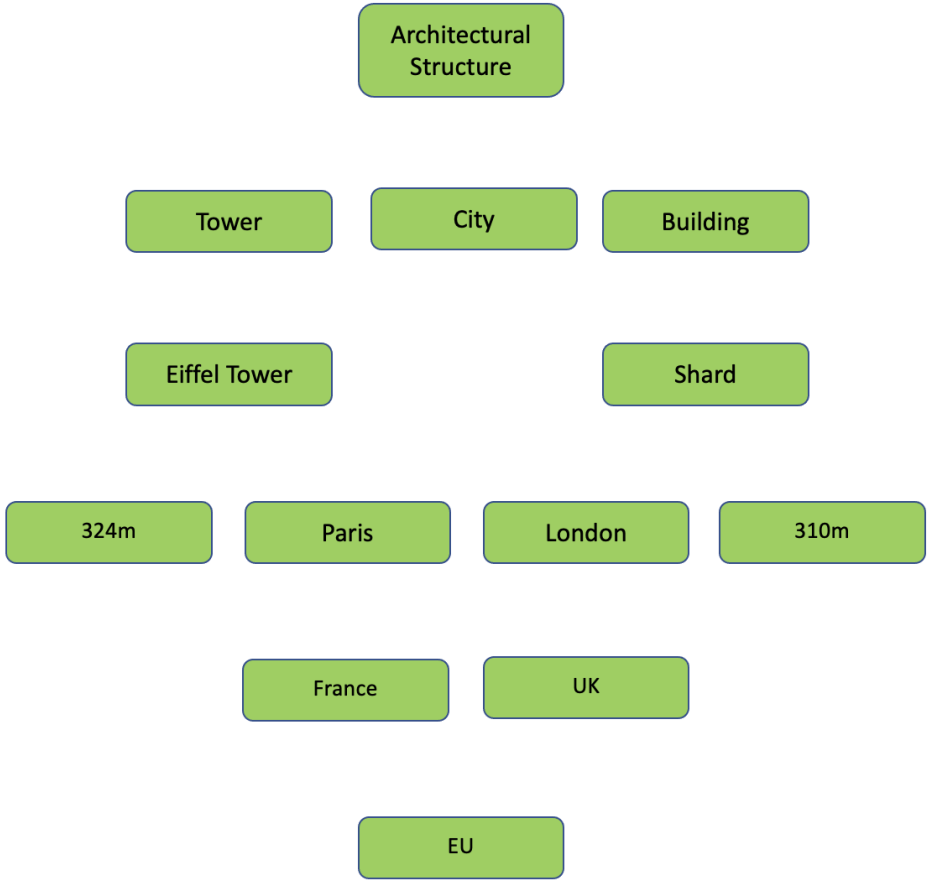
Recommendation & Personalization Using Knowledge Graphs

Ian Horrocks

Knowledge Graph Basics

Anatomy of a Knowledge Graph



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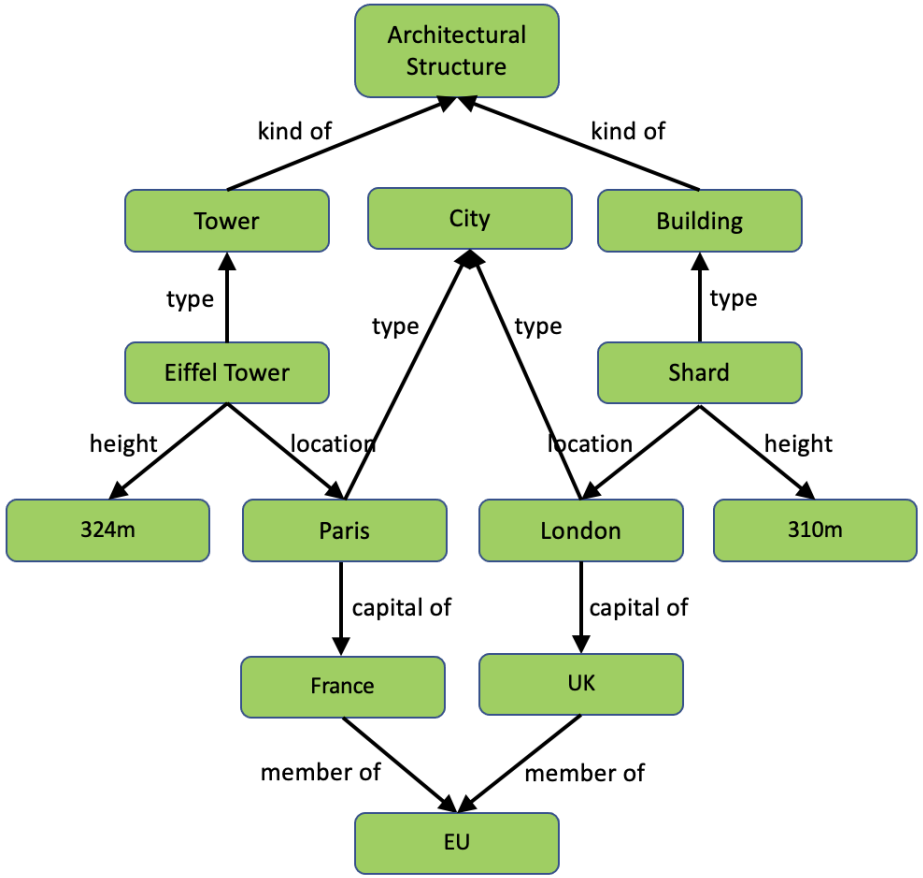
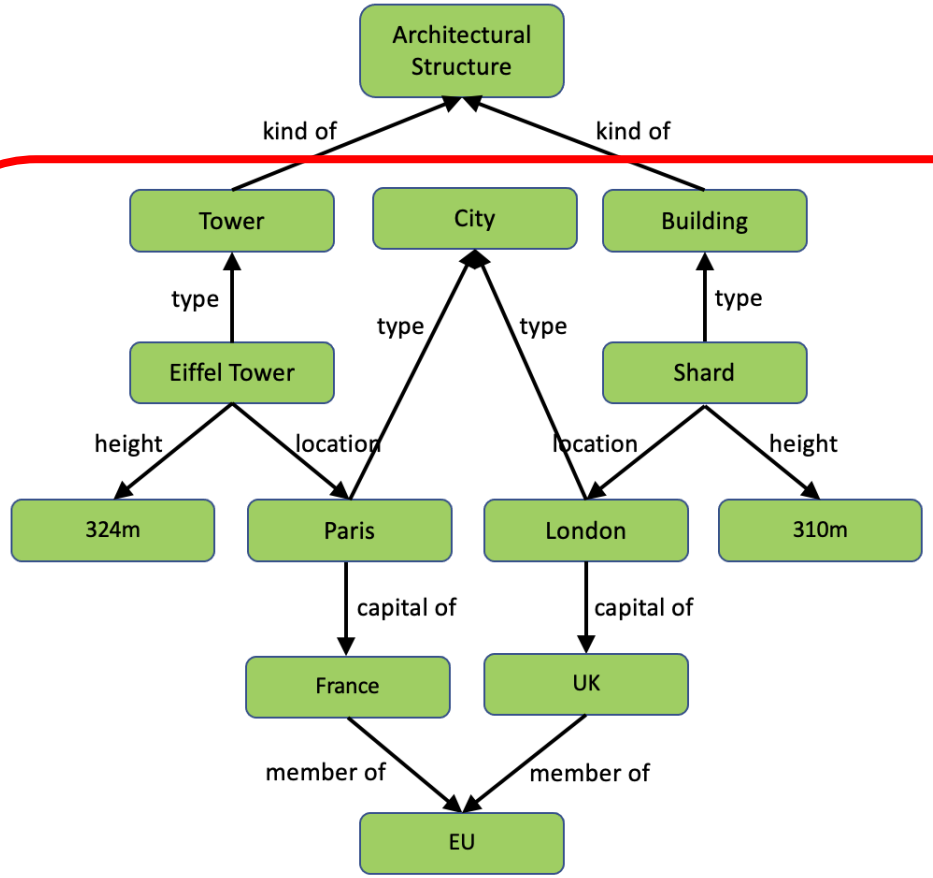
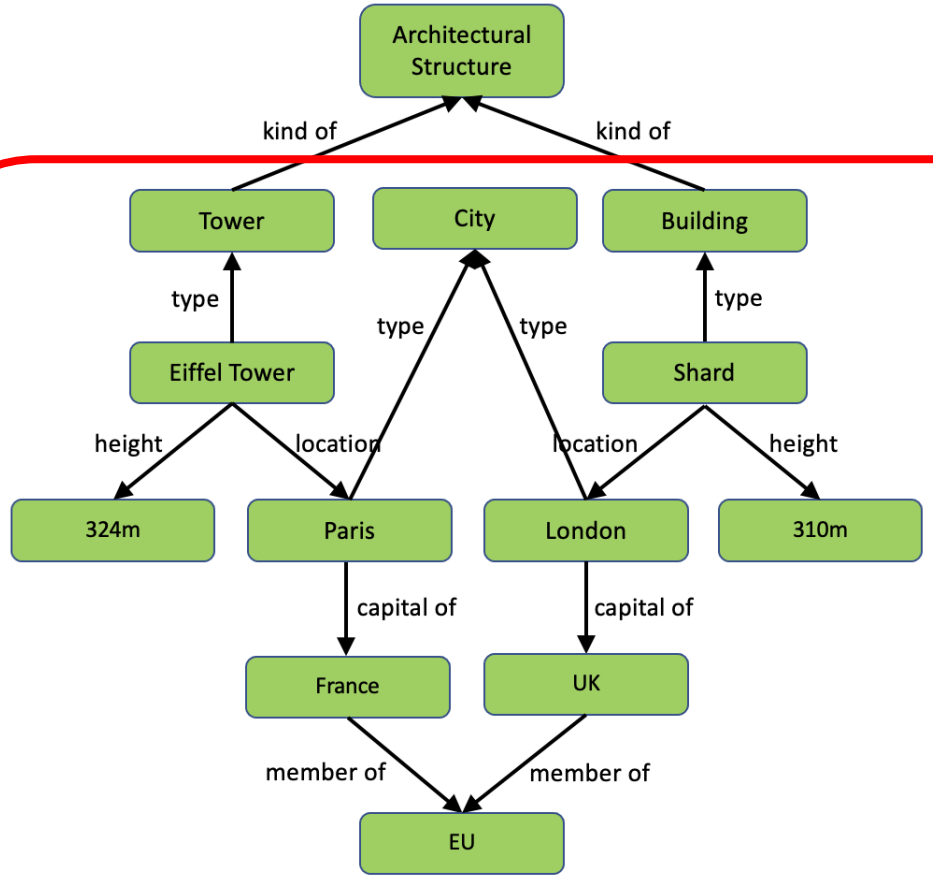


Data



Eiffel Tower is a Tower
Eiffel Tower has location Paris
Eiffel Tower has height 324m
Shard has location London
...

