Language, Ontology, and the Semantic Web

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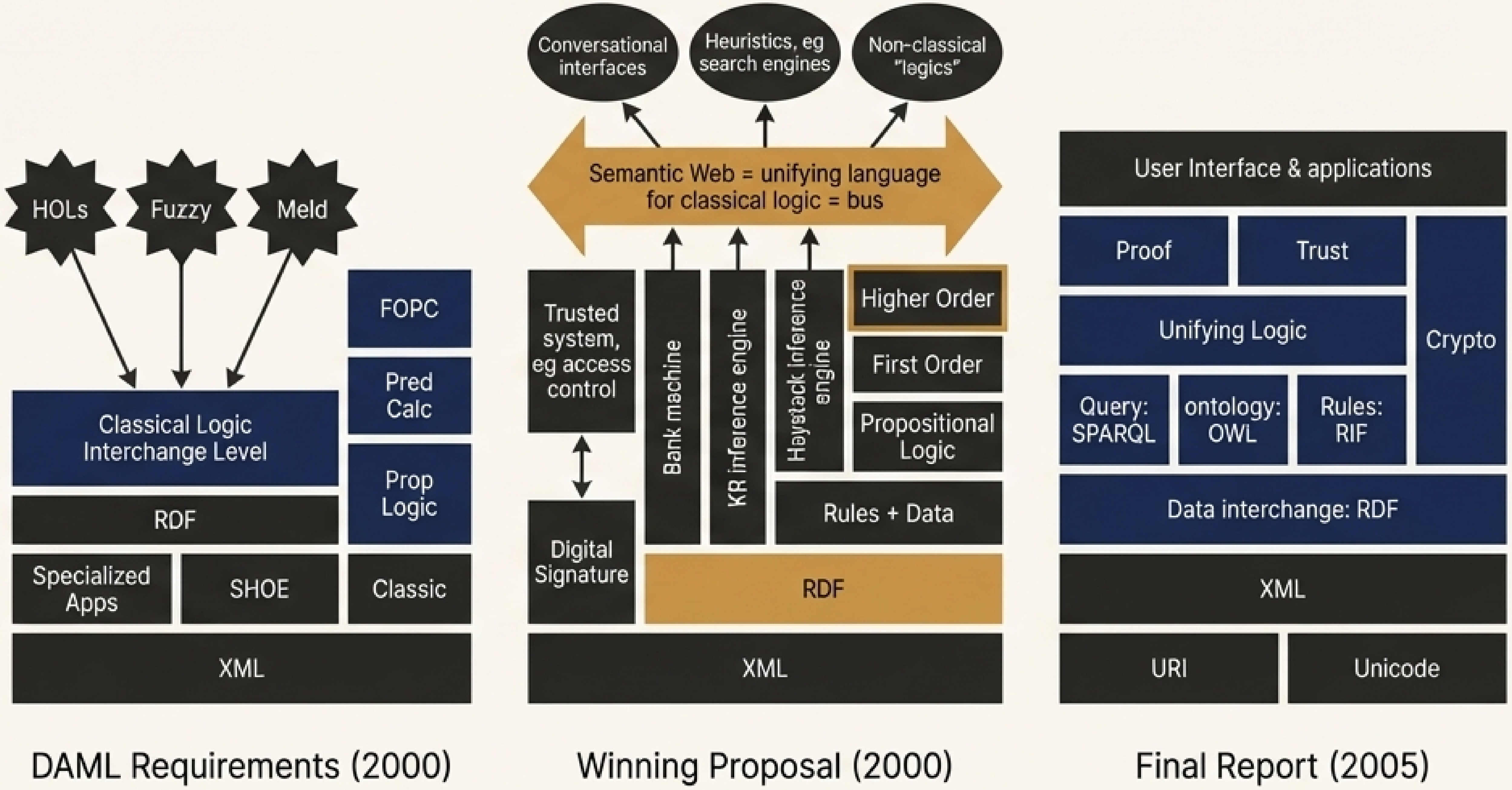
Extended Semantic Web Conference (ESWC)

The Semantic Web's Vision of 2000 Was More Ambitious Than the Realility of 2005.

The original proposal described:

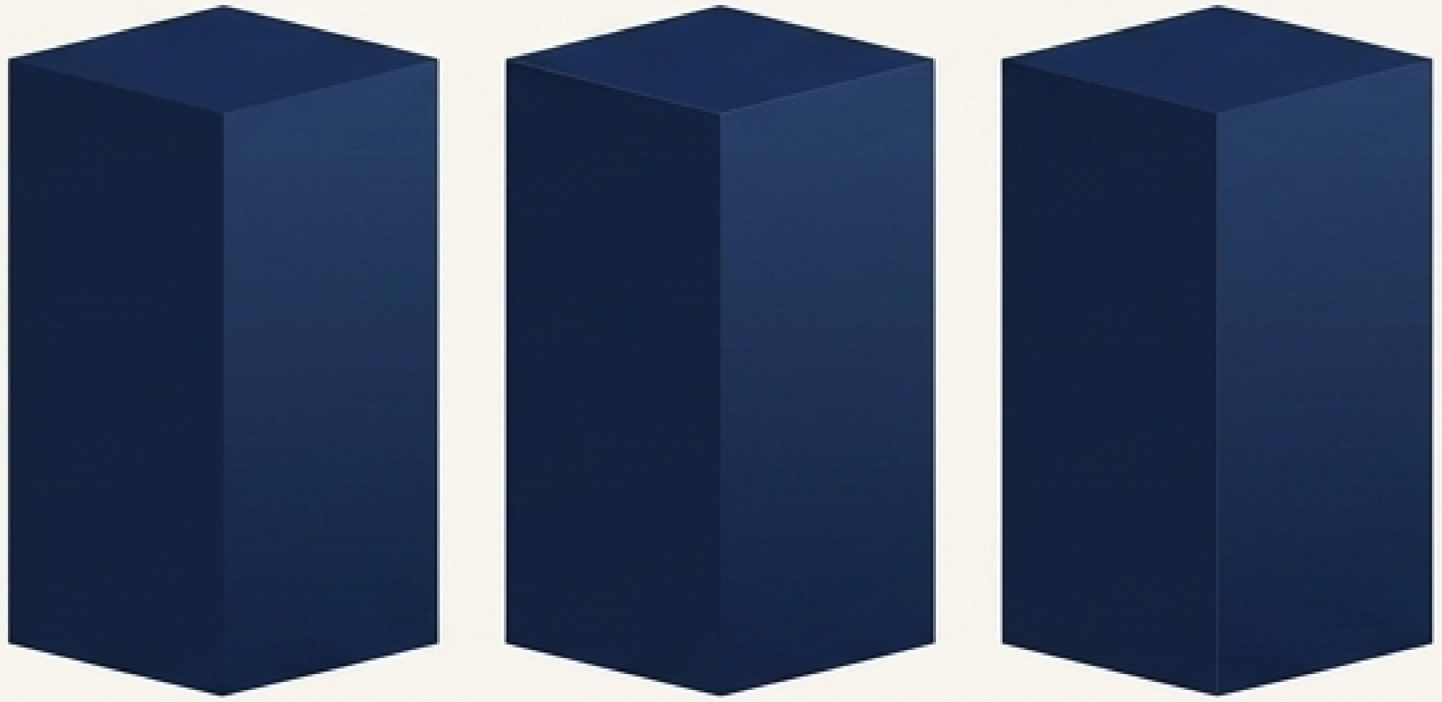
- A Semantic Web as a **"unifying language for classical logic = bus."**
- A powerful **"Semantic Web Logic Language"** (SWeLL) extending RDF with nega-tilation, quantification, and support for first-order and higher-order logic.
- A system pairing **simple, reliable systems** with **complex, heuristic ones**.



The Result: A Landscape of Powerful but Incompatible Systems.

"Any one of those tools, by itself, is a tremendous aid to productivity, but any two of them together will kill you."

- Terry Rankin



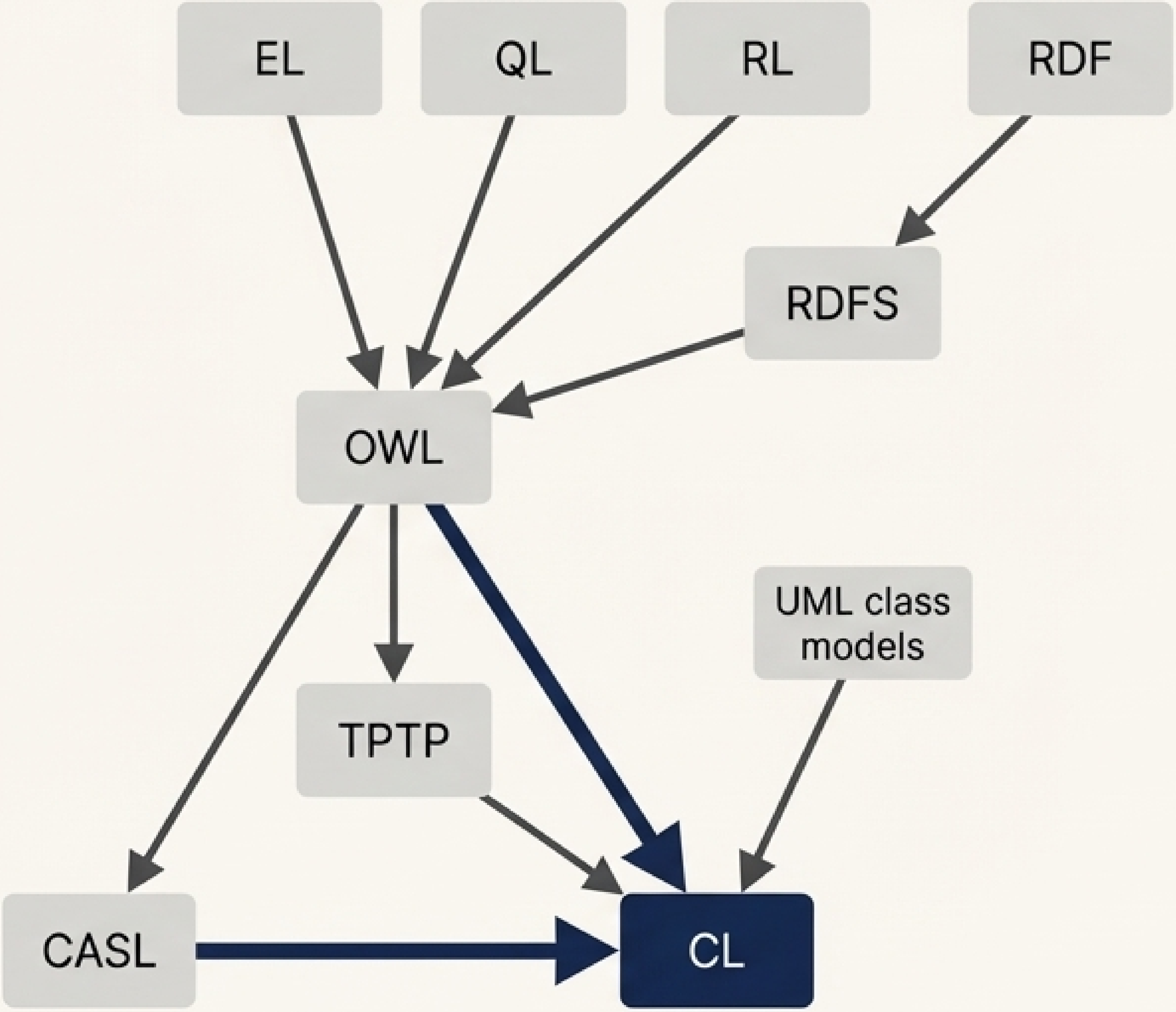
- Advanced AI like Google's Knowledge Graphs and IBM Watson have emerged, leveraging RDF and a wide range of sophisticated techniques (NLP, ML, logical form generation).

