Chain-of-thought Prompting

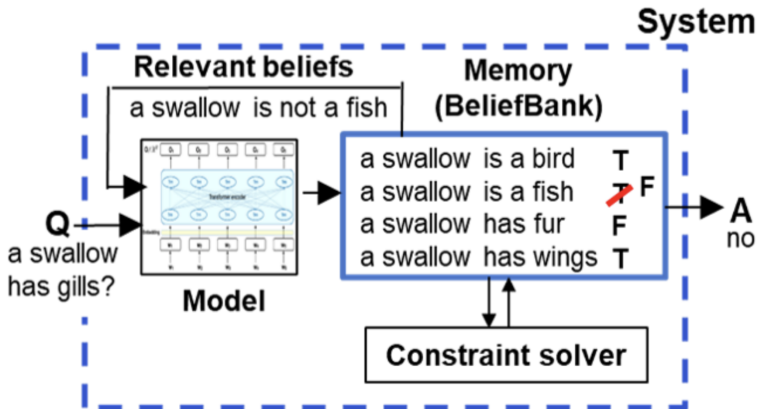# Large Language Models (LLMs)

Learning goals

- illustrate chain-of-thought and point out the benefits it brings to LLMs

- illustrate tree-of-thought and point out the benefits it brings to LLMs
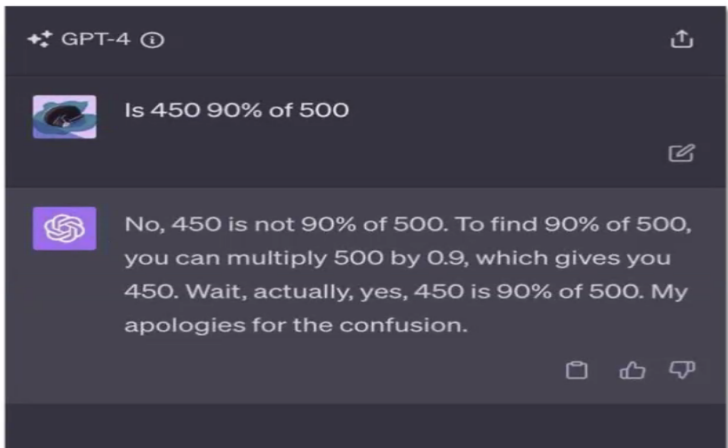
CHAIN-OF-THOUGHT MOTIVATION

How to boost the reasoning capabilities of LLMs? ▸ Wei et al., 2021

- Use formal approaches, e.g., logic, symbolic reasoning
  - Example: ▸ BeliefBank
  - Difficult to train and deploy, not widely used
- Standard few-shot learning via prompting works for many tasks
  - Still, it works poorly for many tasks that require reasoning
- Chain of thought (CoT) prompting
  - A new form of few-shot prompting
  - Prompts in the form <input, *chain of thought*, output>
  - chain of thought:
    series of reasoning steps that lead to the final answer
  - applications: complex, commonsense, symbolic reasoning
    tasks etc

NEUROSYMBOLIC APPROACH
(CURRENTLY INFREQUENTLY USED)

LLMS NOT GOOD AT REASONING TASKS

GPT-4 ⓘ

> Is 450 90% of 500

> No, 450 is not 90% of 500. To find 90% of 500, you can multiply 500 by 0.9, which gives you 450. Wait, actually, yes, 450 is 90% of 500. My apologies for the confusion.

Question: What is the problem here?

CHAIN-OF-THOUGHT PROMPTING PARADIGM (MOVE TO NEXT SLIDE FOR CHAIN OF THOUGHT)

Standard Prompting

Model Input

Q: Roger has 5 tennis balls. He buys 2 more cans of tennis balls. Each can has 3 tennis balls. How many tennis balls does he have now?

A: The answer is 11.

Q: The cafeteria had 23 apples. If they used 20 to make lunch and bought 6 more, how many apples do they have?

Model Output

A: The answer is 27. ❌

Chain-of-Thought Prompting

Model Input

Q: Roger has 5 tennis balls. He buys 2 more cans of tennis balls. Each can has 3 tennis balls. How many tennis balls does he have now?

A: Roger started with 5 balls. 2 cans of 3 tennis balls each is 6 tennis balls. 5 + 6 = 11. The answer is 11.

Q: The cafeteria had 23 apples. If they used 20 to make lunch and bought 6 more, how many apples do they have?

Model Output

A: The cafeteria had 23 apples originally. They used 20 to make lunch. So they had 23 - 20 = 3. They bought 6 more apples, so they have 3 + 6 = 9. The answer is 9. ✅

▸ Source: Wei et al., 2022

CHAIN-OF-THOUGHT PROMPTING PARADIGM

Chain-of-Thought Prompting

Model Input

Q: Roger has 5 tennis balls. He buys 2 more cans of tennis balls. Each can has 3 tennis balls. How many tennis balls does he have now?

A: Roger started with 5 balls. 2 cans of 3 tennis balls each is 6 tennis balls. 5 + 6 = 11. The answer is 11.