Data



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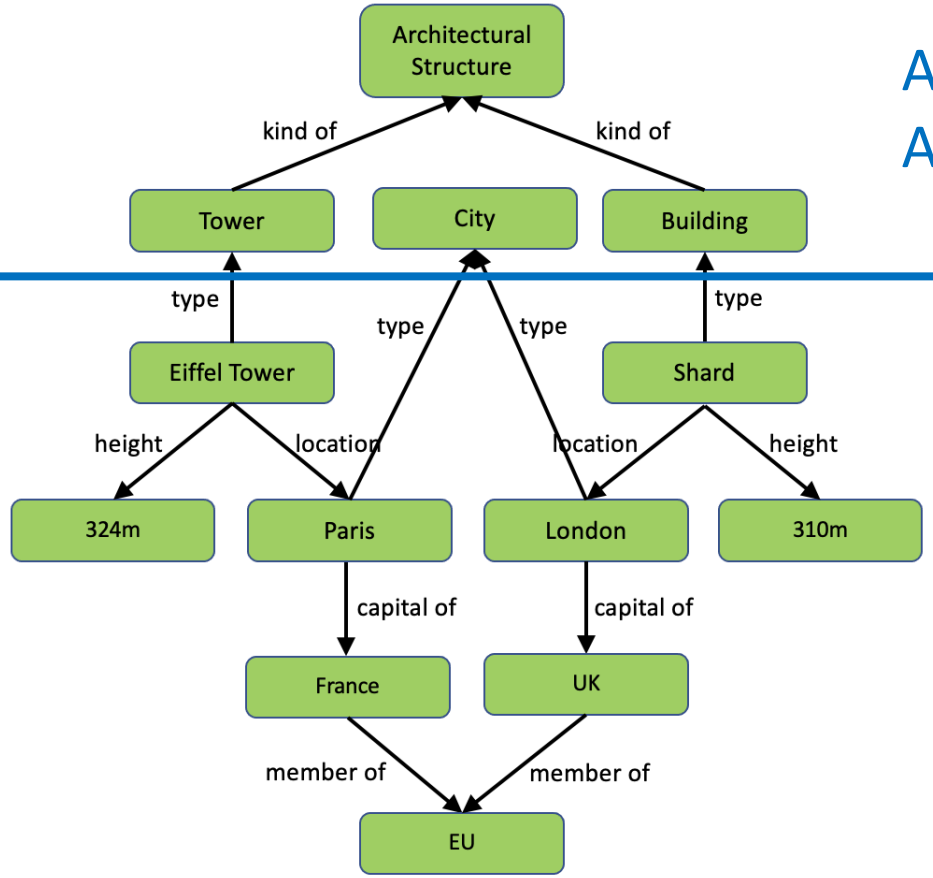
Architectural Structure			
name	**location**	**height**	**kind**
Shard	London	310m	Building
Eiffel Tower	Paris	324m	Lattice Tower
...	...	...	...

City	
name	**capital of**
London	UK
Paris	France
...	...

member of	
country	**organisation**
France	EU
UK	EU
...	...

Expert Knowledge (simple)

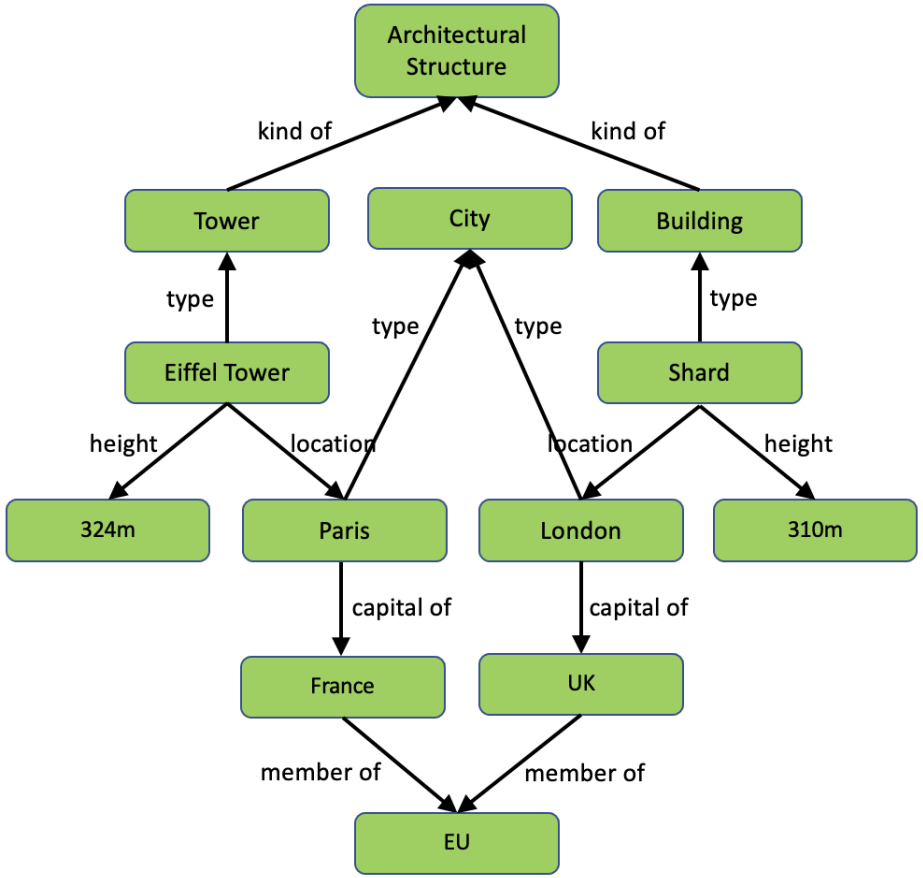


A tower is a kind of architectural structure
A building is a kind of architectural structure

Formalized using rules:

$$\text{Tower}(x) \rightarrow \text{ArchitecturalStructure}(x)$$
$$\text{Building}(x) \rightarrow \text{ArchitecturalStructure}(x)$$

Expert Knowledge (more complex)



A thing located in the capital of a country is located in that country
A thing located in a member of a union is located in that union

Formalized using rules:

$$\text{location}(x, y) \wedge \text{capital\_of}(y, z) \rightarrow \text{location}(x, z)$$
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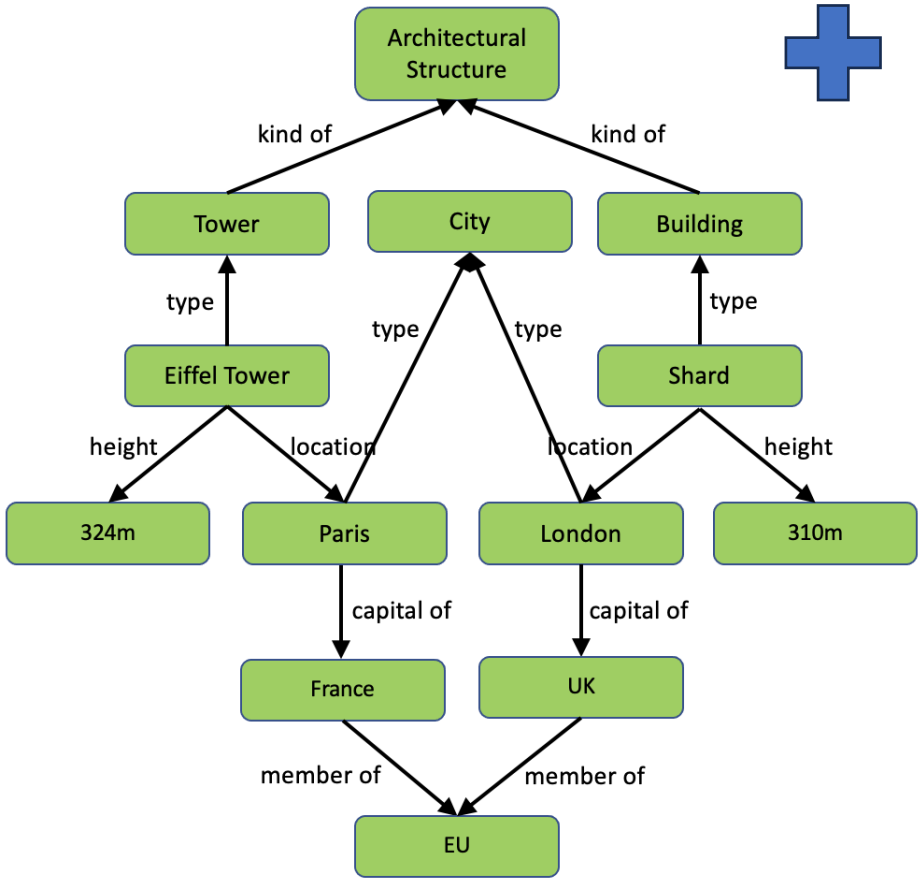
Query Answering (Reasoning)



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Architectural structure located in the EU?

