LLM-Symbolic Integration for Robust Temporal Tabular Reasoning

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Code and TEMPTABQA-C dataset: https://coral-lab-asu.github.io/llm_symbolic
Link to preprint: https://arxiv.org/abs/2506.05746

“LLMs are Powerful… but Not Perfect”

LLMs have made huge strides. Today, they can:

- ✍️ Craft poems and stories
- 📚 Summarize complex information
- ➗ Solve math problems
- 💻 Write and debug code

But they still face serious challenges…

(Especially when it comes to grounded reasoning on semi-structured and temporal data)

➡️ *Let’s take a look at how they perform on temporal tabular QA...*

Yohan Blake's Medal Record:		
Olympic Games		
Medal	**Year**	**Format**
Gold	2012 London	4×100 m relay
Gold	2016 Rio de Janeiro	4×100 m relay
Silver	2012 London	100 m
Silver	2012 London	200 m
World Championships		
Gold	2011 Daegu	100 m
Gold	2011 Daegu	4×100 m relay
Commonwealth Games		
Bronze	2018 Gold Coast	100 m
Bronze	2018 Gold Coast	4×100 m relay
World Relays		
Gold	2014 Bahamas	4×100 m
Gold	2014 Bahamas	4×200 m
Bronze	2017 Bahamas	4×200 m
World Junior Championships		
Gold	2006 Beijing	4×100 m relay
Silver	2008 Bydgoszcz	4×100 m relay
Bronze	2006 Beijing	100 m
Pan American Junior Championships		
Silver	2007 São Paulo	100 m
Bronze	2007 São Paulo	4×400 m relay
CAC Junior Championships (U20)		
Gold	2006 Port of Spain	100 m
Gold	2006 Port of Spain	200 m
Gold	2006 Port of Spain	4×100 m relay
CARIFTA Games		
Gold	2006 Les Abymes	200 m
Gold	2006 Les Abymes	4×100 m relay
Gold	2007 Providenciales	100 m
Gold	2007 Providenciales	4×100 m relay
Gold	2008 Basseterre	100 m
CARIFTA Games		
Gold	2005 Bacolet	100 m
Gold	2005 Bacolet	200 m
Continental Cup		
Gold	2018 Ostrava	4×100 m

Problem

Q. In which city did Yohan Blake win his first medal?

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Olympic Games		
Medal	**Year**	**Format**
Gold	2012 London	4×100 m relay
Gold	2016 Rio de Janeiro	4×100 m relay
Silver	2012 London	100 m
Silver	2012 London	200 m
World Championships		
Gold	2011 Daegu	100 m
Gold	2011 Daegu	4×100 m relay
Commonwealth Games		
Bronze	2018 Gold Coast	100 m
Bronze	2018 Gold Coast	4×100 m relay
World Relays		
Gold	2014 Bahamas	4×100 m
Gold	2014 Bahamas	4×200 m
Bronze	2017 Bahamas	4×200 m
World Junior Championships		
Gold	2006 Beijing	4×100 m relay
Silver	2008 Bydgoszcz	4×100 m relay
Bronze	2006 Beijing	100 m
Pan American Junior Championships		
Silver	2007 São Paulo	100 m
Bronze	2007 São Paulo	4×400 m relay
CAC Junior Championships (U20)		
Gold	2006 Port of Spain	100 m
Gold	2006 Port of Spain	200 m
Gold	2006 Port of Spain	4×100 m relay
CARIFTA Games		
Gold	2006 Les Abymes	200 m
Gold	2006 Les Abymes	4×100 m relay
Gold	2007 Providenciales	100 m
Gold	2007 Providenciales	4×100 m relay
Gold	2008 Basseterre	100 m
CARIFTA Games		
Gold	2005 Bacolet	100 m
Gold	2005 Bacolet	200 m
Continental Cup		
Gold	2018 Ostrava	4×100 m

Problem

Q. In which city did Yohan Blake win his first medal?

LLM's Answer: Beijing. In 2006, Yohan Blake won his first medal at the World Junior Championships in Beijing, where he secured a Gold in the 4x100 m relay and a Bronze in the 100 m.

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Olympic Games		
Medal	**Year**	**Format**
Gold	2012 London	4×100 m relay
Gold	2016 Rio de Janeiro	4×100 m relay
Silver	2012 London	100 m
Silver	2012 London	200 m
World Championships		
Gold	2011 Daegu	100 m
Gold	2011 Daegu	4×100 m relay
Commonwealth Games		
Bronze	2018 Gold Coast	100 m
Bronze	2018 Gold Coast	4×100 m relay
World Relays		
Gold	2014 Bahamas	4×100 m
Gold	2014 Bahamas	4×200 m
Bronze	2017 Bahamas	4×200 m
World Junior Championships		
Gold	2006 Beijing	4×100 m relay
Silver	2008 Bydgoszcz	4×100 m relay
Bronze	2006 Beijing	100 m
Pan American Junior Championships		
Silver	2007 São Paulo	100 m
Bronze	2007 São Paulo	4×400 m relay
CAC Junior Championships (U20)		
Gold	2006 Port of Spain	100 m
Gold	2006 Port of Spain	200 m
Gold	2006 Port of Spain	4×100 m relay
CARIFTA Games		
Gold	2006 Les Abymes	200 m
Gold	2006 Les Abymes	4×100 m relay
Gold	2007 Providenciales	100 m
Gold	2007 Providenciales	4×100 m relay
Gold	2008 Basseterre	100 m
CARIFTA Games		
Gold	2005 Bacolet	100 m
Gold	2005 Bacolet	200 m
Continental Cup		
Gold	2018 Ostrava	4×100 m

Problem

Q. In which city did Yohan Blake win his first medal?

LLM's Answer: Beijing. In 2006, Yohan Blake won his first medal at the World Junior Championships in Beijing, where he secured a Gold in the 4x100 m relay and a Bronze in the 100 m.

