Report D6.6
"Report on the outcomes on the second OntoCommons Horizontal Workshop as well as with Synergies with related projects"

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Task	T6.2 | OntoCommons horizontal workshops, synergies with wider stakeholder community, related projects and initiatives
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Glossary of terms

Item	Description
BFO	Basic Formal Ontology
CNR	National Research Council
DDMS	Digital Design, Manufacturing and Services
DOLCE	Descriptive Ontology for Linguistic and Cognitive Engineering

EMMO	Elementary Multiperspective Material Ontology
ENIT	École Nationale d'ingénieurs de Tarbes
HCI	Human-Computer-Interaction
IAOA	International Association for Ontology and its Applications
IOF	Industrial Ontologies Foundry
IoT	Internet of Things
ISO	International Organization for Standardization
ISTC	Institute of Science and Technology for cognition
LOA	Laboratory for Applied Ontology
KTE	Knowledge Engineering Translator
NIST	National Institute of Standards and Technology
OCES	Ontology Commons EcoSystem
OBO	Open Biomedical Ontology
OIP	Open Innovation Platform
PPC	Pay Per Click
SDO	Standard Development Organisation
TLO	Top Level Ontology
TUPPER	Top Level Ontology within Standards

Keywords

Ontology; Industry5.0; Digitalisation; Horizontal Workshop; Global Workshop; Stakeholders Engagement; Strategic Roadmap;

Disclaimer

Executive Summary

This deliverable reports on the **second Horizontal Workshop of OntoCommons** The four-day event provided the platform for engagement between more than 200[1] European and International stakeholders (from 39 different countries) to discuss and identify priorities and recommendations on the future of standardized data documentation. The event showcased best practices, identified future challenges and provided recommendations which will feed into the final release of the OntoCommons Strategic Roadmap due in M36.

The workshop featured 27 sessions with over 75 expert speakers, as well as prototyping labs and students training, 29 posters exhibitions and 15 presentations from the OntoCommons demonstrators.

The 2nd Horizontal Workshop has helped identify some actions to work on in the future. Please note that the impacts and recommended actions derived from each session are partial reflections of the content discussed. They do not offer a comprehensive view or capture the entirety of insights and suggestions shared during the sessions. Readers are encouraged to consult the full session materials for a more in-depth understanding.

[1] The actual number of registrations is 400, however, not all of the registered people joined the event, and the attendees joined different sessions at different times, with an average of 60 attendees per session, 30 physical and 30 online. For this reason, we don't specify this number in the Executive Summary, and we mention "more than 200 attendees", to indicate that we have achieved and overcome the objective originally previewed for this workshop, of 200 attendees. The details of the attendance are included in Annex 2 of this document.

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1. Introduction

The OntoCommons **Second Horizontal Workshop** took place in Oslo from 13 to 16 June 2023. Prior to the workshop, on 12 June, the project consortium convened for the **annual Consortium Meeting**. This workshop featured a closed-doors **prototyping lab**, commencing on the 12th of June and spanning the entire four days. This lab culminated in a final, public session where the outcomes of the prototyping activities were presented.

This document offers insights and feedback from each session. Unlike the previous version of this report, it omits the dissemination activities surrounding the event. These will be addressed in D6.4 (Report on Dissemination, Communication & Stakeholder Engagement Strategy and Plan), set to be released in September, M35.

This event was a continuation of the first Horizontal Workshop held entirely online in November 2021. This iteration took a hybrid approach via the Airmeet platform, accommodating nearly 400 attendees both in-person and online (please see Annex 2 for the details of the attendance). The workshop aimed to foster engagement between diverse European and international stakeholders, focusing on discussions to pinpoint priorities and recommendations for the future of standardized data documentation. It also sought feedback on the inaugural version of the OntoCommons Roadmap, setting the stage for the release of its final rendition—a collaboratively designed, community-driven strategy for the sustained development of the ontology and data documentation, ensuring their long-term relevance and implementation.

Inputs from each workshop session are documented in Chapter 2, while overarching recommendations from the sessions are summarized in this document's Executive Summary.

1.1 Background and purpose of the Horizontal Workshop

Objective 6.2 of Work Package 6 (OntoCommons Dissemination, Exploitation & Sustainability) is devoted to the conceptualization and execution of two Horizontal Workshops spanning diverse domains and industrial sectors. These workshops aim to garner **end-user requirements** and to facilitate dynamic **input and feedback** throughout the OntoCommons Strategic Roadmap's development and evolution, set for completion in M36. The second Horizontal Workshop was especially pivotal in gathering insights for the **final roadmap iteration**, encompassing crucial policy recommendations to enhance Data Sharing for the European Single Market, bolstering the digital transformation of the industry. This endeavour aligns with Task 6.2, emphasizing synergistic engagements with an expansive stakeholder community and allied projects and initiatives. The workshop successfully assembled various key initiatives and projects that resonate with OntoCommons, and is intricately connected to specific activities undertaken in other work packages:

- Cooperation on Standardisation (T1.2)
- OntoCommons for FAIR initiatives (T1.3)
- Integration of OntoCommons within the EOSC landscape (T1.4)
- Ontology-based digital-marketplaces cooperation (T1.5)

- Industry Commons Translator (T1.6)
- OntoCommons Roadmap (T1.7)
- Top Reference Ontology (WP2)
- Industrial Domain Ontologies (WP3)
- OntoCommons Demonstrators (WP5)
- Exploitation and Sustainability (T6.3)

To ensure a comprehensive representation of each work package and its corresponding activities—and to optimize time and effort—the workshop was structured around four thematic days. Details and the event agenda can be viewed on the online description: https://www.ontocommons.eu/news-events/events/second-global-workshop-ontocommons-addressing-challenges-industry-50-transition

The workshop's core was rooted in four primary thematic areas: Demonstrators, Standardisation, Industry, and Innovation. Each day centered around these themes, with a series of interactive sessions led by consortium work package leaders. They were joined by a selection of international experts drawn from the OntoCommons community, which boasts over 700 experts and a total of 1357 website users. To cater to various target audiences, specific custom-designed parallel sessions, along with the prototyping lab, were orchestrated. These combined open, subject-focused discussions and impulse talks from guest speakers external to the project. Every session was recorded, with the recordings promptly uploaded to the website post-workshop. This allowed participants or stakeholders to revisit sessions they might have missed.

In agreement with the Consortium, and in order to gather the attention of the wide stakeholder community, the Horizontal Workshop was promoted on the web under the name: "**Second Global Workshop: Ontology Commons addressing challenges of the Industry 5.0 transition**".

1.2 Target Groups

The OntoCommons Workshop was designed to cater to five primary stakeholder groups, all integral in refining the OntoCommons Roadmap:

Industrial ecosystem: Central to industries aiming to enhance interoperability using ontologies. Their involvement with the OntoCommons project is evidenced by 22 industrial demonstrators, underlining the project's industry-centric nature and emphasizing the power of data harmonization in ontology-based systems. This target group is composed of industrial players interested in adopting ontologies to improve the intra- and cross-domain interoperability and reusability of the data used in their ecosystems. These use cases aim to create evidence of the effectiveness of the OntoCommons Ontology Commons EcoSystem (OCES) and provide insights on the use of standardised ontologies to resolve issues with material sciences and manufacturing data documentation, data re-use and cross-domain interoperability.

Ontologists: Encompassing experts from philosophers to ontology developers, this community provides invaluable feedback for the OntoCommons activities. Their analyses and recommendations fill existing ontology gaps, propelling the OntoCommons Roadmap and fortifying the OntoCommons Ontology Commons EcoSystem (OCES).

Policy makers: As a bridge between the project and policy formulation, OntoCommons is working on a strategic Roadmap, aiming to release its final version by M36. In an age of rapid digital transformation, a coherent strategy is paramount. The OntoCommons Roadmap offers a comprehensive blueprint for integrating ontological advancements into the fabric of policy-making. By emphasizing areas like top reference ontologies, industrial domain ontologies, ecosystem toolkits, and industrial applications, the roadmap becomes an invaluable tool for policy makers. It provides insights into the evolving landscape of data, interoperability, and industry-specific needs, ensuring that legislative and strategic actions are grounded in cutting-edge knowledge.

Research and Academia: Representing domain experts, these stakeholders offer a rich avenue for discussions, exploring how OntoCommons' theoretical concepts seamlessly translate into tangible industrial solutions.

Standardisation ecosystem: This group, comprising of standardisation organizations and SDOs, plays a crucial role in defining uniform protocols and guidelines across various industries. Ontologies are systematic representations of knowledge in a specific domain. They capture essential concepts, relationships, and terminologies, serving as a foundational layer for defining standards. In essence, ontologies offer a structured way to define, understand, and categorize information, making them invaluable in the standardization process. OntoCommons' emphasis on standardized documentation rooted in ontologies ensures that a coherent, consistent language and understanding is achieved across sectors. This not only reduces ambiguities but also fosters a shared understanding of domain-specific knowledge. OntoCommons' collaborations with bodies like IOF, ISO, and StandICT.eu signify its commitment to intertwining the worlds of ontologies and standardisation. By integrating the two, the project ensures that standards are both robust and adaptable, addressing current needs while

being flexible enough to accommodate future innovations. The project's engagement with such standardisation groups makes it a pivotal player in shaping the future of industry-specific protocols.

The benefits encountered by each target group in joining the OntoCommons 2nd Horizontal Workshop, are summarised in the figure below.