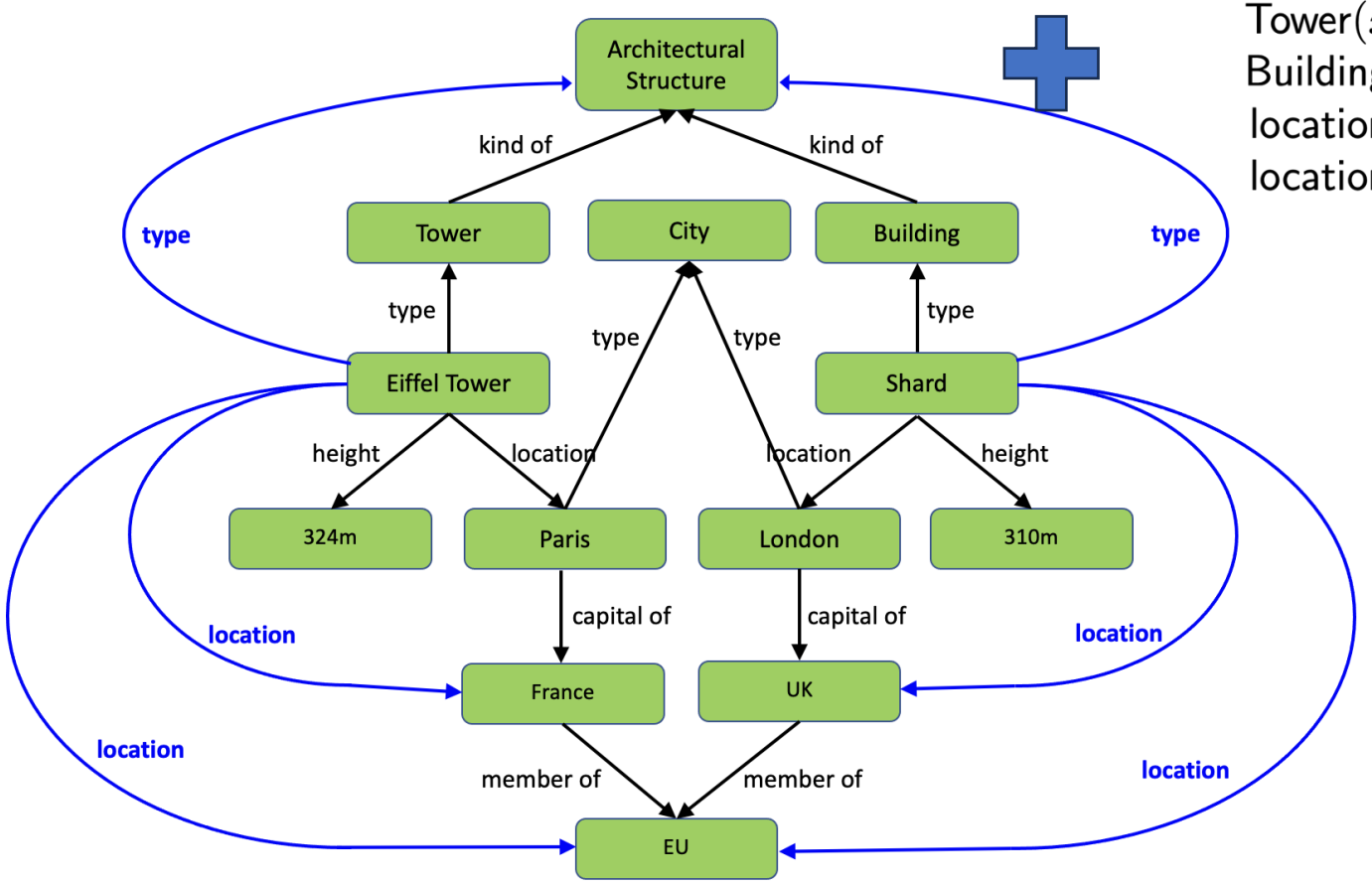
Formalized using SPARQL:

```
SELECT ?X WHERE
{ ?x a Architectural_Structure.
  ?X location EU }
```

Answer:

```
Eiffel Tower, Shard
```

Query Answering (Reasoning)



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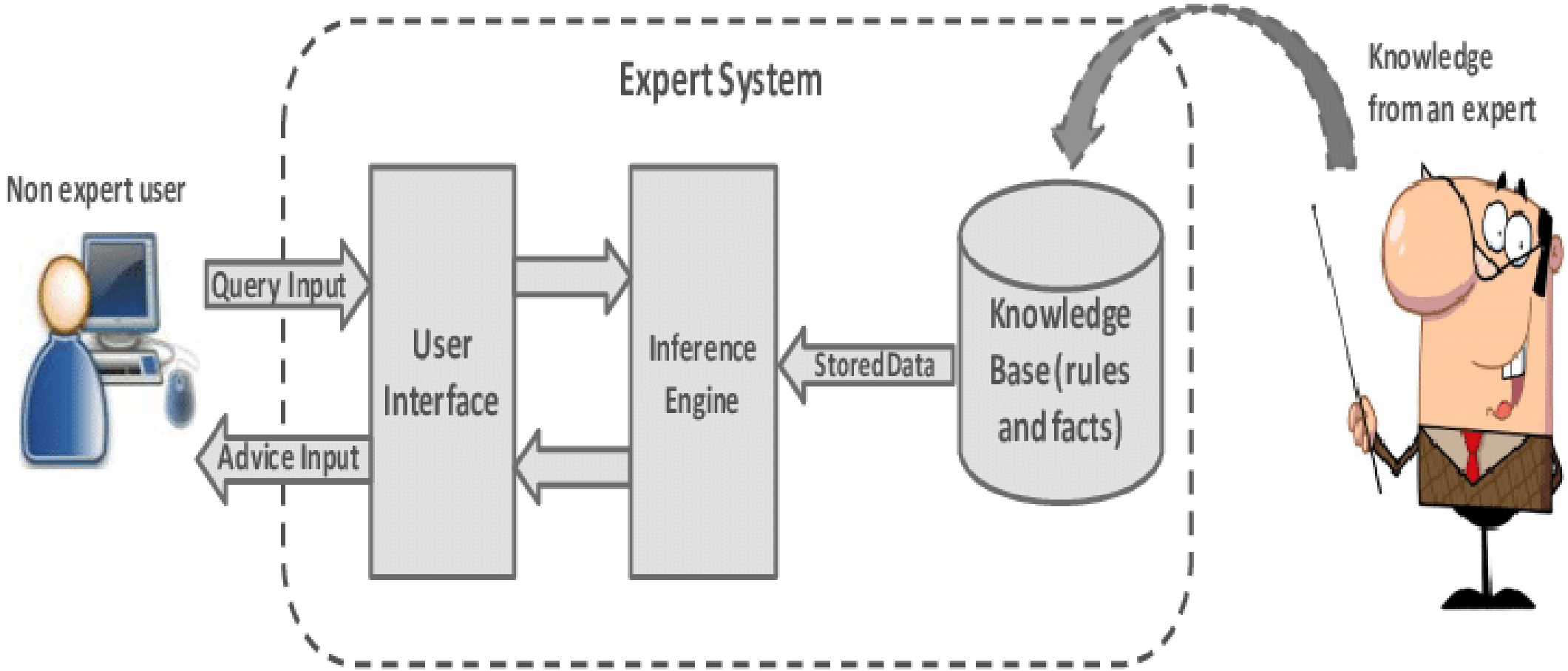
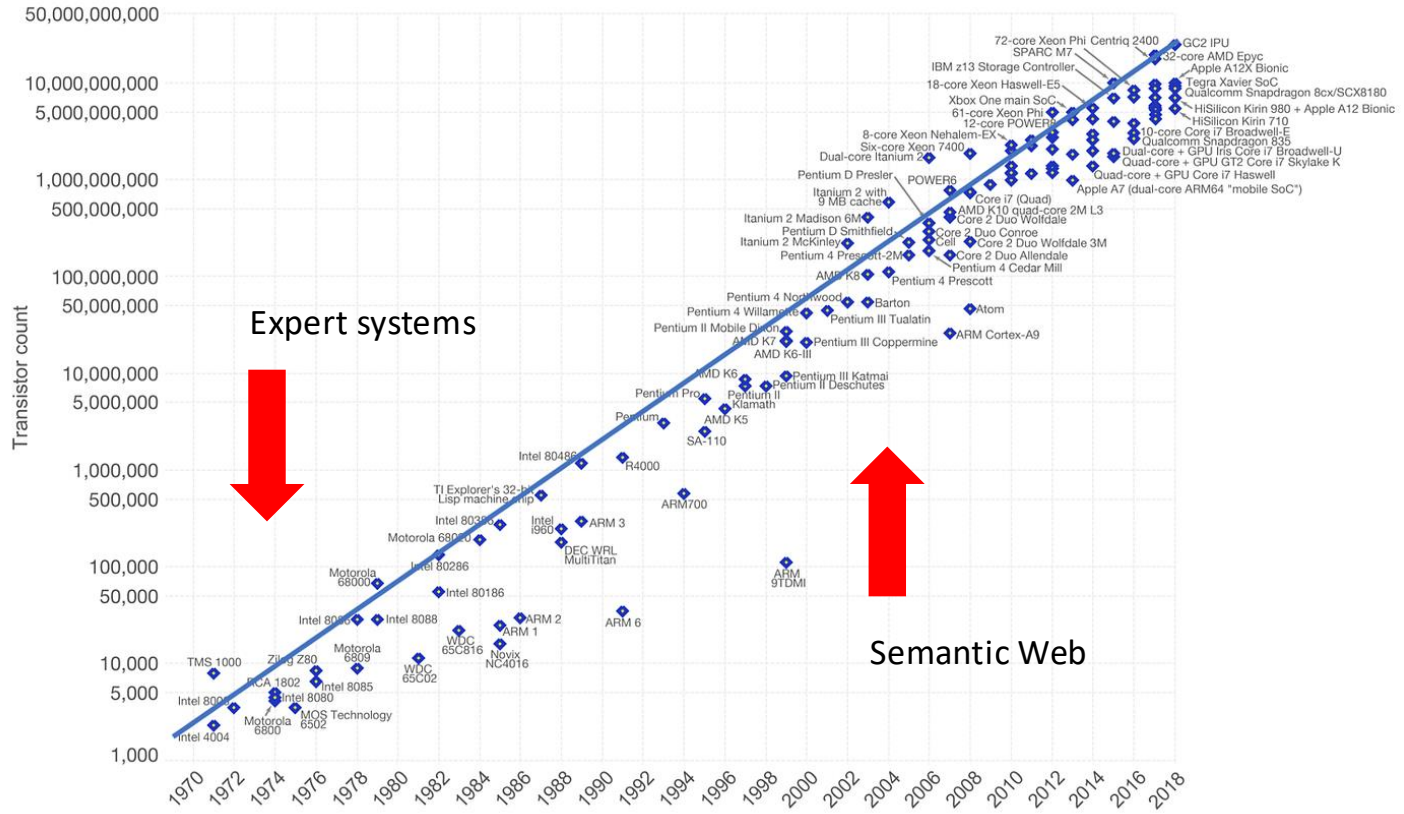
GOFAI?

Graph + Rules + Reasoning = (Symbolic) AI



Why Now (and not then)?

Moore's law



Why Now (and not then)?