Correct Answer: Bacolet

TakeAway

Introduced TEMPTABQA-C, a synthetic dataset for **precise and controlled evaluation** of temporal tabular reasoning across **diverse and complex scenarios**.

Analyzed the limitations of direct prompting, including reliance on **memorization**, sensitivity to **table size**, and difficulty with **multi-step and counterfactual reasoning**.

Proposed a symbolic intermediate representation, enabling LLMs to **generate and execute SQL queries** on structured schemas, enhancing **interpretability**, reducing **biases**, and improving **generalization**.

TEMPTABQA-C Generation

In order to evaluate this problem we developed TEMPTABQA-C a large-scale benchmark to test Temporal Tabular Reasoning in LLMs

Wikipedia Infobox

Knowledge Graph

Michael Phelps

Personal information	
Born	June 30, 1985 (age 38) Baltimore, Maryland, U.S.
Height	6 ft 4 in (1.93 m)[3]
Weight	194 lb (88 kg)[4]
Coach	Bob Bowman

Medal record [hide]		
Men's swimming		
Representing the United States		
Olympic Games		
G	2004 Athens	100 m butterfly
G	2012 London	4×100 m medley
G	2012 London	100 m butterfly
World Championships (LC)		
G	2001 Fukuoka	200 m butterfly
S	2009 Rome	200 m freestyle
B	2011 Shanghai	4×100 m freestyle
World Championships (SC)		
G	2004 Indianapolis	200 m freestyle
Pan Pacific Championships		
G	2002 Yokohama	200 m medley
G	2014 Gold Coast	4×200 m freestyle
S	2006 Victoria	200 m backstroke

Figure 1: Wikipedia Infobox

```
Michael Phelps
├─ Personal Information
│  ├─ Birth Date
│  │  └─ 1985-6-30
│  ├─ Birth Place
│  │  └─ Baltimore
│  ├─ Height
│  │  └─ 6 ft 4 in
│  ├─ Weight
│  │  └─ 194  lb
│  └─ Coach
│     └─ Bob Bowman
└─ Country Representing: United States
   ├─ Olympic Games
   │  ├─ 100 m butterfly
   │  │  ├─ MedalGold | 2004 | Athens
   │  │  └─ MedalGold | 2012 | London
   │  ├─ 4x100 m medley
   │  │  └─ MedalGold | 2012 | London
   ├─ World Championships (LC)
   │  ├─ 200 m butterfly
   │  │  └─ MedalGold | 2001 | Fukuoka
   │  ├─ 200 m freestyle
   │  │  └─ MedalSilver | 2009 | Rome
   │  ├─ 4x100 m freestyle
   │  │  └─ MedalBronze | 2011 | Shanghai
   ├─ World Championships (SC)
   │  └─ 200 m freestyle
   │     └─ MedalGold | 2004 | Indianapolis
   └─ Pan Pacific Championships
      ├─ 200 m medley
      │  ├─ MedalGold | 2002 | Yokohama
      ├─ 4x200 m freestyle
      │  └─ MedalGold | 2014 | Gold Coast
      └─ 200 m backstroke
         └─ MedalSilver | 2006 | Victoria
```

```
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│   ├── Birth Date
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    │   │   ├── MedalGold | 2004 | Athens
    │   │   └── MedalGold | 2012 | London
    │   ├── 4x100 m medley
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    │   ├── 200 m butterfly
    │   │   └── MedalGold | 2001 | Fukuoka
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    │   ├── 4x100 m freestyle
    │   │   └── MedalBronze | 2011 | Shanghai
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    │   └── 200 m freestyle
    │       └── MedalGold | 2004 | Indianapolis
    └── Pan Pacific Championships
        ├── 200 m medley
        │   ├── MedalGold | 2002 | Yokohama
        ├── 4x200 m freestyle
        │   └── MedalGold | 2014 | Gold Coast
        └── 200 m backstroke
            └── MedalSilver | 2006 | Victoria
```

