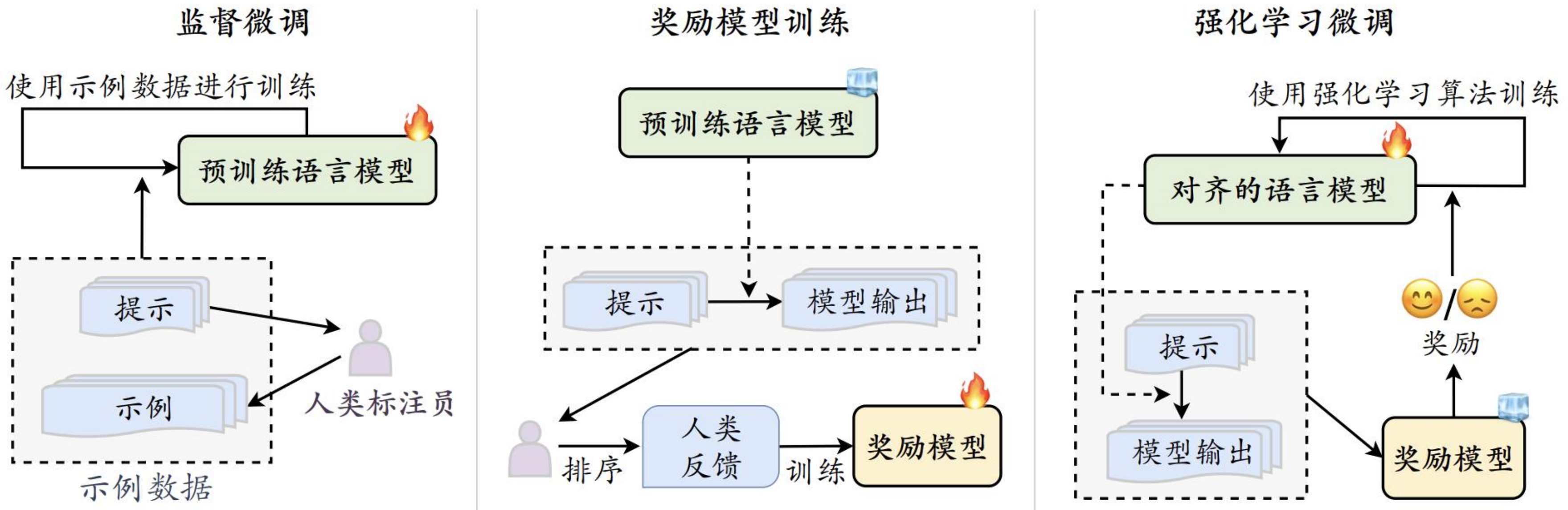
- 大语言模型后训练（Post-Training）
  - 指令微调（Instruction Tuning）
    - 使用输入与输出配对的指令数据对于模型进行微调
    - 提升模型通过问答形式进行任务求解的能力





大语言模型构建概览

- 大语言模型后训练（Post-Training）
  - 人类对齐（Human Alignment）
    - 将大语言模型与人类的期望、需求以及价值观对齐
    - 基于人类反馈的强化学习对齐方法（RLHF）