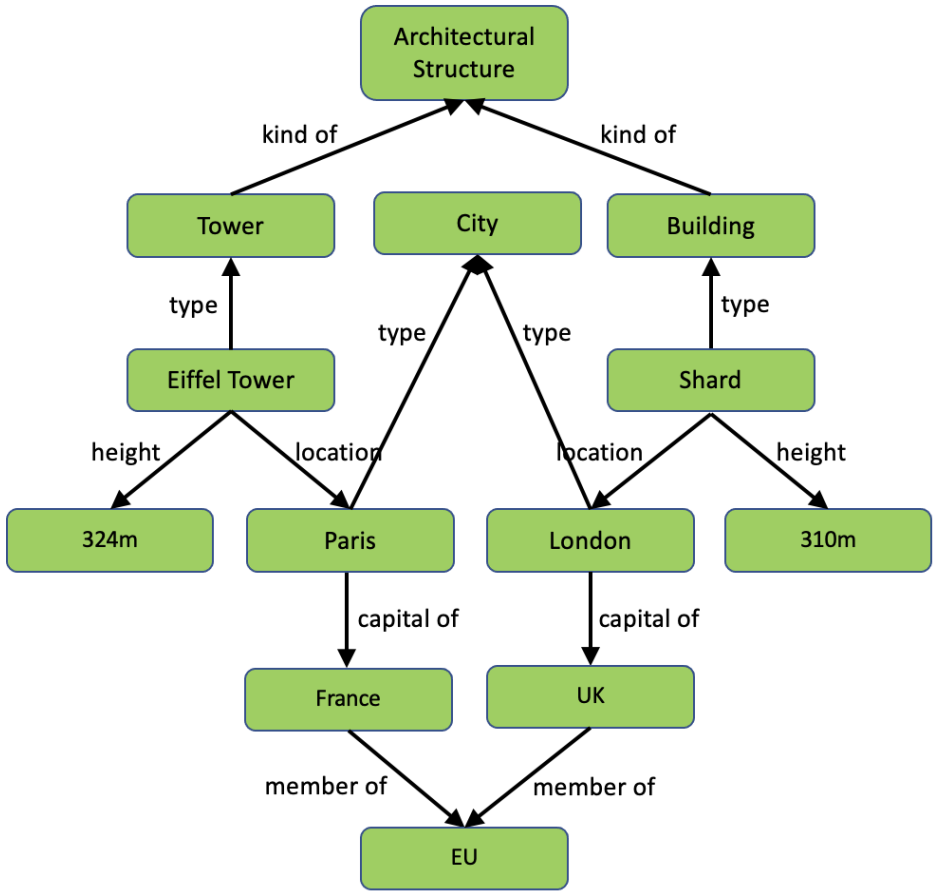
Digital transformation

Why Now (and not then)?

Research

- Parallelized semi-naïve materialization
  - Concurrent data structures
  - Optimized RAM-based storage
- View maintenance & incremental reasoning
  - DRed algorithm
  - Backwards/forwards algorithm
- …

Parallelized semi-naïve materialization



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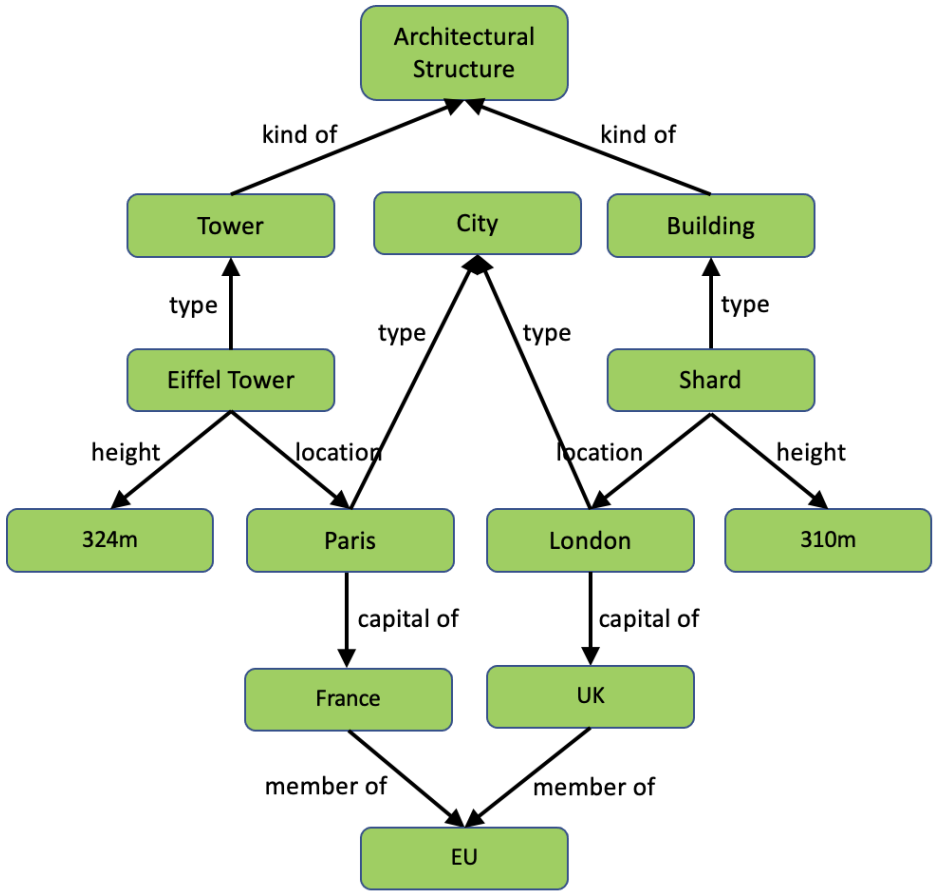
Parallelized semi-naïve materialization



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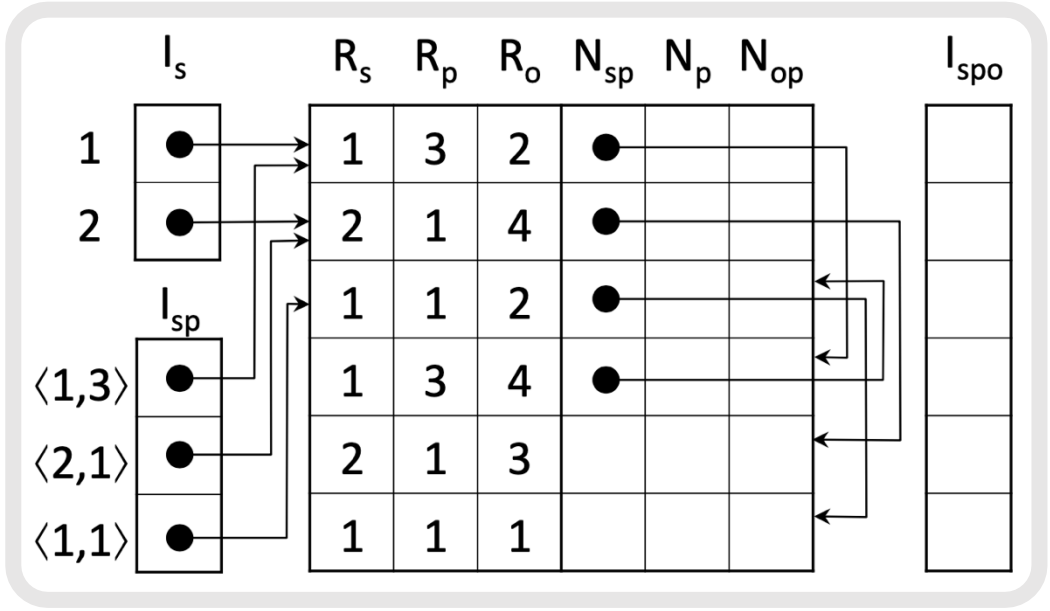

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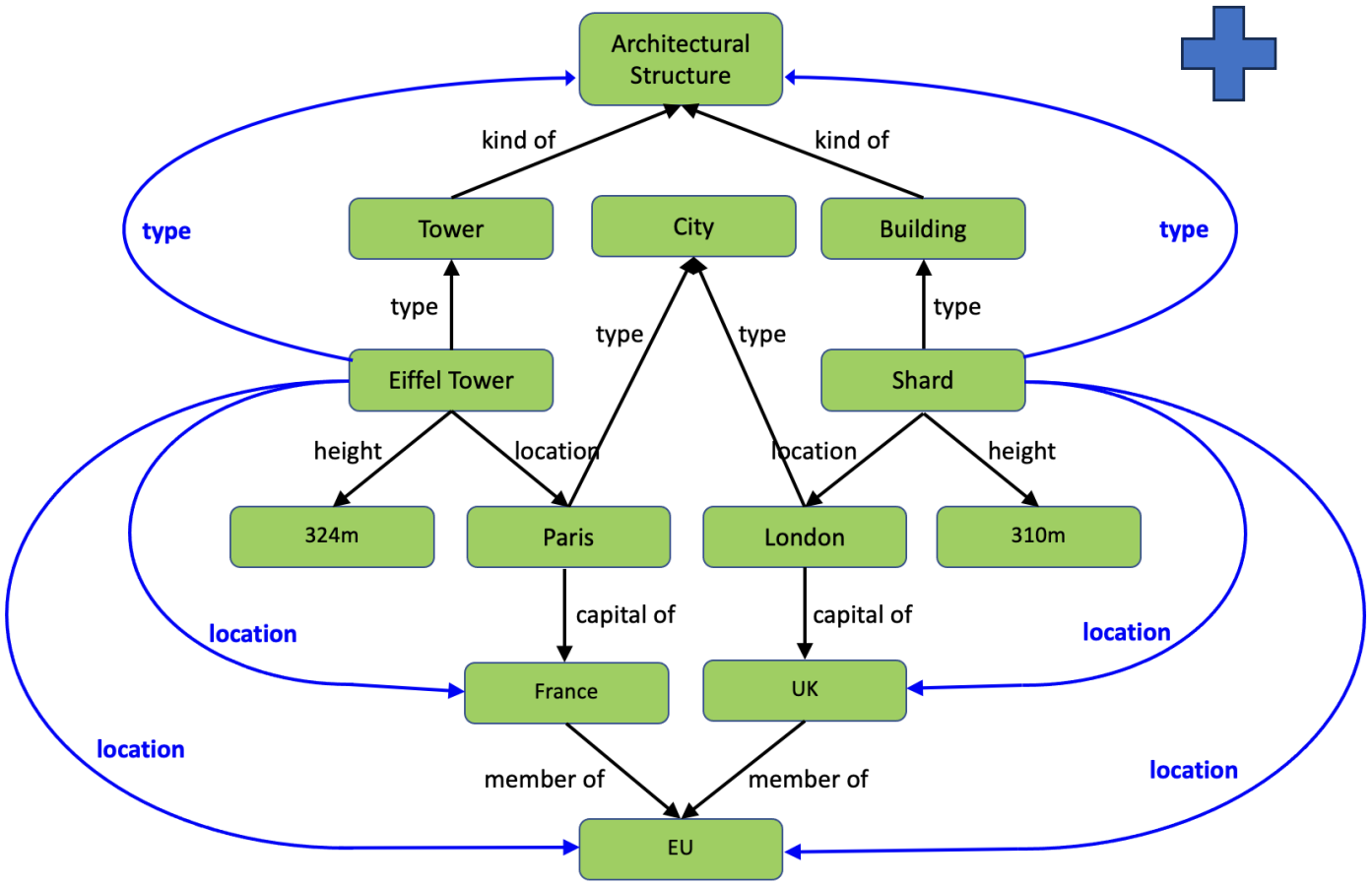