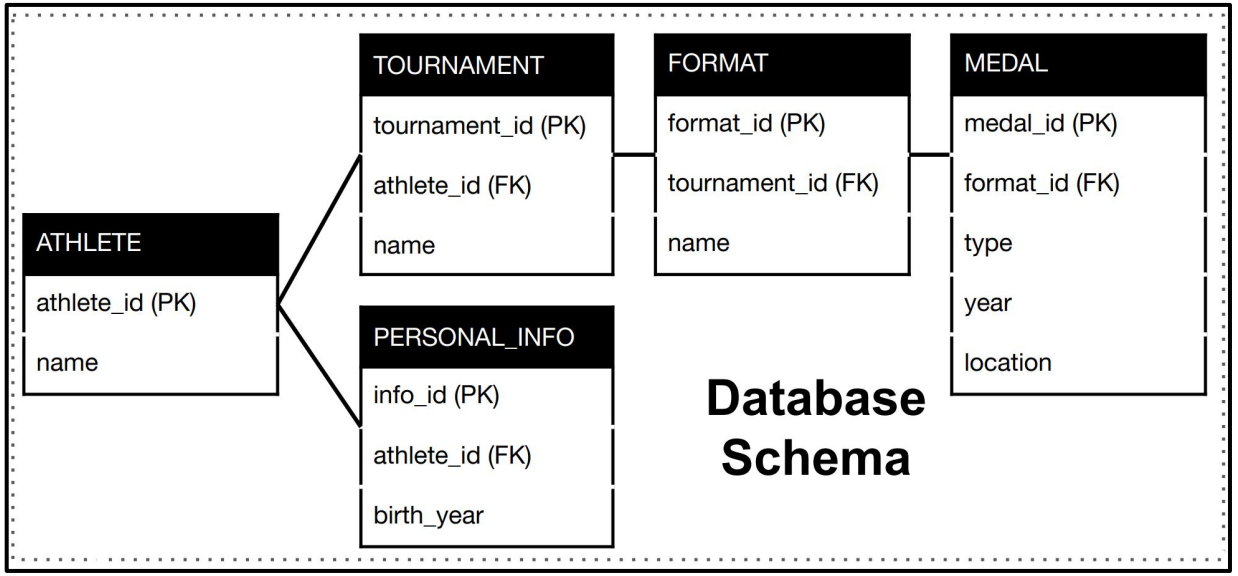

Original Table

```
Michael Phelps
├─ Personal Information
│  ├─ Birth Date
│  │  └─ 1985-6-30
│  ├─ Birth Place
│  │  └─ Baltimore
│  ├─ Height
│  │  └─ 6 ft 4 in
│  ├─ Weight
│  │  └─ 194  lb
│  └─ Coach
│     └─ Bob Bowman
└─ Country Representing: United States
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   │  │  ├─ MedalGold | 2004 | Athens
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   │  ├─ 200 m butterfly
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      ├─ 4x200 m freestyle
      │  └─ MedalGold | 2014 | Gold Coast
      └─ 200 m backstroke
         └─ MedalSilver | 2006 | Victoria
```

CounterFactual Table

```
Michael Phelps
├─ Personal Information
│  ├─ Birth Date
│  │  └─ 1983-6-30
│  ├─ Birth Place
│  │  └─ Melbourne
│  ├─ Height
│  │  └─ 5 ft 4 in
│  ├─ Weight
│  │  └─ 154  lb
│  └─ Coach
│     └─ Bob Bowman
└─ Country Representing: United States
   ├─ World Championships (SC)
   │  └─ 4x200 m freestyle
   │     ├─ MedalSilver | 2013 | Melbourne
   │     └─ MedalBronze | 2000 | Barcelona
   ├─ World Championships (LC)
   │  ├─ 200 m medley
   │  │  ├─ MedalSilver | 2003 | Shanghai
   │  │  └─ MedalGold | 2009 | Montreal
   │  └─ 4x100 m freestyle
   │     └─ MedalGold | 2012 | Indianapolis
   └─ Pan Pacific Championships
      └─ 100 m butterfly
         ├─ MedalGold | 2022 | Delhi
         └─ MedalBronze | 2005 | Amsterdam
```

```
Michael Phelps
├── Personal Information
│   ├── Birth Date
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│   ├── Birth Place
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        ├── 4x200 m freestyle
        │   └── MedalGold | 2014 | Gold Coast
        └── 200 m backstroke
            └── MedalSilver | 2006 | Victoria
```
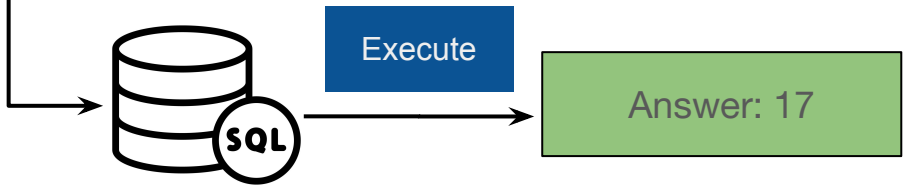
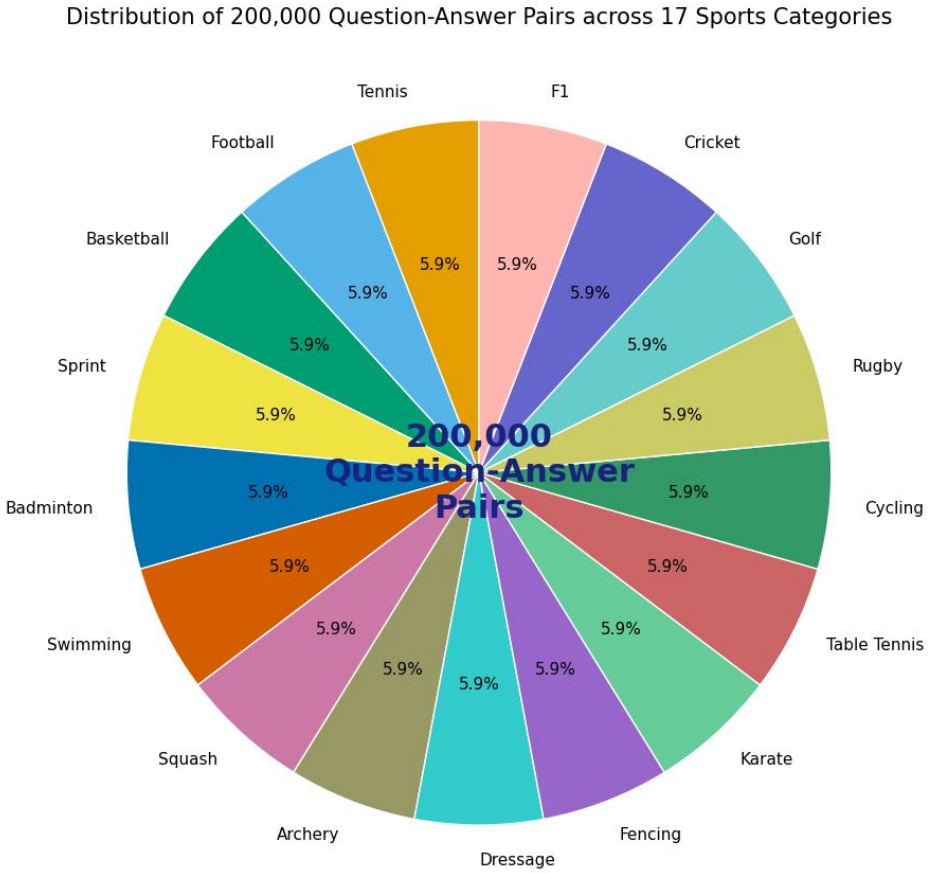

How old was <Player_Name> when he won his first <Tournament_Name> ?