大语言模型构建概览

➢ 大模型的研发已经成为一项系统工程

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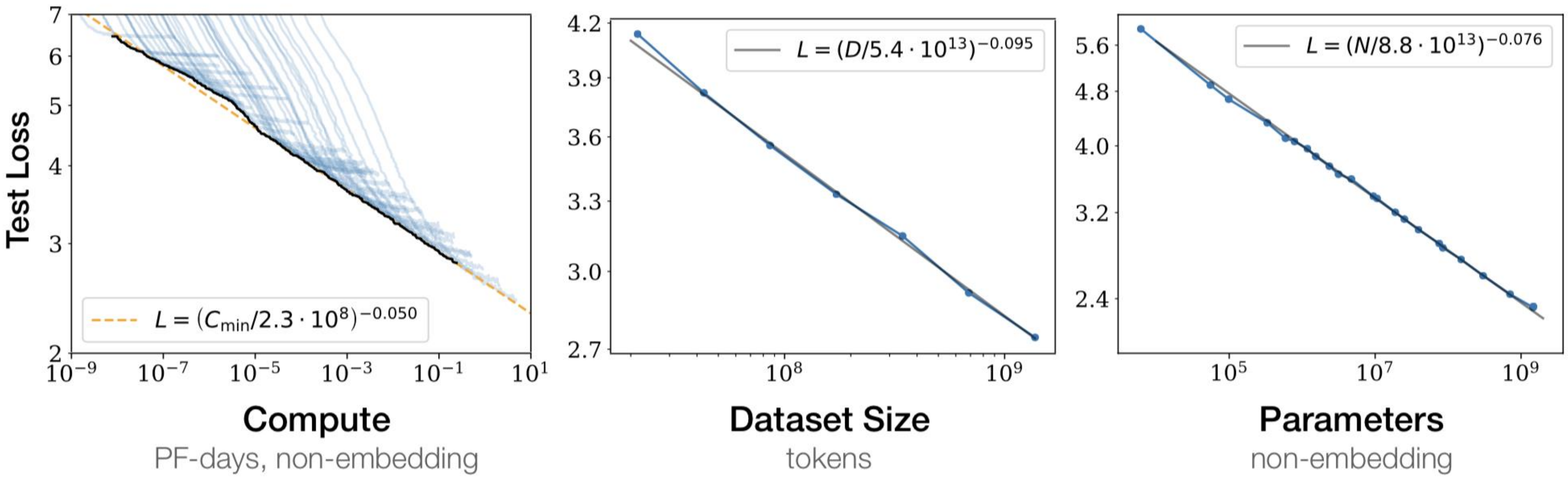
GPT-4 Technical Report

扩展定律

- 什么是扩展定律
  - 通过扩展参数规模、数据规模和计算算力，大语言模型的能力会出现显著提升
  - 扩展定律在本次大模型浪潮中起到了重要作用



Scaling Laws for Neural Language Models, Arxiv, 2020

扩展定律

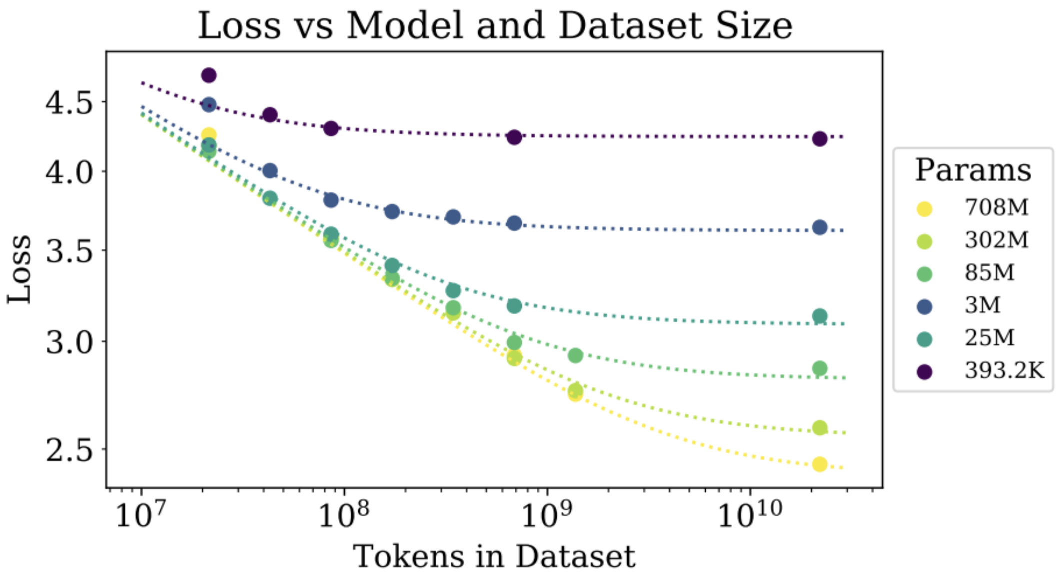
➢ KM扩展定律

➢ OpenAI 团队建立了神经语言模型性能与参数规模（N）、数据规模（D）和计算算力（C）之间的幂律关系

$$L(N) = \left(\frac{N_c}{N}\right)^{\alpha_N}, \quad \alpha_N \sim 0.076, N_c \sim 8.8 \times 10^{13}$$

$$L(D) = \left(\frac{D_c}{D}\right)^{\alpha_D}, \quad \alpha_D \sim 0.095, D_c \sim 5.4 \times 10^{13}$$

$$L(C) = \left(\frac{C_c}{C}\right)^{\alpha_C}, \quad \alpha_C \sim 0.050, C_c \sim 3.1 \times 10^{8}$$