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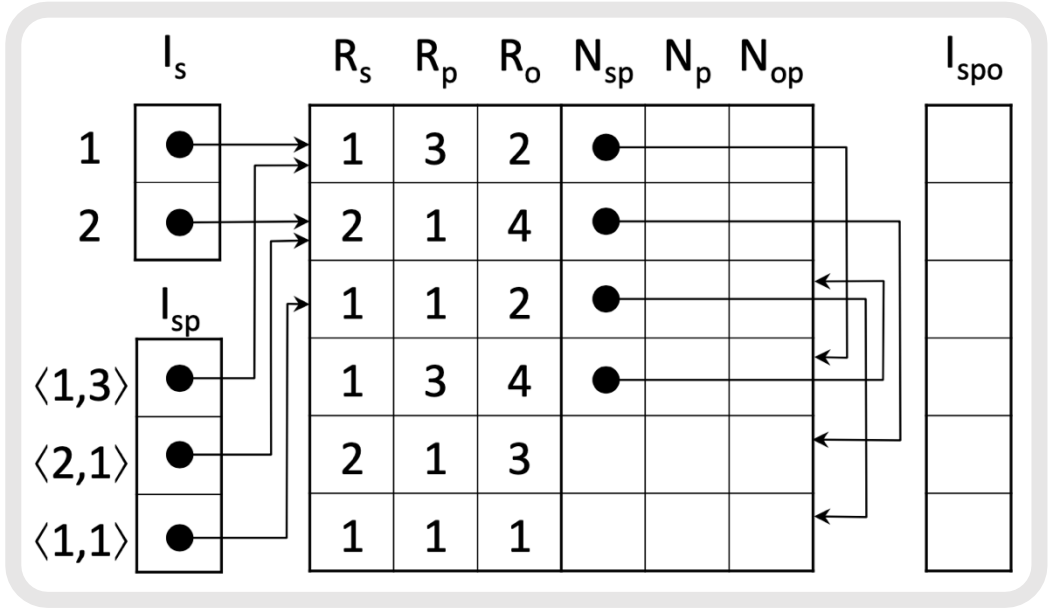
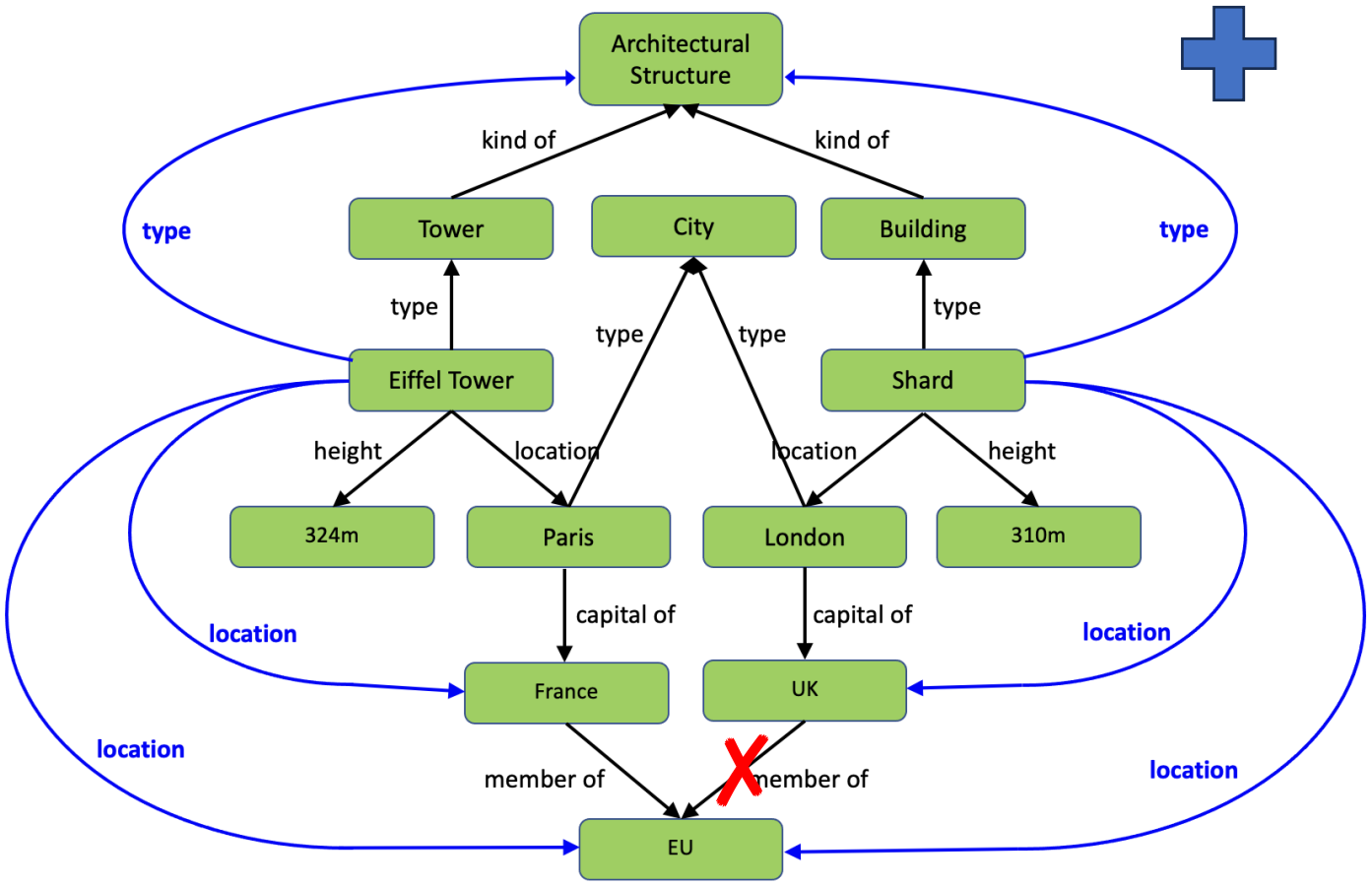


View maintenance & incremental reasoning



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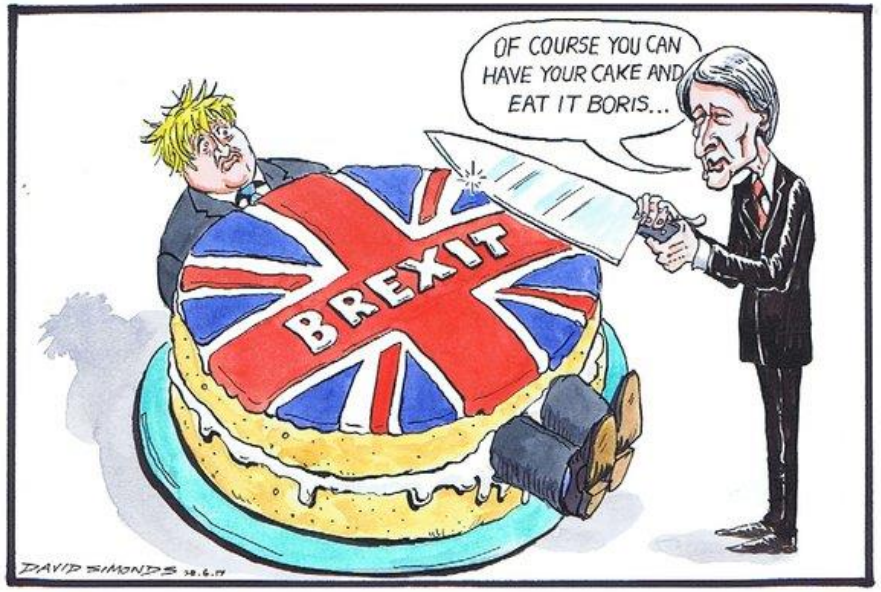

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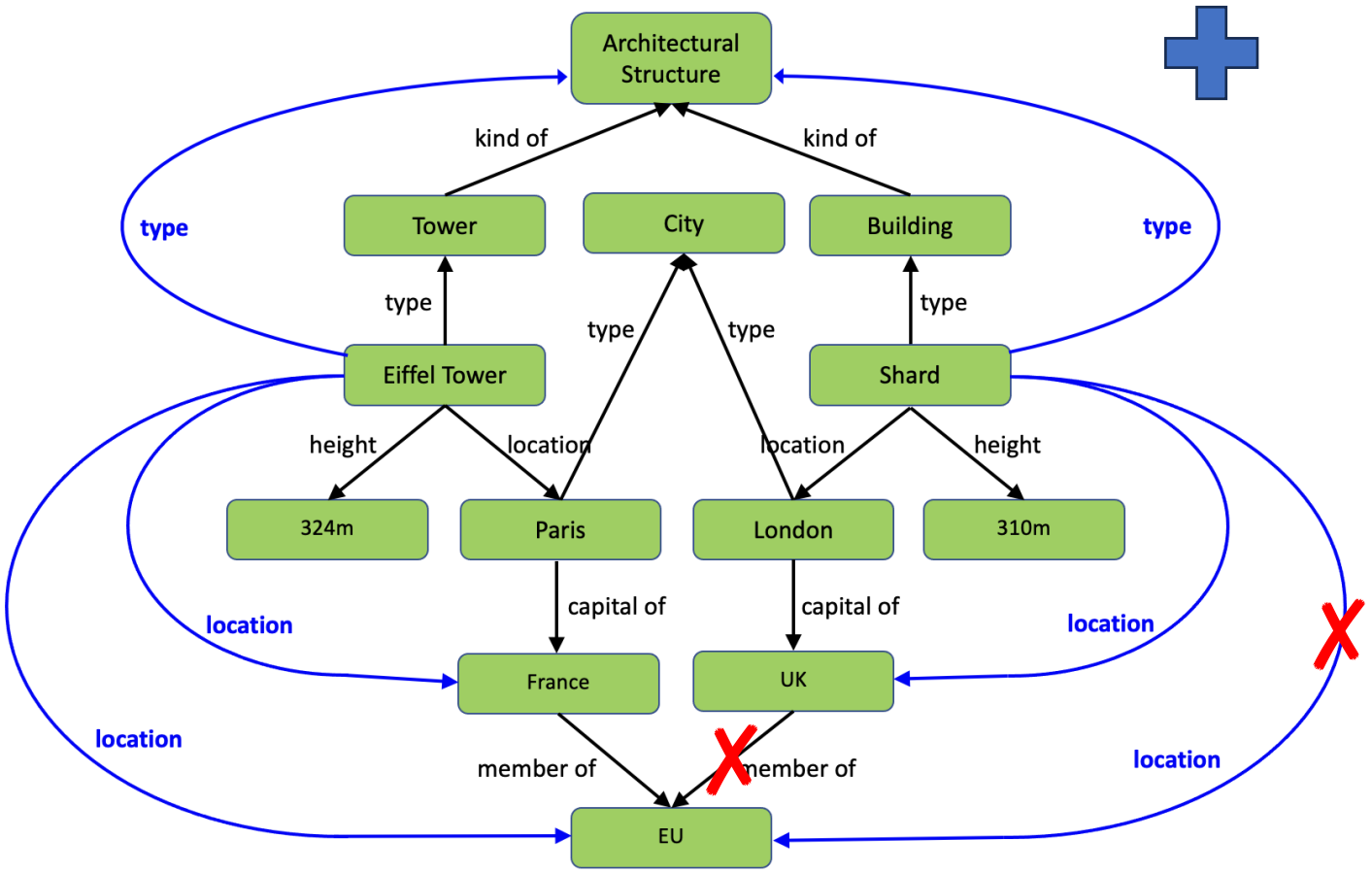

