



# Advanced Machine Learning Neural-Symbolic Reasoning

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# Summary

Lecture	04/04/2025 Friday	Overview Syllabus	Course Materials: o Slides
Lecture	04/11/2025 Friday	Kernel Density Estimation	Course Materials: o Slides o Codebook
Lecture	04/18/2025 Friday	Autoencoder	Course Materials: o Slides o Codebook
Lecture	04/25/2025 Friday	Variational Autoencoder	Course Materials: o Slides o Codebook
Lecture	05/02/2025 Friday	Generative Adversarial Network - Video	Course Materials: o Slides o Codebook o Video
Lecture	05/09/2025 Friday	Diffusion - Video	Course Materials: o Slides o Codes o Video o Math
Lecture	05/16/2025 Friday	Agentic AI 1	Course Materials: o Slides
Lecture	05/23/2025 Friday	Agentic AI 2	Course Materials: o Slides
Lecture	05/30/2025 Friday	Neural Symbolic Learning 1	Course Materials: o Slides o Codes o Video
Lecture	06/06/2025 Friday	Neural Symbolic Learning 2	Course Materials: o Slides
Lecture	06/06/2025 Friday	Paper Presentation	
Due	06/06/2025 23:59 Friday	Project Report Due	

6/13 Next  
Friday



# Conventional Neural-Symbolic Learning



Who can go first ?

- A. The red car
- B. The blue van
- C. The white car

## Neural-Thinking – System 1

- This is intersection
- There are three cars
- One car is turning left, the other car is going straight, the third car is going straight

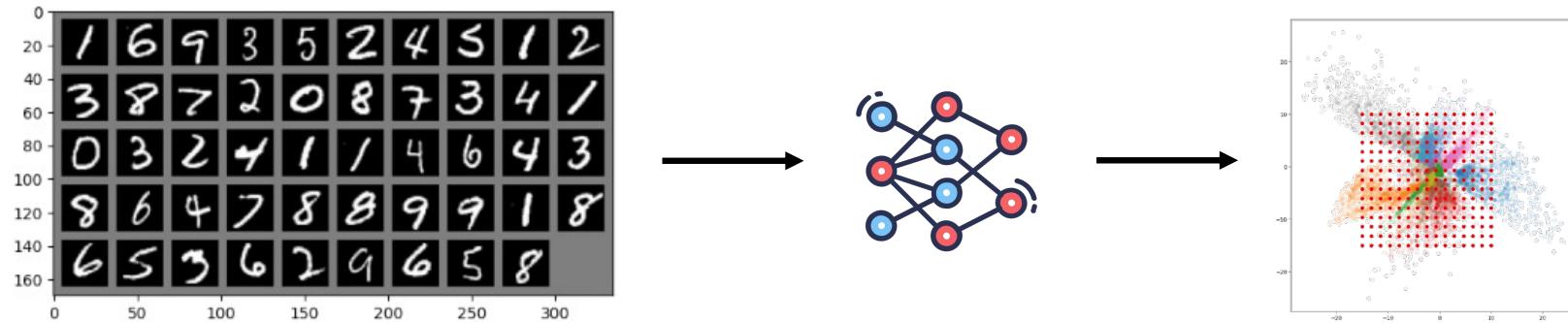
## Symbolic-Thinking – System 2

- Left should wait for straight

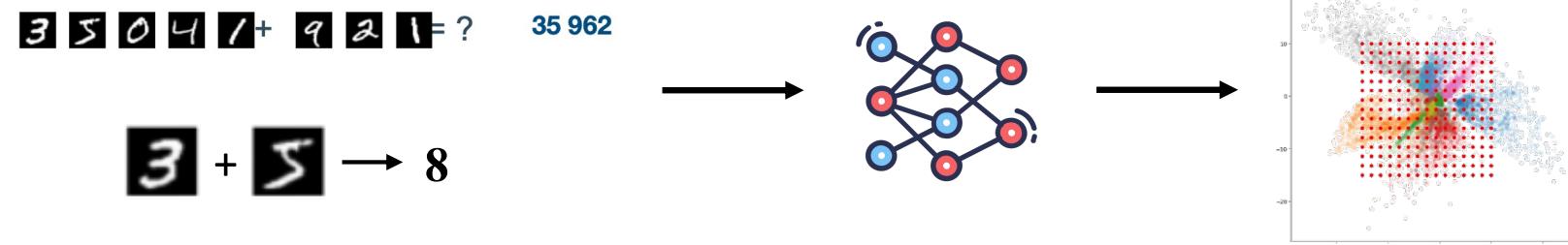


# Conventional Neural-Symbolic Learning

## Benefit of Symbolic Learning on Neural Learning



Digit classification

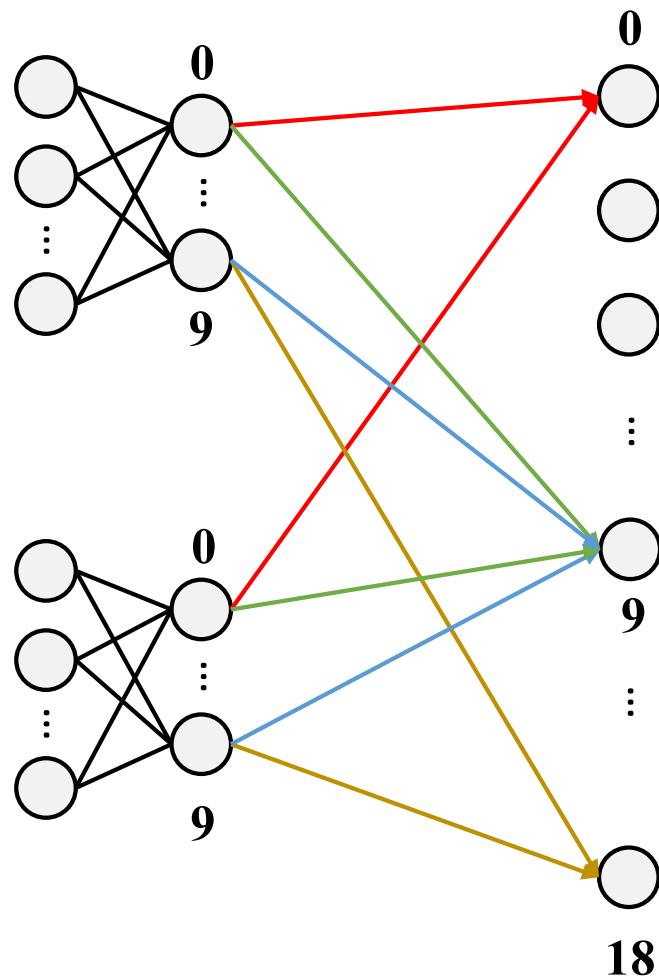


Digit classification with external  
calculation knowledge

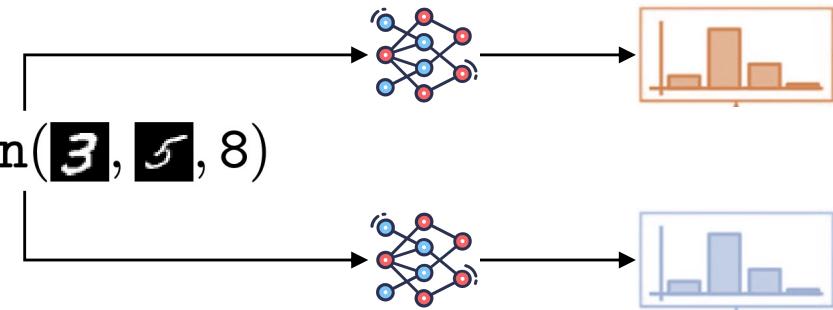


# Conventional Neural-Symbolic Learning

Symbolic as a kind of neural program



addition(**3**, **5**, 8)