- However, these systems are often proprietary and difficult to integrate, reflecting the fragmented landscape foreseen in the 2005 model.

- The core challenge remains: achieving true interoperability among heterogeneous systems.

Common Logic is SWeLL: The Unifying Language We Were Promised.

- The original proposal for the Semantic Web Logic Language (SWeLL) directly evolved into the ISO/IEC standard for Common Logic (CL).
- CL is designed to be the highly expressive interchange level that was missing from the 2005 stack.
- It provides a formal foundation for integrating diverse ontologies, models, and specifications.



A Fallacy of Logic: Expressiveness is Not the Enemy of Performance.

Argument 1: Decidability is a property of the problem, not the notation.

- The best theorem provers (TPTP systems) use syntactic checks to select the right method and are as fast or faster than specialized Semantic Web tools on the same problems.

Argument 2: Restricting expressive power doesn't help; it hurts.

- It makes certain real-world problems impossible to state.
- Natural languages are highly expressive, and users consistently ask for *more* power, not less.

"Users always ask for more expressive power. They never ask for decidability."

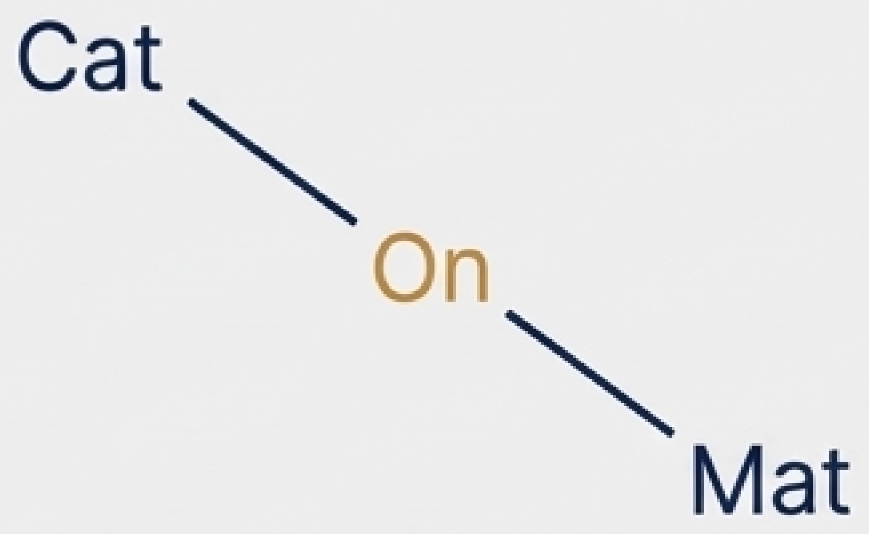
Beyond Syntax: Logic That Mirrors Language and Thought

How to say “A cat is on a mat.”

Predicate Calculus
(Peano, 1895)

$\exists x \exists y \, Cat(x) \wedge On(x, y) \wedge Mat(y)$

Existential Graph
(Peirce, 1897)



CLIP
(Common Logic Dialect)

(∃ x y) (Cat x) (On x y) (Mat y).

Key Insight: Existential Graphs are more “iconic”—they show relationships more directly. CLIP provides a clean, linear syntax that maps directly to this intuitive graph structure.

A Foundational Bridge to Natural Language.