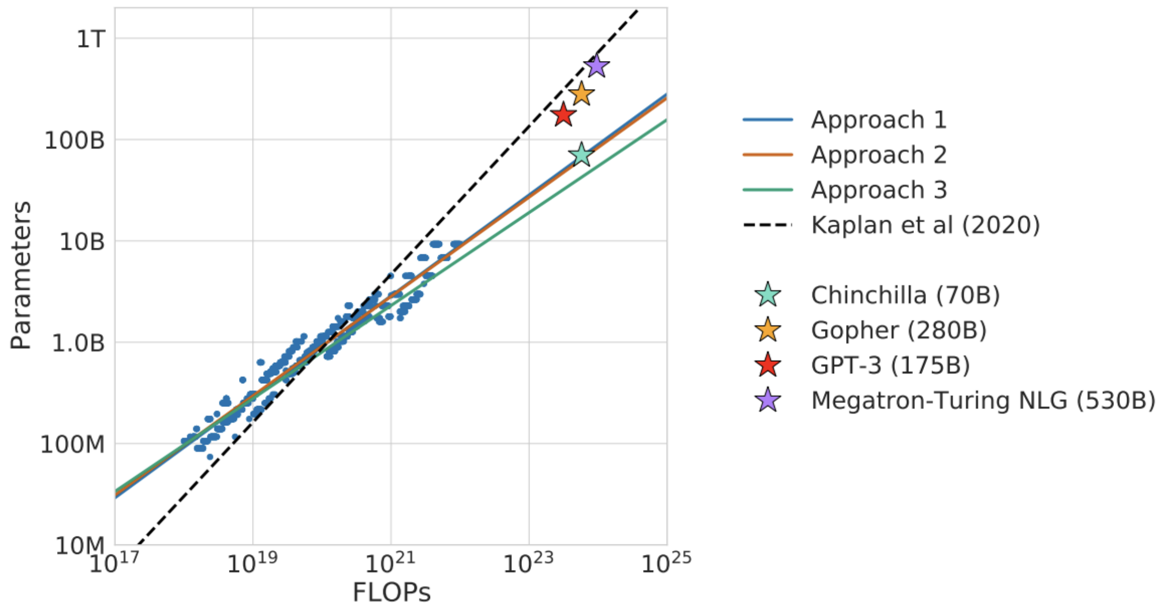
Scaling Laws for Neural Language Models, Arxiv, 2020

扩展定律

- Chinchilla扩展定律
  - DeepMind 团队于 2022 年提出了另一种形式的扩展定律,旨在指导大语言模型充分利用给定的算力资源优化训练

$$L(N, D) = E + \frac{A}{N^{\alpha}} + \frac{B}{D^{\beta}},$$

$$N_{\mathrm{opt}}(C) = G\left(\frac{C}{6}\right)^{a}, \quad D_{\mathrm{opt}}(C) = G^{-1}\left(\frac{C}{6}\right)^{b},$$



Training Compute-Optimal Large Language Models, NIPS 2022

扩展定律

AI Box

- 深入讨论
  - 模型的语言建模损失可以进行下述分解

$$L(x) = \underbrace{L_{\infty}}_{\text{不可约损失}} + \underbrace{\left(\frac{x_0}{x}\right)^{\alpha_x}}_{\text{可约损失}}$$