How old was Michael Phelps when he won his first Pan Pacific Championships ?

```sql
SELECT
    (MIN(m.year) - pi.birth_year) AS age_at_first_win
FROM
    Medal m
JOIN
    Format f ON m.format_id = f.format_id
JOIN
    Tournament t ON f.tournament_id = t.tournament_id
JOIN
    Athlete a ON t.athlete_id = a.athlete_id
JOIN
    PersonalInformation pi ON a.athlete_id = pi.athlete_id
WHERE
    a.name = 'Michael Phelps'
    AND t.name = 'Pan Pacific Championships';
```



Dataset Statistics



TEMPTABQA-C Example Questions

Easy (Simple Lookup):

- List all the formats in which Michael Phelps has won medals.

Medium (Temporal Arithmetic):

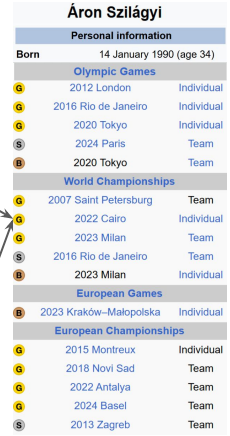
- How old was Michael Phelps when he won his first Pan Pacific Championships ?

Hard (Complex Multi-hop Analysis):

- What is the shortest time span (in years) within which Michael Phelps won all 3 medals (gold, silver, and bronze) in the same event?

Áron Szilágyi

Personal information		
Born	14 January 1990 (age 34)	
Olympic Games		
G	2012 London	Individual
G	2016 Rio de Janeiro	Individual
G	2020 Tokyo	Individual
S	2024 Paris	Team
B	2020 Tokyo	Team
World Championships		
G	2007 Saint Petersburg	Team
G	2022 Cairo	Individual
G	2023 Milan	Team
S	2016 Rio de Janeiro	Team
B	2023 Milan	Individual
European Games		
B	2023 Kraków–Małopolska	Individual
European Championships		
G	2015 Montreux	Individual
G	2018 Novi Sad	Team
G	2022 Antalya	Team
G	2024 Basel	Team
S	2013 Zagreb	Team

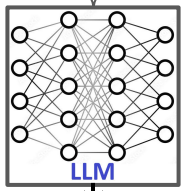


Direct Prompting

Question

Q. *In which year did Áron Szilágyi achieve his personal highest number of gold medal wins?*

Correct answer: 2022



Direct prompt (Chain-of-Thought) — Wrong

In 2020, Áron Szilágyi won a Gold Medal in the Individual format at the Tokyo Olympics. This was his most successful year in terms of highest Gold Medal wins since he did not win multiple Gold Medals in any other format or competition.

Predicted answer: 2020 ✗ (Wrong)

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G	2012 London	Individual
G	2016 Rio de Janeiro	Individual
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S	2024 Paris	Team
B	2020 Tokyo	Team
World Championships		
G	2007 Saint Petersburg	Team
G	2022 Cairo	Individual
G	2023 Milan	Team
S	2016 Rio de Janeiro	Team
B	2023 Milan	Individual
European Games		
B	2023 Kraków–Małopolska	Individual
European Championships		
G	2015 Montreux	Individual
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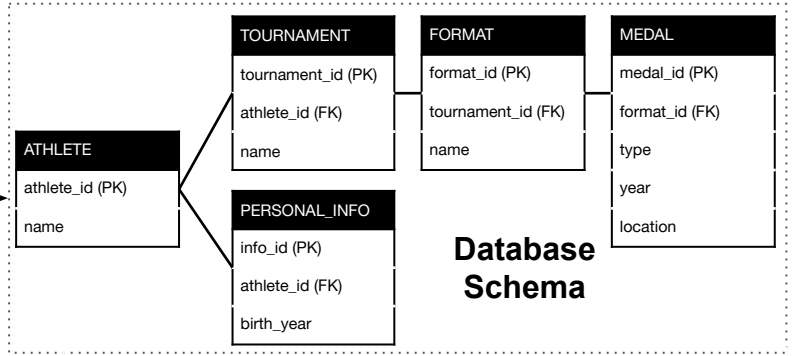
G	2022 Antalya	Team
G	2024 Basel	Team
S	2013 Zagreb	Team



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Symbolic Integration

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Personal information	
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Olympic Games	
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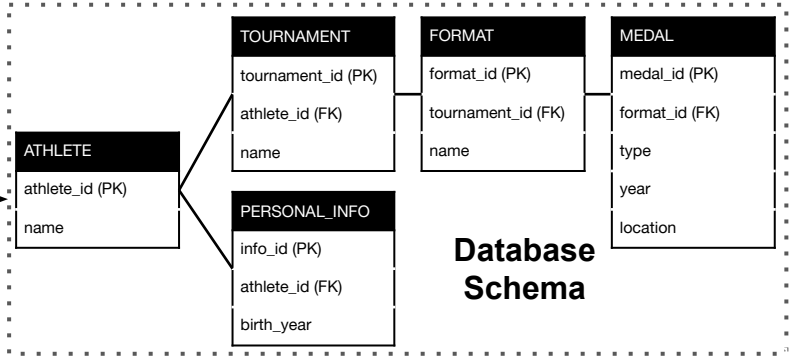
B 2020 Tokyo	Team
World Championships	
G 2007 Saint Petersburg	Team
G 2022 Cairo	Individual
G 2023 Milan	Team
S 2016 Rio de Janeiro	Team
B 2023 Milan	Individual
European Games	
B 2023 Kraków–Małopolska	Individual
European Championships	
G 2015 Montreux	Individual
G 2018 Novi Sad	Team
G 2022 Antalya	Team
G 2024 Basel	Team
S 2013 Zagreb	Team



Q. In which year did Áron Szilágyi achieve his personal highest number of gold medal wins?

LLM

Symbolic Integration

```
WITH gold_medal_counts AS (
  SELECT m.year, COUNT(m.medal_id) AS gold_medals
  FROM Medal m
    JOIN Format f ON m.format_id = f.format_id
    JOIN Tournament t ON f.tournament_id = t.tournament_id
    JOIN Athlete a ON t.athlete_id = a.athlete_id
  WHERE a.name = 'Áron Szilágyi' AND m.type = 'MedalGold'
  GROUP BY m.year)
SELECT year
FROM gold_medal_counts
WHERE gold_medals =
(SELECT MAX(gold_medals) FROM gold_medal_counts);
```

Execute

Answer: 2022

Results

A model that truly reasons about data should not be affected by the origin of the data.