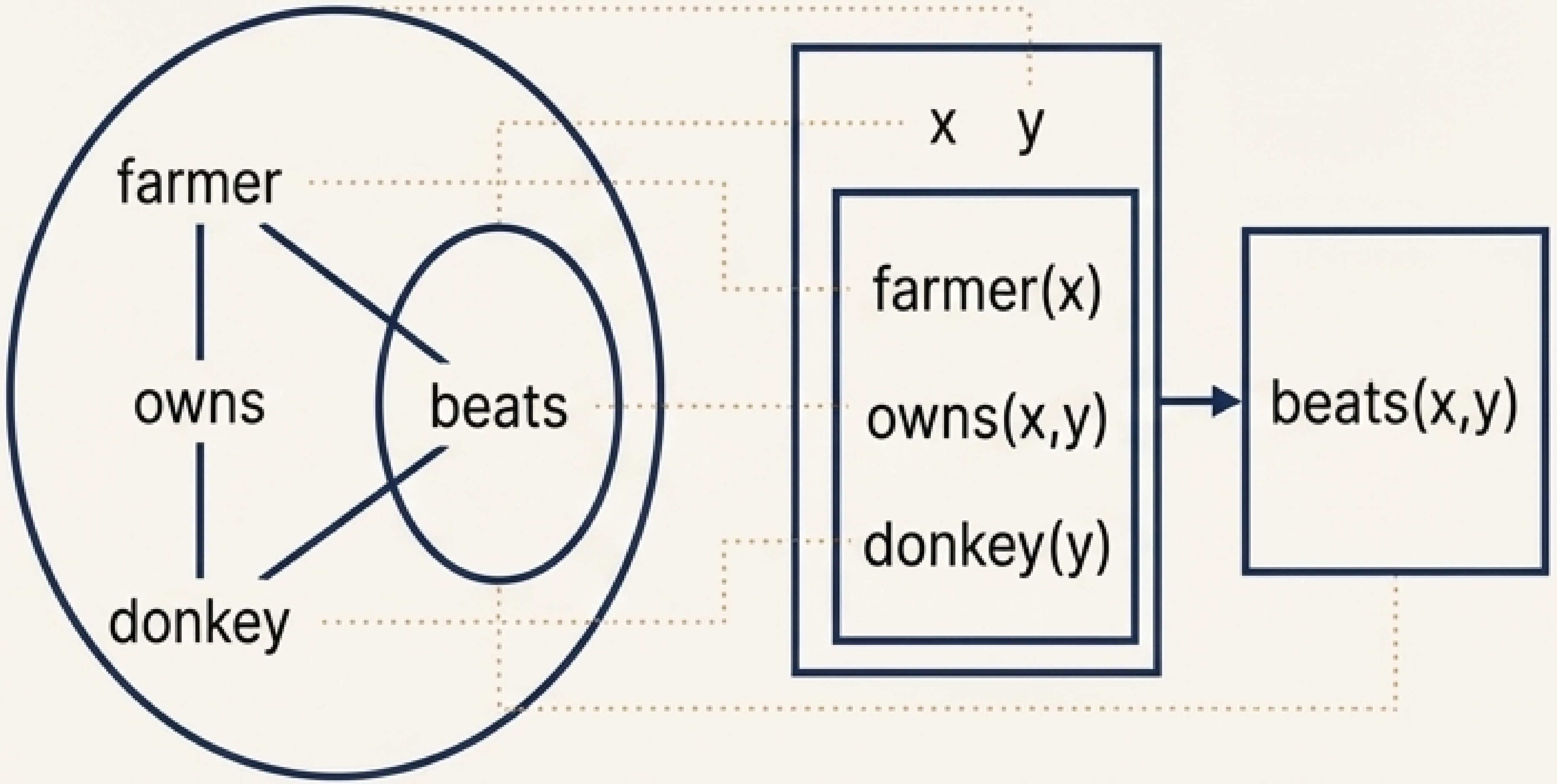
The Problem in Predicate Calculus

Variables cannot cross sentence boundaries (e.g., ‘Pedro is a farmer. *He* owns a donkey.’). Quantifiers in conditional clauses have awkward mappings.

The Solution: EG & DRS

Charles Sanders Peirce (EGs) and Hans Kamp (DRS) independently developed logically equivalent structures that solve these problems.

- Peirce used ovals and lines.
- Kamp used boxes and variables.
- Both map precisely to CLIP, allowing for a more natural representation of linguistic phenomena like anaphora.



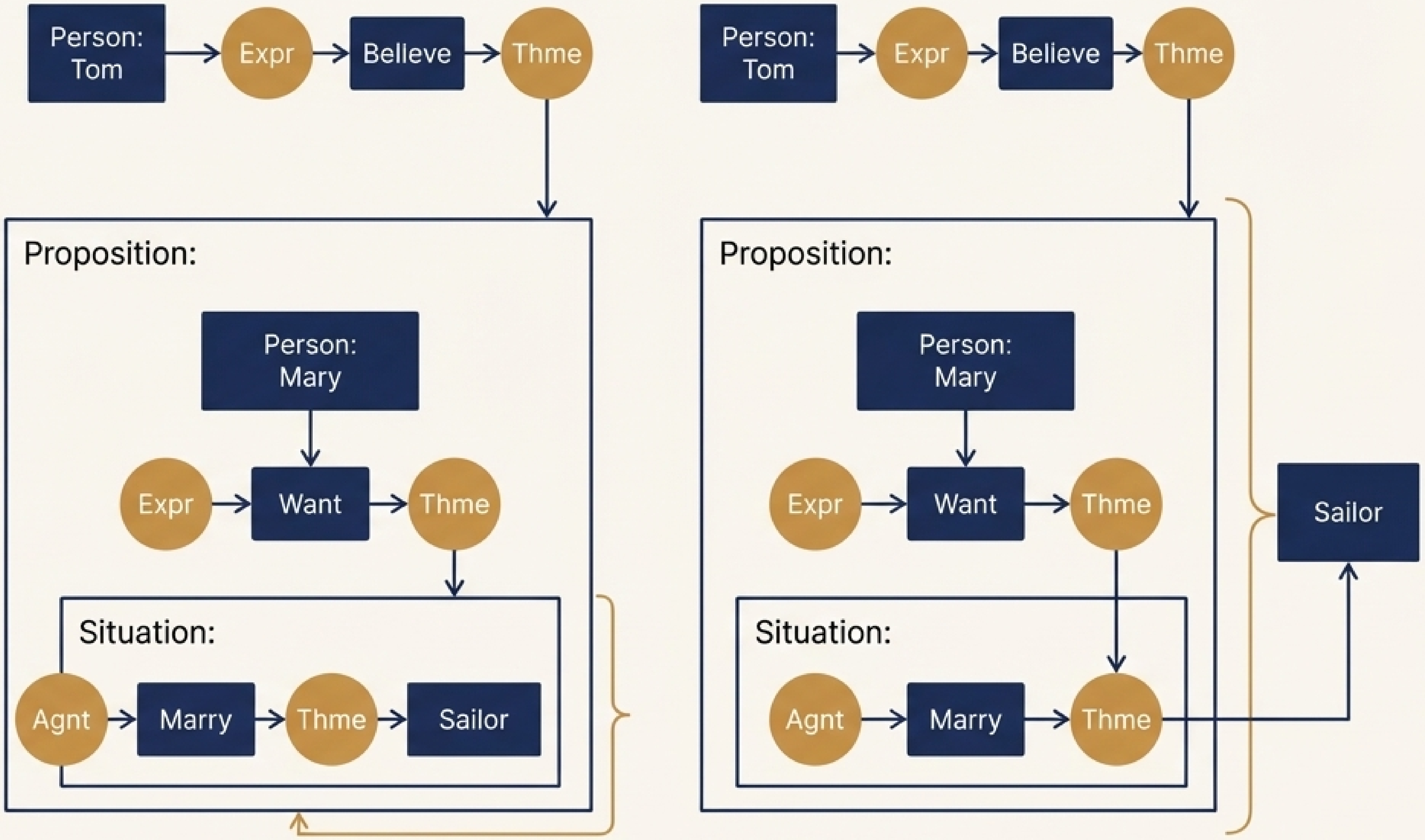
Metalanguage: Representing Beliefs, Situations, and Trust

Core Concept: Metalanguage is language *about* language. The IKL extension to Common Logic allows CLIP to represent propositions about other propositions.

