chain-of-thought prompting

Large Language Models (LLMs)

Learning goals

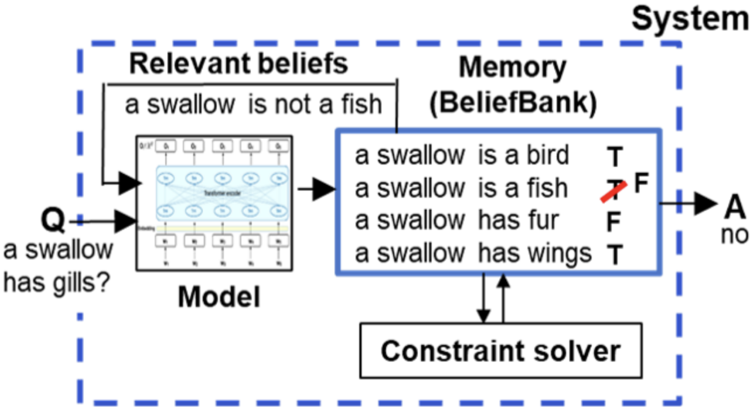
- illustrate chain-of-thought prompting and point out the benefits it brings to LLMs
- illustrate tree-of-thought and point out the benefits it brings to LLMs

chain-of-thought prompting MOTIVATION

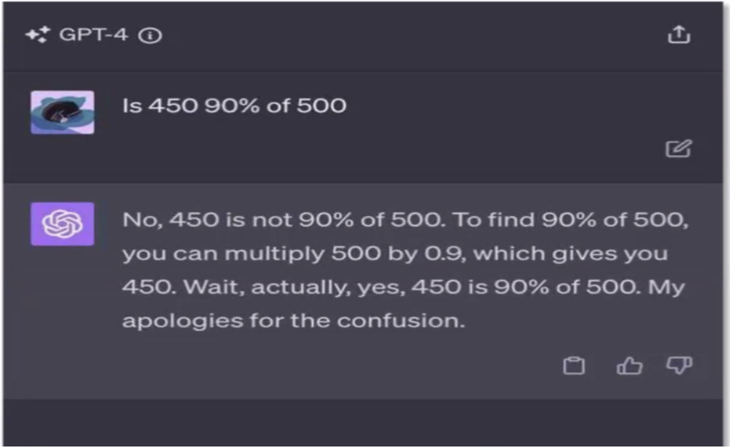
How to boost the reasoning capabilities of LLMs? ▸ Wei et al., 2021

- 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
- COT-P
  - A new form of few-shot prompting
  - Each “training example” has 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)

