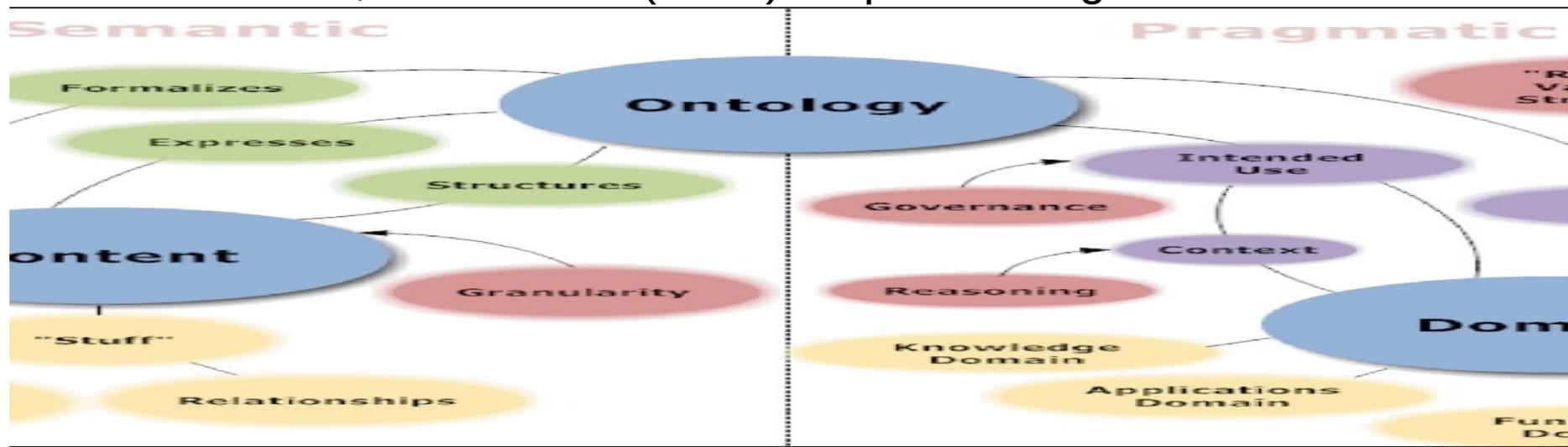# Summit Track on AI and Ontologies and A Brief look at Ontology Summit topics and development of the field over the last 20 years

Gary Berg-Cross, Board Member Ontolog Forum/Retired Knowledge Engineer
Ram Sriram, Chief of the Software & Systems Division (NIST)

"We like to think of AI as a challenge to human intelligence. But what if the real problem isn't how smart AI is becoming—but how little we understand what we mean by knowledge?"
From Nguyen, M., Vuong, QH. Navigating the new landscape of knowledge in the age of generative AI. AI & Soc 40, 6503–6504 (2025). https://doi.org/10.1007/s00146-025-02379-7

Talk Outline

- Some retrospective – 2006 to 2016 - Semantic spectrums

- Introducing our Track on AI and Ontology – an old story moving rapidly now

- A view of this topic and others from the last 9 summits

  } Is that work still going on?

- Brief Look at Track Mission & Track plan

Artificial intelligence

in its broadest sense is a range of techniques to enable software to approximate human thinking and behaviours.

Machine learning

is a subset of AI and uses advanced algorithms to detect patterns in large datasets to allow software to learn and adapt.

Neural networks

are machine learning programs that process inputs and generate outputs through interconnected nodes or artificial neurons. These nodes loosely model the neurons in a brain.

Deep learning

All deep learning systems are made of neural networks. They can recognise complex data patterns.

General-purpose AI

operates on the foundations of machine learning and deep learning. It can handle a broad range of tasks.

Generative AI

is one subset of general purpose AI and can generate text, images, video, sound, etc.

AI — Knowledge Reasoning? KR(R)

Machine learning

Neural networks

Deep learning

Natural language processing (NLP)

General-purpose AI

Generative AI

Large language models

Larg

is a subset of fo

written text.