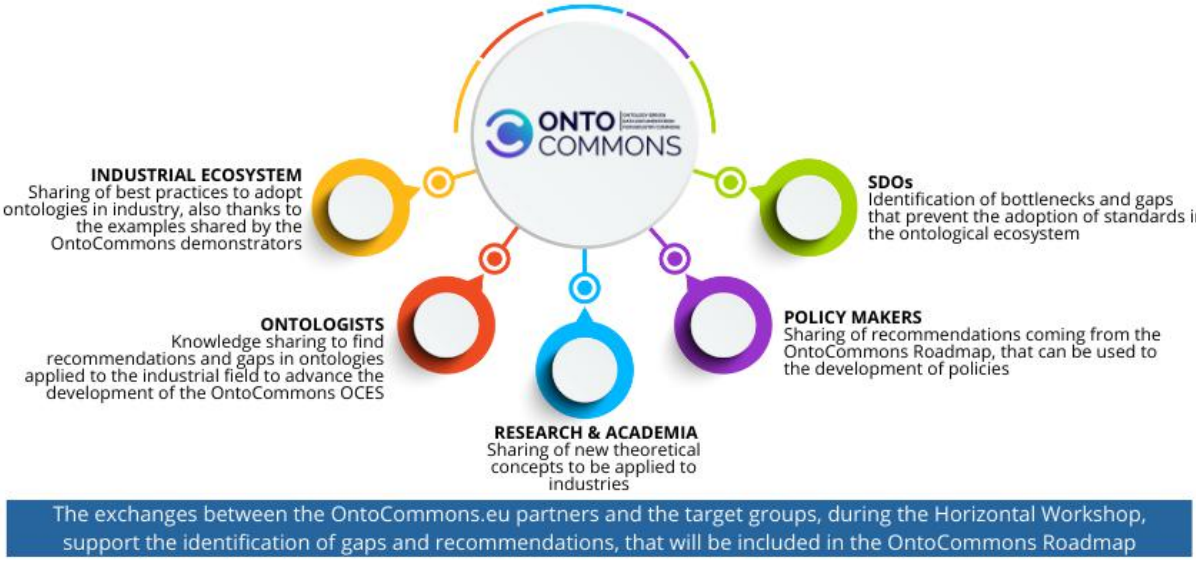


Figure 1 - Benefits for the target groups taking part to the 2nd Horizontal Workshop

A group of 400 people attended the workshop, counting the online and physical overall attendance that was distributed around the various session, with an average of 30 people online, and 30 people physically present in each session. The graphic below offers an overview of the stakeholder group the participants belong to, taking into account that there might be a substantial overlap between some groups, for example the group of Researchers, which partly overlaps with the group of ontologists.

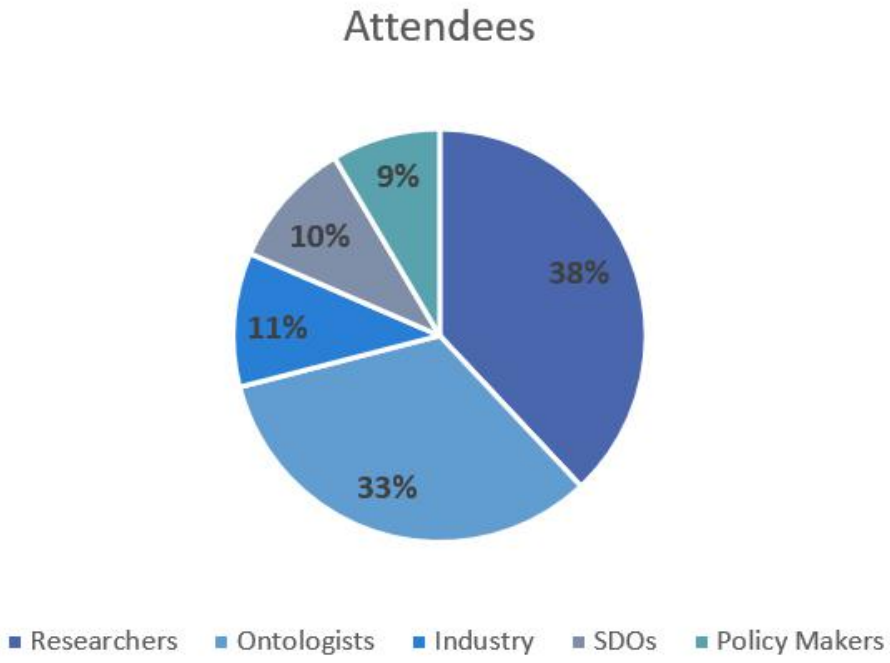


Figure 2 - type of target groups participating in the workshop

2. Deep Dive into the Sessions & Insights of the Workshop

2.1 Day 1: Demonstrators (13 June 2023)

The first day of the workshop was opened by Nadja Adamovic, OntoCommons Project Coordinator, who welcomed the attendees and presented the main objectives of OntoCommons and the workshop.

The 1st was dedicated to showcasing the substantial impact derived from collaboration with the OntoCommons 22 demonstrators. A sequence of live demonstrations, presentations, and discussions underscored the ontologies and standardisation rules adopted by these industrial use cases, as a proof to verify the efficacy of the OntoCommons Ontology Commons EcoSystem (OCES). The sessions with the demonstrators also helped to highlight recommendations for the application of standards and ontologies in addressing challenges related to material sciences and manufacturing data documentation, as well as facilitating data reusability and cross-domain interoperability.

The primary objectives of Day 1 were:

- gathering insights into the challenges and gaps that have emerged during the extended implementation of the demonstrators,

- demonstrating the adoption of OntoCommons Ontology Commons EcoSystem (OCES) by the demonstrators,
- refining the OntoCommons roadmap by inviting the uses cases and workshop participants' share their valuable input to moulding the roadmap into its final, comprehensive form,
- create a dynamic synergy between external stakeholders and the demonstrators to foster collaboration, exchange ideas, and potential opportunities for future collaborations.

2.1.1 Session 1: Introduction of the OntoCommons demonstrators and posters presentations

The OntoCommons 2nd Global Workshop offered a distinctive platform for demonstration, bringing together the 22 OntoCommons demonstrators, external experts, and industrial stakeholders who incorporate semantic technologies into their use cases. To foster synergy among these diverse participants, a unified poster and demo session were organised. On the morning of Day 1, a total of 23 posters were presented in succinct one-minute segments, acting as engaging "teasers" for the upcoming poster/demo and networking session scheduled for the evening. The session was moderated by Umutcan Serles, Postdoctoral Researcher at STI Innsbruck.

Insights

The session featured 28 posters from both OntoCommons demonstrators and external participants. The diverse range of topics covered by the posters, including nanotechnology, advanced materials, manufacturing, and biotechnology, was highlighted during the session.

Special attention was also given to the OntoCommons Roadmap, highlighting the demonstrators' role in shaping it by providing insights that steer the project's future research and educational objectives.

Impact

The session contributed to the following impacts:

- 23 out of 28 posters were presented by workshop participants (both online and in-person).
- 15 out of 22 demonstrators actively engaged by presenting their posters.

Feedback and recommended actions

A series of recommended actions and future plans can be highlighted from this session:

- Ensure the demonstrators insights continue to guide the project's research and education direction by providing recommendations in the Roadmap.
- Further explore and expand the involvement of external participants and their projects to foster a diverse range of perspectives and topics.
- Promote continued interdisciplinary collaboration across various domains to maintain the interdisciplinary nature of OntoCommons' initiatives.

The full session is available here: https://www.youtube.com/watch?v=uCQUQsJmEOw

2.1.2 Session 2: Demonstration of Industrial Data Documentation

This session, moderated by Umutcan Serles, Postdoctoral Researcher at STI Innsbruck, spotlights three OntoCommons demonstrators (Tekniker, IKEA and Bosch) from the materials and manufacturing domains. Their presentations provided elucidations on the strides made in their respective use cases, all while shedding light on the application of semantic technologies in the domain of industrial data documentation.

The session focused on three main objectives:

- Gaining Valuable Insights: by delving into the experiences and lessons learned from an extended period of use case implementation, the three demonstrators sought to uncover the challenges faced and the gaps that emerged.
- Witnessing OCES Adoption: A core focus was to witness firsthand the extent to which the OntoCommons Ontology Commons EcoSystem (OCES) has been embraced and integrated by these pioneering demonstrators.
- Guiding the Roadmap: The session also served as a platform for gathering invaluable input. The insights shared by the demonstrators will contribute towards the refinement and crystallisation of the OntoCommons Roadmap, ensuring its alignment with the evolving needs of the community.

Speakers:

- Umutcan Serles (UIBK), Moderator
- Patricia Casla (Tekniker)
- Katariina Kari (IKEA)
- Evgeny Kharlamov (Bosch)
- Zhuoxun Zheng (Bosch)

Insights

During the session, key insights were presented by the speakers. Patricia Casla, Senior Reseacher at **Tekniker**, highlighted the use case of this company, a specialist research center focused on the materials and manufacturing sectors. The demonstrator aims to shorten the time and the number/size of experiments required to identify the behaviour of a material or combination of them (e.g., metal, coating, lubricant) with respect to specific operating conditions. The main challenge faced by this use case was the lack of standardised formalisation for ontological experiments.

The approach Tekniker adopted is the following:

- *Semantic Technologies for Formal Representation*: The Tekniker team used semantic technologies for the unambiguous representation of data. They developed the "Tribo Ontology," focusing on main classes, relationships, and aligning it with other relevant ontologies.
- *Ontology Design and Alignment*: The "Tribo Ontology" was designed using UML diagrams and Protégé. Tekniker decided to align the ontology with existing ones to enhance interoperability.

- *Modular Approach*: The ontology was modular, covering main aspects of tribological characterisation of materials experiments.
- *Instantiation and Evaluation*: The ontology was instantiated and tested for consistency and metrics. The alignment process with other ontologies was complex but essential for interoperability.
- *Publication and Assessment*: The ontology was published in web repositories (industryportal) and underwent fairness assessment, which highlighted good scores in interoperability and reusability but indicated room for improvement in findability and accessibility.

The second use case was presented by Katariina Kari, Lead Ontologist at Inter IKEA Systems, where she discussed the **IKEA** use case where they built a knowledge graph for providing customers with quality recommendations for furniture accessories.

IKEA uses a knowledge graph to capture the relationships between furniture and accessories. They distinguish between ontology, taxonomy, and data levels:

- *Ontology*: This defines the business rule data model. It contains concepts and properties that determine how accessories fit furniture.
- *Taxonomy*: This level defines specialised instances by combining taxonomy concepts. It captures the control vocabulary of the organisation.
- *Data Level*: This represents the actual data in the knowledge graph. It involves transforming data into RDF and storing it in a triple store.

The presentation concluded with the observation that there's no standard way to build semantic models and that it is crucial to use vocabularies, taxonomies, and knowledge graphs in making recommendations.