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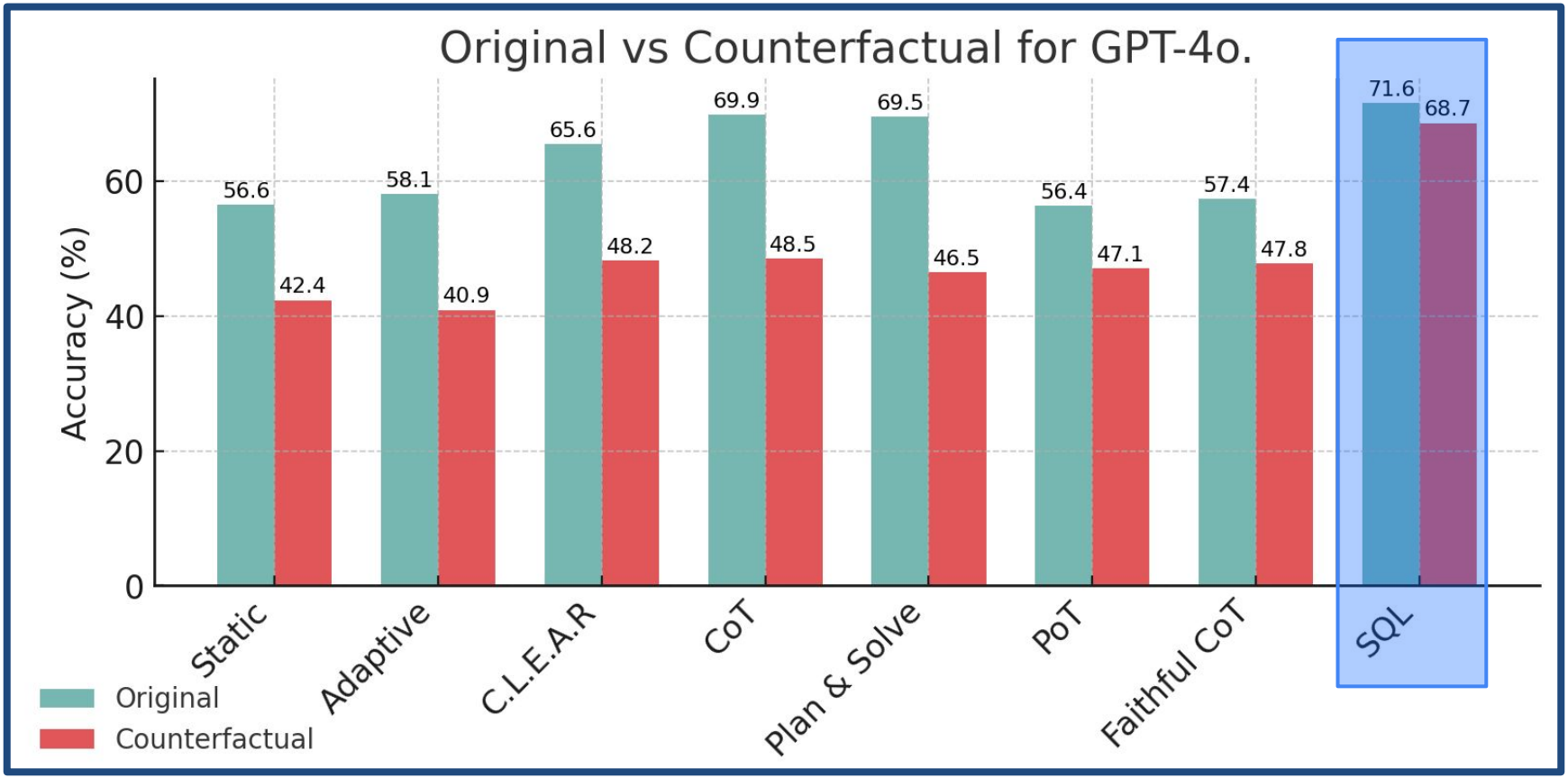