The **semantic spectrum** (AKA the ontology spectrum or the smart data continuum or semantic precision)is a series of increasingly precise/semantically expressive definitions for data elements in a krep language ready for machine processing
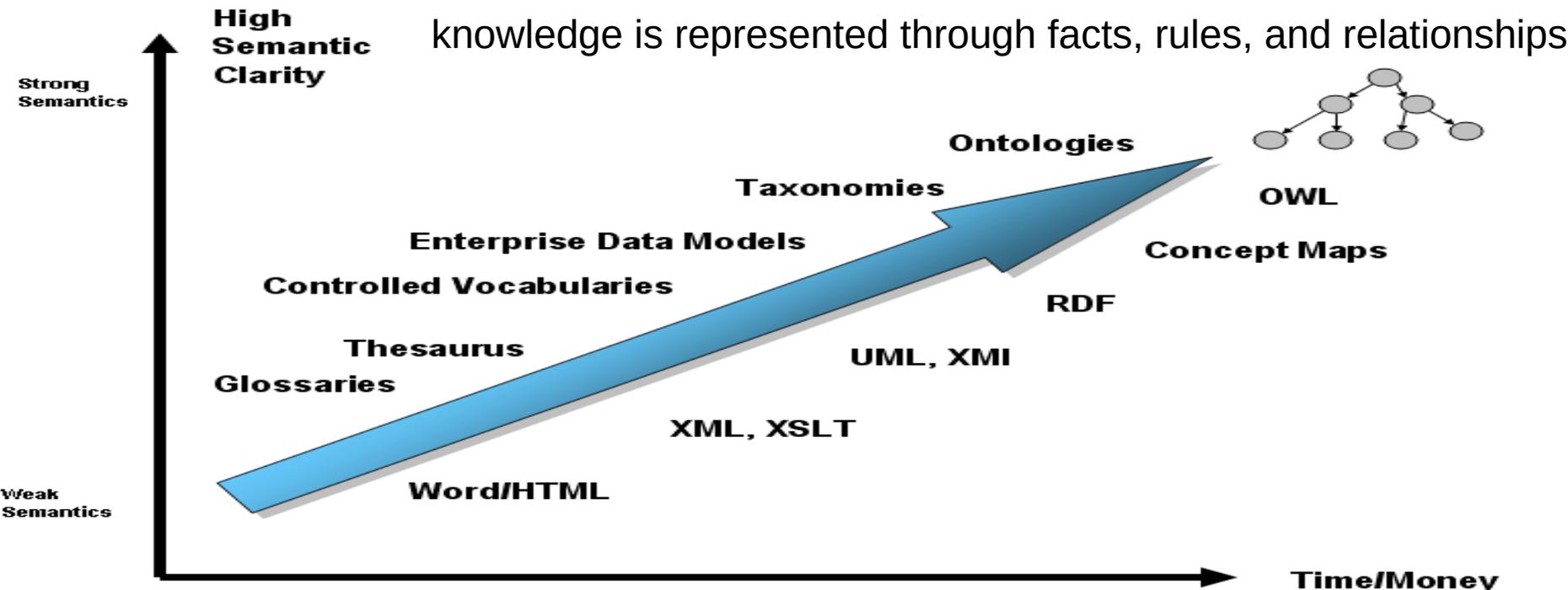
At the low end of the spectrum is a simple binding of a single word or phrase and its definition. At the high end is a full ontology that specifies relationships between data elements using precise URIs for relationships and properties. (Origin 1999 AAAI Ontologies Panel, later modified in Leo Obrst's *The Semantic Web)*

Term Definitions in a Semantic Spectrum (Silos?)
Terms may be standardized but the *meaning* has to be too.