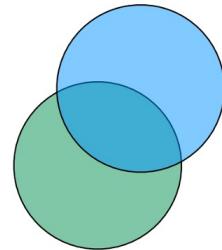


# Conventional Neural-Symbolic Learning

## Symbolic as a kind of Constraints

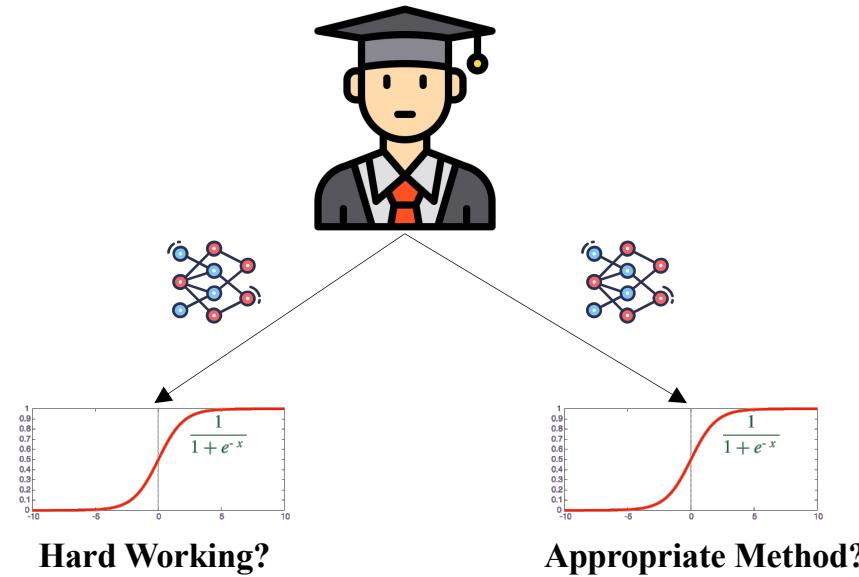
### Fuzzy Logic

- $\text{AND}(a, b) = \min(a, b)$
- $\text{OR}(a, b) = \max(a, b)$
- $a \rightarrow b = \max(1 - a, b)$