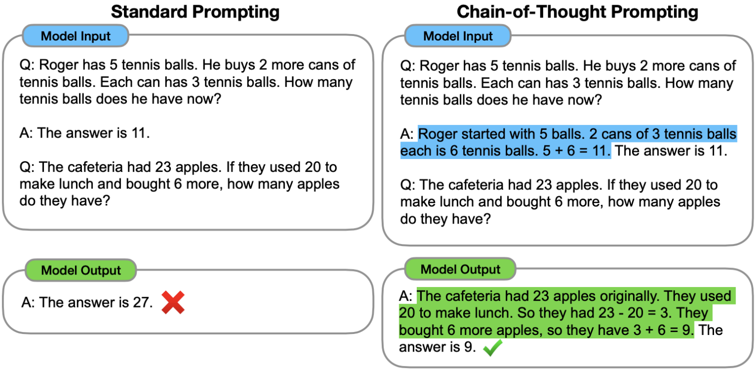


LLMS NOT GOOD AT REASONING TASKS



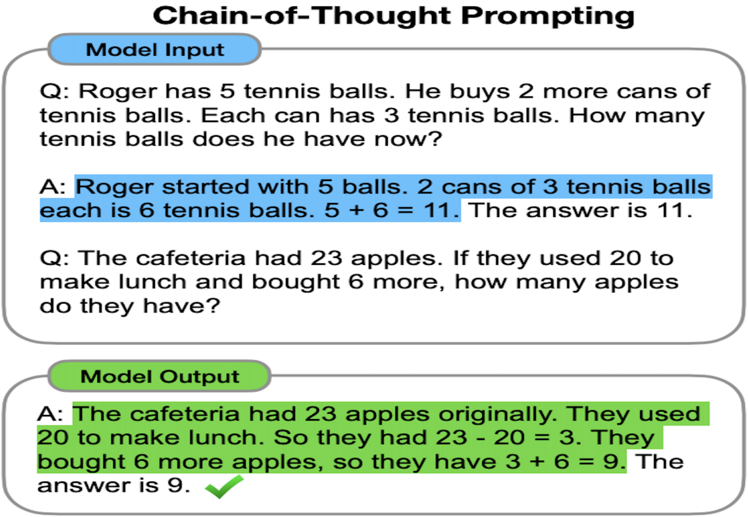
Question: What is the problem here?

chain-of-thought prompting PARADIGM



▸ Source: Wei et al., 2022

chain-of-thought prompting PARADIGM



BENEFITS OF chain-of-thought prompting

- 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 chain-of-thought prompt, can solve problems they otherwise would not be able to solve.

EXAMPLES OF chain-of-thought prompting

Examples of $<$input, chain of thought, output$>$ triples for commonsense and symbolic reasoning

▸ Source: Wei et al., 2022

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.

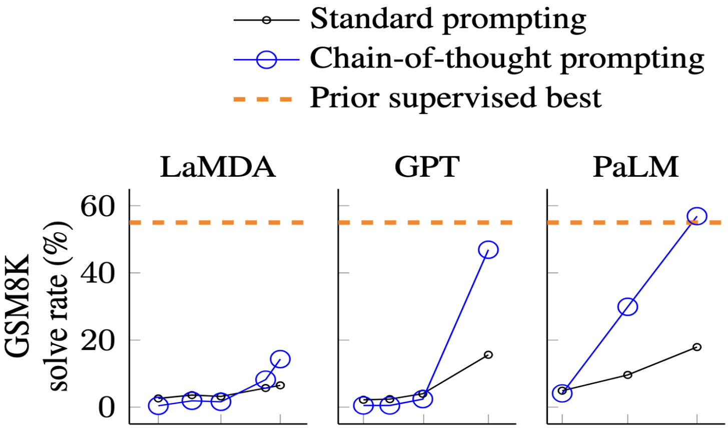
EXAMPLES

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.

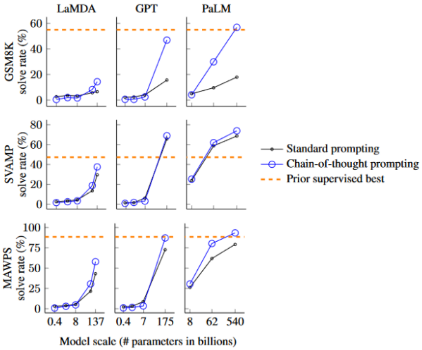
COT-P IMPROVES ARITHMETIC



COT-P IMPROVES ARITHMETIC

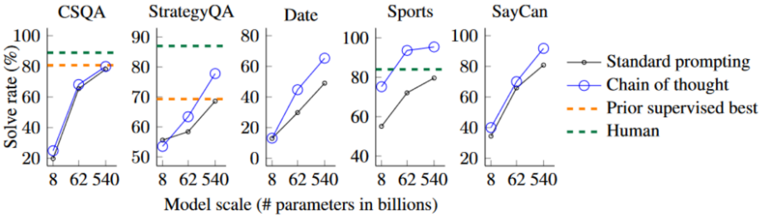
SVAMP: math word problems with varying structures; MAWPS: repository unifying math problems from different sources;

▸ Source: Wei et al., 2022



COT-P 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.



