Speculations on Test-Time Scaling

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Cornell

Outline

Introduction

The Clues

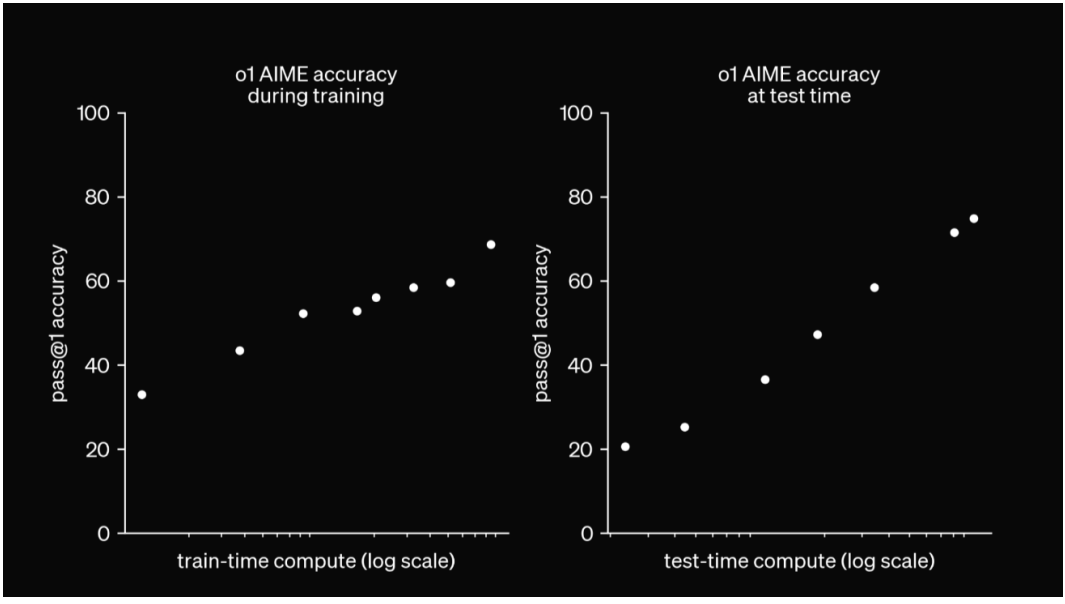
Guess and Check

Guided Search

Full AlphaZero

Learning to Search

Something Wild


o1 AIME accuracy
during training
100
80
60
40
20
0
pass@1 accuracy
train-time compute (log scale)
o1 AIME accuracy
at test time
100
80
60
40
20
0
pass@1 accuracy
test-time compute (log scale)

Context

- LLM (2018-2024) driven by training scaling
- Speculation: Benefit of static data running out

Implication

- Breakthrough in large-scale RL Training
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What have we seen?

- Public demo model
- Strong result in constrained domains.

This Talk

- Survey of the public literature
- Synthesis of discussions with expert
- Gossip and hearsay

Thanks

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What we know

Our large-scale **reinforcement learning algorithm** teaches the model how to think productively using its **chain of thought** in a highly **data-efficient** training process.

What we know

- RL - Signal from verifiable problems
- CoT - “Thinking” occurs in token stream
- Data Efficient - Fixed set of good problems

From Gossip

- Single final model
- Not learned from expert examples
-

Chain of Thought

o1 learns to hone its chain of thought and refine the strategies it uses. It learns to recognize and **correct its mistakes**. It learns to **break down tricky steps** into simpler ones. It learns to try a **different approach** when the current one isn't working.

Review: Chain of Thought

-

Planning

Backtracking

Strategies

Summary

- Solves problems by very long CoT
- CoT includes “thinking” (search / planning)
- Core novelty: Inducing this behavior

The Suspects

- Guess + Check
- Guided Search
- AlphaZero
- Learn to Search
- Wildcard

A Note About Names

- Many different communities
- Names conflict and overlap with past methods
- This talk: First explain, then discuss names

Informal: Guess + Check

- Sample N CoTs
- Check if successful
- Train on good ones

Simple Formalization: EM

- Sample N CoTs
- Check if successful
- Train on good ones

Online Formalization: Policy Gradient

- Sample N CoTs
- Check if successful
- Train on good ones

Terminology

- STaR
- ReST
- ReST-EM
- Filtered Rejection Sampling
- Best-of-N

Why might this be right?

- Extremely simple and scalable
- Good baseline in past work

Why might this be wrong?

- No evidence this learns to correct, plan
- Well-explored in literature with marginal gains

Alternative

- Can we improve upon the process of finding adequate CoTs?

Informal: Guided Search

- Sample several next steps for CoT
- Check with a guide model for which to pursue
- Continue to the end
- Train on good ones

Where does the guide come from?

PRM/RollOuts

[Uesato et al., 2022]

- Point 1
- Point 2
- Point 3

Full AlphaZero

[Silver et al., 2017]

- Point 1
- Point 2
- Point 3

Learning to Search

[Gandhi et al., 2024]

- Point 1
- Point 2
- Point 3

Something Wild

[Brown et al., 2024]

- Point 1
- Point 2
- Point 3

Reference I

[Brown et al., 2024] Brown, B., Juravsky, J., Ehrlich, R., Clark, R., Le, Q. V., Ré, C., and Mirhoseini, A. (2024). Large language monkeys: Scaling inference compute with repeated sampling. *arXiv [cs.LG]*.

[Gandhi et al., 2024] Gandhi, K., Lee, D., Grand, G., Liu, M., Cheng, W., Sharma, A., and Goodman, N. D. (2024). Stream of search (SoS): Learning to search in language. *arXiv [cs.LG]*.

Reference II

[Silver et al., 2017] Silver, D., Hubert, T., Schrittwieser, J., Antonoglou, I., Lai, M., Guez, A., Lanctot, M., Sifre, L., Kumaran, D., Graepel, T., Lillicrap, T., Simonyan, K., and Hassabis, D. (2017).
Mastering chess and shogi by self-play with a general reinforcement learning algorithm.
arXiv [cs.AI].

Reference III

[Uesato et al., 2022] Uesato, J., Kushman, N., Kumar, R., Song, F., Siegel, N., Wang, L., Creswell, A., Irving, G., and Higgins, I. (2022).
Solving math word problems with process- and outcome-based feedback.
arXiv [cs.LG].