可约损失：真实分布和模型分布之间KL散度，可通过优化减少

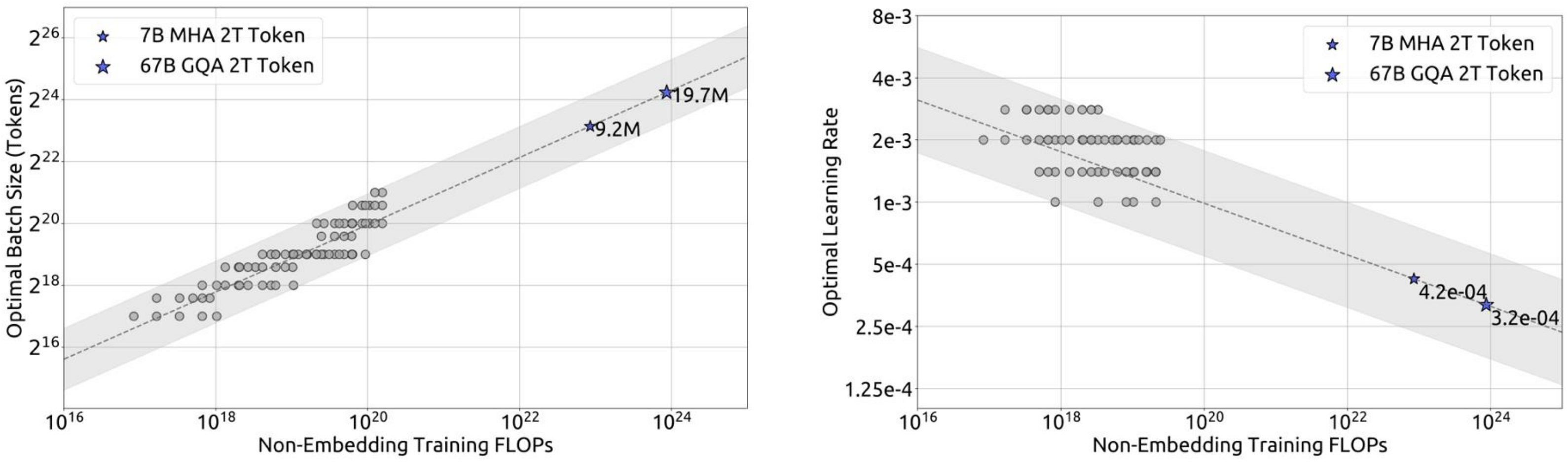
不可约损失：真实数据分布的熵，无法通过优化减少

  - 扩展定律可能存在边际效益递减
    - 随着模型参数、数据数量的扩展，模型性能增益将逐渐减小
    - 目前开放数据已经接近枯竭，难以支持扩展定律的持续推进

扩展定律

AI Box

- 深入讨论
  - 可预测的扩展（Predictable Scaling）
    - 使用小模型性能去预估大模型的性能，或帮助超参数选择
    - 训练过程中使用模型早期性能来预估后续性能