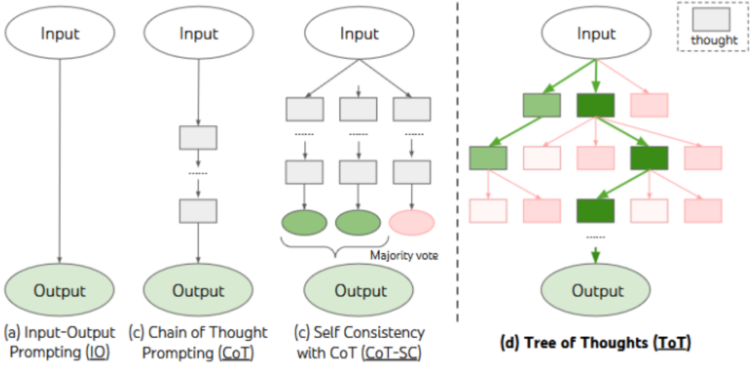
Source: Wei et al., 2022

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

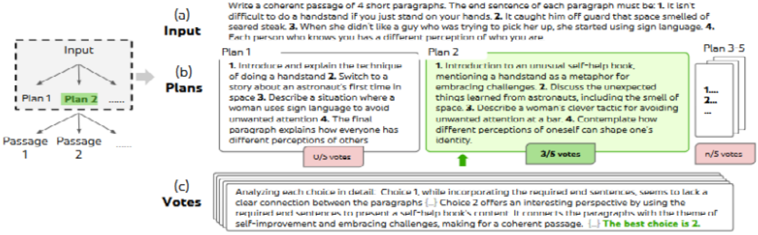
Schematic illustrating three approaches to problem solving with LLMs. Rectangle box = *thought* = a coherent language sequence serving as an intermediate step in problem solving.



▸ Yao et al., 2023

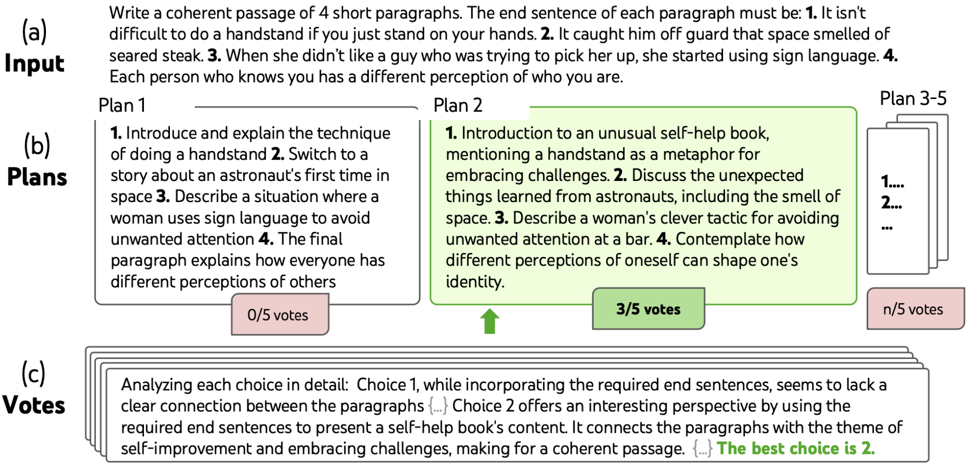
TREE-OF-THOUGHT FOR CREATIVE WRITING

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)



chain-of-thought prompting: ERROR BREAKDOWN

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

chain-of-thought prompting: 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 chain-of-thought prompt, can solve problems they otherwise would not be able to solve.
- **Question:** What could go wrong?

chain-of-thought prompting: WHY DOES IT WORK?

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

chain-of-thought prompting: WHY DOES IT WORK?

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

CHAIN-OF-THOUGHT: TERMINOLOGY

- Shot = “training example”
- few-shot prompting = few-shot learning
- The prompt “think step by step” by itself (without shots) is not chain-of-thought prompting.
- chain-of-thought prompting is defined as including shots.
- Chain-of-Thought is currently used as a general term to refer to the idea of LLMs using explicit reasoning steps to arrive at an answer.
- So the current usage of Chain-of-Thought is more general than chain-of-thought prompting.

CHAIN-OF-THOUGHT IN OPENAI'S O1

- openai
- We are introducing OpenAI o1, a new large language model trained with reinforcement learning to perform complex reasoning. o1 thinks before it answers – it can produce a long internal chain of thought before responding to the user.
- internal!

GENERATOR-VERIFIER GAP (NOAM BROWN)

- For many important problems, it is much easier to verify a solution than generating one.
- Chain-of-thought is expected to help for such problems with a generator-verifier gap.
- Problems with generator-verifier gap: Sudoku, doing math, programming
- Problems with less of a generator-verifier gap: knowledge questions (what is the capital of bhutan?), simple pattern matching (which language is this?)

SLIDO

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