Capability: This enables reasoning about:

- Source and reliability of data
- Modality (possibility, necessity)
- Intentional states (hopes, beliefs)
- Metaphor, vagueness, and fraudulent information

Example: "Tom believes that Mary wants to marry a sailor."



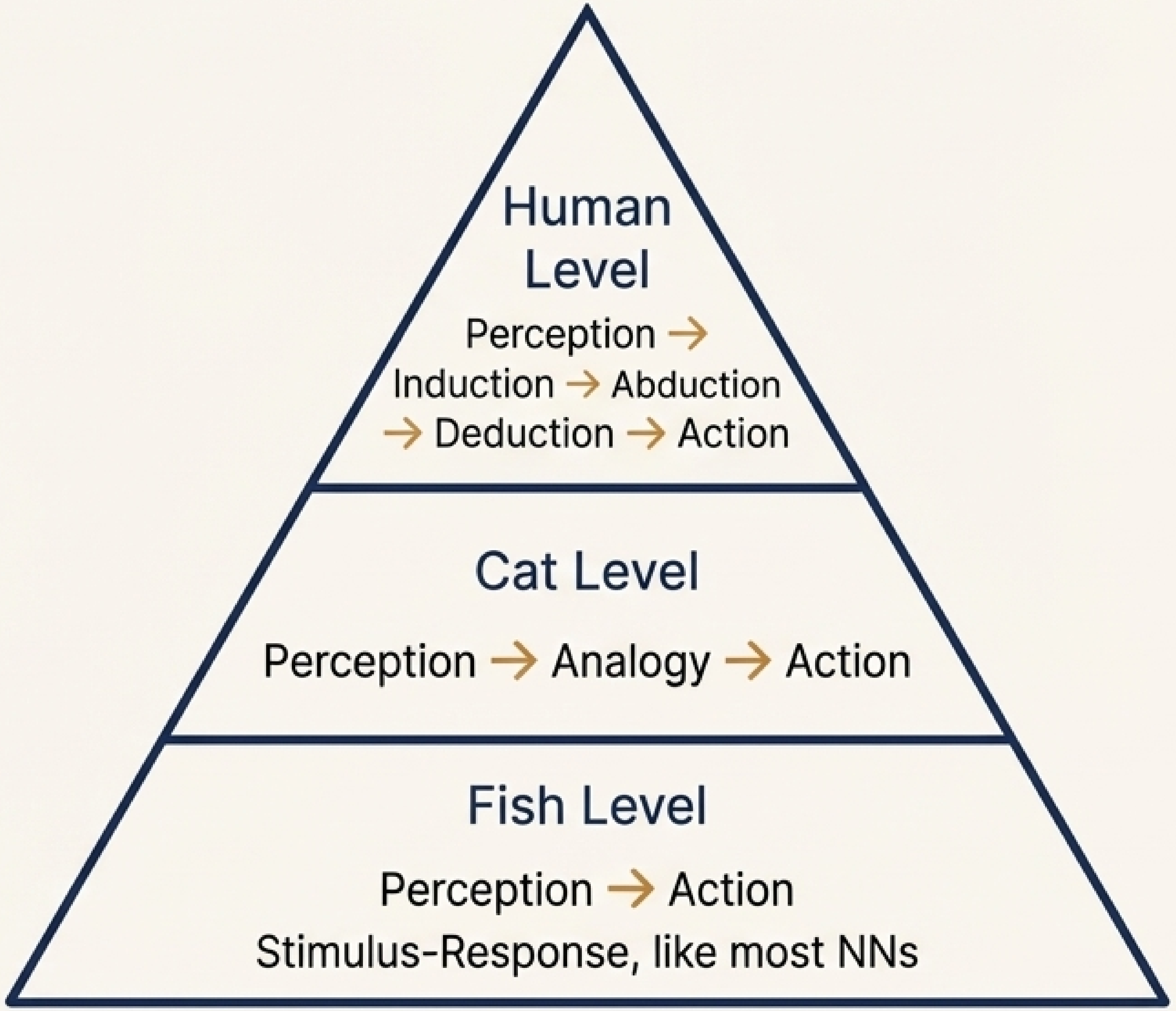
Beyond the First Second: From Perception to Cognition

The Power and Limit of Modern Machine Learning

- Most ML excels at learning a function $f: x \to y$, the basis for pattern recognition and perception.
- **Andrew Ng:** Current ML automates tasks that take humans **less than one second** of mental effort (e.g., photo tagging, speech recognition).

The Cognitive Gap

- These systems cannot perform complex reasoning, planning, or deep language understanding.



NotebookLM

The Brain's Blueprint for Understanding.

The fMRI Study

Researchers scanned participants' brains as they learned how mechanical devices work.