Evgeny Kharlamov, Senior Expert at Bosch, and Zhuoxun Zheng, PhD student at Bosch Center for Artificial Intelligence, presented the **Bosch** use case. Their presentation was related to industrial applications of ontologies and knowledge graphs in manufacturing analytics and discussed the use of semantics and ontologies to address challenges in manufacturing operations.

In particular, their presentation focused on a use case in discrete manufacturing where pieces of metal are connected through welding. This operation requires automation and smart solutions for improving quality. Challenges encountered in building it, include data integration, communication, and reusability of machine learning pipelines. A solution to overcome these challenges, as stated by the speakers are ontologies as semantics can help bridge gaps in communication and standardise documentation of machine learning pipelines.

Bosch developed a specialised ontology for welding operations, based on various standards. The ontology covers concepts related to welding processes, resources, and functionalities. The development process involved formulating concepts, validation, and aligning with existing ontologies. Through this, they enable users, including non-experts, to generate knowledge graphs and execute them through executable scripts as they combine semantic technologies and data analysis. This system facilitates transparency, documentation, and reusability in machine learning practices for industry.

Impact

The impact gathered by this session are highlighted below:

- *Exemplifying Tekniker Demonstrator Adoption*: The Tekniker demonstrator offers a striking example of the extensive uptake of multiple OCES components. Notably, the integration of the LOT Methodology and the IndustrialPortal underscores a tangible progression towards enhanced operational efficiency.
- *IKEA's Advancements in Knowledge Graphs and Ontologies*: IKEA's achievements encompass the integration of knowledge graphs and ontologies to seamlessly fuse IKEA product data. This amalgamation has propelled the development of intelligent applications, transcending the confines of collaborative reasoning and ushering in pioneering solutions such as advanced recommender systems.
- *Bosch's Notable Strides*: Bosch's presentation was marked by significant strides in their respective use case. The discourse encapsulated valuable insights gained through experiential learning, providing a comprehensive picture of the intricate lessons drawn from their journey.
- *Valuable Roadmap Input Accumulated*: A pivotal aspect of the session was the accumulation of invaluable input that has substantially enriched the OntoCommons roadmap. A discerning analysis revealed the facets that yielded favorable outcomes in industrial data documentation, alongside instances that fell short of expectations. For example, IKEA elucidated how their knowledge graph deployment translated into substantial cost savings. However, Bosch underlined the ongoing challenge of involving domain experts in the ontology engineering process.

Feedback and recommended actions

A series of recommended actions and future plans can be highlighted from this session:

- Tekniker emphasised the importance of semantics in materials sharing across the value chain. Their vision extends towards the seamless integration of third-party data and the continuous enhancement of ontologies.
- IKEA is exploring the possibility of using large language models to suggest business rules and collaborating with technical experts for logical accuracy. They are also looking into real-time reasoning for more efficient evaluation of recommendations.
- Bosch discussed plans to make their developed ontology available in the OntoCommons ecosystem. They highlighted the importance of automation in ontology construction for scalability.

The full session is available here: https://www.youtube.com/watch?v=E3GsQj3CLcs

2.1.3 Session 3: Presentation of the OntoCommons Roadmap

Hedi Karray, Professor at ENIT and OntoCommons Technical Coordinator, opened the third session, which aimed to present the preliminary results of the OntoCommons Roadmap. This session's structure was presented by chapters that cover the different aspects of the roadmap, presenting the needs, gaps, defined success metrics, and recommended actions for each topic.

Speakers:

- Hedi Karray (ENIT, OntoCommons Technical Manager), Moderator
- Emanuele Ghedini (UNIBO)
- Yan Lang (University of Ireland, Galway)
- Florina Piroi (TU Wien)
- Ana Correia (ATB-Bremen)
- Cristina Mancarella (Trust-IT)
- Michela Magas (ICF)

Insights

Emanuele Ghedini, Full Professor at Universita' di Bologna, presented the first chapter of the Roadmap, which focused on the significance of the top reference ontology. Top-level ontologies represent the interlink to create a unified lens through which various ontologies from distinct top-level references can be comprehended. This ontology-centric framework serves as the bedrock for effectively organising data structures and propelling innovation. Nevertheless, there are substantial challenges to surmount. These encompass a lack of enthusiasm to align with top-level ontologies, an insufficient grasp of ontology concepts, and a dearth of adequate tools and resources.

Yan Lang, Postdoctoral Researcher at National University of Ireland, Galway, followed the speech to present the Ontology Commons Ecosystem Toolkit, underscoring its pivotal role in facilitating ontology development through a comprehensive array of methodologies, tools, and guidelines. A key focal point of the discussion is the pressing need for collaborative synergy among stakeholders. The toolkit is expressly designed to address this requirement, with its architecture crafted to facilitate seamless collaboration. This collaborative approach, bolstered by flexibility and the integration of diverse tools, is a cornerstone for ensuring the successful development and implementation of ontologies.

Florina Piroi, Senior Scientist at TU Wien, shedded light on the pivotal role of research infrastructure within the roadmap framework. Unveiling the industrial needs, her presentation revolved around the crucial requisites for secure collaborative tools, interactive data visualisation, data quality assurance, and establishing dependable data repositories. Within this context, Florina emphasised certain gaps that warrant attention. Among these gaps are the limited maturity of existing infrastructure components, the absence of foundational low-level ontologies, the complexities surrounding ontology data provisioning, and the inherent challenge of transitioning from the realm of research and development to practical implementation.

Ana Correia, Engineer at ATB-Bremen, delved into the sphere of ontology adoption, unveiling both the industry's needs and the gaps that warrant attention. Her presentation revolved around the necessity for a common communicative language, the crucial requirement for user-friendly ontology tools, and benefits associated with ontology utilisation. The gaps identified encompass barriers to learning, the burdensome costs linked to ontology development, the perplexing absence of well-defined motivations for aligning with top-level ontologies, and the palpable dearth of comprehensive domain-specific ontologies.

Cristina Mancarella, Researcher at Trust-IT, underscored the pivotal role of standardisation within OntoCommons, emphasising its significance through the lens of industry stakeholders' input. She added that the overarching objective of the project is to cultivate a unified landscape, where ontologies and standards seamlessly coexist.

Michela Magas, Chair at ICF and OntoCommons Innovation Manager, took a closer look at innovation, breaking it down into different types. She connected OntoCommons to driving both groundbreaking and ongoing innovation across a variety of industries. This connection highlights the importance of being transparent, making technology work well together, and considering societal and environmental factors.

Impact

The roadmap follows a systematic approach, involving identifying industrial needs, analysing the current state of the field, pinpointing gaps, defining goals, and proposing actions. This session presentation emphasised that while the adoption of ontology-based practices is currently limited, the goal is to promote wider adoption, showcasing the benefits for businesses. The roadmap aims not only for individual company benefits but also for cross-domain opportunities and data sharing within a broader ecosystem.

Feedback and recommended actions

A series of recommended actions and future plans can be highlighted from this session:

- Defining adoption routes, promoting education initiatives, and fostering collaboration. These measures bolster the scalability of ontologies, aligning with the project's overarching goals.
- Urgent need for collaborative synergy among stakeholders.
- Refining user experience, enhancing scalability, and nurturing collaboration in the complex field of ontology development.
- Promoting knowledge engineering education.

The full session is available here: https://www.youtube.com/watch?v=bknwifyQbvM

All the main recommendations of the first release of the OntoCommons Roadmap were unveiled in April 2022. The second release of the OntoCommons Roadmap is scheduled for October 2023.

2.1.4 Session 4: Insights from the workshop "Towards Materials and Manufacturing Commons – the enablers Digital Marketplaces, FAIR principles and Ontologies"

The aim of this session, moderated by Martin Horsch, Associate Professor at NMBU, was intended to focus on the main outcomes of the "Towards Materials and Manufacturing Commons Workshop" that took place in Berlin from 4 to 6 April 2023. The previous workshop served as a forum for academic researchers and industrial practitioners to convene and deliberate on the pivotal drivers of the Materials and Manufacturing Commons, specifically Digital Marketplaces, FAIR Principles, and Ontologies.

Speakers:

- Martin Horsch (NMBU), Moderator
- Silvia Chiacchiera (UKRI)
- Pablo de Andres (Fraunhofer IWM)
- Amit Bhave (CMCL)

Insights

The session explored the interconnection between digital marketplaces and the OntoCommons Roadmap. The workshop delved into semantic techniques, technology, business models, and real-world examples related to materials production, design, and manufacturing. Emphasis was placed on platform security, usability, data traceability, transparency, and added value for users and providers.

One central theme that emerged during the workshop was the establishment of common data spaces, a concept not devoid of its challenges. Issues like attracting developers to such spaces, concerns regarding data confidentiality and security, managing complexity, and the quest for sustainable business models were debated. Another significant challenge addressed was bridging the gap between domain experts and ontologies. It became evident that manual intervention remains essential in this context, yet there was a growing consensus on the potential of AI-assisted ontology creation and the development of intermediate representations.

The workshop also underscored the importance of adaptable interfaces tailored to individual users, user involvement in the co-design of products, effective data visualisation, and the willingness to share intellectual property for collaborative problem-solving.

Impact

The «Towards Materials and Manufacturing Commons» workshop contributed to enrich participants with insights into the digital marketplaces' environment. As a matter of fact, they could deepen the understanding of semantic techniques, technological advancements, innovative business models, and real-world applications in materials production, design, and manufacturing. Moreover, participants could learn about best practices that can influence the development of future digital marketplaces, ensuring they meet high standards of quality and user satisfaction.

Feedback and recommended actions

The following recommended actions were highlighted from this session:

- *Bridging gaps with ontologies*: Participants recognised the need to bridge the gap between domain experts and ontologies. To facilitate this bridge, recommended actions include:
  - Exploring AI-assisted ontology creation tools to streamline the process.
  - Promoting the development of intermediate representations to enhance semantic integration.
  - Encouraging collaboration between domain experts and ontology specialists.
- *Diverse Perspectives on Data*: Acknowledging the varying perspectives of different stakeholders on different data layers, participants recommended actions such as:
  - Facilitating cross-disciplinary dialogues and collaboration to achieve a holistic understanding of data.

- Developing tools and frameworks that accommodate multiple viewpoints on data representation.
- *Fairness vs. Data Quality*. The distinction between fairness and data quality raised important questions. Recommended actions include:
  - Establishing clear criteria for assessing data quality in addition to fairness.

