Gaia-X MAGAZINE

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HIGHLIGHT

Why Trust Matters

Christoph Strnadl, CTO at Gaia-X

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AI-Powered Semantic Hubs: Automating the Assessment and Compliance of Data Conformity with Standards

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In an increasingly interconnected world, the ability to exchange and understand data across diverse systems and sectors has become essential. While technical solutions have made it possible to transmit data seamlessly, ensuring that this data retains its intended meaning—known as semantic interoperability—remains a significant challenge.

AI technologies now offer promising solutions to automate and enhance semantic interoperability, enabling more effective data collaboration and compliance with evolving standards. This article explores the role of AI-powered Semantic Hubs in transforming data spaces, highlighting their potential to bridge semantic gaps and drive smarter, more reliable data ecosystems across Europe and beyond.

Semantic Interoperability: Ensuring Meaningful Data Integration Across Domains

Semantic interoperability enables systems, organisations, and domains to exchange data with a shared understanding of its meaning. Unlike technical interoperability, which ensures data can be transmitted between systems, semantic interoperability maintains the integrity of that data's meaning across different contexts. This is especially critical in fields such as healthcare, energy, transportation, construction, and industry, where the same terms can be interpreted differently. Without semantic interoperability, integrating data from diverse sources risks misinterpretation, flawed insights, and operational mistakes.

In today's data-driven world, semantic interoperability is essential for enabling effective collaboration, innovation, and automation. By ensuring a common understanding of concepts, relationships, and data structures, it lays the groundwork for scalable AI applications, cross-domain analytics, and smarter digital services.

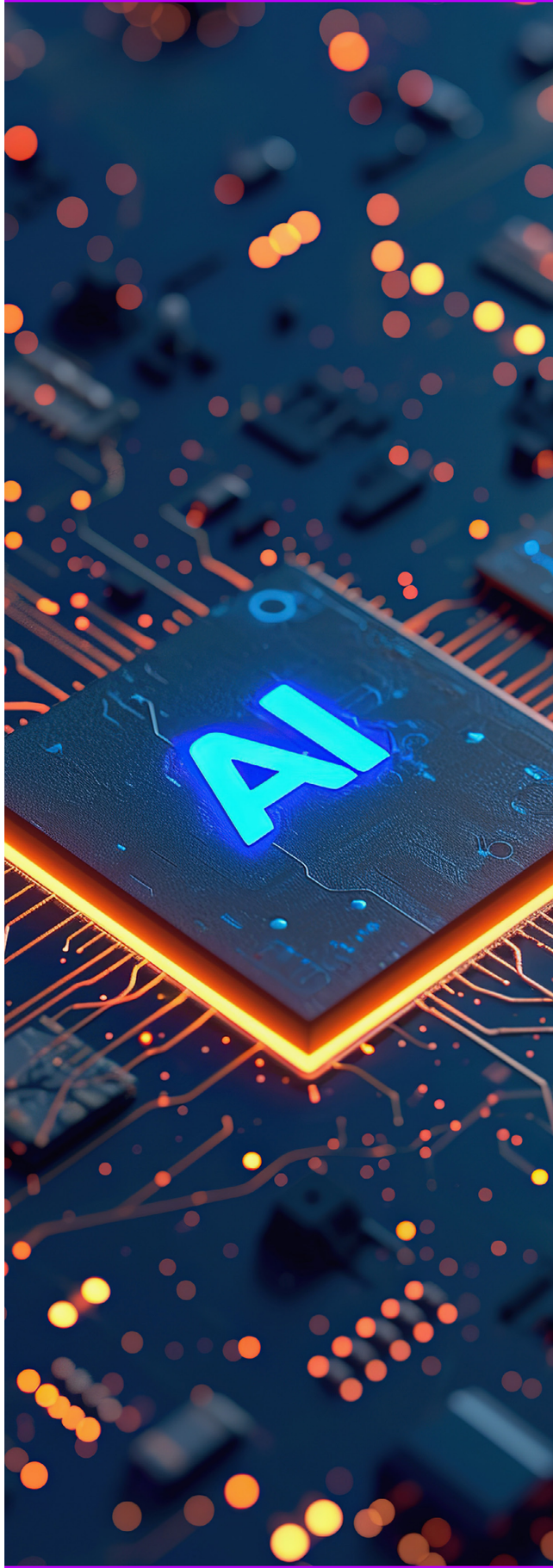
AI: A Catalyst for Semantic Interoperability in European Data Spaces