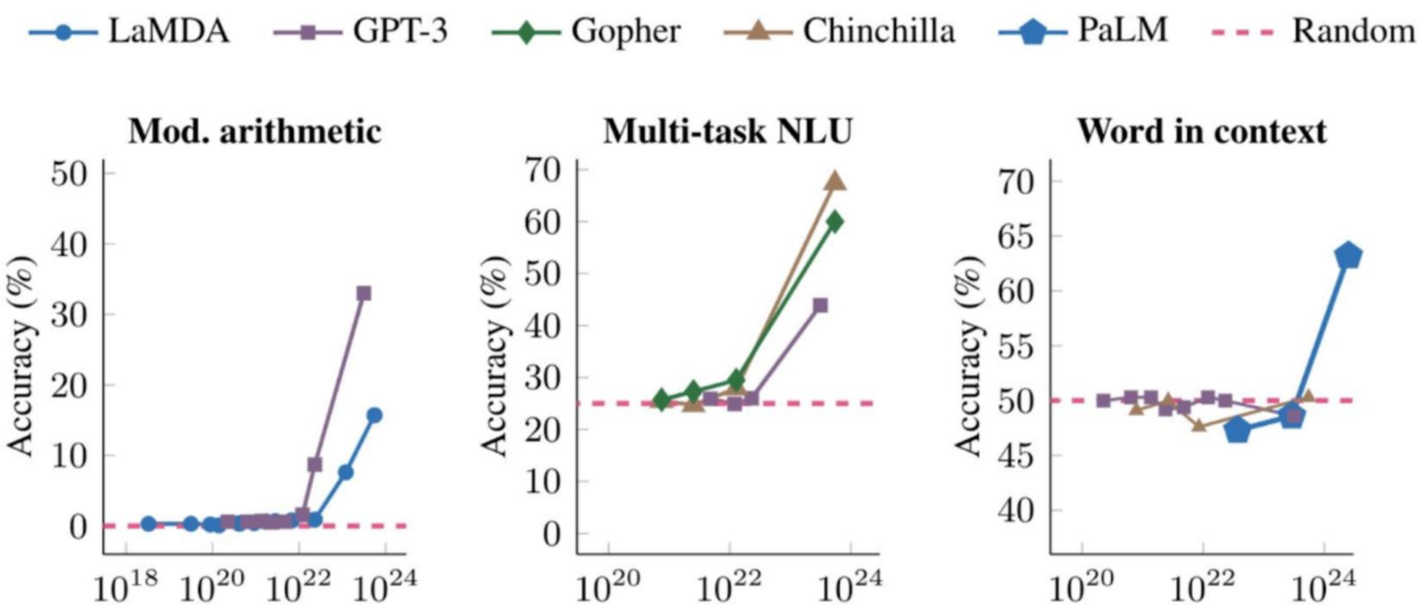


(a) Batch size scaling curve (b) Learning rate scaling curve

DeepSeek LLM Scaling Open-Source Language Models with Longtermism, Arxiv, 2024

涌现能力

- 什么是涌现能力
  - 原始论文定义：“在小型模型中不存在、但在大模型中出现的能力”
  - 模型扩展到一定规模时，特定任务性能突然出现显著跃升趋势，远超随机水平



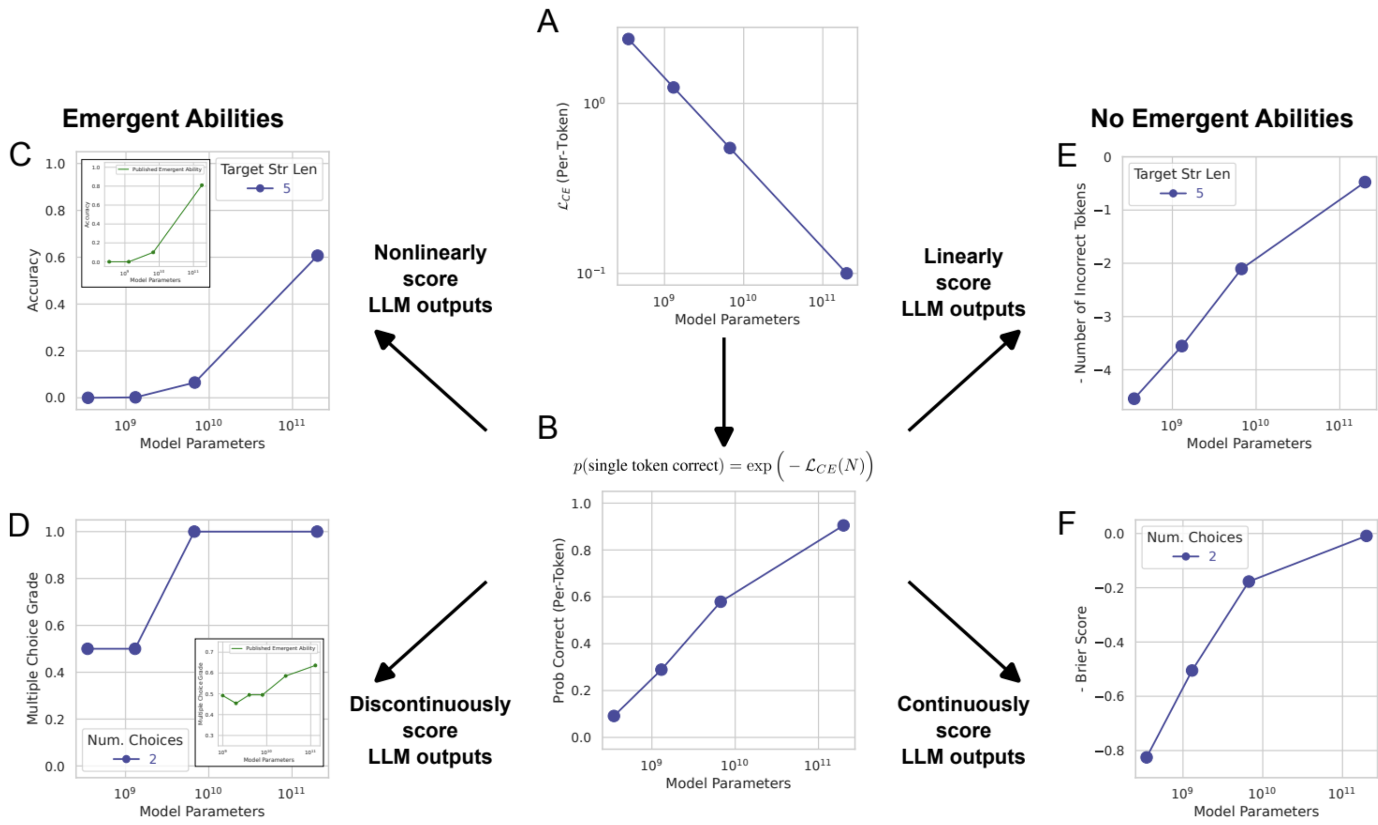
Emergent Abilities of Large Language Models, TMLR 2022