Promoting the development of data quality assurance mechanisms and standards.

The full session is available here: https://www.youtube.com/watch?v=mz7s25cDS0w

2.1.5 Session 5: The way towards ontology Commons for materials and manufacturing

The aim of the last session of the 1st Day was moderated by Dimitris Kiritsis, Professor Emeritus at University of Oslo. It focused on exploring advancements in materials and manufacturing methodologies and systems.

The participants could gain insights on complexity of ontologies and the need for practical adoption, the concept of Industry Commons in relation to materials and manufacturing, the representation of materials from a logical perspective within the context of the EMMC (European Materials Modelling Council) and the development of the Industrial Ontologies Foundry (IOF) and its historical roots.

Speakers:

- Dimitris Kiritsis (UiO), Moderator
- Arild Waaler (UiO)
- Michela Magas (ICF)
- Emanuele Ghedini (University of Bologna)
- Barry Smith (Buffalo University)

Insights

The insights of this session collectively emphasized the importance of ontologies in addressing complex challenges in materials, manufacturing, and industry and highlight various approaches and collaborative efforts to make ontologies practical and impactful in these domains. The main insights can be summarised as follow:

- *Collaboration between Academia and Industry*. an industry-driven ontology development is seen as a valuable best practice to follow in the academic and industrial environments, as academia provides ontology precision, and industry offers pragmatic solutions.
- *Industry Commons*. the concept of Industry Commons, emphasises data sovereignty and decision-making powers for actors within this model. It also highlights the importance of ecosystem integration, transparency, and technological harmonisation.
- *Materials Representation*. the session emphasised the importance of representing materials at various scales and introduced a multi-perspective approach that connects data to physical entities.

- *Collaborative efforts:* the session also highlighted collaborative efforts in advancing industrial ontologies, with mentions of contributions from different regions and organisations.

Impact

The concept of ontology commons in the industrial field can contribute to generate the following impacts:

- ontologies play a crucial role in various fields, particularly in materials, manufacturing, and industry. They can be practically adopted in real-world applications if the collaboration between academia and industry is strengthened.
- The concept of Industry Commons is introduced as a novel approach that empowers individual actors, promotes cooperation, and emphasises data sovereignty and decision-making powers.
- The discussion on materials representation within the EMMC demonstrates the need of a logical and comprehensive framework for materials knowledge.

The development of the Industrial Ontologies Foundry (IOF) showcases the practical application of ontologies in managing data related to industrial processes and product lifecycles.

Feedback and recommended actions

The following recommended actions were highlighted from this session:

- *Foster Collaboration*: Encouraging more collaboration between academia and industry to bridge the gap between ontology precision and practical implementation through the establishment of platforms or initiatives that facilitate it.
- *Learn from Industry-Driven Projects*: Analysing successful industry-driven ontology projects to extract best practices and apply them to other domains within materials and manufacturing.
- *Promote Industry Commons*: Promoting the concept of Industry Commons, emphasising data sovereignty and decision-making powers for individual actors and encourage organisations to adopt this approach in their operations.
- *Enhance Ecosystem Integration*: Developing strategies for better ecosystem integration, focusing on transparency and technological harmonisation and creating frameworks that support diverse capabilities within the ecosystem.
- *Advance Materials Ontology*: Supporting efforts to advance materials ontology, with a focus on comprehensive representation that includes various scales and physics-based approaches. Collaborating with organisations like the EMMC to further these goals.
- *IOF Expansion*: Expanding the Industrial Ontologies Foundry (IOF) project, involving contributors from different regions. Exploring opportunities for its application in various industrial contexts.
- *Standardisation and Roadmaps*: Encouraging discussions on standardisation within the materials and manufacturing domain and developing roadmaps for the future to guide the development and adoption of ontologies.

The full session is available here: https://www.youtube.com/watch?v=cyNxIjQ56l0

2.2 Day 2: Standardisation (14 June 2023)

The second day was opened by Laszlo Hetey, OntoCommons Policy Officer, who provided insights from the European Commission's Directorate-General for Research and Technological Development (DG RTD). He highlighted the key goal accelerating the design of advanced materials through digitalisation, circularity, innovation, skills development, and international cooperation. He concluded his speech by stressing the relevance of data management, interoperability, and data sharing, especially in the context of open and trusted federated concepts and standards.

Moreover, Day 2 aimed to showcase the pivotal role played by standards in ensuring that ontologies are well-structured, widely applicable, and capable of fostering interoperability and collaboration among diverse stakeholders and systems. The following paragraphs present the main outcomes of the sessions organised on Day 2.

2.2.1 Session 1: OntoCommons Top Reference Ontologies

The first session of DAY 2 offered an update on the latest developments in terms of top-level reference ontologies, which serve as the foundation for the OntoCommons ecosystem. As a matter of fact, the overarching objective of the OntoCommons project is to establish a set of aligned top-level ontologies. This alignment is aimed at enabling practical pluralism. In essence, it seeks to facilitate the sharing of formalised knowledge across different top-level ontologies within various frameworks. This alignment is considered a crucial enabler for aligning and sharing knowledge within mid-level ontologies.

Throughout the session, various presenters covered topics related to top-level ontology alignment, as showcased in the next paragraphs below.

Speakers of the session:

- Emanuele Ghedini (University of Bologna), Moderator
- Claudio Masolo (Consiglio Nazionale delle Ricerche)
- Francesco Antonio Zaccarini (University of Bologna)
- Arkopaul Sarkar (École Nationale d'Ingénieurs de Tarbes)

Insights

The main insights from this session can be summarised as follow:

- The session provided an update on the development of the OntoCommons Ontology EcoSystem, focusing on the top-level reference ontologies.
- One of the main points discussed was the importance of enabling practical pluralism, allowing for the sharing of formalised knowledge across different top-level ontologies.
- The session highlighted the importance of standards in ontology development. Standards help create an ontology ecosystem where different top-level ontologies can coexist and be linked together, allowing for semantic integration and interoperability.

Building top-level ontologies can bring challenges in alignment as one-to-one mappings are not feasible given the complexity of mapping numerous ontologies incrementally.

Impact

The main impacts generated by this session are summarised below:

- *Sharing of best practices*: during the session the speakers and attendees had the opportunity to discuss about key concepts in the ontological field, such as pluralism, inclusivity, ontology alignment, and the use of bridge concepts. These concepts contribute to the development of robust ontologies and foster interoperability.
- *Tool Awareness:* The session introduced participants to tools like TACOMA, emphasising their roles in facilitating ontology alignment, data interoperability, and the prevention of misalignment errors. This promotes awareness and adoption of such tools.
- *Encouragement of Collaboration*: By showcasing the efforts to align top-level ontologies and develop frameworks, the session encouraged collaboration among ontology developers and users.
- *Resource Accessibility*: The session highlighted the availability of tutorials and repositories, making educational resources and practical tools accessible to those interested in ontology development and alignment.

Feedback and recommended actions

The session also provided a series of recommended actions, summarised below:

- *Promotion of Practical Pluralism*: The speakers of the session encouraged the alignment of top-level ontologies to facilitate the sharing of formalised knowledge across different frameworks. As a way forward, it is crucial to support initiatives that promote inclusivity and multiple representations for problem-solving.
- *Understanding of Mapping Challenges*: Acknowledging the challenges in mapping between ontologies, especially when dealing with different ontological commitments and foundational assumptions helps recognise how demanding this task is. In order to overcome this obstacle, it is key to invest in deep understanding and rigorous documentation to establish meaningful mappings.
- *The benefits of Bridge Concepts*: If involved in ontology alignment efforts, it can beneficial to consider the practical use of bridge concepts. Understanding their role in connecting different ontologies, promoting formal constraints, and aiding in reasoning and data sharing support the alignment of top-level ontologies.

Recommending Ontology Reuse: Encouraging the reuse of ontologies from established ontology stacks and methodologies helps incorporate elements from trusted sources into ontology engineering practices.

The full session is available here: https://www.youtube.com/watch?v=znlz_vZipO4

2.2.2 Session 2: Ontology Standards – IEEE, ISO & more

The second session held on DAY 2, aimed to bring forward the discussion on topics related to ontology, standards, interoperability, and ontology development methodologies.

The main objectives of the session were:

- Discussing different approaches to ontology development, including starting from standards, developing ontologies first, or merging standards and ontologies.
- Exploring the importance of testing and community use before moving towards standardisation.
- Evaluating the quality of ontologies and standards.
- Addressing challenges related to interoperability between ontologies and standards.

Overall, the session emphasised the role of standards in ontology development, the importance of collaboration with standards organisations, and practical examples of standards-based ontology development.

Speakers:

- Hedi Karray (École Nationale d'Ingénieurs de Tarbes), Moderator
- Barry Smith (Buffalo University)
- Alexandru Todor (DIN Software GmbH)
- Jim Wilson (OAGi)
- Johan Wilhelm Klüwer (DNV)

Insights

The main insights on standards and ontology standardisation from this session include:

- *Smart Standards Development*: The concept of Smart Standards Development involves modernising traditional standards by digitising them, making them machine-readable and machine-interpretable.
- *Integration of Standards and Ontologies*: The integration of standards and ontologies was explored, emphasising the use of terminology, requirements, and instance data from standards to develop ontologies. This approach aims to link standards and ontology development.
- *Knowledge Base Creation*: The session discussed the process of creating a knowledge base based on information extracted from standards and integrated into ontologies. This knowledge base can support various applications.
- *Collaboration with Standards Committees*: Collaboration with standards committees is crucial to ensure that ontologies developed based on standards align with the standards themselves. This collaborative process can lead to revisions and improvements in standards.

Impact

The impacts of the session are multifaceted and presented below:

- *Awareness and Education*: The session served as an educational platform, introducing concepts such as Smart Standards Development and ontology standardisation to a wider audience. It raised awareness about the importance of modernising standards and integrating them with ontologies.
- *Integration of Standards and Ontologies*: Highlighting the integration of standards and ontologies encourages the development of more coherent and interoperable systems. This can lead to better data management and utilization across domains.
- *Industry Relevance:* The sessions addressed industry-specific needs, such as those related to agriculture and digital manufacturing. The adoption of standards and ontologies in the industrial sector can drive innovation and efficiency in data management.