Artificial Intelligence is becoming a key enabler of semantic interoperability, helping unlock the full potential of data reuse across European Data Spaces. Although legal, organisational, and technical interoperability have advanced significantly, semantic interoperability remains the essential layer that ensures data retains its meaning when exchanged between systems and organisations.

In the EU, **legal interoperability** has already been established through frameworks like the Data Governance Act (DGA, 2023) and the Data Act (DA, 2025). These regulations ensure that organisations operating under different legal systems can collaborate, thanks to aligned policies and legislation that facilitate cross-border and cross-sector data sharing.

Organisational interoperability has advanced through the work of the Data Space Support Center (DSSC), who introduced the role of Data Space Governance Authority (DSGA) to orchestrate Data Space in this perspective. This dimension ensures that identities and claims are properly verified between entities, and that there are clearly defined agreements, responsibilities, and coordination mechanisms in place.

Technical interoperability has been reinforced by initiatives like Gaia-X, Trusted Data Transaction, and the Data Space Protocol (DSP), which provide robust standards for seamless communication between IT systems. These include protocols,



APIs, data formats, and security measures, ensuring that systems can reliably exchange data through agreed-upon standards.

However, **semantic interoperability** — the most complex layer — is essential for truly interoperable data spaces. It involves ensuring that data exchanged retains its original meaning, requiring standardised vocabularies, metadata, and ontologies. AI technologies can bridge gaps between data models, support semantic enrichment, and facilitate meaningful, machine-readable cross-domain collaboration.

Towards AI-Powered Semantic Hubs for Data Spaces

To ensure that data within European Data Spaces is not only exchanged but also meaningfully interpreted and compliant with relevant standards, AI-powered automation is increasingly important. Therefore, there is a need for a solution such as an AI-Powered Semantic Hub for Data Spaces, designed to automate the evaluation and enforcement of data conformity through advanced AI models and intelligent control mechanisms.

At the heart of the system is a Semantic Hub that harmonises data from diverse, interconnected data spaces with established cross-sector standards. By integrating advanced technologies—including Generative AI, Large Language Models (LLMs), and semantic tools such as OWL, RDF, and SPARQL—the hub is able to interpret, align, and transform data according to standardised semantic frameworks.

From training models to live deployment, the AI-Powered Semantic Hub serves as a link between raw, often heterogeneous data and structured, interoperable information. It provides a suite of automated compliance features, including:

- Conformity checks to validate data complies with established semantic rules.
- Structural modification to standardise data formats and relationships.
- Data transformation to unify diverse datasets into harmonised structures.
- Verification and gap analysis to detect inconsistencies and identify areas for enhancement.

The AI-Powered Semantic Hub aligns with the European Commission's overarching ambitions by offering practical value and actionable benefits tailored for Data Space orchestrators, such as:

1. **Creating a common language** within your data space.
2. **Removing frictions** for seamless data exchange.
3. **Facilitating interoperability** with other data ecosystems.

The AI-Powered Semantic Hub approach not only streamlines data integration across domains but also ensures reliability, scalability, and semantic integrity in dynamic, cross-sectoral environments.

The Gaia-X initiative fosters trust in the digital ecosystem by ensuring that systems not only connect but truly understand each other, speaking a shared language that builds confidence through clarity and mutual comprehension.

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