涌现能力

AI Box

➢ 涌现能力可能部分归因于评测设置

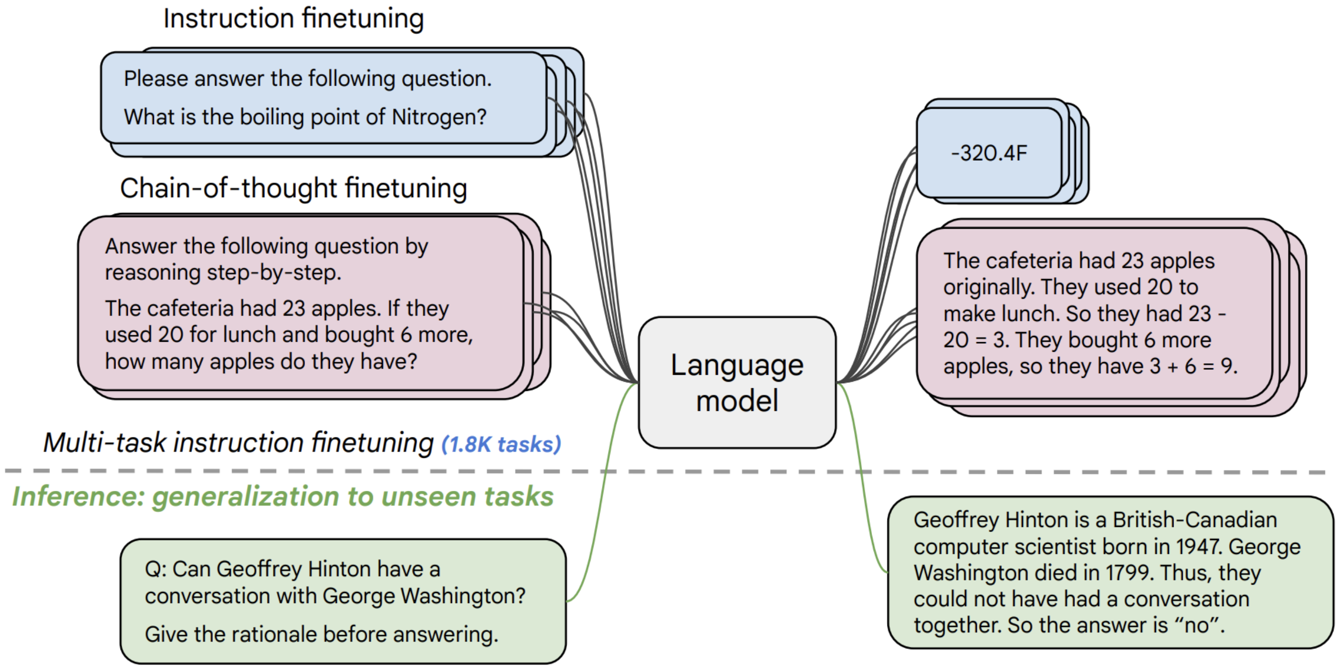
➢ 本课程定义其为“**代表性能力**”，并不区分是否在小模型中存在



Are Emergent Abilities of Large Language Models a Mirage?, NIPS 2023

涌现能力

- 代表性能力
  - 指令遵循（Instruction Following）
    - 大语言模型能够按照自然语言指令来执行对应的任务



Scaling Instruction-Finetuned Language Models, JMLR 2024

涌现能力

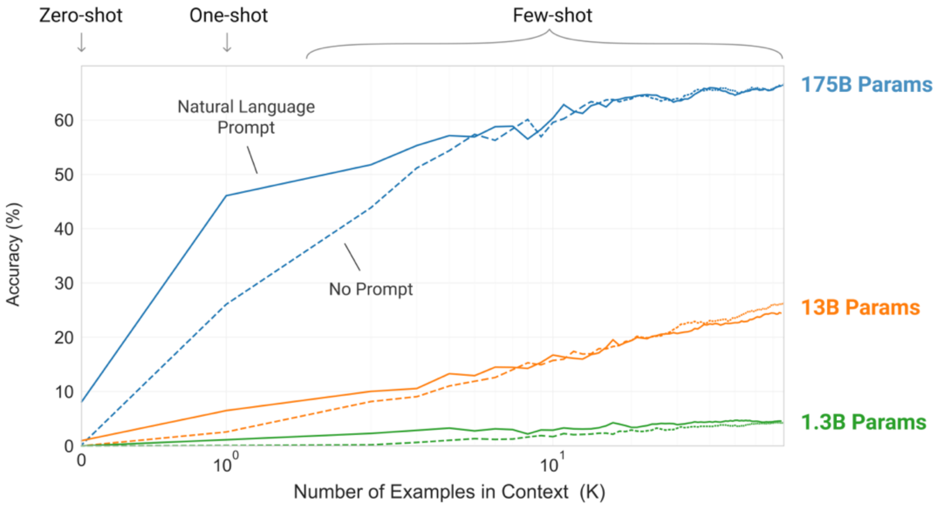
- 代表性能力
  - 上下文学习（In-context Learning）
    - 在提示中为语言模型提供自然语言指令和任务示例，无需显式梯度更新就能为测试样本生成预期输出