Feedback and recommended actions

Feedback and recommended actions from this session can help improve the effectiveness and impact of adopting standards and ontologies in the materials and manufacturing fields:

- *Advancement in Standardisation*: The discussions around Smart Standards and their integration with ontologies provide a roadmap for the advancement of standards. This can lead to more efficient and effective standardization processes, benefitting various industries.
- *Organisation of Hands-On Workshops*: To enhance learning, it is a good practice to organise hands-on workshops or tutorials where participants can understand how to practically use standards and ontologies for data management purposes.

Implementing Guidelines: It is useful to provide practical implementation guidelines or resources for organisations looking to standardise their ontologies. The guidelines should balance between technical details and non-technical explanations to cater to both technical and non-technical users.

The full session is available here: https://www.youtube.com/watch?v=TzK7TCC_GYU

2.2.3 Session 3: Priorities in TLO/MLOs

The session "Priorities in Top Level Ontologies / Middle Level Ontologies" aims to promote a scientific approach to foundation ontologies and provide insights into their practical use and comparison. The session centred around the integration of standards into ontology and the challenges and strategies associated with this integration, particularly in the context of materials ontology

Speakers:

- Francesco Antonio Zaccarini (Universita' di Bologna), Moderator
- Emanuele Ghedini (Universita' di Bologna)
- Chris Partridge (BORO Solutions)
- Stefano Borgo (Consiglio Nazionale delle Ricerche)

Insights

The session provided insights from materials ontology and standards integration to the balance between standardisation and innovation and the scientific approach to ontology development.

The main insights of the session are summarised as follow:

- *Usage and integration of standards*: The session highlighted the importance of using standards as a basis for materials ontology development, like EMMO.
- *Integration of Standards and Plurastic Approach:* The idea of a pluralistic approach to standards integration, focusing on concepts rather than terms, is introduced.
- *Flexible Ontological Framework*: One of the main goals shared by the participants was to develop an ontological framework that respects existing standards while allowing for flexibility and accommodating diverse standards.
- *Adoption of a scientific approach*: The session emphasized the importance of a scientific attitude when developing ontologies, encouraging a critical and evidence-based approach.

Impact of Session 3

The session acknowledged the importance of using standards as a basis for ontology development. An interesting discussion revolved towards cultural evolution and market diffusion. Speakers and participants highlighted the need to consider the cultural and contextual aspects of standard adoption. This insight can guide organisations in effectively implementing standards.

Feedback and recommended actions of Session 3

The main recommended actions, coming from the session, are the following ones:

- *Challenges Acknowledgment*: Recognising challenges in comparing ontologies, such as stability and flexibility, can lead to more realistic expectations and better strategies for ontology development and evaluation.
- *Practical Steps:* The suggestion to explore real scenarios and data for concrete ontology model development offers a practical path forward. This can result in more meaningful ontology comparisons and informed decisions.

The full session is available here: https://www.youtube.com/watch?v=s_ixqSNqVa4

2.2.4 Session 4: Semantic interoperability and FAIR Semantics

The 4th session of DAY 2 aimed to bridge the gap between FAIR principles and ontologies, providing a framework for assessing and improving the FAIRness of semantic artifacts while fostering collaboration within the community. To bring these discussions forward the speakers invited are experts in the fields of open science and data management.

Speakers:

- Yann Le Franc (e-Science Data Factory), Moderator
- Daniel Garijo (Universidad Politécnica de Madrid)
- Robert Pergl (Technical University in Prague)
- Jana Martinkova (e-Science Data Factory)
- Wolmar Nyberg Akerstrom (EOSC Association)

Insights

The main insights shared during this session are summarised below:

- *Highlighting the Importance of Semantic Interoperability*: The session emphasised the importance of semantic interoperability, especially in the context of ontologies and semantic artifacts. It addressed challenges related to metadata, vocabulary reuse, and availability of ontologies on the web.
- *Harmonising FAIR Assessment Tools*: The session outlined efforts to harmonise different FAIR assessment tools, making it easier for users to select and apply relevant tests for their semantic artifacts.
- *Highlighting the Importance of Fairness Assessment*: the session emphasised the importance of fairness assessment in the context of semantic artifacts.
- *Developing Guidelines for FAIR Mappings*: The session seeked to establish guidelines for creating FAIR mappings. This involved defining best practices and principles that ensure mappings are findable, accessible, interoperable, and reusable (FAIR).
- *Creating a Common Exchange Model*: To facilitate the sharing and reuse of mappings, the session proposed a common exchange model. This model will enable mappings to be easily understood and used by machines, fostering smoother exchange and collaboration among different communities
- *EOSC Task Force on Semantic Interoperability*: The session highlighted the work of the task force focused on semantic interoperability within EOSC. This task force addresses challenges associated with semantics and aims to find solutions for encoding and exchanging information across different domains. This work is crucial to ensure FAIRness in data management.

Impact

The impacts of the session are summarised below :

- *Engaging the Ontology Community*: The session encouraged participation and engagement from the ontology community in discussions and collaborative efforts related to FAIR principles and semantic interoperability.
- *Bridging the gaps between FAIR principles and ontologies*: providing a framework for assessing and improving the FAIRness of semantic artifacts while fostering collaboration within the community.
- *Advancing the understanding and implementation of FAIR and interoperable semantic artifacts*: the session in particular had a focus on defining metadata standards and making them machine-actionable.
- *Understanding and implementing FAIR mapping practices*: this can be delivered through practical guidelines and tools to enhance the sharing and reuse of mappings in the context of semantic artifacts.

Feedback and recommended actions

The session explored future directions that can be taken by the ontology community in terms of FAIR adoption. This includes semantic mappings, W3C profile vocabulary, and API specifications, to further enhance the use of the defined metadata schema.

The full session is available here: https://www.youtube.com/watch?v=vPIjJQr3VK8

2.2.5 Session 5: Education in Standards

The session focused on training and education in ontology interoperability. It informed the audience about ontology standards, standardisation processes, the importance of ontology interoperability in various domains and how EU-funded initiatives, like HSBooster, can increase the overall adoption of standards in industries.

Speakers

- Michela Magas (Industry Commons Foundation), Moderator
- Arkopaul Sarkar (ENIT)
- Paul Harvey (University of Glasgow)
- Ivana Mijatović (University of Belgrade)
- Anders Gjerver (Abel)

Insights

The speakers provided a comprehensive overview of ontology standards, standardisation processes, and the significance of ontology repositories across various domains:

- *Ontology Standards and Categorisation*: As part of the StandICT.eu Technical Working Group, chaired by Arkopaul Sarkar, the team categorised ontology and standards based on criteria like endorsement, project development, and academic acceptance. The ontology standards were classified into five groups: standard specification, technical specification, products, project ontologies, and academic ontologies.
- *Ontology and Standards Relationship*: during the session, the speakers discussed how ontologies aspire to become standards and standards incorporate ontology concepts. It also highlighted how EU-funded initiatives like HSBooster.eu can support the implementation of standardisation processes.
- *Networking and Collaboration activities*: Participation in standardization activities offers networking opportunities and helps researchers identify meaningful use cases.
- *HSBooster.eu and the Training Academy*: HSBooster.eu aims to bring standardisation closer to researchers and offers services and training. The Training Academy provides various training activities, including textbooks, webinars, and workshops to overcome knowledge gaps.
- *Industry Standards to Ontologies*: The participants also discussed the possibility of converting mature industry standards into ontologies for designing and constructing products.

Impact

The session contributed to the following impacts:

- Ontology Standards and Categorisation provides a structured approach to categorize ontology standards, enhancing clarity and accessibility. It also facilitates the selection of relevant ontologies for specific domains or applications, saving time and effort for users.
- Ontology and Standards Relationship encourages cross-disciplinary collaboration and knowledge sharing, promoting innovation.

- Services, like the Training Academy, empower researchers with the knowledge and tools needed to navigate the standardization process effectively, potentially increasing their research's real-world.
- Industry Standards to Ontologies addresses the need to convert mature industry standards into ontologies, ensuring data exchange and semantic reasoning. It advances the long-term ontology building in industries, streamlining product design and development processes.

Feedback and recommended actions

All the recommended actions gathered through the session aim to enhance the effectiveness of ontology standards and standardisation processes. The main recommendations are summarised below:

- Develop and maintain live ontology repositories for up-to-date ontology information access.
- Encourage the adoption of formal definitions in standards and foundational concept formalisation in ontologies to enhance their relationship.
- Continue offering a range of training activities and encourage contributions from the standardisation community

The full session is available here: https://www.youtube.com/watch?v=qvb7P2JQhs4

2.2.6 Session 6: Training and Education

This session was dedicated to addressing the human resources aspect of integrating semantic technologies into the industrial sector. The role of human resources was also a pivotal component in the OntoCommons roadmap, and we the team is actively shaping it in collaboration with the community. The full session is available here: https://www.youtube.com/watch?v=jNFl_sAYSN8

Speakers

- Gerhard Goldbeck (Goldbeck Consulting Group), Moderator
- Florina Piroi (TU Wien)
- Umutcan Serles (STI Innsbruck)
- Henriette Harmse (EMBL-EBI)
- Nicole Vasilevsky (Critical Path Institute)
- Claire Johnson (SciBite Limited)

Insights

The session aimed to contribute to the advancement of human resources and skill development in the context of semantic technologies, aligning with the goals of the OntoCommons initiative, as summarised below:

- *Assessing the Current State of Semantic Technology Skills and Education*: The speakers discussed the existing landscape of skills and educational offerings in the field of semantic technologies

- *Identifying Industry Skill Needs:* The session aimed to ascertain the skill requirements of the industrial sector concerning emerging technologies.
- *Mapping Available Training and Professional Development Resources*: The session explored the available resources and opportunities for training and professional development.
- *Evaluating Educational and Up-Skilling Experiences*: Participants shared their experiences and insights related to education, training, and up-skilling efforts.
- *Defining Best Practices*: Together, we establish a set of best practices to guide the development and acquisition of skills in semantic technologies.