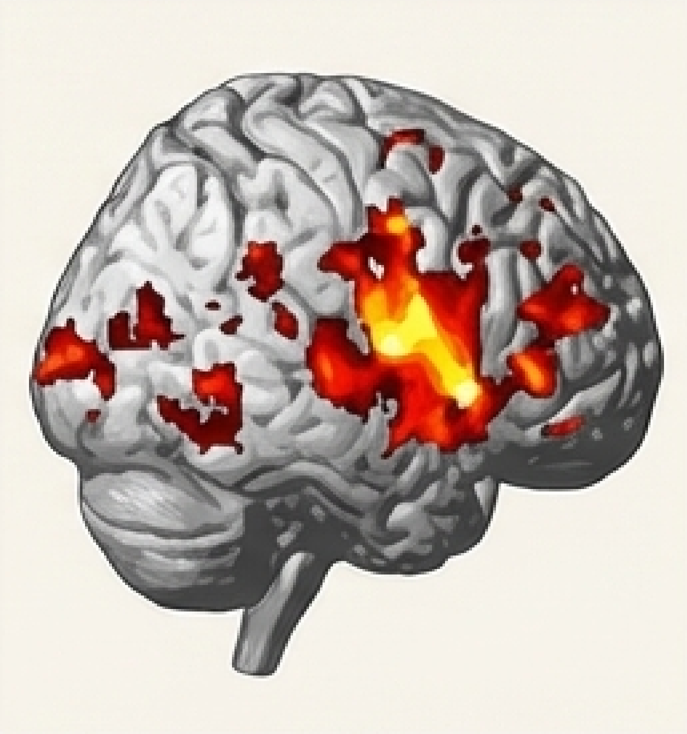
Cognition Unfolds in Stages:

- 1. **Visual Perception:** Recognizing shapes and parts activates the occipital lobes.
- 2. **Thinking about Structure:** Understanding how parts relate activates the parietal lobes.
- 3. **Thinking about Causality:** Hypothesizing how the system works activates the frontal lobes and connections across the entire brain.

Key Takeaway: Cognitive learning isn't just pattern matching; it's the integration of perception with structural and causal reasoning.

1. Visual perception

2. Thinking about structure



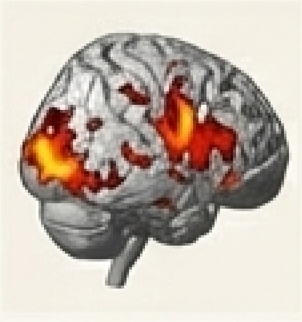
3. Thinking about causality

Neuro-Symbolic Reasoning: Peirce's Logic in the Brain.

1. Visual perception

Firstness
(Quality)

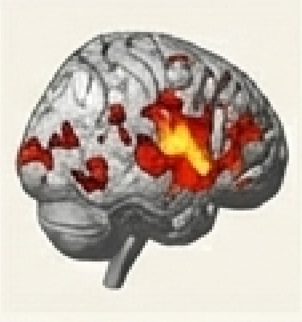
Corresponds to **Perception** of monadic properties. Localized prototypes in the occipital lobe.



2. Thinking about structure

Secondness
(Reaction)

Corresponds to understanding **Structure** and dyadic relations. Long-distance connections in the parietal lobes.



3. Thinking about causality

Thirdness
(Mediation)

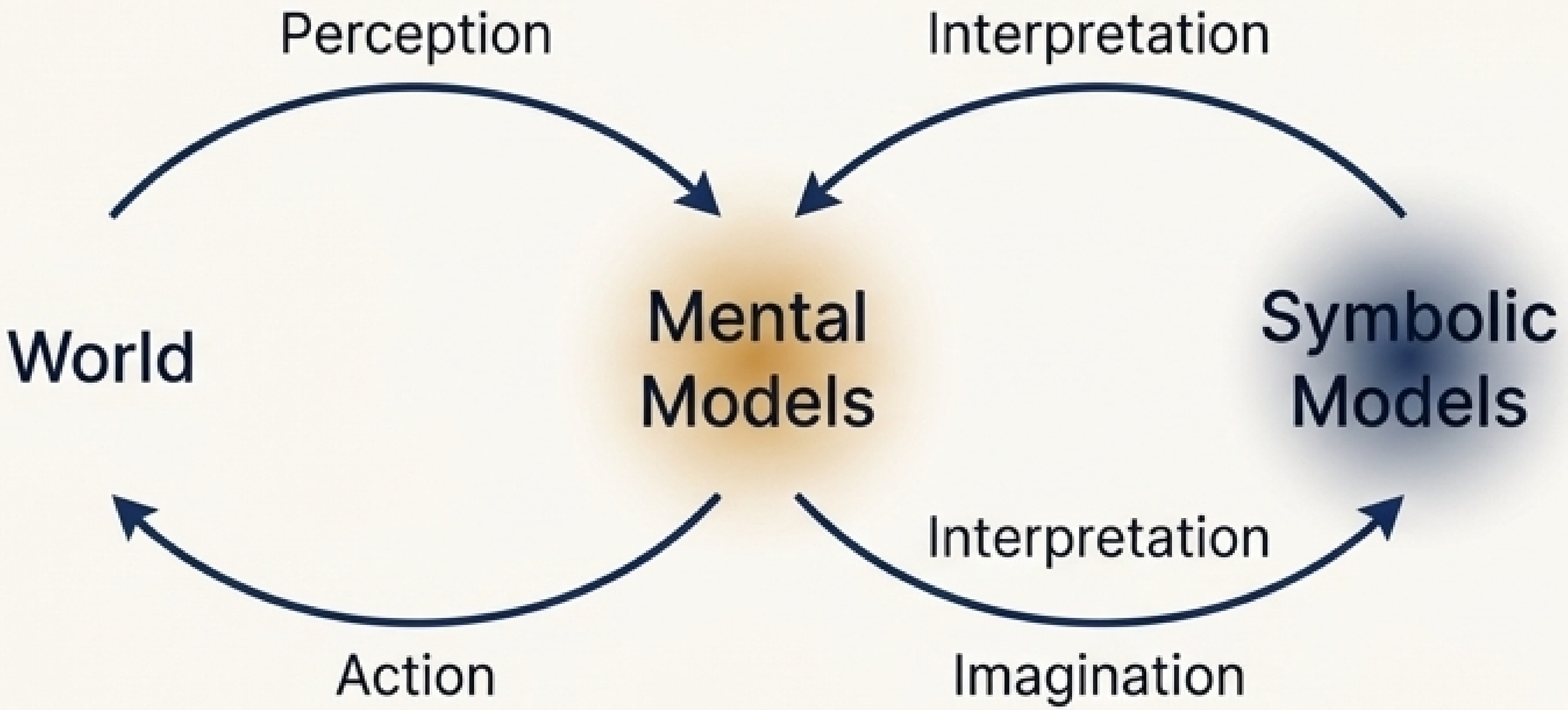
Corresponds to reasoning about **Causality** and intention via triadic relations. Processed in the frontal lobes.