Probability - Logic

Differentiable



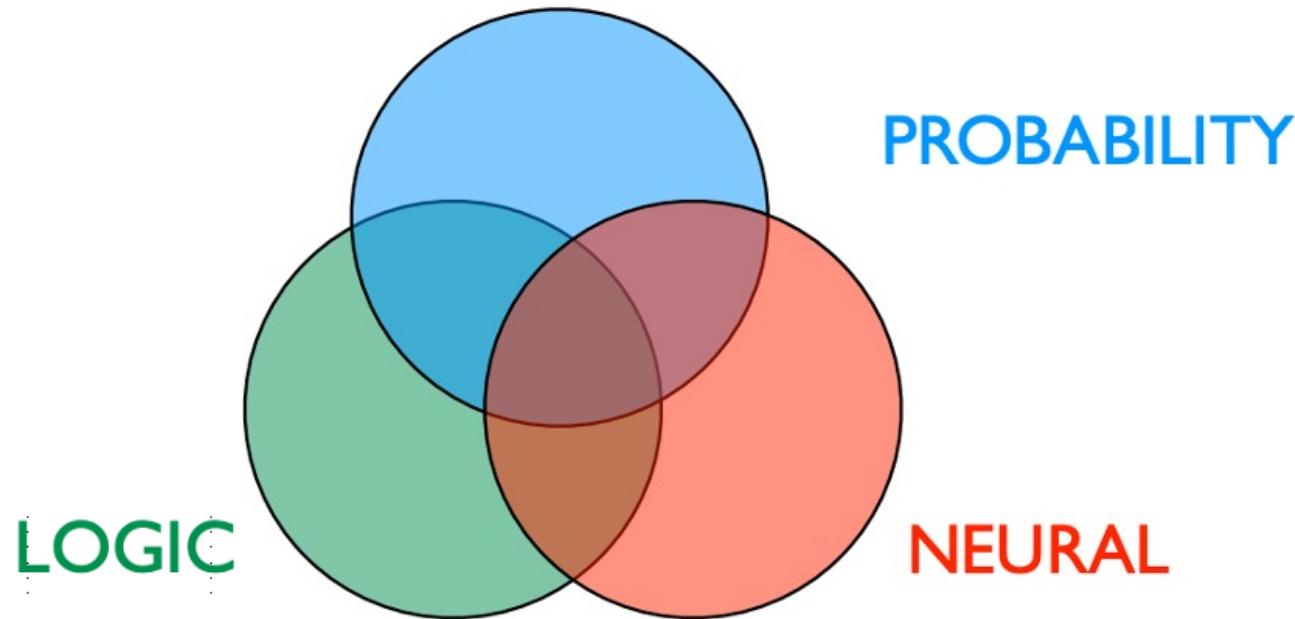
Hard Working **AND** Appropriate Method

Hard Working **OR** Appropriate Method

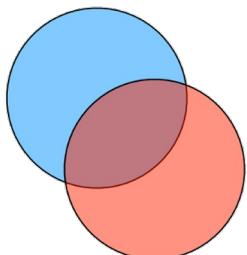
Hard Working -- Appropriate Method



# Conventional Neural-Symbolic Learning

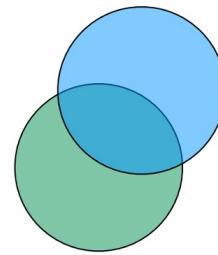


## Probability - Neural



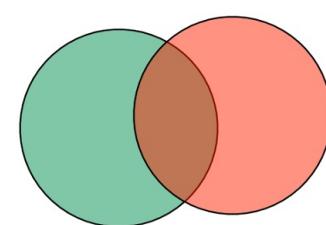
- VAEs
- Diffusion
- Policy Gradient

## Probability - Logic



- $C = A \text{ AND } B$
- $A: P(A \geq 0.5)$
- $B: P(B \geq 0.5)$

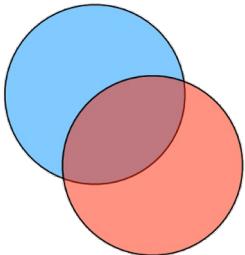
## Logic - Neural





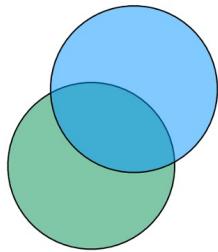
# Modern Neural-Symbolic Learning

## Probability - Neural



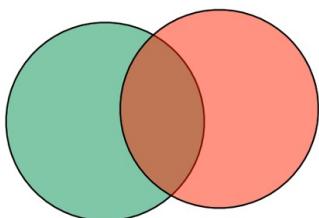
- VAEs
- Diffusion
- Policy Gradient

## Probability - Logic

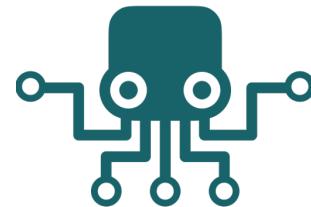


- $C = A \text{ AND } B$
- $A: P(A \geq 0.5)$
- $B: P(B \geq 0.5)$

## Logic - Neural

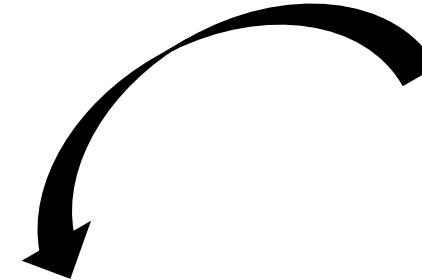


You now can describe logic in the textual format

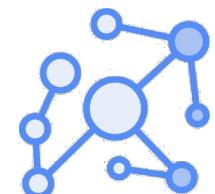


LLM Agent  
as Neural

Rule to  
regulate  
LLM



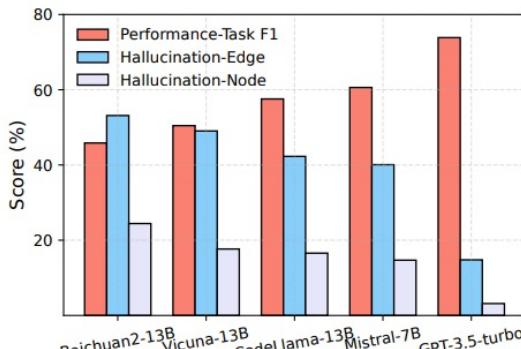
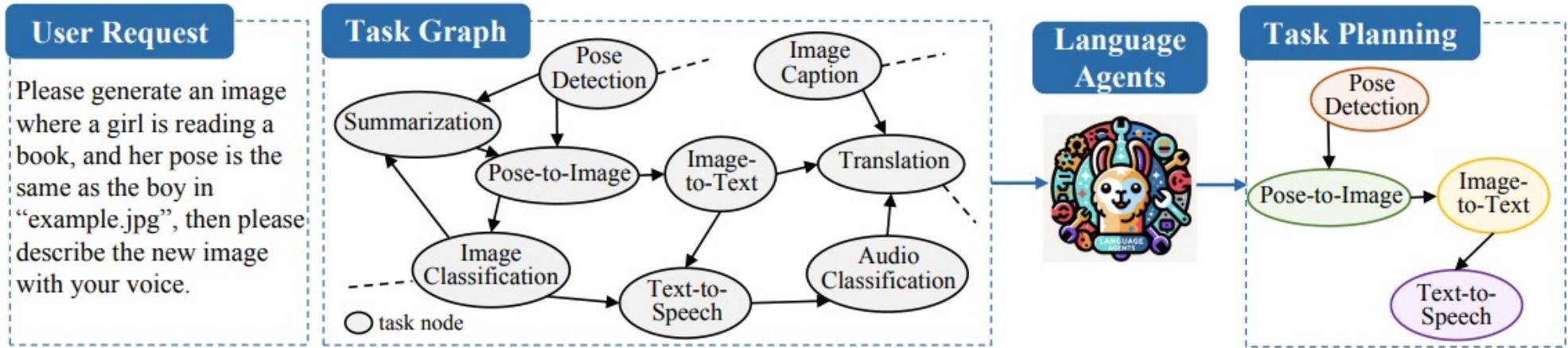
LLM to  
choose/gene  
rate/retrieve



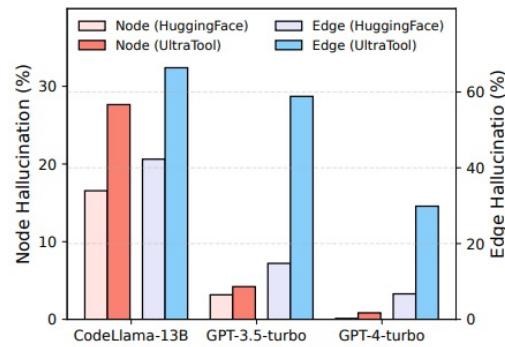


# Modern Neural-Symbolic Learning

## Task Planning



(a) Performance and Hallucination ratios



(b) Hallucination ratios across datasets

$$v_i = \operatorname{argmax}_{v \in \mathcal{N}(v_{i-1})} \langle \mathbf{h}_v, \mathbf{x}_i^{\text{step}} \rangle$$



# Modern Neural-Symbolic Learning

## Search-R1

**Search-r1:** Training LLMs to reason and leverage **search engines** with reinforcement learning

[B Jin, H Zeng, Z Yue, J Yoon, S Arik, D Wang...](#) - arXiv preprint arXiv ..., 2025 - arxiv.org

... , we introduce **SEARCH-R1**, a novel RL framework that enables LLMs to interact with **search engines** in an interleaved manner with their own reasoning. Specifically, **SEARCH-R1** ...

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Search-R1 Public  
Watch 19 Fork 179 Star 2.5k  
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PeterGriffinJin add bibtex 665d74d - 3 days ago 65 Commits  
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arxiv.org/pdf/2503.09516  
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### Submission history

From: Bowen Jin [view email]

[v1] Wed, 12 Mar 2025 16:26:39 UTC (196 KB)

[v2] Wed, 19 Mar 2025 21:40:12 UTC (196 KB)

[v3] Tue, 8 Apr 2025 14:03:26 UTC (311 KB)

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Answer the given question. You must conduct reasoning inside `<think>` and `</think>` first every time you get new information. After reasoning, if you find you lack some knowledge, you can call a search engine by `<search>` query `</search>`, and it will return the top searched results between `<information>` and `</information>`. You can search as many times as you want. If you find no further external knowledge needed, you can directly provide the answer inside `<answer>` and `</answer>` without detailed illustrations. For example, `<answer> xxx </answer>`. Question: **question**.

---



# Modern Neural-Symbolic Learning

## Search-R1

**Question:** Curious is a women's fragrance by a singer born in what city and state?

**Ground Truth:** McComb, Mississippi

R1:

<think> The singer is Beyoncé, who was born in Houston, Texas. </think>  
<answer> Houston </answer>

SEARCH-R1:

<think> I need to find out which city and state a singer, by whom the women's fragrance "Curious" was created, was born in. </think>

<search> Curious fragrance information </search>

<information> Doc 1(Title: "Curious (fragrance)") Curious (fragrance) Curious is a women's fragrance by Britney Spears for Elizabeth Arden, and is the first perfume to be endorsed by Britney Spears, preceding "'Fantasy.'" Spears reportedly earned \$52 million from the endorsement. "'Curious'" was released in September 2004, and was very successful internationally. It was the number one fragrance of 2004 in department stores, and in 2005, "'Curious'" was honored by the Fragrance Foundation as Best Women's Fragrance. The fragrance is a white floral scent. Its notes are Louisiana magnolia, golden Anjou pear, lotus flower, tuberose, star jasmine, pink cyclamen, vanilla-infused musk, sandalwood and blonde woods. Elizabeth Arden ... </information>

<think> I need to find out which city and state Britney Spears, the singer behind "Curious" fragrance, was born in. </think>

<search> Britney Spears birthplace </search>

<information> Doc 1(Title: "Britney Spears") the best-selling female albums artist of the 2000s. In 2004, she launched a perfume brand with Elizabeth Arden, Inc., from which sales exceeded US\$1.5 billion. Spears was born in McComb, Mississippi, the second child of Lynne Irene Bridges and James Parnell Spears. Her maternal grandmother, Lillian Portell, was English (born in London), and one of Spears's maternal great-great-grandfathers was Maltese. Her siblings are Bryan James and Jamie Lynn. Britney was born in the Bible Belt, where socially conservative evangelical Protestantism is a particularly strong religious influence. Spears was baptized into the Southern Baptist Convention, but later in life studied ... </information>

<think> Since Britney Spears was born in McComb, Mississippi, I need to find out which city and state that is. </think>

<search> McComb, Mississippi location </search>

<information> Doc 1(Title: "McComb, Mississippi") McComb, Mississippi McComb is a city in Pike County, Mississippi, United States, approximately south of Jackson. As of the 2010 census, the city had a total population of 12,790. It is the principal city of the McComb, Mississippi Micropolitan Statistical Area. McComb was founded in 1872 after Henry Simpson McComb of the New Orleans, Jackson and Great Northern Railroad, a predecessor of the Illinois Central Railroad (now part of the Canadian National Railway), decided to move the railroad's maintenance shops away from New Orleans, Louisiana, to avoid the attractions of that city's saloons. The railroad purchased land in Pike County, ... </information>

<think> I have found that Britney Spears was born in McComb, Mississippi. Since the question asks for the city and state, I just need to confirm the state, which I already know from the previous search. </think>

<answer> McComb, Mississippi </answer>



# Modern Neural-Symbolic Learning

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**Algorithm 1** LLM Response Rollout with Multi-Turn Search Engine Calls
 

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**Require:** Input query  $x$ , policy model  $\pi_\theta$ , search engine  $\mathcal{R}$ , maximum action budget  $B$ .