Interoperability/shared understanding

Strategy: *Harmonize* each "level" and then harmonize the levels

Systems may require representations at multiple levels of abstraction beyond a single symbolic level.
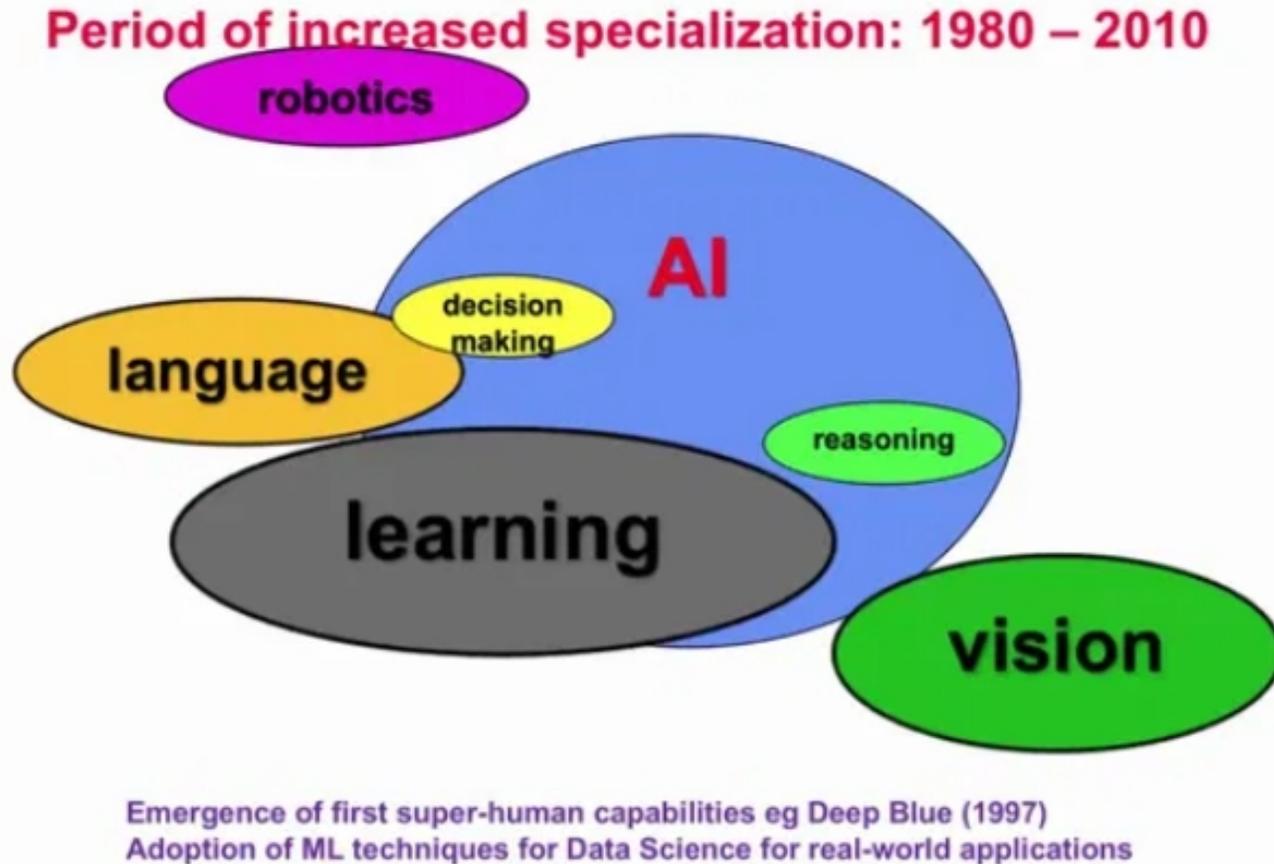
Strong semantics

Modal Logic
First Order Logic

Is

Local Domain Theory

Description Logic
DAML+OIL,OWL
UML

disjoint

subclass

w. transitivity
property

Conceptual Model

RDF/S
XTM
Extended ER

Is subclass of

Thesaurus

ER

Has narrower meaning than

Schema

Taxonomy

Relational Model

Is subclassification of

Terms

An ice shelf is a type of ice mass.
Is it just text?