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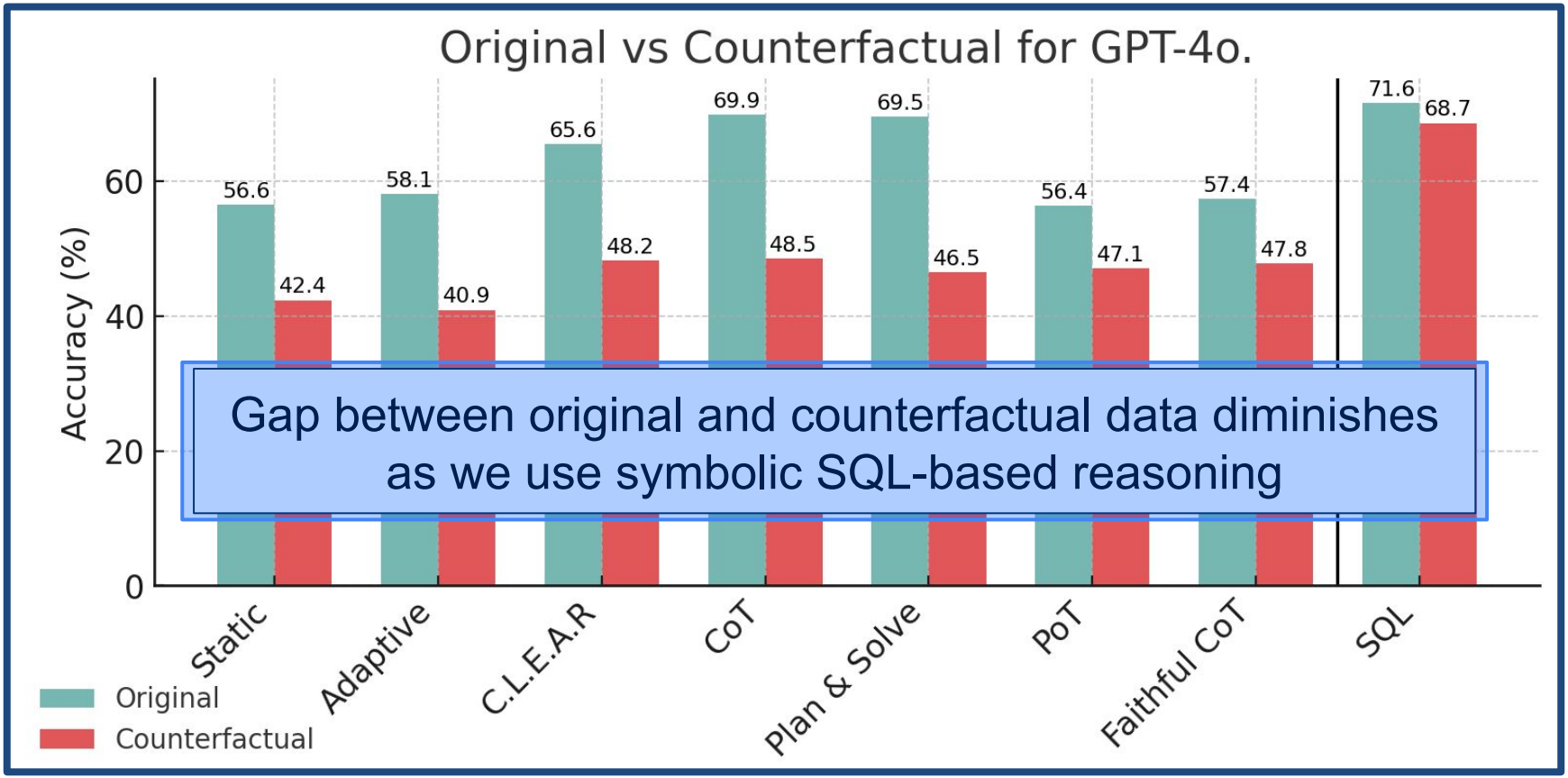