**Ensure:** Final response  $y$ .

```

1: Initialize rollout sequence  $y \leftarrow \emptyset$ 
2: Initialize action count  $b \leftarrow 0$ 
3: while  $b < B$  do
4:   Initialize current action LLM rollout sequence  $y_b \leftarrow \emptyset$ 
5:   while True do
6:     Generate response token  $y_t \sim \pi_\theta(\cdot | x, y + y_b)$ 
7:     Append  $y_t$  to rollout sequence  $y_b \leftarrow y_b + y_t$ 
8:     if  $y_t$  in [ $</\text{search}>$ ,  $</\text{answer}>$ ,  $<\text{eos}>$ ] then break
9:     end if
10:    end while
11:     $y \leftarrow y + y_b$ 
12:    if  $<\text{search}>$   $</\text{search}>$  detected in  $y_b$  then
13:      Extract search query  $q \leftarrow \text{Parse}(y_b, <\text{search}>, </\text{search}>)$ 
14:      Retrieve search results  $d = \mathcal{R}(q)$ 
15:      Insert  $d$  into rollout  $y \leftarrow y + <\text{information}>d</\text{information}>$ 
16:    else if  $<\text{answer}>$   $</\text{answer}>$  detected in  $y_b$  then
17:      return final generated response  $y$ 
18:    else
19:      Ask for rethink  $y \leftarrow y + \text{"My action is not correct. Let me rethink."}$ 
20:    end if
21:    Increment action count  $b \leftarrow b + 1$ 
22:  end while
23: return final generated response  $y$ 
  
```

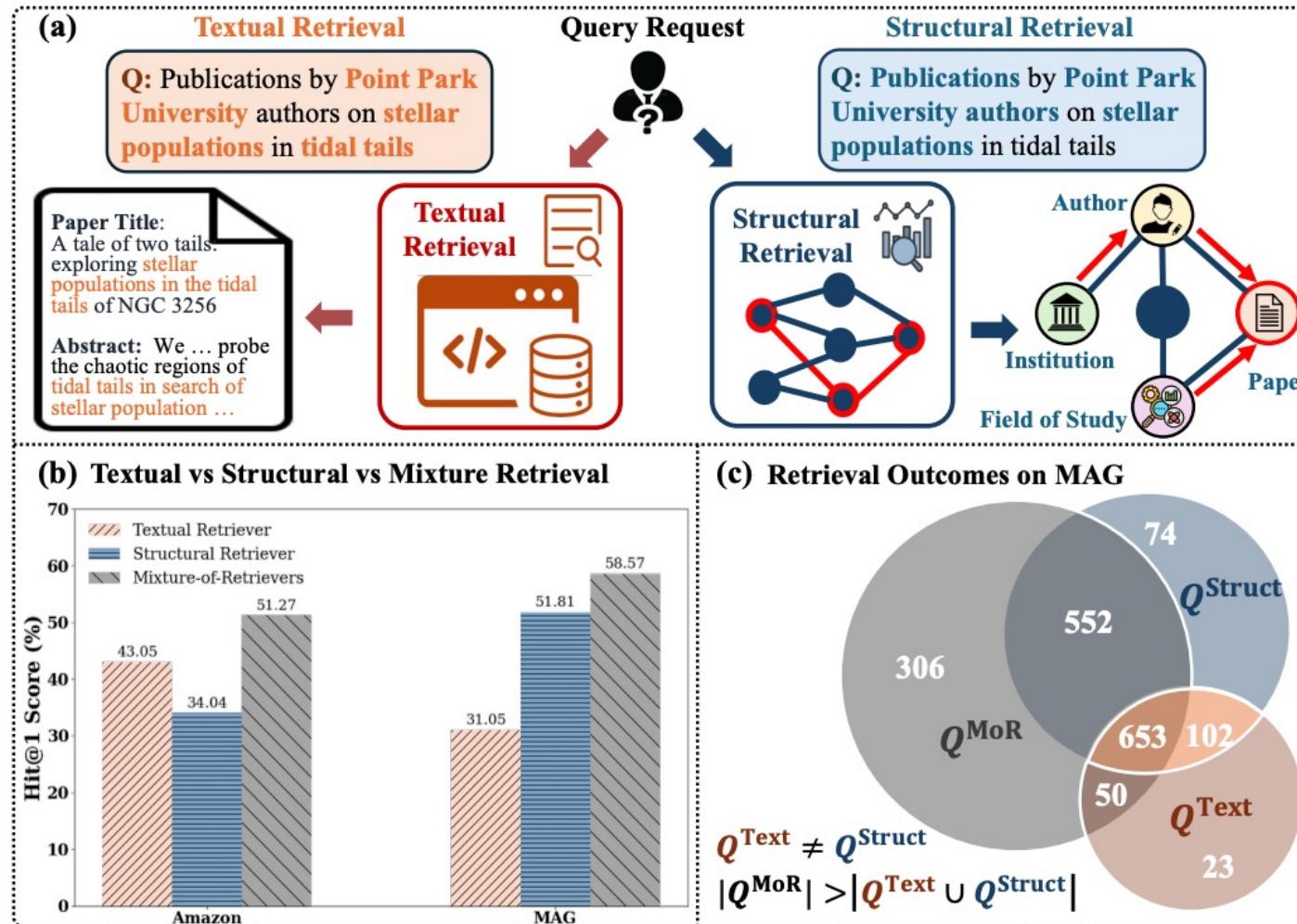
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$$\max_{\pi_\theta} \mathbb{E}_{x \sim \mathcal{D}, y \sim \pi_\theta(\cdot | x; \mathcal{R})} [r_\phi(x, y)] - \beta \mathbb{D}_{\text{KL}} [\pi_\theta(y | x; \mathcal{R}) || \pi_{\text{ref}}(y | x; \mathcal{R})],$$