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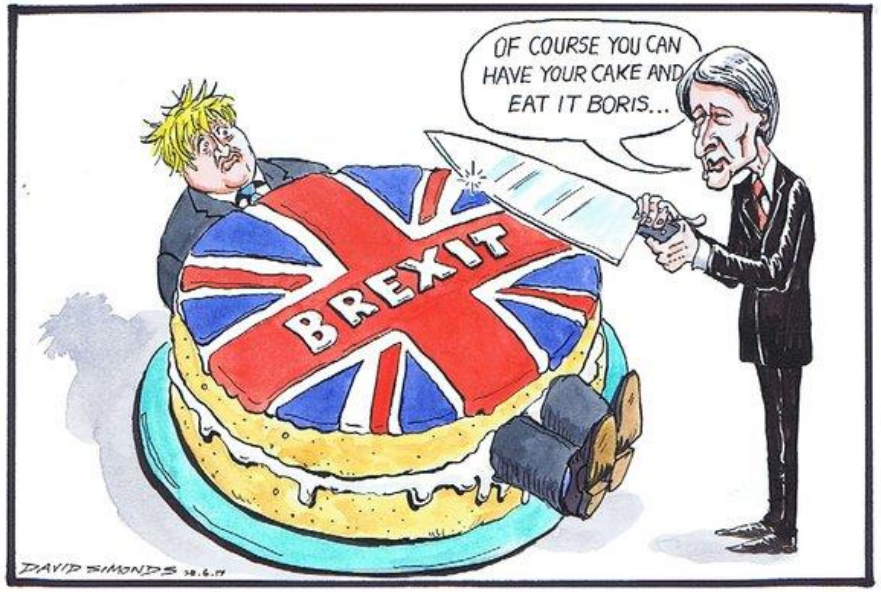
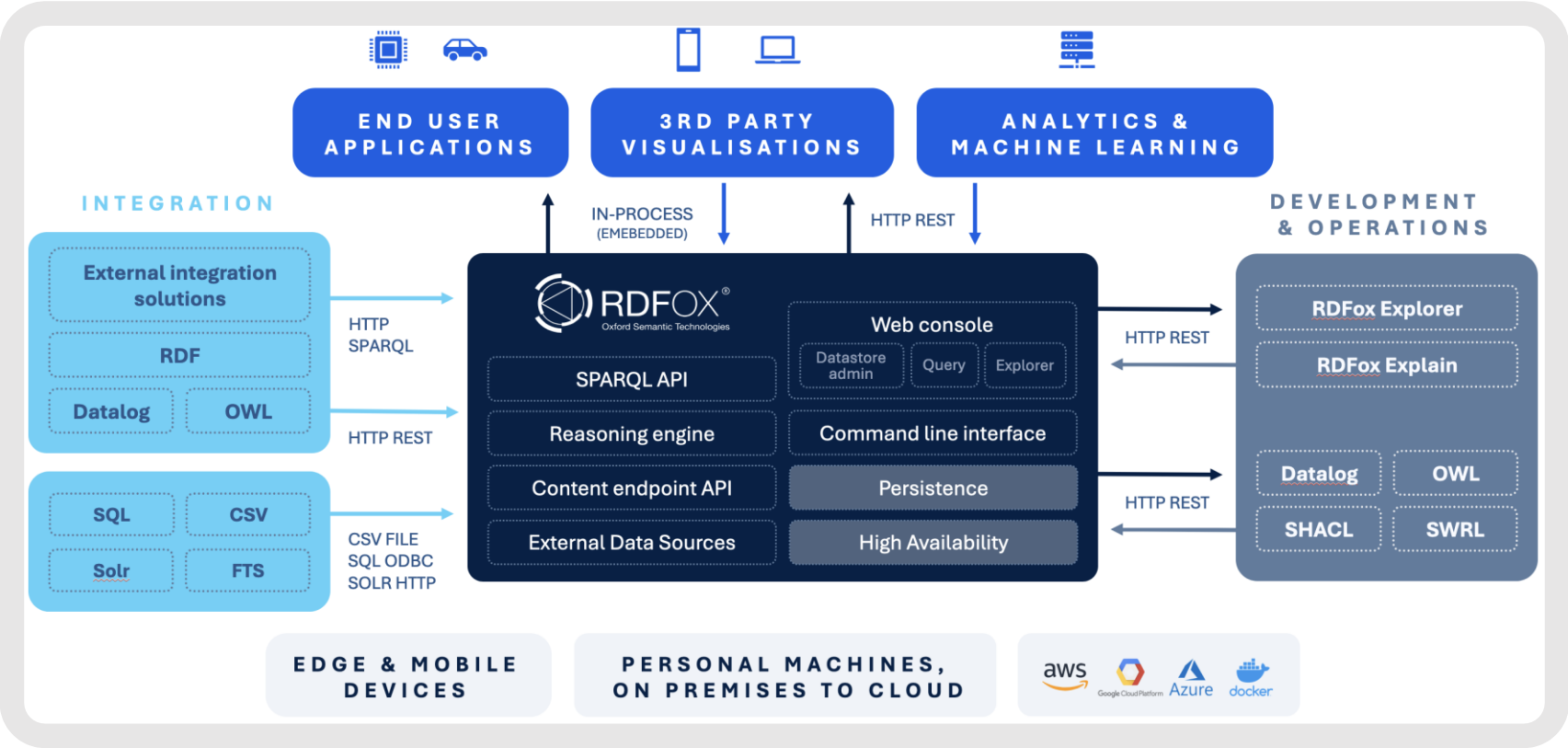


Why Now (and not then)?

RDFOX®
Oxford Semantic Technologies

Development



What About ML/LLM/GenAI?

ML & LLM (Non-symbolic AI)

Low information density

Randomly deleting data would have **little impact** on outputs

Vague knowledge

Rules are **uncertain or unknown**

Static knowledge

Knowledge changes **rarely/slowly**

Low cost of failure

Some errors **can be tolerated**

KGs (Symbolic AI)

High information density

Randomly deleting data would have **big impact** on outputs

Precise knowledge

Rules are **precise and known**

Dynamic knowledge

Knowledge changes **often/rapidly**

High cost of failure

Errors **cannot be tolerated**

Example Use Cases

Semantic Search & Recommendation

E.G. RETAIL

High information density

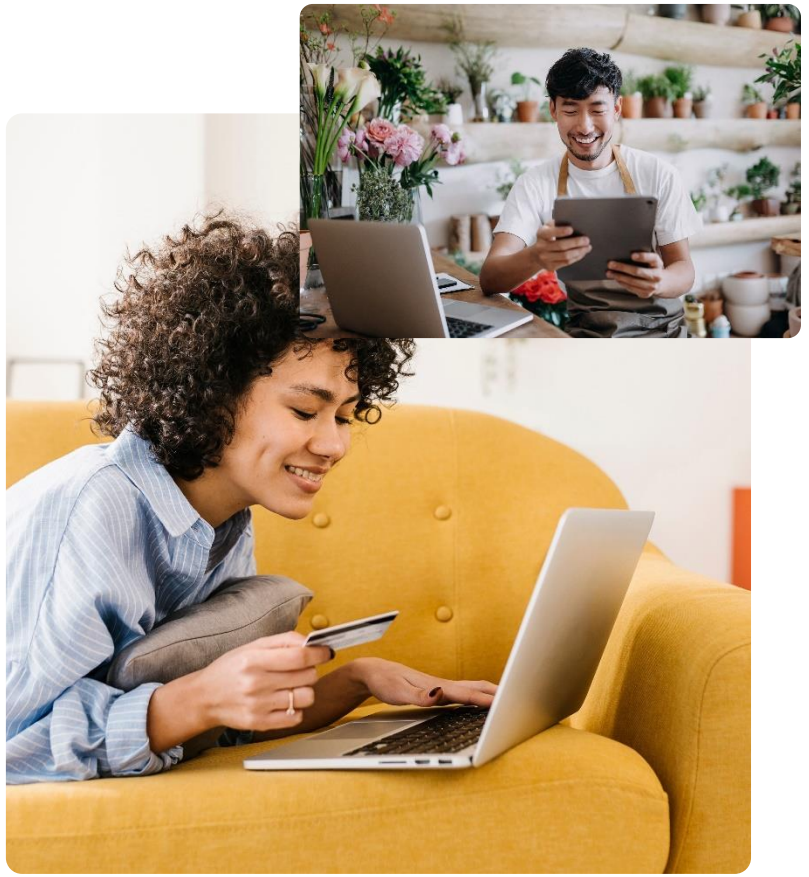
- Details of products and customers have **big impact**

Dynamic knowledge

- Product catalogue and customer details change **often/rapidly**

High cost of failure

- Customers have **low tolerance for errors**



Compatibility & Configuration

E.G. INDUSTRIAL PRODUTION LINE SYSTEMS

High information density

- Details of components and requirements have **big impact**

Precise knowledge

- Of component **specifications**, **compatibilities** and customer **requirements**