Impact

The session highlighted the importance of adapting education and training to meet evolving industry needs, promoting collaboration, addressing data challenges, and advocating for the value of ontologies in various domains:

- *Diversifying Student Skillsets*: The adoption of cross-domain education prepares students for diverse careers in engineering, information technology, logistics, and beyond, enhancing their employability.
- *Industry Collaboration*: Collaborations with guest lecturers from various domains introduce students to real-world problems, facilitating collaborative problem-solving skills and real-world relevance in their education.
- *Focus on Semantics*: MSc courses introduce students to semantic technologies, knowledge graphs, Semantic Web, and Smart Data, aligning education with emerging trends in the field.
- *Training Methods*: Adapting training methods, including one-on-one instruction and screen sharing, helps researchers overcome barriers related to using ontology tools.

Feedback and recommended actions

The session highlighted the importance of making semantic technologies more accessible, addressing skill gaps, fostering collaboration, and promoting the gradual adoption of ontologies and semantics in both academic and industrial settings, as summarised below:

- *Promote Early Exposure*: Encourage universities to introduce ontologies and semantics at the undergraduate level to make them more accessible and appealing to students.
- *Provide User-Friendly Tools*: Develop and promote user-friendly tools for working with semantics to make it more attractive and accessible to academic communities.
- *Industry-Academia Collaboration*: Facilitate collaboration between industry and academia to ensure that domain experts are trained in semantic technologies, and continuous training resources are made available.
- *Awareness and Value Recognition*: Raise awareness about the availability and value of training resources like the OBO academy and commercial software training among individuals with data.
- *Address Scepticism*: Address the scepticism regarding the relevance of ontologies by showcasing real-world use cases and demonstrating the benefits of semantic technologies in knowledge sharing.

- *Gradual Adoption*: Encourage a gradual adoption approach, allowing individuals and organizations to take small steps and witness the value of semantics at each stage.
- *Budget Allocation*: Involve budget holders in the decision-making process to allocate resources for training and education in semantic technologies.

2.2.7 Session 7: Ontology Interoperability

The last session of DAY 2 aimed to address challenges in achieving interoperability through ontology alignment, provide formal and tooling support, and gather feedback for future developments and use cases in the field of ontological modelling and alignment.

Speakers

- Stefano Borgo (Consiglio Nazionale delle Ricerche), Moderator
- Till Mossakowski (University of Magdeburg)
- Torsten Hahmann (University of Maine)
- Riccardo Pigazzi (Politecnico di Milano)

Insights

The main insights gathered by this session are presented below:

- *Interoperability in Ontologies and Modelling*: the session provided space to discuss about the challenges in achieving interoperability in ontology modelling and the importance of ontology alignment for achieving interoperability.
- *Semantics for Ontology Alignments*: Two methods for providing semantics to ontology alignments were explored.
    - Integration of ontology alignments in a logically grounded manner.
    - Cross-language ontology alignment and integration.
- *Formal Details and Tooling*: The following formal details and tools related to ontology alignment were presented:
    - The Distributed Ontology Language (DOL) and its alignment syntax.
    - The use of analysis and proof tools for ontology alignment and consistency checking.
- *Combining Ontologies in Different Languages*: Techniques for aligning ontologies written in different ontology languages were demonstrated.

Impact

All the impacts gathered by this session are summarised below:

- *Interoperability in Ontologies and Modelling*: the session helped increase awareness of the challenges in achieving interoperability in ontology modelling and of the recognition of the three crucial levels of interoperability: instances, terminologies, and languages.
- *Semantics for Ontology Alignments*: the session enhanced knowledge of methods to provide semantics to ontology alignments.
- *Formal Details and Tooling*: The session disseminated formal details and tools related to ontology alignment.

- *Combining Ontologies in Different Languages*: The session helped to recognise the potential for integrating diverse-language ontologies into a unified ontology. It also highlighted the benefits of reconciling ontologies for improved interoperability.

Feedback and recommended actions

The session has sparked recommendations for further research, tool development, and standardization efforts across various aspects of ontology alignment, interoperability, and semantics:

- Participants recommended conducting more in-depth studies and research to address specific challenges in achieving interoperability in modelling and ontologies.
- The need for practical guidelines and best practices for ontology alignment was highlighted, along with the development of alignment tools and frameworks.
- Further research was recommended to explore the impact of different levels of alignment and provide guidelines for selecting the appropriate level based on specific use cases.
- Participants suggested the development of more user-friendly and accessible tools for ontology alignment, along with educational resources to train practitioners.
- Continued research and tool development for aligning ontologies in different languages are encouraged, along with sharing best practices.
- Participants encouraged the exploration of more real-world use cases and scenarios, such as the alignment of specific ontologies using first-order logic formulas.

The full session is available here: https://www.youtube.com/watch?v=b7JJa9AagfY

2.3 Day 3: Industry (15 June 2023)

Day three day of the workshop was dedicated to Industry, in terms of domains: the morning sessions were focused around two main themes: Domain Interoperability, and Harmonisation. The OntoCommons Eco System (OCES) will consist of a hierarchy (top, middle, domain, and application levels) of networked ontologies, a set of tools and methodologies and a set of specifications. In the afternoon, two sessions have been presented, one on Ontology Validation and the other one on Ontology tools. Moreover, a keynote speech from Alessandro Oltramari (Bosch) was included in agenda. The prototyping lab ran in parallel in the course of day three in a separate room.

2.3.1 Session 1: Domain Interoperability

The first session, focused on Domain Interoperability, has seen the participation of Barry Smith (University of Buffalo), Silvia Chiacchiera (UKRI), David Cameron (UiO), and Francesca L. Blaken (SINTEF).

The objectives of this session were the following:

- Collect community input on domain ontologies and interoperability in materials modelling, characterisation, and manufacturing.
- Guide harmonisation, find agreements, and enhance intra- and cross-domain interoperability.
- Present updates on domain ontologies within the OntoCommons project.

- Gather feedback on needs, challenges, and actions in the OntoCommons Roadmap.
- Foster coordination and collaboration among groups developing industrial ontologies.
- Review and gather insights on interoperability, technical components, and practical challenges.
- Present an industrial use case study involving digital twins and ontologies, explore the role of information modelling in oil platform development, emphasize the modelling approach, system abstraction, and domain challenges.
- Discuss the significance of documenting data for achieving interoperability, explain how ontologies play a crucial role in semantic understanding and share practical approaches and challenges in implementing data documentation and ontology-driven interoperability.

Insights of Session 1

Barry Smith addressed the strategy to achieve domain interoperability by tackling challenges in developing industrial engineering domain ontologies. He emphasized the need for coordination among groups working on similar ontologies to prevent duplication and disconnect and introduced the Industrial Ontologies Foundry (IOF), promoting collaboration through specialized working groups. The IOF Core, a foundational ontology, was discussed, focusing on planned processes for industrial domains. Handling digital entities, capabilities were highlighted as functions of artifacts. The IOF's goal to include rights and intellectual property was underlined. Solutions for challenges in ontology development, such as addressing non-existent entities, were explored. The session concluded by showcasing IOF's existing working groups and inviting proposals for new groups, aiming to create a successful ontology effort for industry, mirroring accomplishments in biology.

Silvia Chiacchiera talked about the progress in the OntoCommons Project's task of reviewing semantic interoperability, especially related to ontologies, in the domain of materials and manufacturing. The session's goal was to gather input for the project's deliverable, which aims to guide developers of domain ontologies and tools. Silvia Chiacchiera outlined the domains being addressed, such as system engineering, material science, manufacturing, product and service, and maintenance. The division of work falls into three working groups: terminology classifications, technical components, and scenarios. The presentation showcased current results, including analysis of interoperability scenarios, initiatives in interoperability, interoperability terms and flavours, and identified technical components.

David Cameron from the University of Oslo presented an industrial case study exemplifying the application of ontologies for enhancing digital twins in the context of oil platform development. He discussed the collaborative effort between Norwegian oil and engineering companies to leverage information modelling and ontologies for improved field development. The case involved modelling the process hierarchy in a top-down manner, linking requirements to information objects, and addressing the distinction between process steps and equipment. The presentation emphasized the need for semantically informed interoperable representations, covering process steps, physical objects, and attributes while maintaining non-fragile attribute models. The speaker highlighted challenges arising from semantic ambiguity in terminology. The case study demonstrated the utility of ontologies in creating a structured and standardized framework for digital twin development in complex engineering projects.

Francesca L. Blaken emphasized the importance of making data FAIR (Findable, Accessible, Interoperable, and Reusable) by documenting it effectively. Interoperability, defined as the exchange of data with shared, unambiguous meaning, was explored through various levels of communication and semantic context. The need for common language and tools, similar to human communication, was emphasized. The process of achieving interoperability was discussed, encompassing cataloguing, structural documentation, and semantic documentation. The use of data models and their alignment with ontologies was highlighted to bridge the gap between data sources and sinks. The concept of reusable partial pipelines, combining documentation and ontology mapping, was introduced as a framework for achieving comprehensive interoperability while allowing domain experts to work closely with data and ontology specialists.

Impact of Session 1

The speaker acknowledged challenges in ontology development, particularly when dealing with non-existent entities and complex systems. They proposed solutions, including using BFO in conjunction with a modal relations ontology for addressing non-existent entities.

- Strategies for achieving domain interoperability highlighted, focusing on challenges in industrial engineering domain ontology development.
- Emphasis on coordination among ontology development groups to prevent duplication and disconnection, encouraging collaboration.
- Introduction of specialized working groups like the Industrial Ontologies Foundry (IOF) to address challenges and promote collaboration.
- Introduction of the IOF Core, a mid-level ontology, focusing on planned processes for industrial domains.
- Handling digital entities and capabilities as functions of artifacts discussed.
- Inclusion of rights and intellectual property emphasized as a goal.
- Solutions explored for ontology development challenges, including addressing non-existent entities.
- Progress in reviewing semantic interoperability, particularly in materials and manufacturing domains, showcased.
- Three working groups identified: terminology classifications, technical components, and scenarios.
- Current results presented, including interoperability scenarios analysis, initiatives, terms, flavours, and technical components.
- Industrial case study demonstrated the application of ontologies for enhancing digital twins in complex projects.
- Need for semantically informed interoperable representations underlined, addressing challenges of terminology ambiguity.
- Importance of making data FAIR (Findable, Accessible, Interoperable, Reusable) emphasized.
- Process of achieving interoperability discussed, involving cataloguing, structural and semantic documentation.
- Use of data models aligned with ontologies highlighted to bridge data sources and sinks.