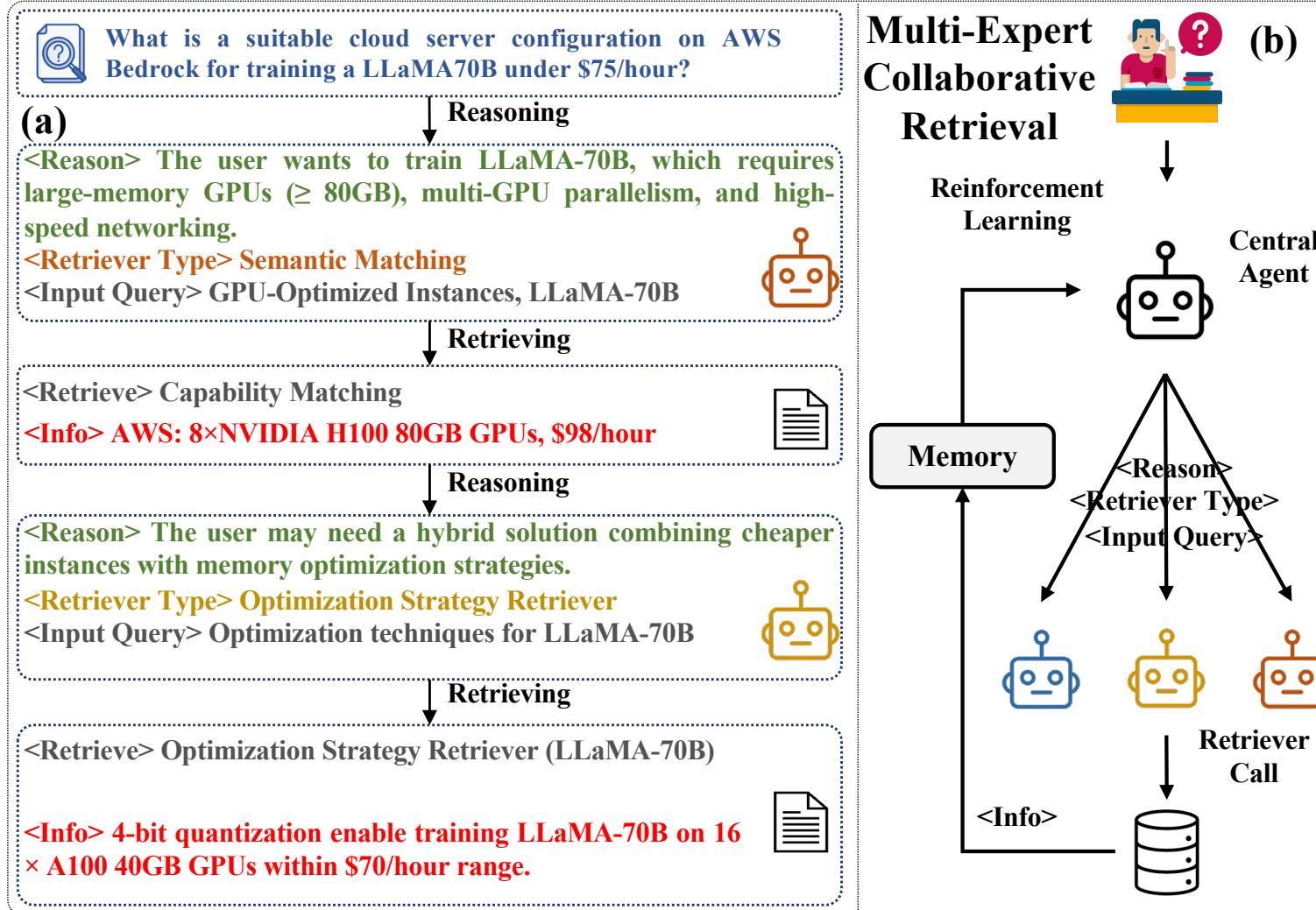
# Modern Neural-Symbolic Learning

## Mixture of Textual-and-Structural Retrieval



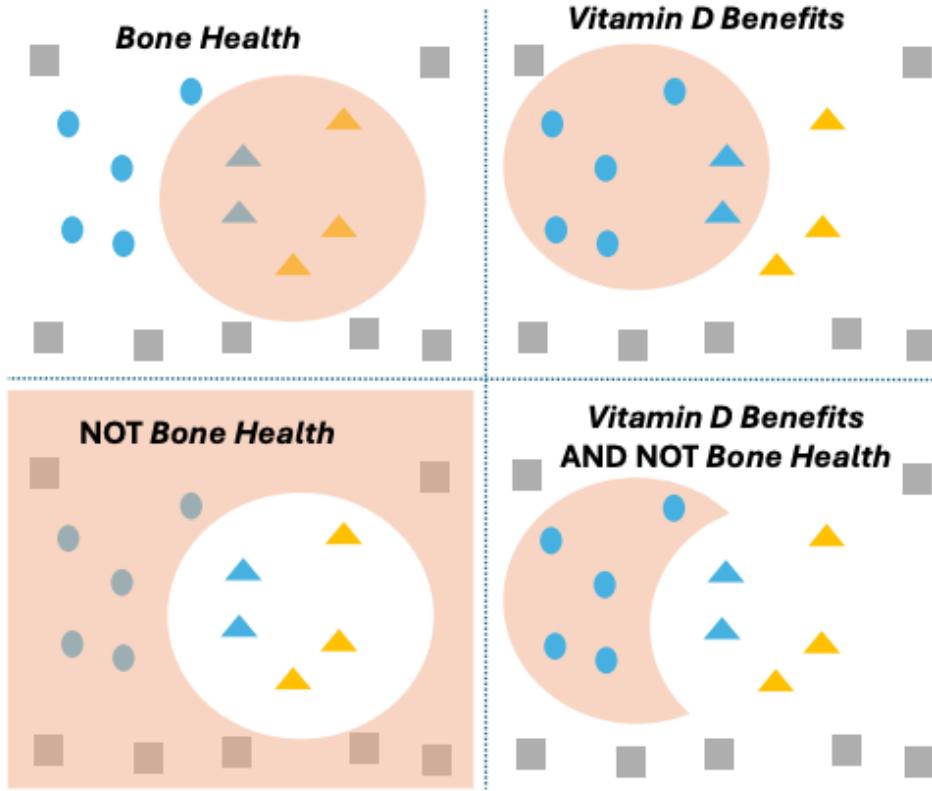


# Modern Neural-Symbolic Learning





# Modern Neural-Symbolic Learning



What are the benefits of vitamin D, focusing on benefits other than bone health?

Logical Query Transformation

Term Embedding and Similarity Computation

Score Composition Based on Logical Relations

$$(t_1 \text{ OR } t_2) \text{ AND NOT } t_3.$$

$$s_i = \text{OP}_{AND}(\text{OP}_{OR}(s_{1i}, s_{2i}), \text{OP}_{NOT}(s_{3i})),$$

$$\text{OP}_{AND}(x, y) = x * y \mid x + y \mid \min(x, y)$$

$$\text{OP}_{OR}(x, y) = x + y \mid \max(x, y)$$

$$\text{OP}_{NOT}(x, y) = 1 - x \mid 1/x$$



# Modern Neural-Symbolic Learning

To Make Calzones, here are the steps and the times needed for each step.

**Step 1.** Preheat the oven to 425 degrees. (10 min)

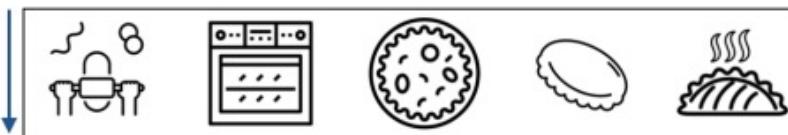
**Step 2.** Roll out the dough. (10 min)

**Step 3.** Add the filling. (15 min)

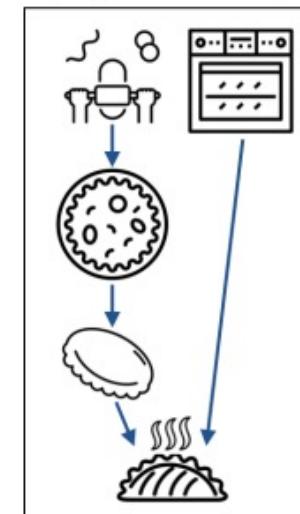
**Step 4.** Fold and pinch the dough. (5 min)

**Step 5.** Bake the calzones. (25 min)

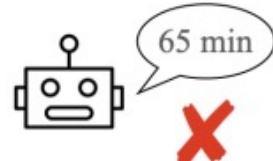
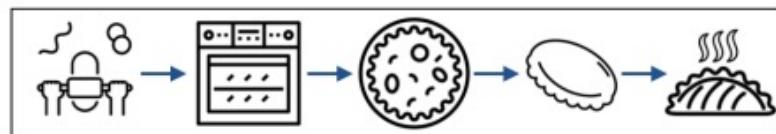
## Parallel