Q: The cafeteria had 23 apples. If they used 20 to make lunch and bought 6 more, how many apples do they have?

Model Output

A: The cafeteria had 23 apples originally. They used 20 to make lunch. So they had 23 - 20 = 3. They bought 6 more apples, so they have 3 + 6 = 9. The answer is 9. ✓

BENEFITS OF CHAIN-OF-THOUGHT

- Decompose multi-step problems and thus allocate more compute to problems requiring more reasoning steps
- By describing the reasoning, interpretability is increased. It provides the possibility to observe where reasoning went wrong
- It is closer to how humans solve tasks using language
- Language models, if given a well designed prompt chain-of-thought prompt, can solve problems they otherwise would not be able to solve.

EXAMPLES FOR CHAIN OF THOUGHT

Examples of $\langle$**input, chain of thought, output**$\rangle$ **triples for commonsense and symbolic reasoning**

EXAMPLES

StrategyQA

Q: Yes or no: Would a pear sink in water?

A: The density of a pear is about 0.6 g/cm^3, which is less than water. Thus, a pear would float. So the answer is no.

EXAMPLES

Date Understanding

Q: The concert was scheduled to be on 06/01/1943, but was delayed by one day to today. What is the date 10 days ago in MM/DD/YYYY?

A: One day after 06/01/1943 is 06/02/1943, so today is 06/02/1943. 10 days before today is 05/23/1943. So the answer is 05/23/1943.

EXAMPLES

Sports Understanding

Q: Is the following sentence plausible? "Joao Moutinho caught the screen pass in the NFC championship."

A: Joao Moutinho is a soccer player. The NFC championship is part of American football, not soccer. So the answer is no.

EXAMPLES

SayCan (Instructing a robot)

Human: How would you bring me something that isn't a fruit?

Explanation: the user wants something to eat that isn't a fruit. An energy bar is not a fruit, so I will bring the user an energy bar.
Plan: 1. find(energy bar) 2. pick(energy bar) 3. find(user) 4. put(energy bar) 5. done().

EXAMPLES

> **Last Letter Concatenation**
>
> Q: Take the last letters of the words in "Lady Gaga" and concatenate them.
>
> A: The last letter of "Lady" is "y". The last letter of "Gaga" is "a". Concatenating them is "ya". So the answer is ya.
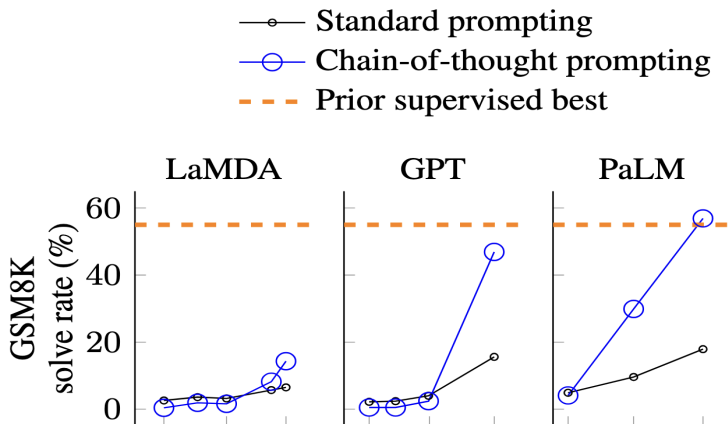
EXAMPLES

Coin Flip (state tracking)

Q: A coin is heads up. Maybelle flips the coin. Shalonda does not flip the coin. Is the coin still heads up?

A: The coin was flipped by Maybelle. So the coin was flipped 1 time, which is an odd number. The coin started heads up, so after an odd number of flips, it will be tails up. So the answer is no.
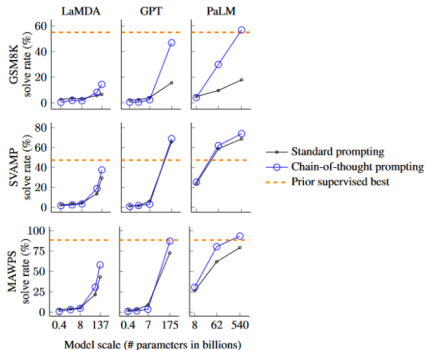
COT IMPROVES ARITHMETIC

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SVAMP: math word problems with varying structures; MAWPS: repository unifying math problems from different sources;