Weak semantics

KGs

From Berg-Cross presentation on harmonization 2021 Ontology Summit

First 11 Years of Ontological Summits

OntologySummit2016 - **"Framing the Conversation: Ontologies within Semantic Interoperability Ecosystems"**

OntologySummit2015 - **"Internet of Things: Toward Smart Networked Systems and Societies"**

OntologySummit2014 - **"Big Data and Semantic Web Meet Applied Ontology"** (Big data used to train LLMs too)

OntologySummit2013 - **"Ontology Evaluation Across the Ontology Lifecycle"** (Now GenAI can help)

OntologySummit2012 - **"Ontology for Big Systems"**

OntologySummit2011 - **"Making the Case for Ontology"**

OntologySummit2010 - **"Creating the Ontologists of the Future"** (John Beverly & Barry Smith update)

OntologySummit2009 - **"Toward Ontology-based Standards"** (MIRO?)

OntologySummit2008 - **"Toward An Open Ontology Repository"** (Solved??)

OntologySummit2007 - **"Ontology, Taxonomy, Folksonomy: Understanding the Distinctions"** (The spectrum)

UpperOntologySummit **(2006) - the "Upper Ontology Summit"**

Not everyone sees knowledge as a core ingredient in recent AI history

Period of increased specialization: 1980 – 2010

robotics

AI

decision making

language

reasoning

learning

vision

Emergence of first super-human capabilities eg Deep Blue (1997)
Adoption of ML techniques for Data Science for real-world applications

5

From
Selman, Bart (2022-07-06). "AAAI2022: Presidential Address: The State of AI".

Or by 2019 *The Bitter* (AI) *Lesson* that, in the long run, approaches that scale with available computational power (such as brute-force search or statistical learning from large datasets) tend to outperform ones based on domain-specific understanding because they take advantage of Moore's law. (Richard Sutton)

AI & Ontology - A View from the Previous 9 Years of Ontological Summits

[OntologySummit2025](#) - **"Conceptualization, Analysis and Formalization"** (Conceptual)
OntologySummit2024 - **"Neuro-Symbolic Techniques for and with Ontologies and Knowledge Graphs"** (pros & cons & Hybrid views)
OntologySummit2023 - **"Helping scientific researchers make better use of ontologies"**
OntologySummit2022 - **"Dealing with Disasters"**
[OntologySummit2021](#) - **"Ontology Generation and Harmonization"** (AI helps)

OntologySummit2020 - **"Knowledge Graphs" (**the accumulation of large factual knowledge (facts or instances, typically stored as triples) can be usefully structured with the help of ontologies...but this is a light use)
[OntologySummit2019](#) - **"Explanations"** (including the role/issue of commonsense)
[OntologySummit2018](#) - **"Contexts in Context"** (need to take the intentional context of cognitive agents into account – gets cognitive)
OntologySummit2017 - **"AI, Learning, Reasoning, and Ontologies"**

Topics: "Using Automation and ML to Extract Knowledge and Improve Ontologies" & Alessandro Oltramari (Research Scientist at Bosch)
*"From machines that learn to machines that **know**: the role of ontologies in machine*
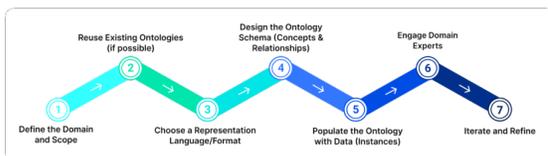
Upper Ontologies work over the Last 20 Years

Increased Adoption and Standardization

- Basic Formal Ontology (BFO) has been widely adopted across 600 projects and has become an ISO/IEC standard, illustrating its substantial role in various research fields, especially in biomedical sciences.

- The Common Core Ontologies (CCO) based on BFO have been adopted as baseline standards by U.S. federal agencies like the DoD , to enhance data management and interoperability.

Community and Collaboration (BOB Foundry for example)

- Efforts like the Industrial Ontology Foundry (IOF) have emerged, collaborating across government, academia, and industry to ensure consistent use of <u>foundational ontologies</u>, reflecting how upper ontologies are used in collaborative environments.

Intelligence = Learning from Data + Knowledge/Experience + Reasoning???