## Asynchronous

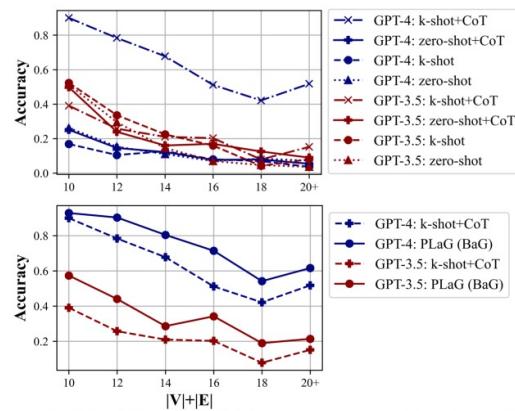
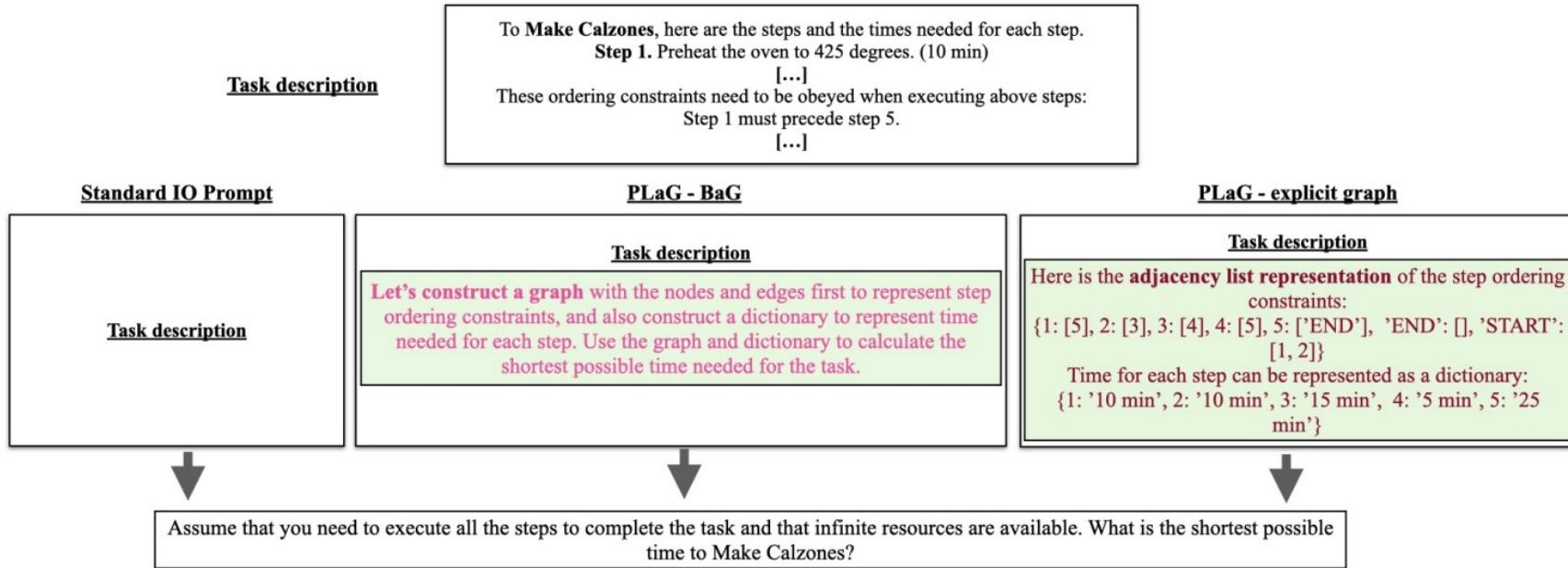


## Sequential





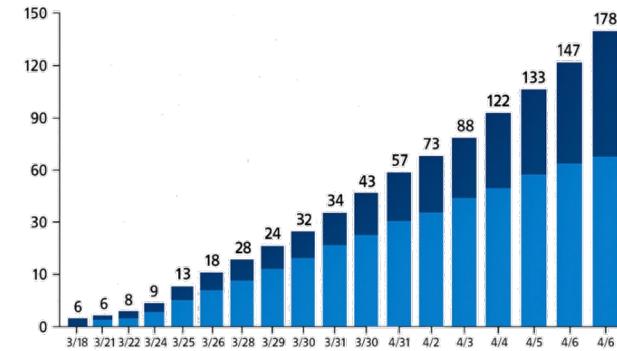
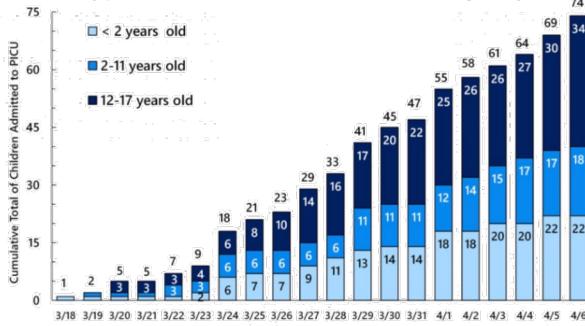
# Modern Neural-Symbolic Learning





# Modern Neural-Symbolic Learning

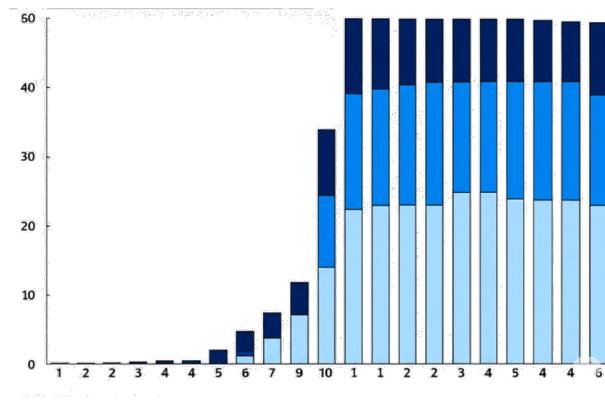
Figure 1.  
Cumulative Number of Confirmed COVID-19 Pediatric Intensive Care Patients  
United States, March 18, 2020 to April 6, 2020 (Source: myvps.org)