COT IMPROVES COMMONSENSE

CSQA: Contains around 200K dialogs with a total of 1.6M turns. Further, unlike existing large scale QA datasets which contain simple questions that can be answered from a single tuple, the questions in the dialogs require a larger subgraph of the KG.
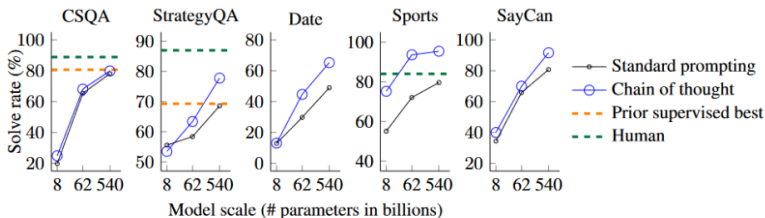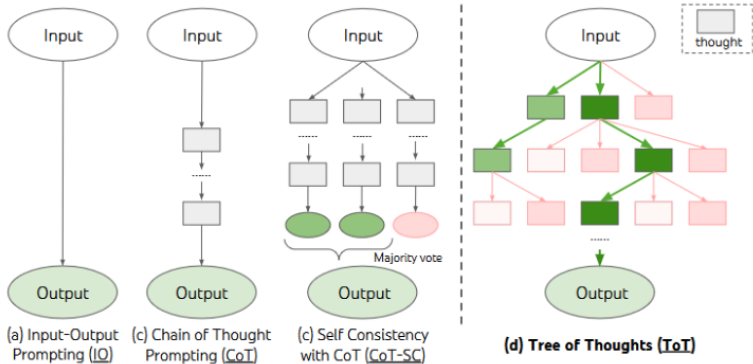

▸ Source: Wei et al., 2022

TREE-OF-THOUGHT: MOTIVATION

- The token-level and left-to-right decisions of the autoregressive mechanism pose a limitation for:
  - Tasks where initial decisions play a pivotal role
  - Tasks requiring exploration or strategic lookahead
- Strategy to solve those:
  - Maintain and explore diverse alternatives instead of just picking one
  - Evaluate current status and look ahead or backtrack to make global decisions

TREE-OF-THOUGHT: PROMPTING PARADIGM

Schematic illustrating three approaches to problem solving with LLMs.
Rectangle box = *thought* = a coherent language sequence serving as
an intermediate step in problem solving.

(a) Input-Output Prompting (IO)

(c) Chain of Thought Prompting (CoT)

(c) Self Consistency with CoT (CoT-SC)

(d) Tree of Thoughts (ToT)

▸ Yao et al., 2023

TREE-OF-THOUGHT FOR CREATIVE WRITING

A step of deliberate search in a randomly picked Creative Writing task.
Given the input, the LM samples five different plans, and then votes five
times to decide which plan is best.
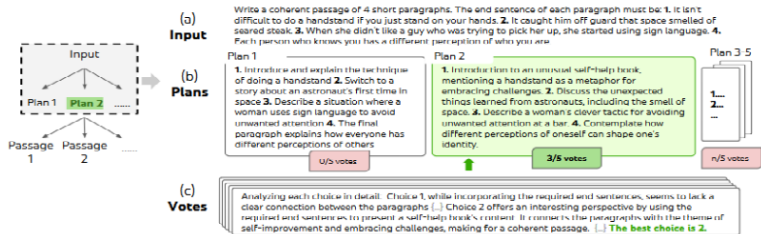
▶ Yao et al., 2023

TREE-OF-THOUGHT FOR CREATIVE WRITING (2)

(a) Input

Write a coherent passage of 4 short paragraphs. The end sentence of each paragraph must be: **1.** It isn't difficult to do a handstand if you just stand on your hands. **2.** It caught him off guard that space smelled of seared steak. **3.** When she didn't like a guy who was trying to pick her up, she started using sign language. **4.** Each person who knows you has a different perception of who you are.

(b) Plans

Plan 1

1. Introduce and explain the technique of doing a handstand **2.** Switch to a story about an astronaut's first time in space **3.** Describe a situation where a woman uses sign language to avoid unwanted attention **4.** The final paragraph explains how everyone has different perceptions of others

0/5 votes

Plan 2

1. Introduction to an unusual self-help book, mentioning a handstand as a metaphor for embracing challenges. **2.** Discuss the unexpected things learned from astronauts, including the smell of space. **3.** Describe a woman's clever tactic for avoiding unwanted attention at a bar. **4.** Contemplate how different perceptions of oneself can shape one's identity.

3/5 votes

Plan 3-5

1....
2...
...

n/5 votes

(c) Votes

Analyzing each choice in detail: Choice 1, while incorporating the required end sentences, seems to lack a clear connection between the paragraphs {…} Choice 2 offers an interesting perspective by using the required end sentences to present a self-help book's content. It connects the paragraphs with the theme of self-improvement and embracing challenges, making for a coherent passage. {…} **The best choice is 2.**

CHAIN OF THOUGHT: ERROR BREAKDOWN

- 8% calculator error
- 16% symbol mapping error
- 22% one missing step error
- rest: semantic issues, incoherent CoT
- Source: Stanford CS25: Beyond LLMs: Agents, Emergent Abilities, Intermediate-Guided Reasoning

CHAIN OF THOUGHT: WHAT COULD GO WRONG?

- Decompose complex problems into a sequence of reasoning steps
- By describing the reasoning, interpretability is increased. It provides the possibility to observe where reasoning went wrong
- It is closer to how humans solve tasks using language
- Language models, if given a well designed prompt chain-of-thought prompt, can solve problems they otherwise would not be able to solve.
- **Question:** What could go wrong?

CHAIN OF THOUGHT: WHY DOES IT WORK?

- **Question:** Why does it work?

CHAIN OF THOUGHT: WHY DOES IT WORK?

- **Question:** Do top-of-the-line LLMs use chain of thought?