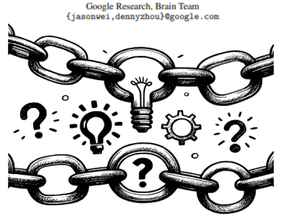
GOOGLE, 2022

Chain-of-Thought Prompting Elicits Reasoning in Large Language Models

Jason Wei Xuezhi Wang Dale Schuurmans Maarten Bosma
Brian Ichter Fei Xia Ed H. Chi Quoc V. Le Denny Zhou
Google Research, Brain Team
{jasonwei,dennyzhou}@google.com



Think in INTERMEDIATE STEPS

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?

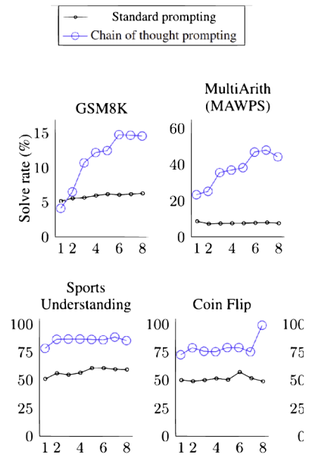
OUTPUT

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.

Example answer with step-by-step reasoning provided in the context

New question

LLM reproduces step-by-step reasoning, resulting in better performance



UNIVERSITY OF TOKYO
GOOGLE, 2022

Large Language Models are Zero-Shot Reasoners

Takeshi Kojima The University of Tokyo t.kojima@weblab.t.u-tokyo.ac.jp
Shixiang Shane Gu Google Research, Brain Team
Machel Reid Google Research*
Yutaka Matsuo The University of Tokyo
Yusuke Iwasawa The University of Tokyo

ZERO-SHOT CoT

Q: A juggler can juggle 16 balls. Half of the balls are golf balls, and half of the golf balls are blue. How many blue golf balls are there?

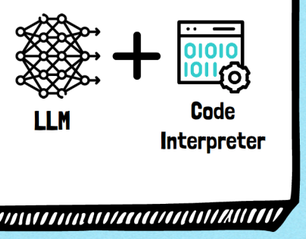
A: Let's think step by step.

There are 16 balls in total. Half of the balls are golf balls. That means that there are 8 golf balls. Half of the golf balls are blue. That means that there are 4 blue golf balls.

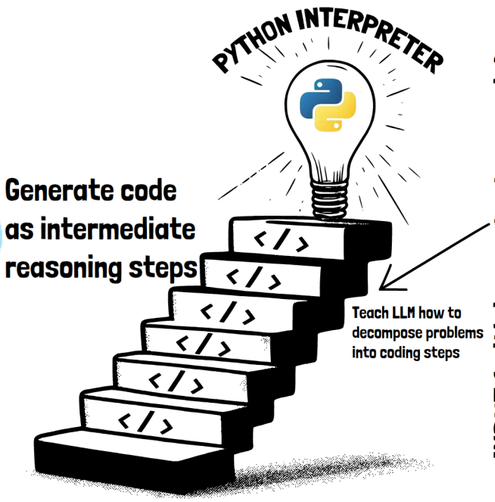
CMU, 2022

PAL: Program-aided Language Models

Luyu Gao*[1] Aman Madaan*[1] Shuyan Zhou*[1] Uri Alon[1]
Pengfei Liu[1 2] Yiming Yang[1] Jamie Callan[1] Graham Neubig[1 2]
{luyug,amadaan,shuyanzh,ualon,pliu3,
yiming,callan,gneubig}@cs.cmu.edu



Generate code as intermediate reasoning steps



Teach LLM how to decompose problems into coding steps

INPUT (with in-context example)

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 tennis balls.
tennis_balls = 5
# 2 cans of 3 tennis balls each is
bought_balls = 2 * 3 tennis balls.
# The answer is
answer = tennis_balls + bought_balls

Q: The Beverly Hills Bakery baked 200 loaves of bread on Monday morning. They sold 93 loaves in the morning and 39 loaves in the afternoon. A grocery store returned 6 unsold loaves. How many loaves of bread did they have left?