Thesis: This suggests a promising direction for AI: systems that architecturally mirror this neuro-symbolic structure.

The Neuro-Symbolic Hybrid: Two Paradigms Are Better Than One.

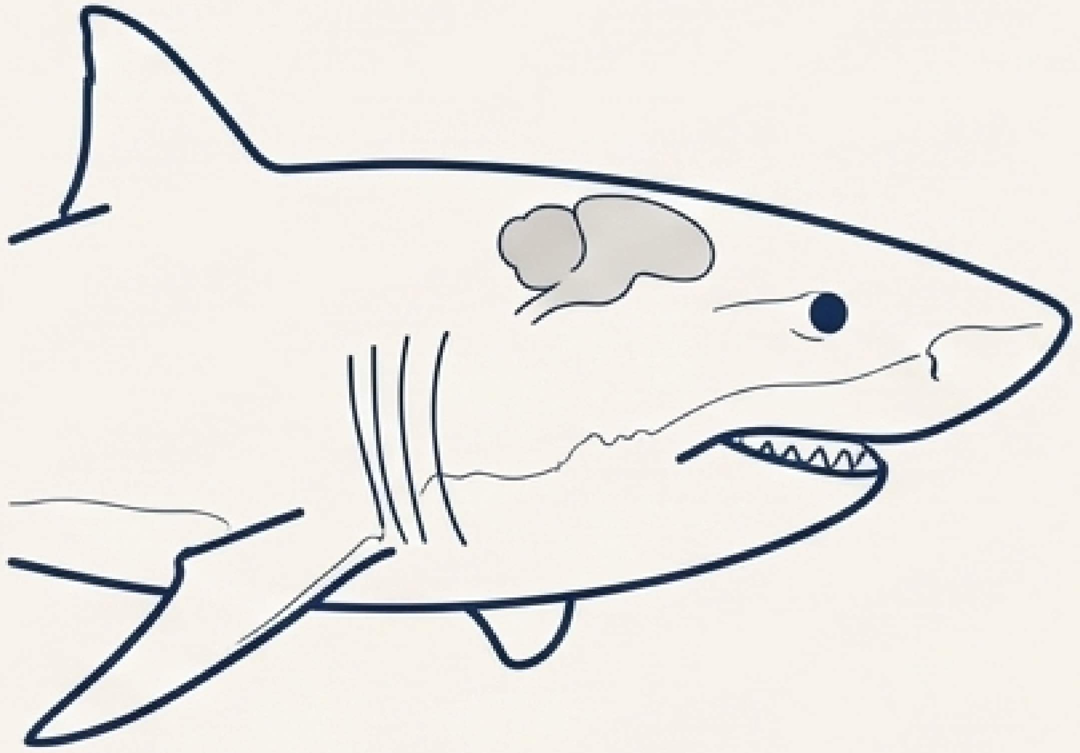
- **Mental Models:** Simulated in the cerebellum, providing fast, intuitive understanding through perception and action.

- **Symbolic Models:** The basis for language and logic, processed in the frontal lobes for slower, deliberate reasoning.



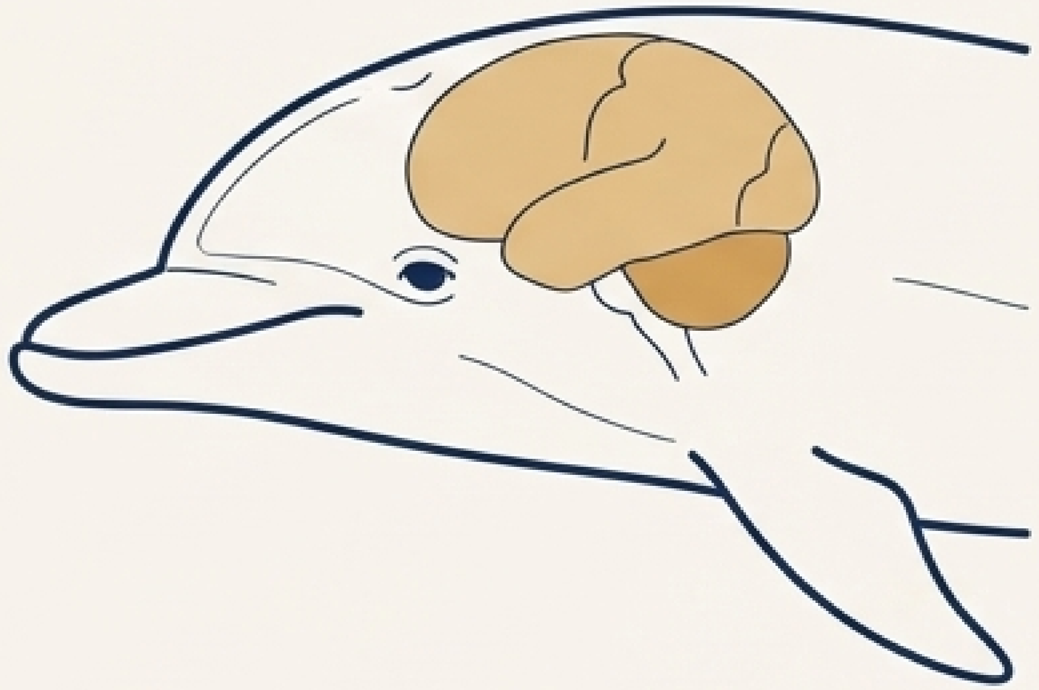
- A hybrid system combines the advantages of both: Neural networks for perception (mental models) and a symbolic framework like Common Logic for reasoning (symbolic models).