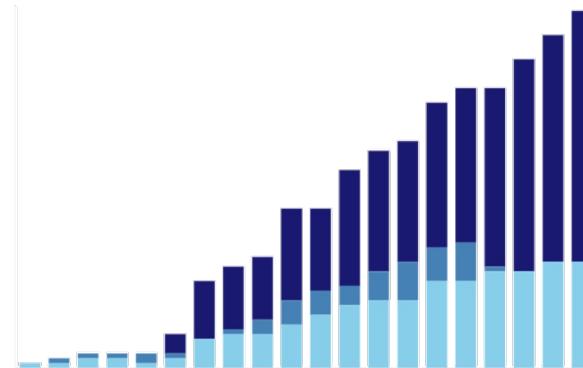
(a) Original

(b) GPT4o

(c) GPT4-o3



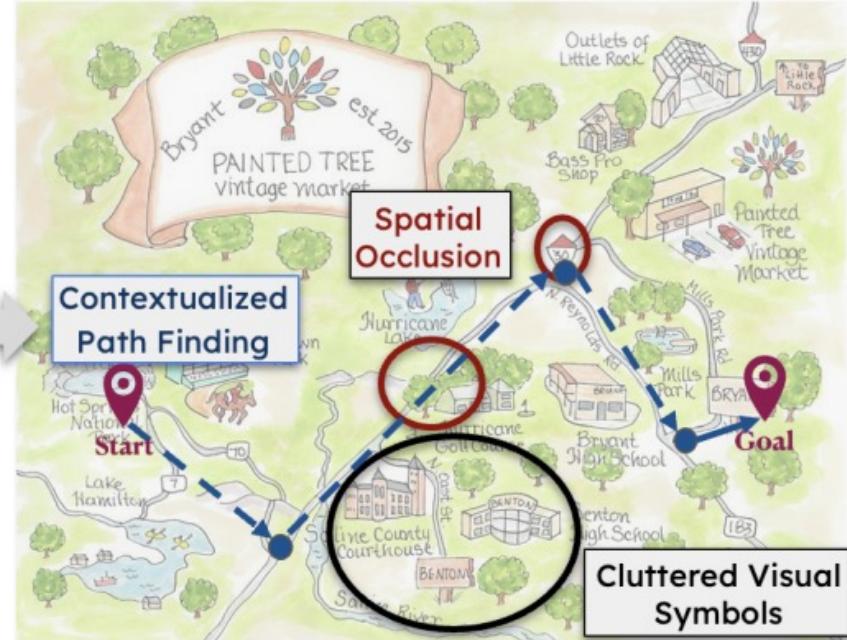
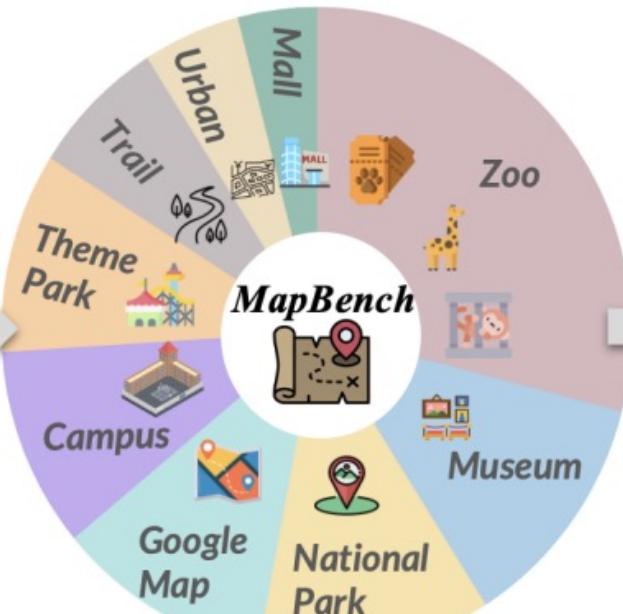
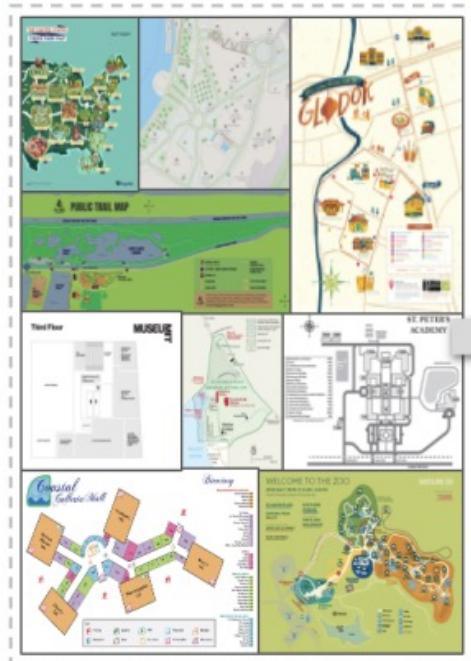
(d) Gemini2.5 pro



(e) Claude Sonnet 4



# Modern Neural-Symbolic Learning



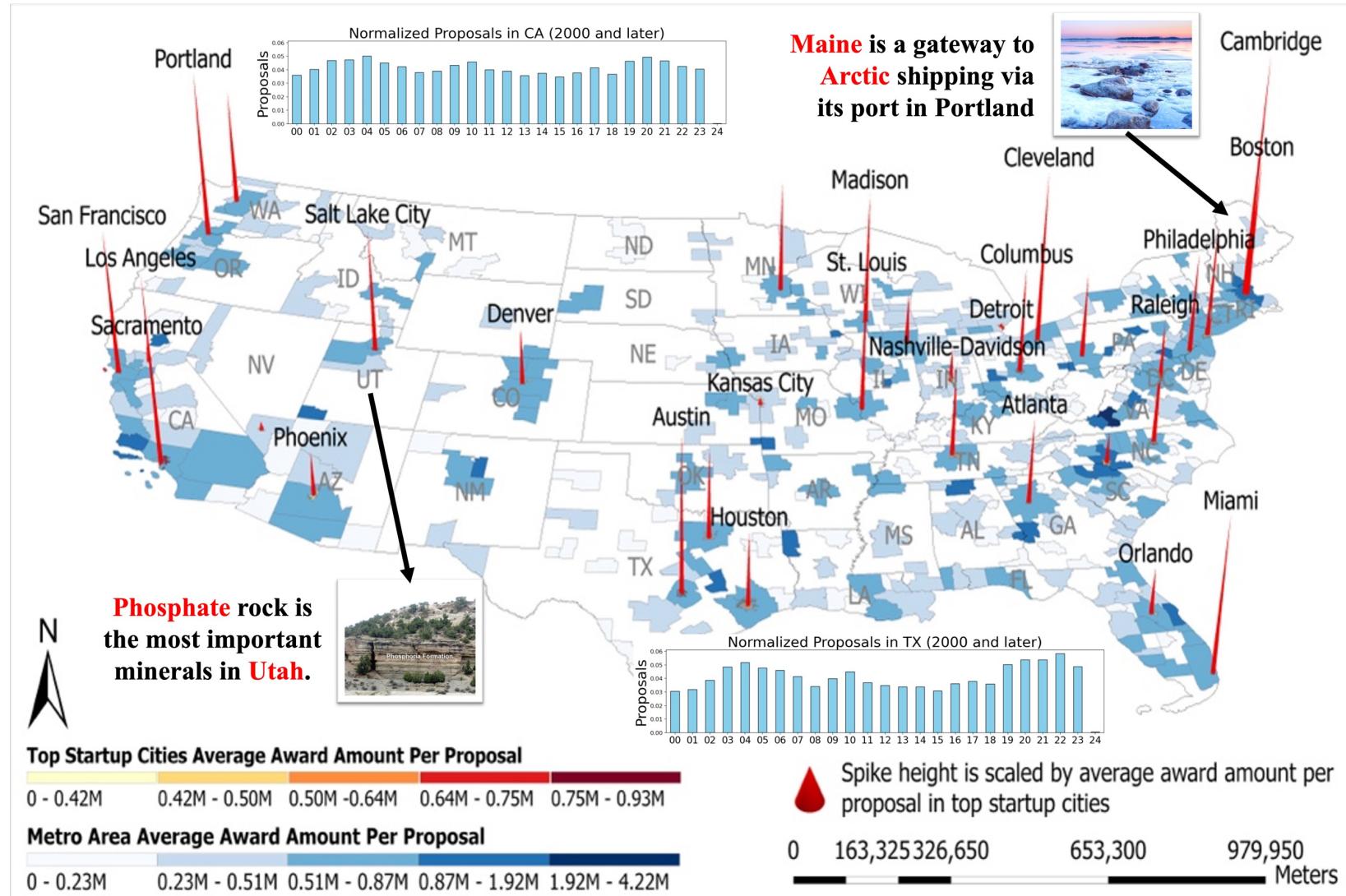
**Map Query:** Please provide me a navigation from Hot Springs National Park to Bryant

**VLM output:** Start from Hot Springs National Park to Oaklawn Park (from Right and Down, moving along Highway 70).  
Move from Oaklawn Park to Saline County Courthouse (from Right and Down, moving along Highway 70)  
Move from Saline County Courthouse to Lake Hamilton (from Right and Down, moving along Highway 30) ...