Code Interpreter

```
>>> print (answer)
74
```

LLM OUTPUT

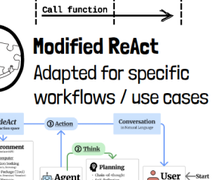
```
#The bakers started with 200 loaves
loaves_baked = 200
#They sold 93 in the morning and
# 39 in the afternoon
loaves_sold_morning = 93
loaves_sold_afternoon = 39
#The grocery store returned 6 loaves.
loaves_returned = 6
#The answer is
answer = loaves_baked - loaves_sold_morning
 - loaves_sold_afternoon + loaves_returned
```

ReAct in Practice

Structured Formats
JSON, XML, ...

```json
{
  "action": "Calculator",
  "action input": "125 * 0.92"
}
```

Function Calling
Offload tool selection to API provider



Fine-tuning
Improve tool usage and agentic workflows (e.g. InternLM)

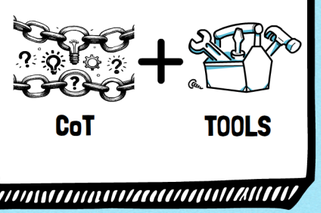
```
<|action_start|><|plugin|>
{
  "name": "calculator",
  "parameters":
    {"expr": "125*0.92"}
} <|action_end|>
```

Modified ReAct
Adapted for specific workflows / use cases

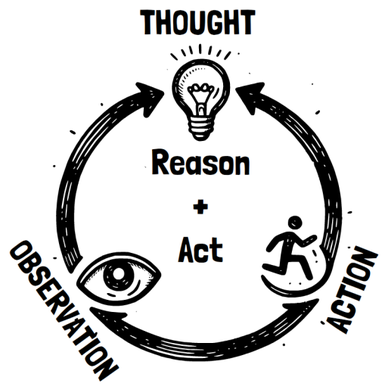
GOOGLE, 2022

ReAct: Synergizing Reasoning and Acting in Language Models

Shunyu Yao*[,1], Jeffrey Zhao[2], Dian Yu[2], Nan Du[2], Izhak Shafran[2], Karthik Narasimhan[1], Yuan Cao[2]
[1]Department of Computer Science, Princeton University
[2]Google Research, Brain team
[1]{shunyuy,karthikn}@princeton.edu
[2]{jeffreyzhao,dianyu,dunan,izhak,yuancao}@google.com



Use tools to solve problems



INPUT (with in-context example)

You operate in a loop of Thought, Action, Observation. You available actions are:

- Calculator(expr)
  computes an arithmetic expression
- Web_search(query):
  searches the Internet
- Finish(answer):
  provides the final answer

Example interaction:

Query: What's 135 * 8
Thought: I should use the calculator
Action: Calculator(135 * 8)
Observation: 1080
Thought: I have the result, I can finish
Action: Finish(1080)

Query: How much is $125 in EUR?

LLM OUTPUT

Thought: I need to find the current USD/EUR exchange rate
Action: WebSearch(USD/EUR exchange rate)
Observation: 0.92 EUR

Thought: I need to multiply 125 by 0.92.
Action: Calculator (125 * 0.92)
Observation: 114.46

Thought: The final answer is 114.46 EUR.
Action: Finish ("$125 is 114.46 EUR")

REASONING TRACES

Feed outputs to the LLM

Detect / Parse Tool Invocations

AGENT EXECUTOR

Execute actions with tools

TOOLS

TOOLS/PLUGINS

Perform actions via function/API calls

Knowledge access
Web search, databases, Wikipedia, ...

Computations
Calculators, code interpreters, ...

Interactions w/ world
Access / alter state of external environment