High cost of failure

- Huge and costly installations mean that **errors cannot be tolerated**

Dynamic knowledge

- Product catalogue under constant **revision and extension**

FESTO

Regulatory & Policy Compliance

E.G. FINANCIAL SERVICES

High information density

- Details of regulations, policies and trades have **big impact**

Precise knowledge

- Regulations, policies and trades are **precisely specified**

High cost of failure

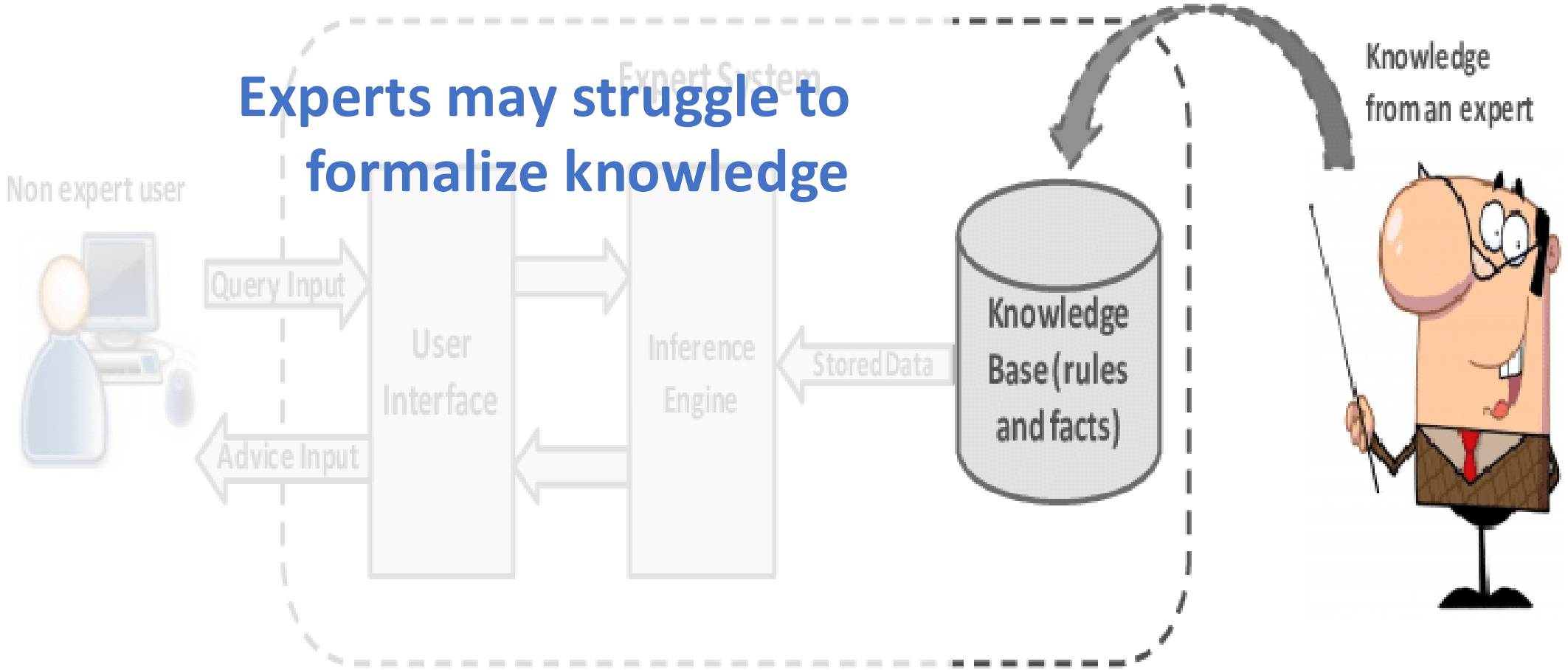
- Failures of regulatory compliance can result in **very large penalties**

Dynamic knowledge

- Regulations and policies under constant **revision and extension**

But…

Experts may struggle to formalize knowledge



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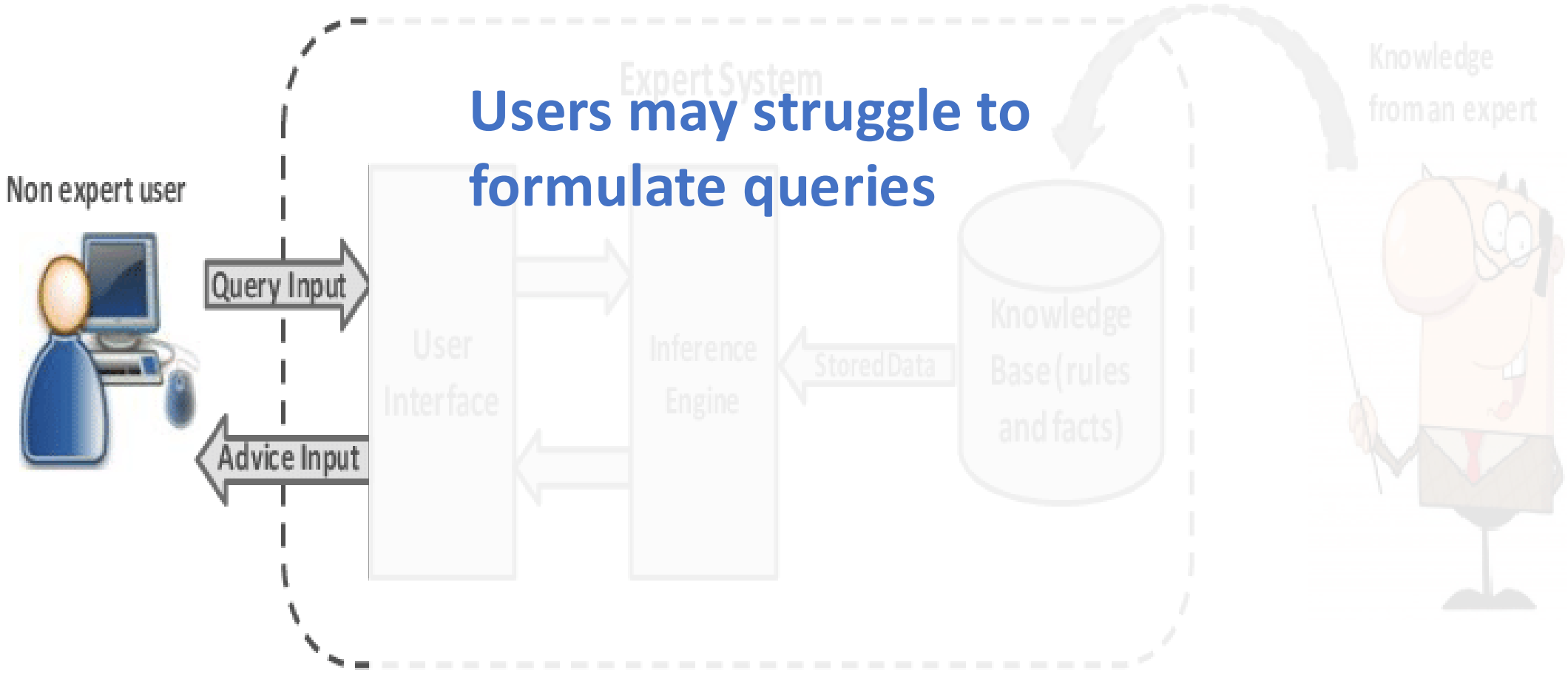
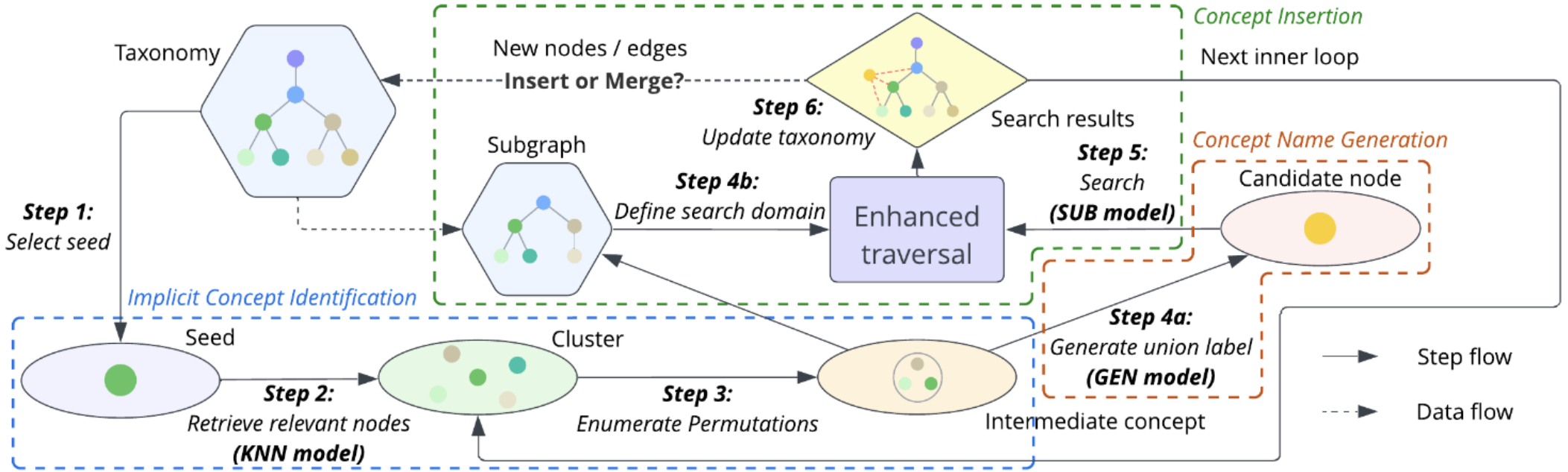


Users may struggle to formulate queries

Hybrid AI: Best of Both Worlds?

ML & LLM for Knowledge Engineering

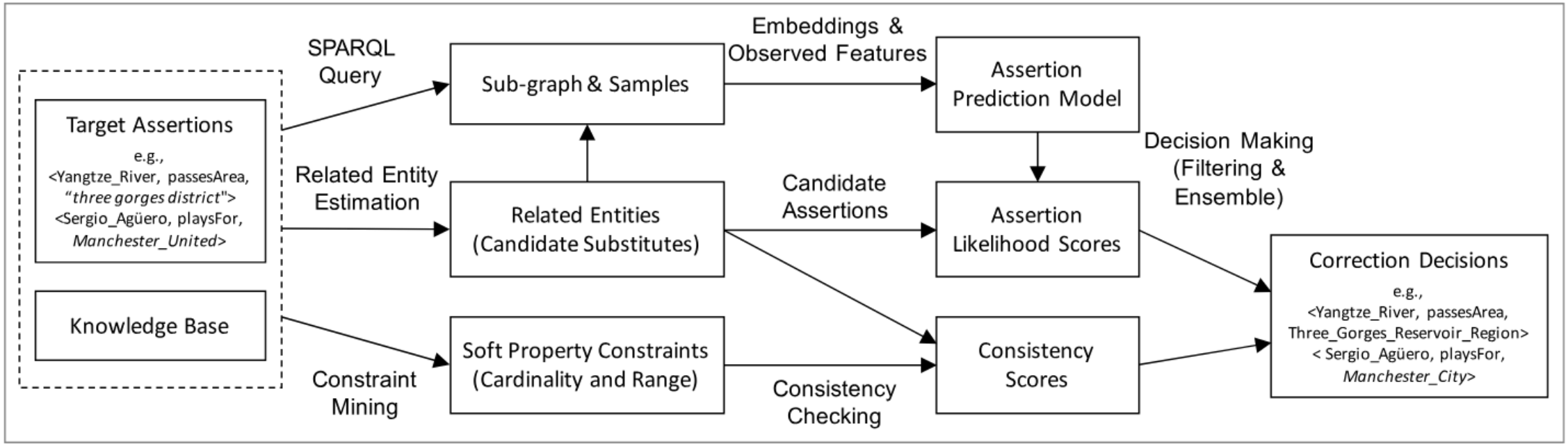
e.g., **Taxonomy completion**



Shi et al. Taxonomy Completion via Implicit Concept Insertion. WWW 2024.