- Concept of reusable partial pipelines introduced as a framework for comprehensive interoperability.

Feedback and recommended actions of Session 1

The session concluded with an overview of existing IOF working groups and the invitation for attendees to propose new working groups to expand the IOF's coverage. The IOF's goal is to create a thriving ontology effort in the industrial domain, akin to the successful initiative in the field of biology.

Attendees were invited to share their insights on definitions, classifications, metrics, principles, solutions, and the role of language models in achieving interoperability. The session emphasized collaboration and input from the community to enhance ontology-driven interoperability efforts within the project and some recommended actions can be drawn from the talks:

- Increasing collaboration and coordination to ensure efficient ontology development.
- Implementing mechanisms for knowledge sharing, preventing duplication, and fostering collaboration among ontology groups.
- Encouraging sharing of detailed findings and insights from the analysis of interoperability scenarios.
- Considering engaging more experts from materials and manufacturing domains in the working groups.
- Exploring potential strategies to minimize semantic ambiguity in complex engineering projects.

The full session is available here: https://www.youtube.com/watch?v=7-LX3hQjS-E

2.3.2 Session 2: Domain Ontology Harmonisation

The session on Domain Ontology Harmonisation, moderated by Silvia Chiacchiera, included an interactive part with discussions among the speakers.

Insights of Session 1

Oystein Linnebo (UiO) discussed the concept of "core constructional ontology," inspired by a UK report from 2017 that recommended the creation of a UK national digital twin, a comprehensive digital representation of national assets. This would require a high level of interoperability. To achieve this, foundational frameworks are essential, which is where the "core constructional ontology" comes into play. The ontology comprises different data layers, with a focus on the foundational data layer that rests on a top-level ontology, which is four-dimensional and extensional. This ontology offers a unified way to handle entities that appear in many top-level ontologies. Drawing inspiration from Kid Fine's work, a "constructional approach" is used to build entities from given objects using constructors. Their approach starts with neurological atoms and then uses various constructors like set, sum, and pair constructors to build upon those atoms. The process iteratively constructs objects, and an example provided involves the construction of sets. The speaker then briefly touches on their use of plural logic to handle the construction process and mentions a technical report on this topic.

Finally, the talk suggests potential future directions, including harnessing more of Kid Fine's resources and constructing intentionally individuated objects like groups or social entities.

Alberto Olivares Alarcos (Technical University of Catalonia) -IEEE Robotics Ontology highlighted IEEE's efforts in standardization of ontologies in robotics, mentioning the multiple standards they have produced or are currently developing. IEEE collaborates with several international organizations, holding annual meetings to harmonize various standards and to ensure collaboration and synergy between them. The speaker also emphasized the organization of workshops that bring together experts in robotics, ontologies, and standards. As a conclusion, the speaker invited attendees to participate in these efforts, offering to connect them with key individuals in the standardization field.

Ilaria Paponetti (UNIBO) presented her work on transitioning from ISO to a more semantically interoperable system for lifecycle assessment. She used the lifecycle of an electric car as a use-case, emphasizing the importance of semantic interoperability. Throughout the car's lifecycle, from design to waste, data is gathered from various heterogeneous sources, raising questions about the volume of data, devices, locations, and other variables. Traditional lifecycle assessment formats focus on syntactic interoperability, while the interpretation phase necessitates semantic interoperability for a meaningful comparison of environmental impacts. Ilaria discussed the development of a formal standard based on existing standards, aiming for better semantic clarity. She emphasized the importance of understanding domain-specific terms and collaborating with experts to construct the ontology. Her presentation touched upon different classes and entities within the lifecycle, with a particular emphasis on the functional unit concept. In conclusion, Ilaria posited that lifecycle in ISO can serve as both a workflow and a semantic object. Leveraging multi-perspective expressiveness, it's possible to enrich and refine existing standards. Her concluding message encouraged leveraging ISO knowledge, using it, and enhancing it for improved outcomes.

The session continued with an interactive questionnaire submitted to the participants. To gather insights about the results of the questionnaire, we suggest watching the full session, available here: https://youtu.be/4tiqSFjo6zs?si=4iQ1Mki5P9vsrE-t&t=2210

Impact

The workshop covered a rich array of topics from core constructional ontology to robotics ontology to lifecycle assessment. The range of discussions provided participants with a broad perspective on the state of ontology in various domains.

- **Highlight on Data Diversity**: The emphasis on the variety of data sources throughout the car's lifecycle, from design to waste, resonated as a significant point. This topic brought out the challenges posed by heterogeneous data sources and the need for interoperability.
- **Comparison of Interoperability Types**: Distinguishing between syntactic and semantic interoperability provided clarity on the different layers of interoperability and the necessity for semantic understanding, especially during the interpretation phase.
- **Emphasis on Collaboration**: The mention of collaboration with domain experts for ontology construction was a crucial takeaway. This emphasizes that true semantic clarity requires interdisciplinary efforts. The presentation on IEEE's efforts underlined the importance of

international collaboration and standardization. The mention of workshops and meetings highlights IEEE's proactive approach to ensuring harmony between different standards.

- **Functional Unit Concept**: Specific concepts like the 'functional unit' were discussed in detail. It gave participants a tangible grasp of the complexities involved in lifecycle assessment.
- **Constructive Concepts**: Oystein Linnebo's discussion on "core constructional ontology" with its emphasis on interoperability, foundational frameworks, and a methodical approach to constructing entities offers a fresh perspective on ontology construction.

Feedback and recommended actions

- Study the UK's "Data for the Public Good" Report to grasp the context of the national digital twin and the importance of lifecycle use cases. Familiarize yourself with the five main phases: design, production, distribution, use, and waste.
- Deepen Understanding of Semantic Interoperability: Focus on constructional approaches, emphasizing givens, constructors, and constructed objects. Push for meaningful environmental assessments, going beyond the limitations of current data formats.
- Engage with IEEE's Robotics Initiatives: Learn about the Robotics and Automation Society's history, its published standards, and upcoming developments. Look for overlaps with other organizational standards and attend relevant robotics conferences for networking and learning.
- Focus on Practical Applications: Explore real-world applications of constructional ontology, especially in areas demanding high interoperability. Delve into cognitive robotics to understand human-robot interactions.
- Collaborate and Contribute: Partner with professionals in assistive and collaborative robotics. Share your knowledge, attend workshops on ontology-based standards, and consider contributing to IEEE's standardizing initiatives.
- Develop and Align Ontologies: Utilize ISO and other standards to craft comprehensive lifecycle ontologies. Work closely with domain experts to ensure accurate term interpretations and align your ontology with top-level structures.
- Stay Updated and Involved: Keep abreast of the latest in robotic ontologies and standards. Attend follow-up sessions and workshops, and be proactive in standardization and workshop participation. Regularly update and refine ontologies based on feedback and new insights.
- Promote Community Engagement: Encourage a broad understanding of ISO lifecycle as both a workflow and a semantic object. Organize or attend seminars to emphasize the significance of semantic interoperability in lifecycle assessments.

2.3.3 Session 3: From Foundational Ontologies to foundational models

The session featured Alessandro Oltramari, a Senior Research Scientist at BOSCH's Research and Technology Centre in Pittsburgh and an Industry Mentor at the Carnegie Bosch Institute. With a rich background in areas like neuro-symbolic reasoning for decision support, knowledge-based systems, learning algorithms, and cognitive architecture, Oltramari's expertise lies notably in developing and building ontologies. The decision to invite him was motivated by the project's challenge in connecting foundational and working ontologies with data. The session aimed to bridge this gap,

offering insights into the integration of various knowledge forms and their underlying technologies. Additionally, Oltramari discussed larger language models and introduced the audience to the realm of neuro-symbolic AI.

Insights of the session

Alessandro Oltramari, a Senior Research Scientist at BOSCH's Research and Technology Centre, discussed the intertwining of foundational ontologies with large language models in the modern AI landscape. He highlighted the rising importance of ontologies even as large language models dominate, illustrating with a project related to industry 4.0. Mentioning his ties with ISTC CNR, Trento Laboratory, and co-authorship of DOLCE, he further delved into BOSCH's human-machine collaboration research. Oltramari charted the shift from detailed ontologies to Knowledge Graphs and neural symbolic AI, emphasizing the merger of Knowledge Graph embeddings with neural models. Despite their potential, he pinpointed their limitations in robust reasoning. Throughout, he critically examined if large language models genuinely comprehend the world or merely imitate human linguistic patterns.

The full session is available here: https://www.youtube.com/watch?v=zb6Low83N7M

Impact, Feedback and recommended actions

- Importance of Foundational Ontologies: The relevance of foundational ontologies in the AI era should not be overlooked. As AI continues to evolve, researchers and ontologists should find synergies between traditional knowledge representation and emerging language models.
- Harmonization of Ontologies and AI: Industry professionals and researchers must explore ways to combine Knowledge Graph embeddings with neural models. The integration promises to improve AI capabilities across various tasks.
- Robust Reasoning Limitations: Current large language models have inherent limitations, especially in areas of robust reasoning. Research efforts should be channelled into rectifying these limitations, with a focus on temporal and common-sense reasoning.
- Emphasis on Grounding: Policy makers and standardization experts should prioritize research and development that aims to ground AI's understanding in real-world contexts, rather than just replicating human discourse patterns.
- Critical Evaluation: Before industry-wide adoption, large language models should be critically evaluated for their understanding capabilities. Blindly relying on them without understanding their limitations could lead to unintended consequences.
- Ethical and Practical Implications: As large language models continue to shape the AI landscape, policy makers should consider the ethical implications, while standardization experts need to set guidelines that ensure their responsible development and use.
- Continuous Learning and Updates: The AI and ontology community should stay updated with the latest publications and findings. This ensures the adoption of best practices and prevents redundancy in research efforts.
- Empirical Verification: Any claims or findings about improved performance or capabilities should be empirically verified, as was highlighted in the session.

2.3.4 Session 4: Ontology Portal and Validation

This session explored ontology methodologies and tools, with specific focus on ontology portal tool interoperability as well as ontology validation.