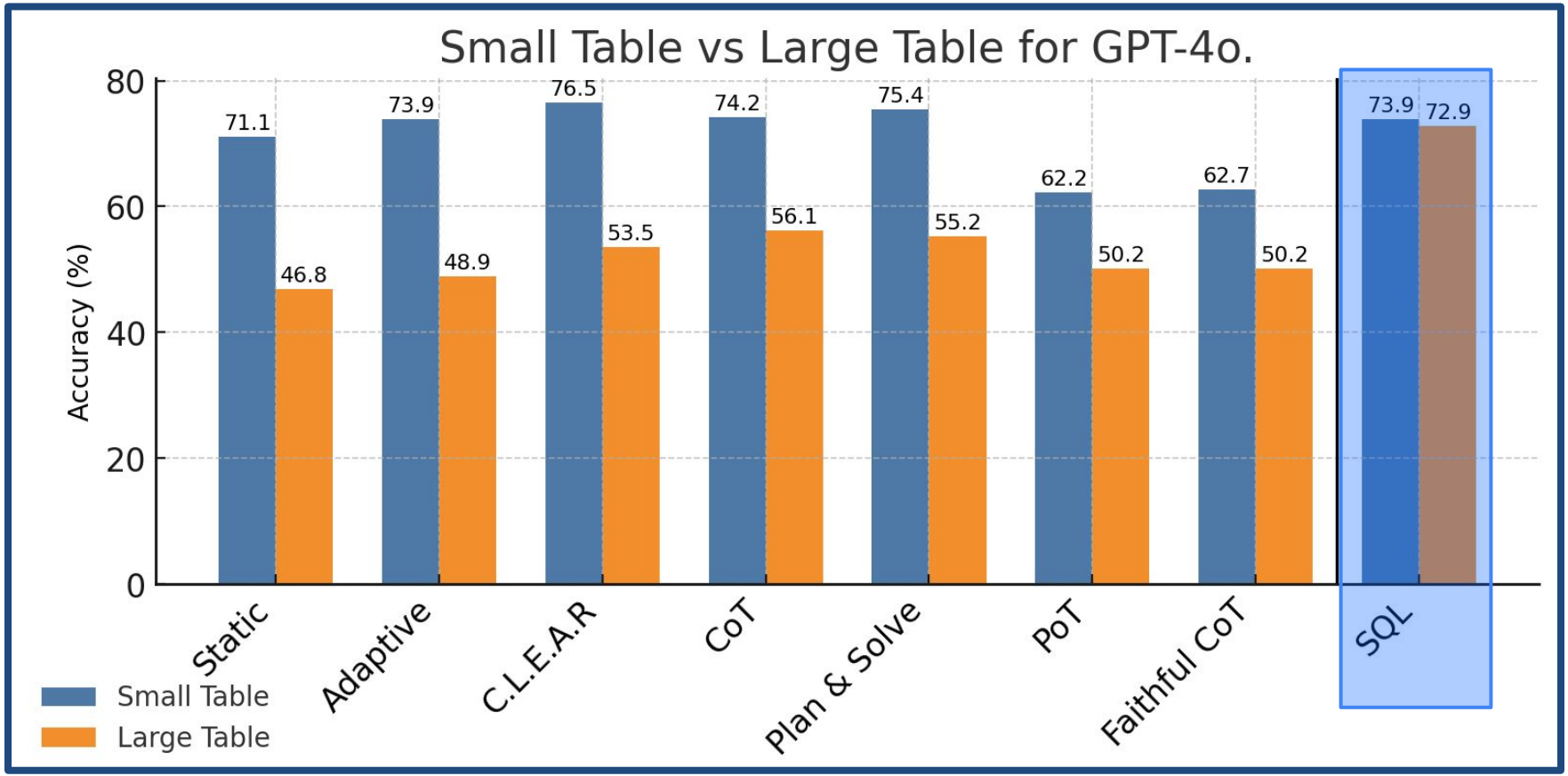
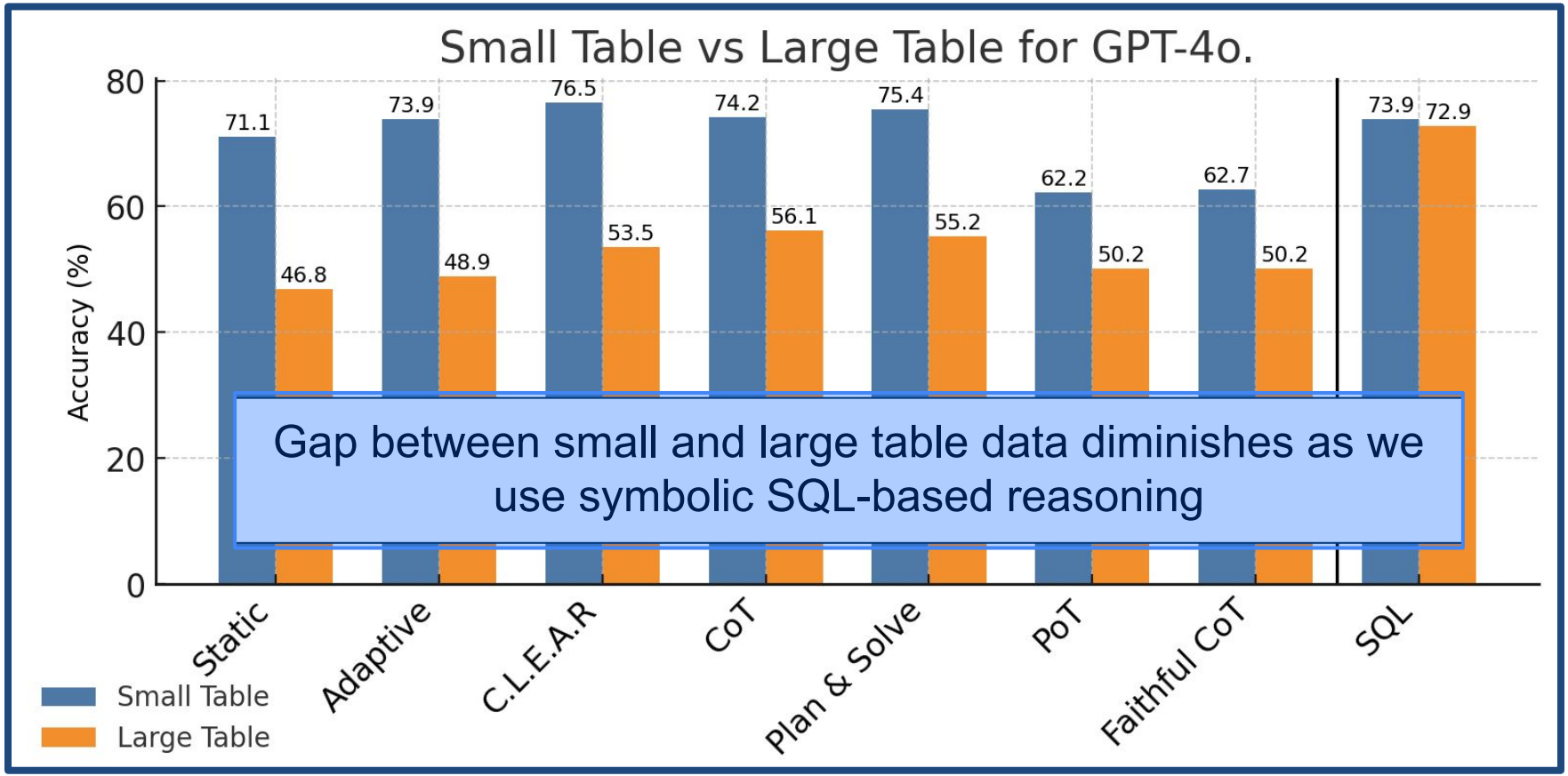