Arguing for the Role of (Upper) Ontologies in AI Over the Last 5 Years

In recent years, ontologies have increasingly been recognized, **by some**, for importance in various AI apps:

Semantic Interoperability

• Upper ontologies facilitate semantic interoperability among different systems and help define a **common vocabulary,** which is essential in a world with vast amounts of data from disparate sources. This allows for consistent **interpretation of terms during data exchange**. (Semantic spectrum issues again?)

Supporting Knowledge Representation (2025 Summit on "Conceptualization, Analysis and Formalization")

• Ontologies **potentially** provide a structured way to represent knowledge, enabling machines to better understand and reason with complex information.

Enhancing AI Systems with features like **Explainability** and Error Avoidance

• They offer a foundation for automated reasoning and explainability in AI systems. As AI transitions to more generative models, the need for structured reasoning guided error checking by ontologies, it is argued becomes critical. (2019 Ontology Summit on Explanations)

Hybrid AI Architectures (Summit 2024)

• Some/many advanced AI applications now integrate large language models with KGs built on/with the help of ontologies. (More on this in our AI track)

Addressing AI Limitations (again Summit 2024 & 2017 "AI, Learning, Reasoning, and Ontologies)

• As AI faces challenges like hallucinations or inconsistencies, upper ontologies & ODPs are being revisited as a foundational structure to ensure AI outputs are grounded in verifiable knowledge.

Mission statement & Context -inspired by continued Intersection of AI and ontologies/KGs.

The 2021 & 2024 Ontology Summits examined and criticized the overall landscape of this intersection & the many kinds of architectures.

1. Advances in <u>machine learning</u> and KGs have accompanied a proliferation of many types of supporting KGs and ontologies.

2. How are each helping and what role will they play in hybrid systems?

3. But these KG-s & ontologies are typically developed independently raising interoperability and <u>communication difficulties.</u>

 How to get agreement about harmonized relationships between respective

        terminologies and formalizations?

5. A major impediment to harmonization is the relatively poor quality of natural language <u>definitions</u> in many ontologies that become axiomitized.

        (<u>Problems at the lower end of the semantic spectrum</u>.)   Can Gen-AI help?

We might also ask what are ethical issues as these system can become more powerful agents.

# A Central Context for this Track is that the semantics of knowledge remains a key challenge
Computational systems that <u>combine</u> knowledge, reasoning & learning

"The aim is to identify a way of looking at and manipulating commonsense knowledge that is consistent with and can support what we consider to be the <u>two most fundamental aspects of intelligent cognitive behaviour</u>: the ability to learn from **experience** and the ability to reason from what has been learned. We are therefore seeking <u>a semantics of knowledge</u> that can computationally support the basic phenomena of intelligent behaviour."
Leslie Valiant see <u>https://cdn.aaai.org/AAAI/2006/AAAI06-247.pdf</u>

So pay attention to formally defined computational semantics as well as relations to commonsense/intuitive explanation.