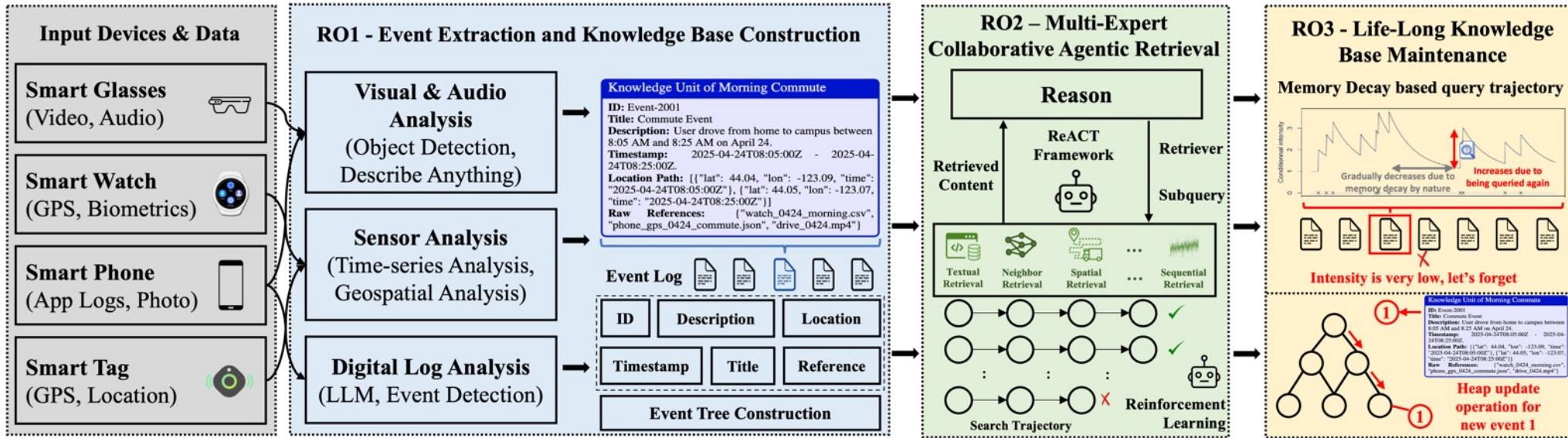


# Modern Neural-Symbolic Learning





# Modern Neural-Symbolic Learning



- Where did I last see my wallet?
- What did I do at the office yesterday afternoon?"
- Have I already taken the medicine?

(1) How to process the multi-modal signals from different user devices and construct the knowledge base?

– Task 1: Event Extraction and Graph Construction

(2) How to retrieve relevant user events based on the query from the knowledge base?

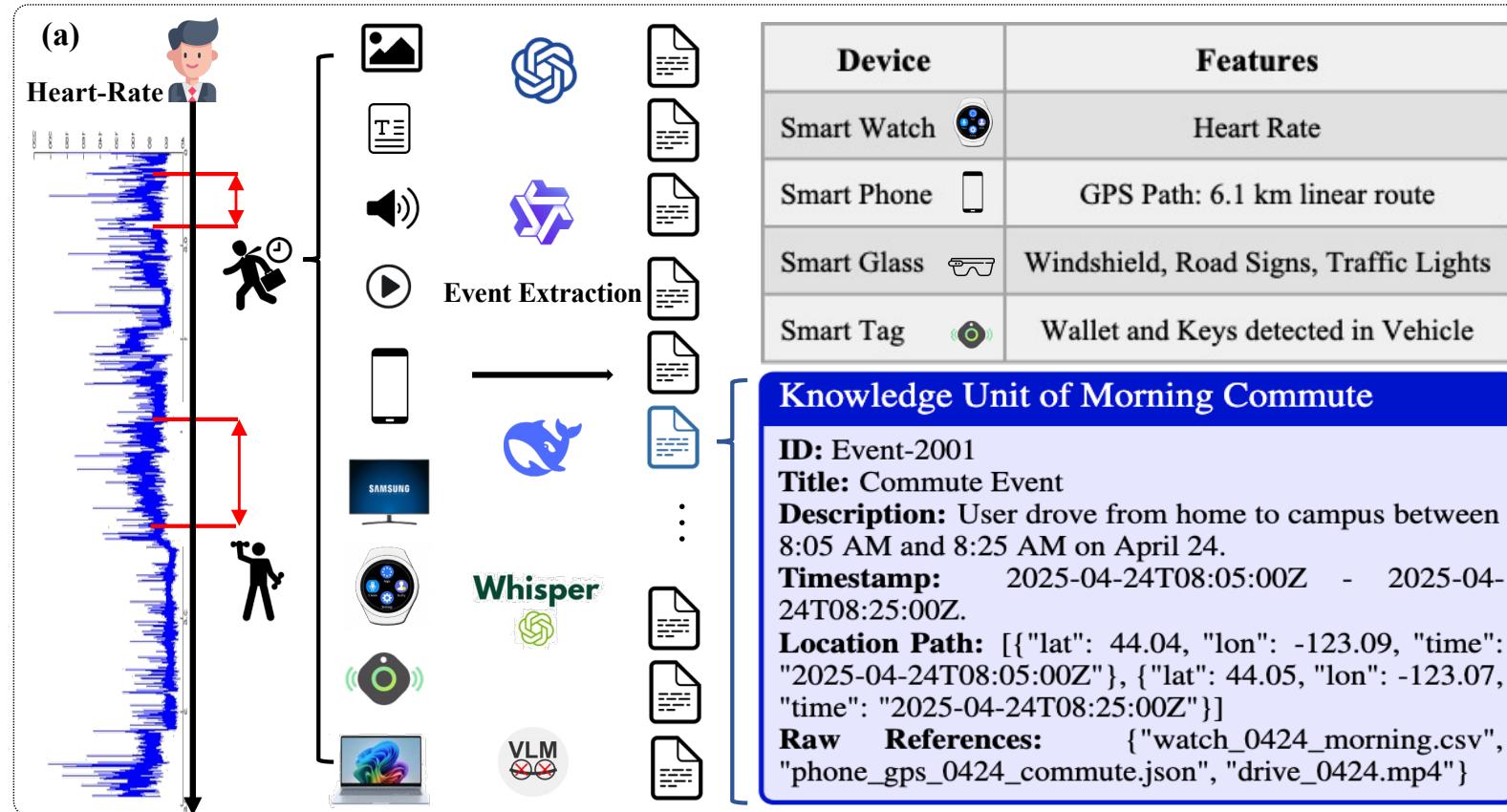
– Task2: Agentic Reason-then-Retrieval with Multi-Retriever Collaboration

(3) How to update the knowledge base?

– Task3: Frequency Estimation and Knowledge Update



# Modern Neural-Symbolic Learning



## Regular Event Extraction

## Anomaly Event Extraction



# New Situation

## AI bubble vs AI Flourishing?

Jiaxuan You  
@youjiaxuan

∅ ...

👉 NeurIPS 2025 might break records as the most submitted-to academic conference ever. One of our submission IDs is already ~23,000 — final count could hit 30,000. Absolute madness.

#NeurIPS2025 #AI

Writing paper is just so easy



## AAAI Launches AI-Powered Peer Review Assessment System

May 16, 2025

Washington, DC — The Association for the Advancement of Artificial Intelligence (AAAI), a leading nonprofit dedicated to advancing scientific research and collaboration, today announced a pilot program that strategically incorporates Large Language Models (LLMs) to enhance the academic paper review process for the AAAI-26 conference. This initiative aims to improve efficiency while maintaining the highest standards of scientific rigor and human oversight.



# New Situation

## AI bubble vs AI Flourishing?

What are you researching?

A screenshot of a digital research interface. At the top, there's a button labeled "Get a detailed report" and some icons for sharing or saving. Below this is a search bar with the text "Research" and a "Add sources" dropdown. To the right are icons for microphone and speaker. A dropdown menu titled "Tools" is open, listing "Create an image", "Search the web", "Write or code", and "Run deep research". The "Run deep research" option has a blue checkmark next to it, indicating it is selected. The background of the interface is white.



# New Situation