A model capable of genuine reasoning should operate independently of data size.

Model capable of right reasoning should operate independently of data size.



Model capable of right reasoning should operate independently of data size.



A drop in performance as complexity increases is expected for both models and humans (though less severe for the latter), the key question is: can we do better and reduce this decline?

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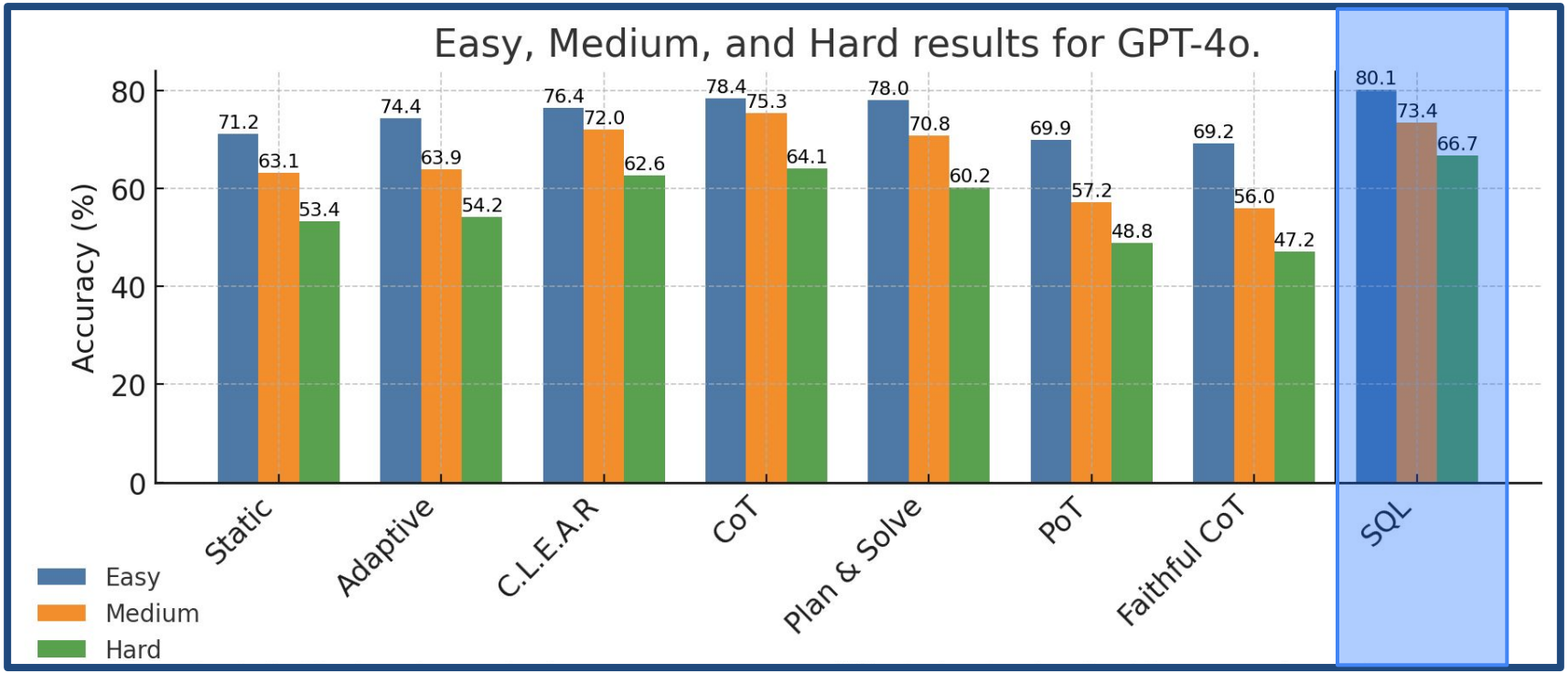

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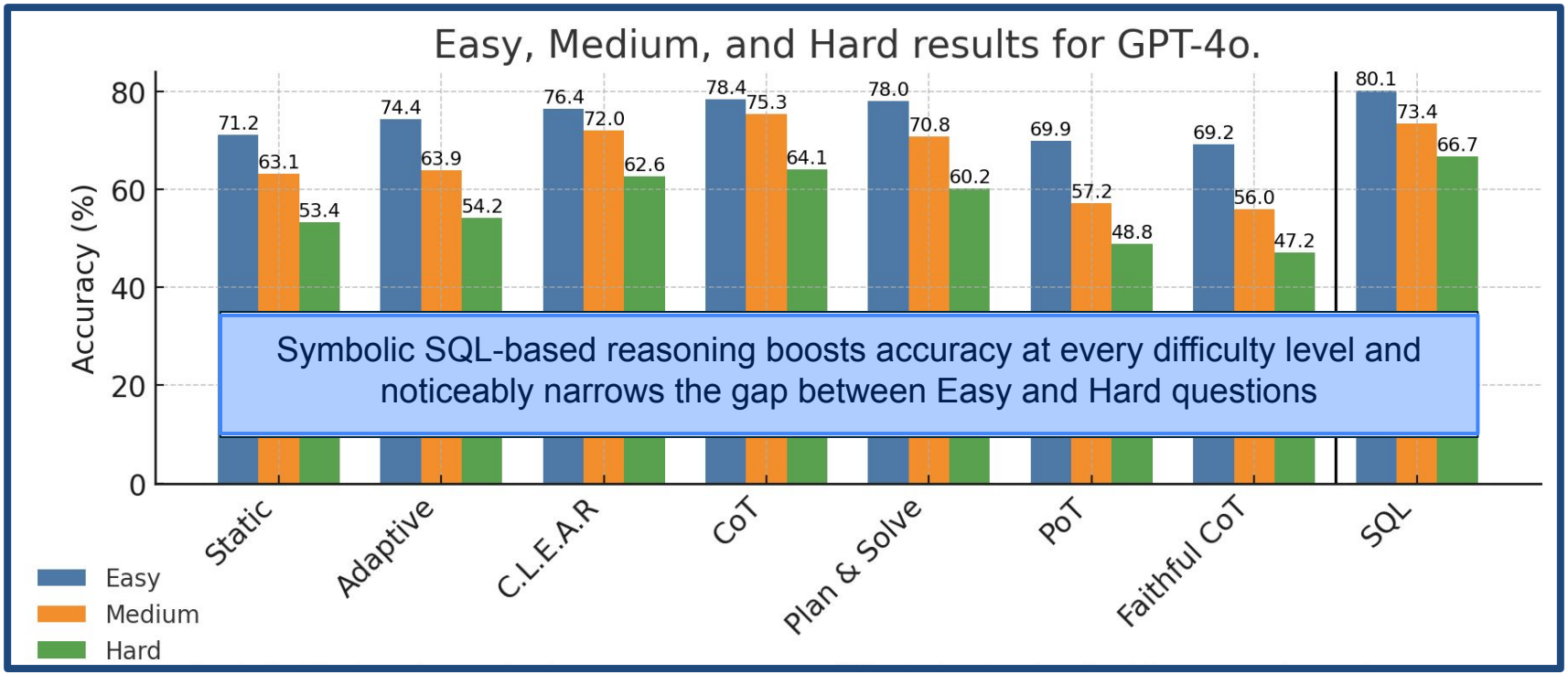

Contributions

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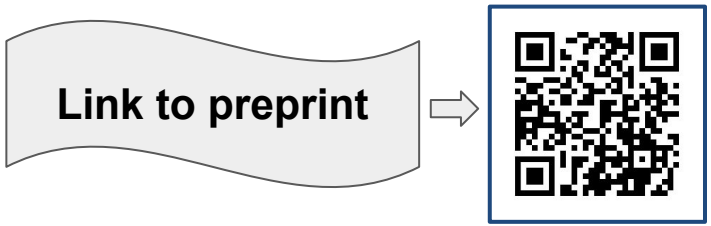

Thank You !

If you have any questions, please feel free to contact me at:
athkulk@unc.edu