We talked about some of this in Track 1 of the 2025 Ontology Summit

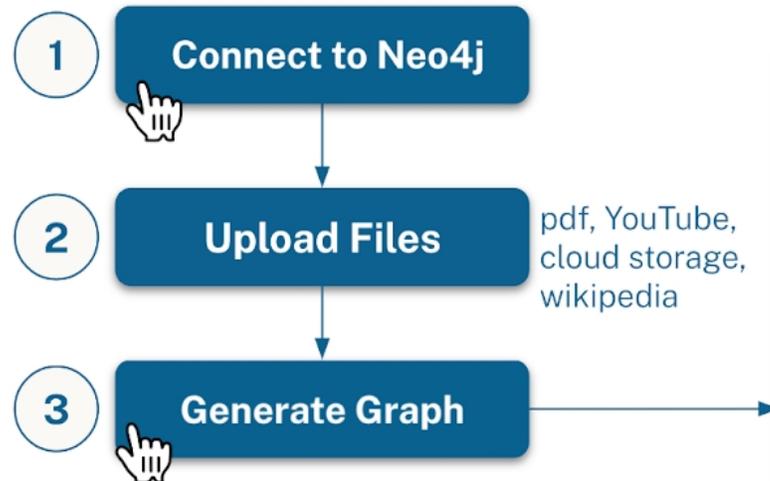

Neural Engine

Symbolic Engine

Task
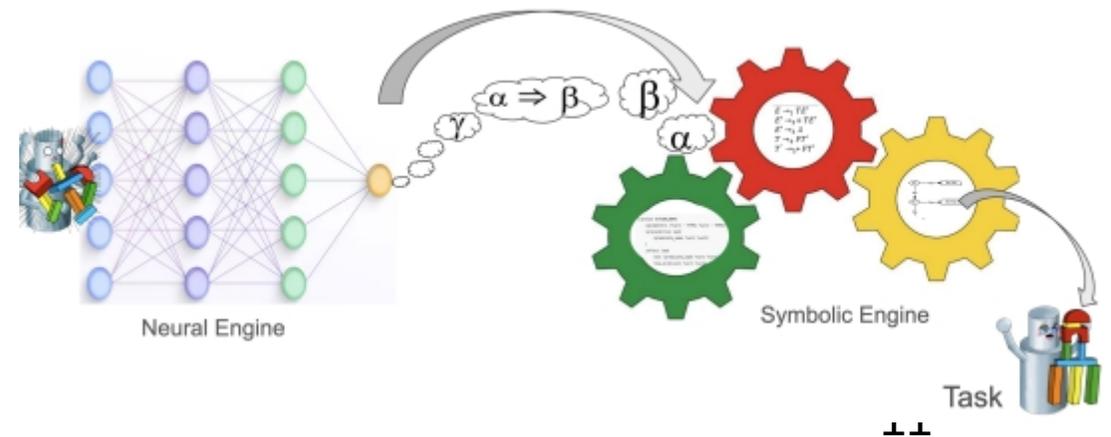
Approach / Track Plan for 2026

- We now have some good years of research from several areas of work:
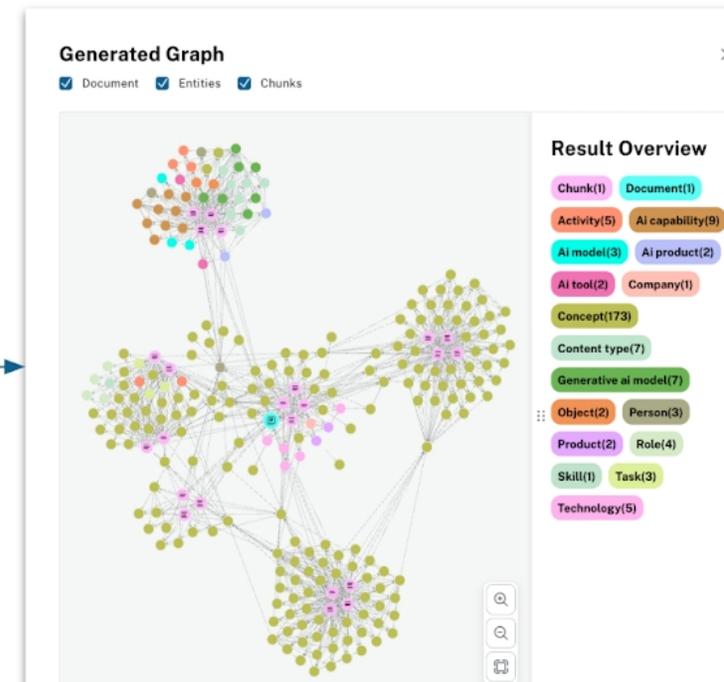
  - ML/GenAI support of KG/Ontologies and even

  - Ontology support for ML/GenAI

  - Neurosymbolic AI, known as neural-symbolic integration

  - Real world semantics, learning via experience & AI

Automatically Build a KG for GenAI

3 Simple Steps

1. **Connect to Neo4j**
2. **Upload Files** — pdf, YouTube, cloud storage, wikipedia
3. **Generate Graph**