Answer the following mathematical reasoning questions:

*N*x

Q: If you have 12 candies and you give 4 candies to your friend, how many candies do you have left?
A: The answer is 8.
Q: If a rectangle has a length of 6 cm and a width of 3 cm, what is the perimeter of the rectangle?
A: The answer is 18cm.

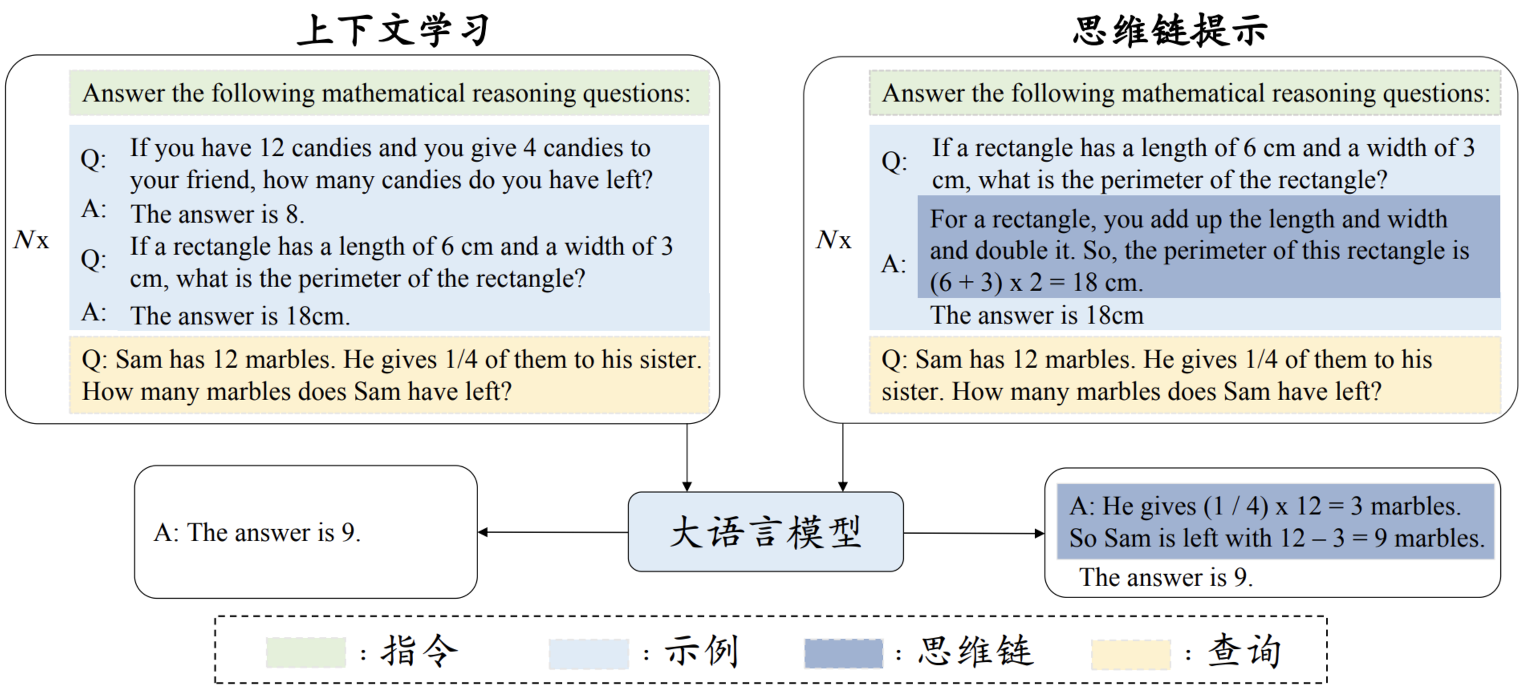
Q: Sam has 12 marbles. He gives 1/4 of them to his sister. How many marbles does Sam have left?