ML & LLM for Knowledge Engineering

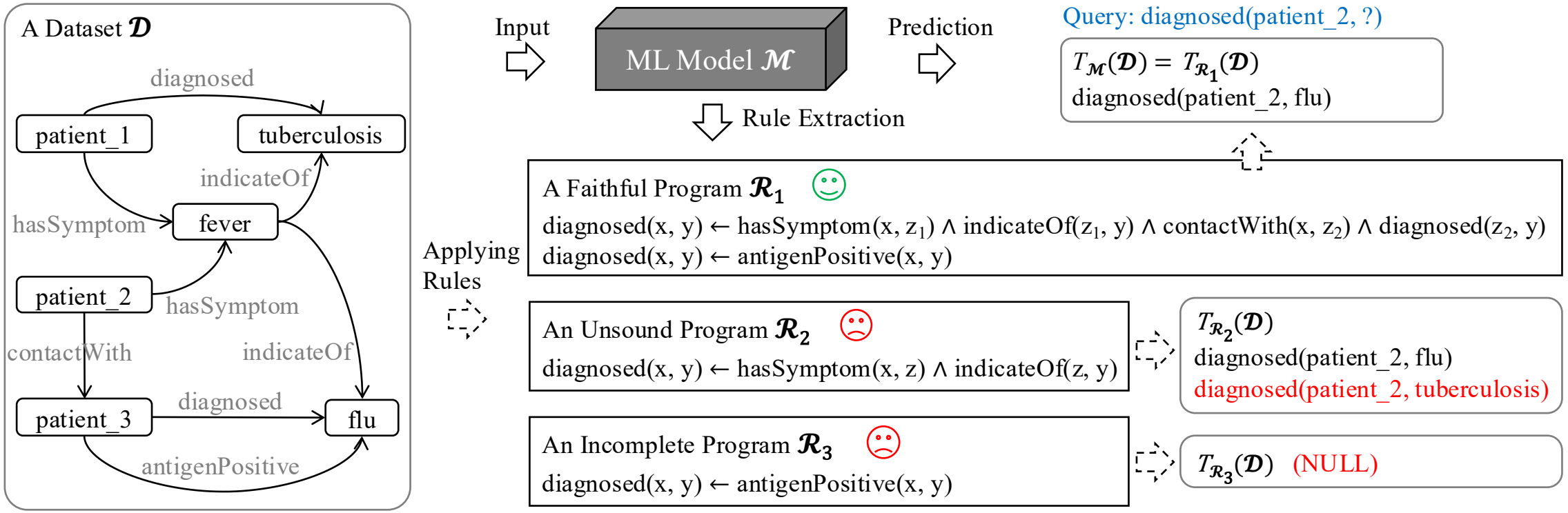
e.g., **Assertion Correction**



Chen et al. An assertion and alignment correction framework for large scale knowledge bases. Semantic Web, 14(1).

Knowledge-based Enhancement of ML & LLM

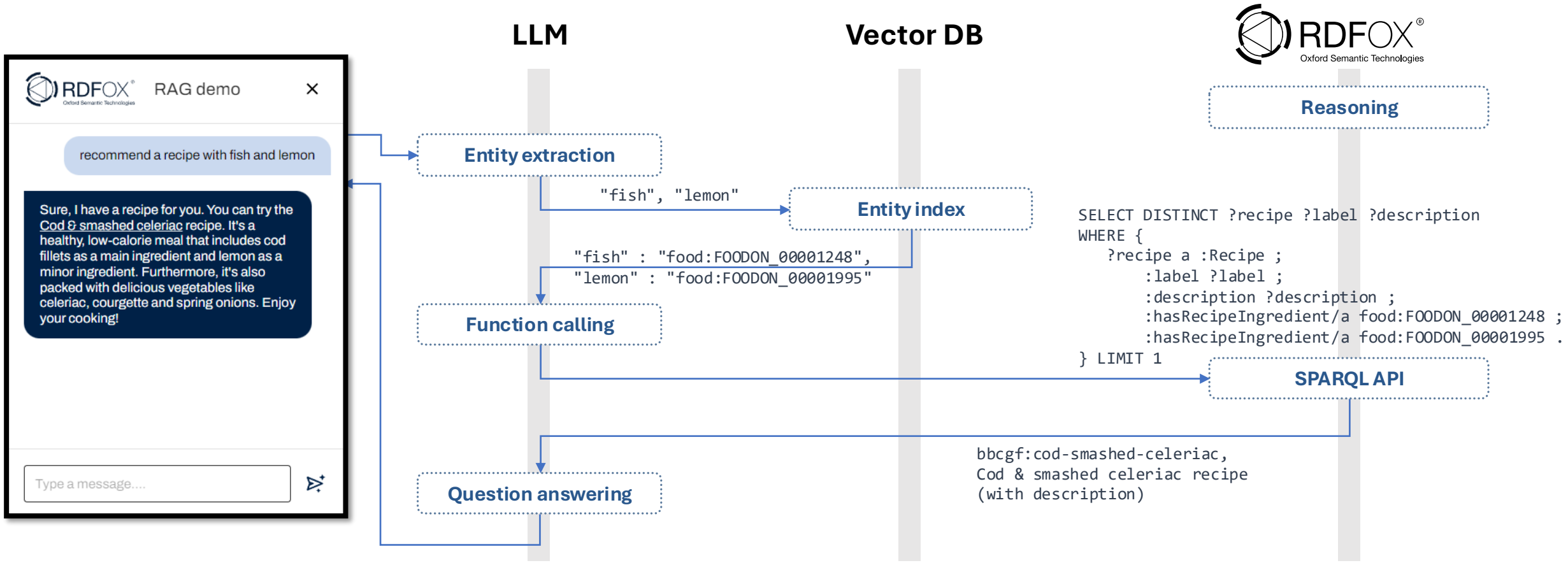
e.g., **Rule extraction** for explanation, auditing, …



Wang et al. Faithful Rule Extraction for Differentiable Rule Learning Models. ICLR 2024.

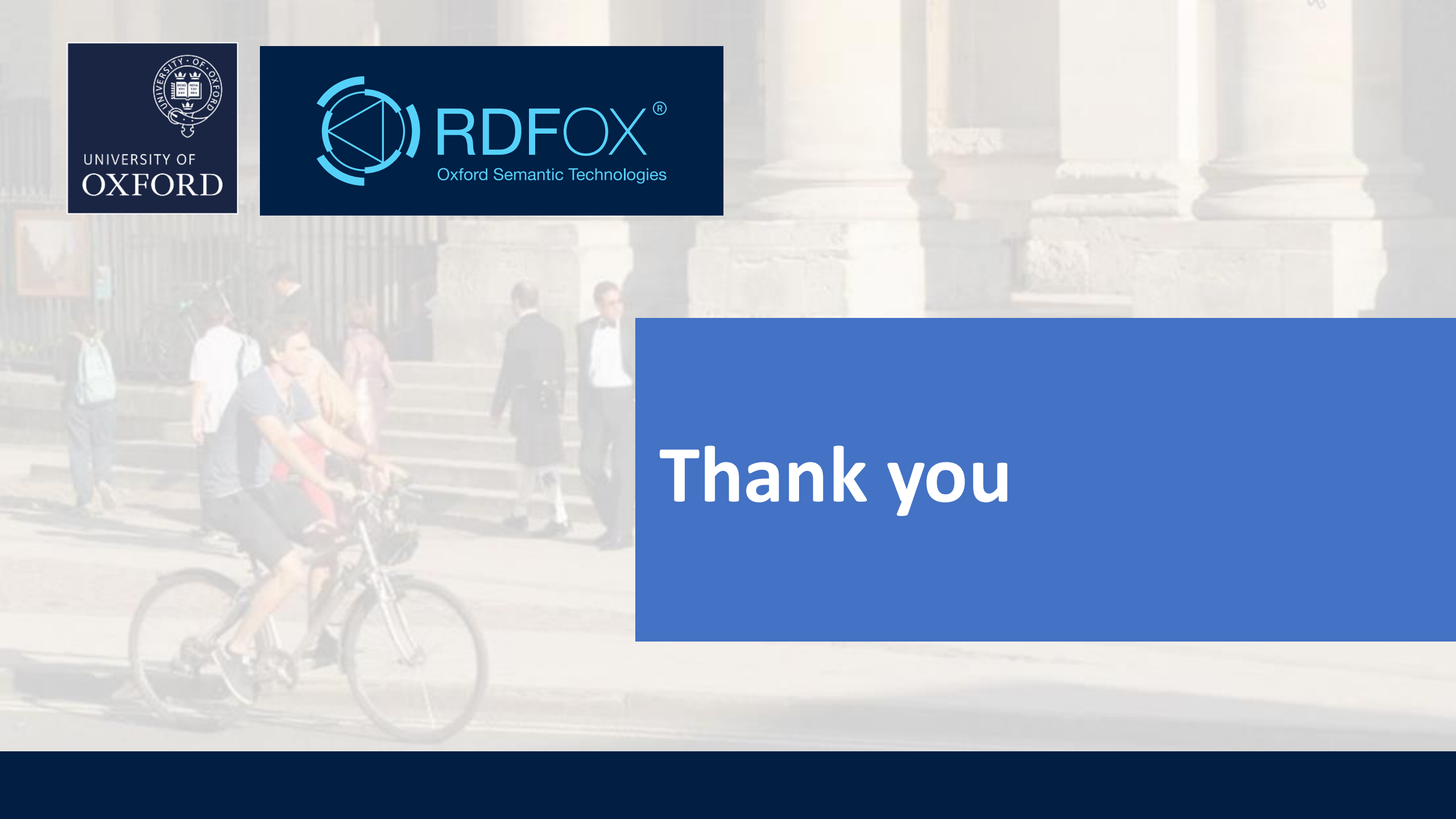
ML & LLM for User Dialogue

e.g., **Graph RAG**



Conclusion

- Knowledge graphs provide mature and robust symbolic AI
- Benefits include precision, predictability, adaptability and interpretability
- Applications include high-stakes systems with low error tolerance
- Use cases in Retail, Industrial, Financial services, …
- Set to play a critical role in the future of Hybrid AI



Thank you