View & Explore Your Graph

Generated Graph
☑ Document ☑ Entities ☑ Chunks

Result Overview

Chunk(1) Document(1)
Activity(5) AI capability(9)
AI model(3) AI product(2)
AI tool(2) Company(1)
Concept(173)
Content type(7)
Generative ai model(7)
Object(2) Person(3)
Product(2) Role(4)
Skill(1) Task(3)
Technology(5)

Approach / Track Plan for 2026 (2)

- We have enlisting a variety of practitioners to discuss GenAI/ontological and application issues and problems, and present their efforts and experiences and to stimulate forum discussion within the broader Ontology Summit community.

- We reference & build on past Ontology Summits and their tracks

- We hope to provide a useful context for later track session & promote discussion of track session topics such as the later AGI track

- Work on a synthesis & Communique.

4-5 Talks Planned for the AI Track

1 Ram and Gary March 4th provide more review and an overview along with some objectives/issues

2 Randy Goebel 3/11 (Alberta Machine Intelligence Institute) interested in the logic of machine, Explainable AI, the Bitter Lesson, Unpacking the black box, The Alberta Plan, the era of systems with Big Experience ("child machine" subject to an education process -Turing)

   The Alberta Plan for AI Research Richard S. Sutton, Michael Bowling, and Patrick M. Pilarski

3 Pascal Hitzler 3/18 University Distinguished Professor, Lloyd T. Smith Chair, Kansas State U. "Ontologies in the Era of Large Language Models – a perspective"

4 Luis Lamb /Manas Gaur Hybrids & Knowledge Graphs for Responsible AI (KG-STAR 2025) (Federal University of Rio Grande do Sul & UMBC)

Additional Slides

Example of Introductory Topics we may consider

1. Knowledge Learning: Can GenAis effectively apply their "language" ability to support KG

& Ontology development/maintenance across their life cycles?

⎬   e.g. sure they may help find resources but how good have they gotten at automatically

⎬   extracting and structuring logically formatted knowledge concepts & relations?

⎬   Or can it elevate semi-structured information into a richer form? Can it harmonize them?

2. GenAI Improvements: Can ontologies and its methods be used as sources to effectively

populate & enhance development and performance of GenAIs?

3. The Case for Hybrid architecture seemingly complementary symbolic & sub-symbolic

 approaches can be combined or even unified as they are in humans (and other species) and

how to evaluate the quality of results.

 Or, what are necessary & sufficient conditions for building the 3 part more general & capable AI

(knowledge, learning reasoning) ?

Can we Update Critiques of GenAIs from 2024 Summit? What about AGI?

Gary Marcus Foundations Needed (for **AGI**)
1 Rich <u>cognitive models</u> that describe mental processes in detail that keep track of dynamic environments
2 Extensive real <u>world knowledge</u> > text
3 Human <u>values</u> – e.g. important for medical apps

John Sowa Some Limitations of LLMs (and AGI needs)
1 <u>No fixed set of meanings</u> can adequately describe a continuous, dynamically changing world.
2 <u>Mental models are more fundamental </u>than language or logic and are needed.

Relevance of Ontologies for AI - Examples of Research

Alam, R., & Tahir, M. (2025). "
[A unified ontological and explainable framework for decoding AI risks from news data.](#)"
Scientific Reports. Discusses how integrating ontologies can enhance the understanding of biases and risks in AI systems, making them more explainable and accountable.

Kovács, E., & Trócsányi, G. (2025).
["Ontology in Hybrid Intelligence: A Concise Literature Review."](#) MDPI. A literature review highlights how ontologies are fundamental in hybrid intelligence systems, emphasizing their role in knowledge representation and automatic reasoning.

Palmer, A. (2025). "
[Ontologies as the semantic bridge between artificial intelligence and human understanding](#)
Frontiers in Digital Health. Argues for the necessity of ontologies in ensuring AI systems understand human language and context effectively.

See 2018 Summit "Contexts in Context"