Language Models are Few-shot Learners, NIPS 2020

涌现能力

- 代表性能力
  - 逐步推理（Step-by-step Reasoning）
    - 在提示中引入任务相关的中间推理步骤来加强复杂任务的求解，从而获得更可靠的答案

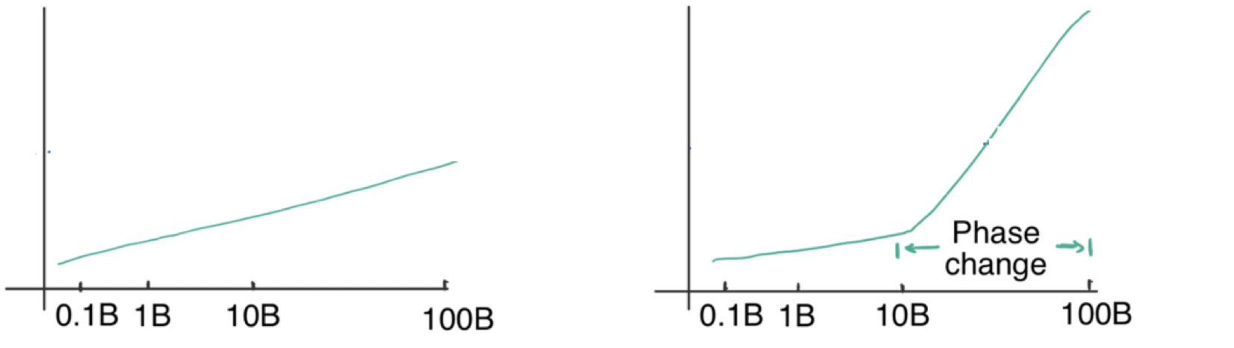


涌现能力

- 涌现能力与扩展定律的关系
  - 涌现能力和扩展定律是两种描述规模效应的度量方法

Scaling law describes a *predictable* increase pattern, but with *diminishing return*

可以理解为是一种较为平滑的多任务损失平均（LM loss）



Scaling Law (~2020 - 2021)　　Emergent Ability (from early 2022)

Model scaling is the key to the emergence of strong abilities

Emergent abilities transcend the scaling law, making the increase *unpredictable but profitable*

非平滑的、某种特定能力或任务的性能跃升（Task loss）

Figure source：https://yaofu.notion.site/A-Closer-Look-at-Large-Language-Models-Emergent-Abilities-493876b55df5479d80686f68a1abd72f

总结

AI Box

- 大模型核心技术
  - 规模扩展：扩展定律奠定了早期大模型的技术路线，产生了巨大的性能提升
  - 数据工程：数据数量、数据质量以及配制方法极其关键
  - 高效预训练：需要建立可预测、可扩展的大规模训练架构
  - 能力激发：预训练后可以通过微调、对齐、提示工程等技术进行能力激活
  - 人类对齐：需要设计对齐技术减少模型使用风险，并进一步提升模型性能
  - 工具使用：使用外部工具加强模型的弱点，拓展其能力范围

谢谢