The Goal: Building Dolphins, Not Sharks



Shark: A master of perception and reaction.

- Has a large cerebellum but a **tiny forebrain**. It hunts in a "food frenzy." Represents purely neural, perception-based AI.



Dolphin: A master of collaboration and communication.

- Has a huge cerebellum *and* a huge cerebral cortex. Dolphins organize hunts, train their young, and communicate. Represents the neuro-symbolic ideal.

The Vision for AI: We should aspire to build systems with dolphin-like traits: collaborative, communicative, and friendly. A neuro-symbolic architecture, grounded in an expressive logic like Common Logic, is the path toward this future.

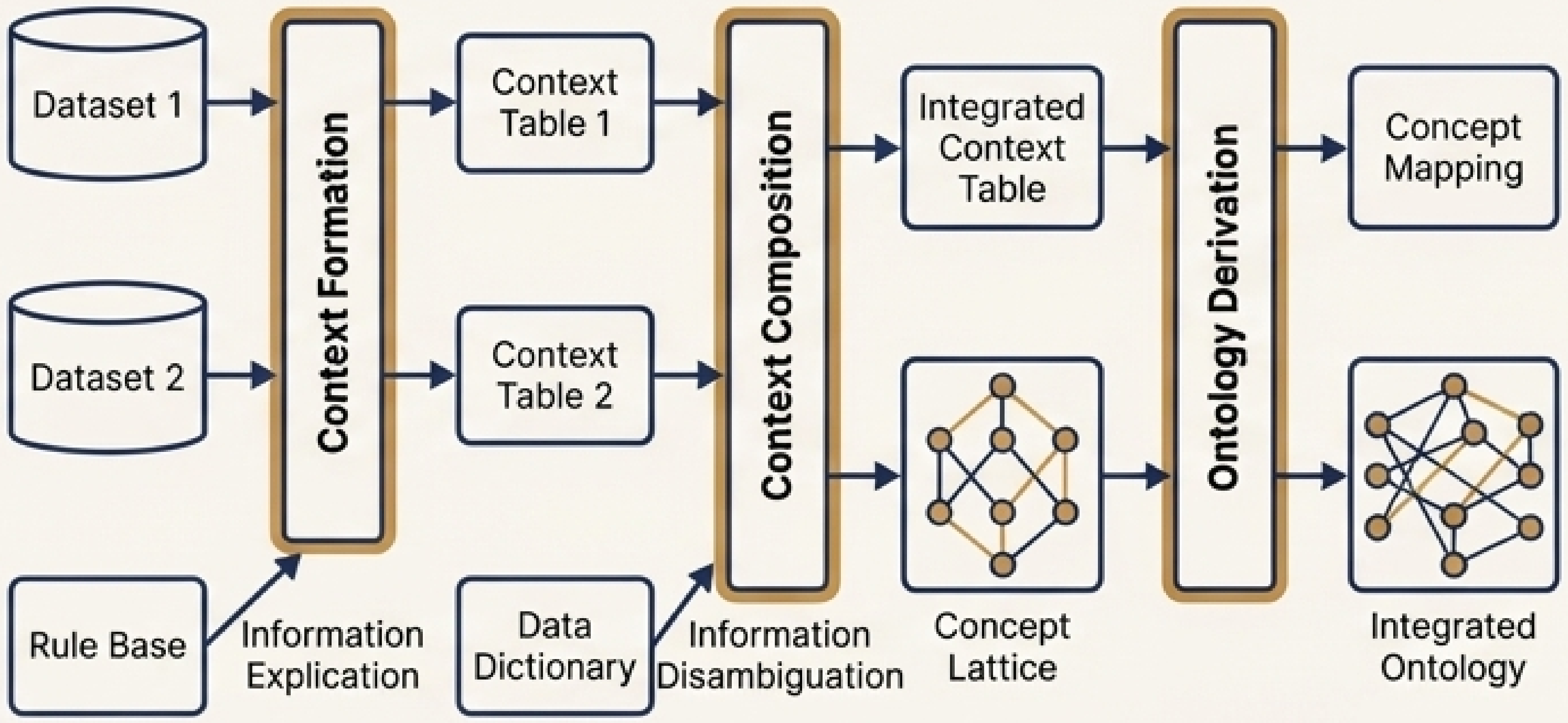
A Practical Path Forward: Semi-Automated Tools.

Methodology: Formal Concept Analysis (FCA)

- A theory and set of tools for semi-automated ontology design.
- Computes a minimal lattice showing all inheritance paths from a set of concepts and their attributes.

Applications:

- Ontology development, alignment, and merging.
- Detecting inconsistencies within or between ontologies (e.g., in OWL).
- Supporting data integration by deriving a merged ontology from multiple sources.



On Knowledge, Certainty, and Open Systems.

"Human knowledge is a process of approximation... The problem is to discriminate exactly what we know vaguely." — Alfred North Whitehead

"It is easy to speak with precision upon a general theme. Only, one must commonly surrender all ambition to be certain. It is equally easy to be certain. One has only to be sufficiently vague." — Charles Sanders Peirce

"Every poem is a momentary stay against the confusion of the world... We rise out of disorder into order." — Robert Frost

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Key References

- ISO/IEC standard 24707 for Common Logic
- Sowa, J. F. (2006) Peirce's contributions to the 21st Century
- Majumdar, A. K., & Sowa, J. F. (2009) Two paradigms are better than one...
- Sowa, J. F. (2011) Peirce's tutorial on existential graphs