Moderator: Lan Yang (NUIG), Speakers:

- Hedi Karray (ENIT), Arkopaul Sarkar (ENIT) - Industry Portal and its future
- Clement Jonquet (LIRMM) - Portals, ontology adoption and the OntoPortal Alliance (Ontology Repositories and Semantic Artefact Catalogues with Entrepreneurial Technology)
- Holger Knublauch (Top Quadrant) - Ontology validation and tools
- Jinzhi Lu (BUAA) and Guoxin Wang (BIT) - Tool interoperability in MBSE
- Lan Yang (University of Galway) - Feedback on roadmap gaps/actions, using Vevox

Insights of the session

Clement Jonquet's talk delved into the advancements of the OntoPortal technology and its shift towards embracing the term "semantic artefact catalogue" - an umbrella term covering semantic resources such as ontologies, vocabularies, and terminologies. The speaker highlighted OntoPortal's function as a service that helps manage these resources. Central to the talk was the emphasis on making these semantic artefacts "fair" - Findable, Accessible, Interoperable, and Reusable. Such an approach is supported by the integration of a Fairness Evaluator tool. The talk also touched upon the inclusion of features to support SCOTS vocabularies and upcoming multilingual capabilities. The speaker brought attention to the community's growth, OntoPortal's evolution into an open-source project, and the vision behind the initiative. In conclusion, the context of the project within the European Open Science Cloud and its focus on metadata and ontologies were discussed.

Holger Knublauch talked about ontology validation, focusing specifically on SHACL (Shapes Constraint Language). SHACL, an official standard since 2017, has gone through contentious phases before becoming widely accepted. While the official standard is established, there is an emerging specification known as the advanced features of SHACL, which introduces innovative features for potential future versions. The speaker highlighted a vibrant community centered around SHACL, evident from active online discussions and a new group focusing on user interface tasks related to SHACL. Importantly, most graph databases now offer built-in support for SHACL, emphasizing its wide industrial applicability. The discussion then turned to the differences and overlaps between SHACL and traditional ontology-building tools, particularly OWL and RDF schema. SHACL differs in that it operates on closed world semantics, aligning it more closely with industry expectations and making it suitable for constraint checking. In contrast, OWL is utilized for inferencing. Yet, both languages share commonalities based on RDF and can express classes and instances. A unique aspect of SHACL is its extensibility, allowing users to introduce new constraint types. The talk concluded by showcasing practical SHACL examples in turtle source code and emphasizing SHACL's current standing as a robust ontology modelling tool for real-world applications.

Jinzhi Lu delivered a presentation on interoperability and model-based systems engineering (MBSE) in China. The main focus was on the challenge of integrating various models, representing different aspects of complex systems, into a unified and standardized format. The presenter emphasized the

significance of ontologies in systems engineering, referencing surveys that underscored their importance. Based on their research, they established an MBSE ontology, aiming to seamlessly integrate heterogeneous data and models within a system's lifecycle. This ontology framework, called GLPI, transforms MBSE models and can represent complex systems like aircraft or spacecraft. They further discussed the potential of mapping these models to knowledge graphs, leading to the creation of AI platforms that can provide cognitive services. A demonstration was provided where they integrated various models into an online platform, with a future vision to utilize these models for intelligent Q&A systems. The speaker concluded by highlighting their progress and future intentions to open source their transformers and develop more tools based on the GLPI ontology.

The full session is available here: https://www.youtube.com/watch?v=znfvJzORD3U

Impact, Feedback and recommended actions

Clement Jonquet on OntoPortal:

- **Impacts**:
  - Advancements in the OntoPortal technology highlight the broader shift in viewing ontologies, vocabularies, and terminologies under the umbrella of "semantic artefact catalogue".
  - The emphasis on making semantic resources "FAIR" (Findable, Accessible, Interoperable, and Reusable) will ensure a broader and more efficient utility for researchers, policy makers, and industrial key players.
  - The project's context within the European Open Science Cloud and its concentration on metadata and ontologies solidify its foundational role in the standardisation space.
- **Recommended Actions**:
  - Embrace the "FAIR" principles for semantic artefacts and make use of tools like the Fairness Evaluator.
  - Support and contribute to OntoPortal as it evolves into an open-source initiative, ensuring its growth and further development.

Holger Knublauch on SHACL:

- **Impacts**:
  - SHACL's evolution and acceptance is indicative of its robustness and utility, particularly given its alignment with industry expectations and its adaptability in terms of constraint checking.
  - With most graph databases offering built-in support for SHACL, it's evident that it holds significant industrial applicability.
  - The distinctions between SHACL and traditional ontology-building tools like OWL and RDF schema underscore the versatility and variety in the ontology space.
- **Recommended Actions**:

- Engage with and be a part of the vibrant SHACL community, particularly with the groups focusing on user interface tasks and online discussions.
- Explore SHACL's extensibility by possibly introducing new constraint types and integrating them in real-world applications.

Jinzhi Lu on Interoperability and MBSE in China:

- **Impacts**:
  - The introduction of the GLPI ontology framework stands to revolutionize the way different models of complex systems, such as aircraft and spacecraft, are integrated into a unified format.
  - The potential of mapping these models to knowledge graphs can lead to the creation of AI platforms, thus broadening the horizons of MBSE and enabling cognitive services.
- **Recommended Actions**:
  - Recognize the importance of ontologies in systems engineering and strive for the integration of heterogeneous data and models across system lifecycles.
  - Support the move to open-source model transformers based on the GLPI ontology and engage with initiatives that utilize these models for applications like intelligent Q&A systems.

2.3.5 Session 5: Tools and Methodologies

Moderator: Maria Poveda, Speakers:

- Claude Fauconnet (TotalEnergies) - SoulsLeSens
- Andrea Cimmino (UPM) - SHACL validation system
- Dermot Doyle (Dynaccurate) - Mapping
- Maria Poveda (UPM) - One-shot system, reference implementation

Insights of the session

Dermot Doyle emphasized the pivotal role of ontologies, taxonomies, and semantic layers in the modern information age. Despite coming from a business background, the speaker touched on the challenges and implications of managing vast amounts of data, particularly in the health and life sciences sectors. Dermot stressed the dynamic nature of "information about information" and how it constantly changes and expands. In this age of misinformation, the importance of authoritative primary sources and the "architecture of truth" was highlighted, with a call for robust systems that ensure data accuracy. He also suggested that tools and technologies to manage this growing semantic layer will become increasingly critical and that public sector investment in such infrastructure is paramount. They wrapped up by underlining the need for such technologies to lay the foundation for further AI development while ensuring societal benefits.

Claude Fauconnet Claude Fauconnet discussed the development of a tool aimed at enhancing data management. Driven by his interests in data, semantics, IT technologies, and philosophy, he observed the industry's difficulties with data understanding and management, especially due to a reliance on Excel and tabular formats. To address this, he championed the use of ontologies for data visualization. Claude and his team developed an open-source tool designed to represent data in graph structures and Java APIs. While the tool offers an innovative approach to data management, its adoption has faced resistance, especially from middle management accustomed to traditional data formats. Nevertheless, the team is expanding the tool's features and forming partnerships. They are also working on establishing a nonprofit to further promote the tool and offer it as an online service to a wider audience.

Andrea Cimino discussed the tool developed by their team, named Astrea. Astrea is designed to automatically generate SHACL shapes from input ontologies. With the proliferation of knowledge graphs and a myriad of ontologies defining their constraints, a significant challenge emerges: how to validate that the vast data aligns with its defining ontology. While manual generation of these shapes is tedious and prone to error, learning them solely from data might produce incorrect shapes. Astrea addresses this by generating SHACL shapes directly from ontologies using mappings her team devised. From their research, they developed 158 mappings to translate ontology patterns into SHACL restrictions, covering around 60% of possible SHACL shapes. Andrea highlighted that Astrea can be accessed as an online service, where users can input ontology URLs to generate corresponding SHACL shapes. The session concluded with potential enhancements for the tool, such as combining Astrea with data-driven shape learning methods and the possibility of round-trip mappings to verify ontology quality.

Impact

The three speeches converged on the central theme of the importance of ontologies and advanced data management in today's information-driven world, highlighting the ever-evolving nature of information and the challenges in managing large datasets, especially in specialized sectors like health and life sciences. There is a strong need for authoritative sources and robust data management systems, where public investment in such technologies is essential for AI growth and societal benefit. These speeches collectively underlined the importance of innovating data management and ontology tools, emphasizing their potential to streamline complex information landscapes and lay foundations for advanced AI systems.

Feedback and recommended actions

- Dermot Doyle's emphasis on the ever-evolving nature of information suggests a need for ontologists and researchers to remain at the forefront of ontological evolution and semantic layers.
- Claude Fauconnet's open-source tool highlights the utility of graph structures over traditional tabular formats. Adopting and experimenting with such tools can aid in visualizing and understanding complex data sets.

- Andrea Cimino's Astrea addresses data validation against its defining ontology. Delving deep into tools like Astrea can help in automatic generation of SHACL shapes, ensuring more accurate ontology constructions.
- Investing in Infrastructure for semantic layer management tools. Recognizing and funding the development of these technologies will be paramount for future advancements.
- Encourage data accuracy and setting regulations for using authoritative primary sources and robust data management systems to combat misinformation.
- Encouraging Open-Source Solutions: With the development of tools like the one presented by Claude Fauconnet, there's a clear advantage in graph-structured data representation. Promoting standards around such innovative solutions can drive broader industry adoption.

The full session is available here: https://www.youtube.com/watch?v=ZFrNrLZ8E0Y&t=1845s

2.3.6 Session 4: The Future of IOF

Boonserm Kulvatunyou, Dimitris Kiritsis, Barry Smith, and Jim Wilson convened provided a comprehensive overview and delve into the intricacies of the Industrial Ontology Foundry (IOF) and its broader implications in the realm of industrial ontologies. The discussions spanned the history, structure, and future vision of IOF, challenges in representing abstract entities within the Basic Formal Ontology, and the evolving state of the IOF in both current and anticipated scenarios.

Moderator: Dimitris Kiritsis (UiO)

Speakers:

- Serm Kulvatunyou
- Dimitris Kiritsis
- Barry Smith
- Jim Wilson

Insights of the sessions

Boonserm Kulvatunyou discussed the Industrial Ontology Foundry (IOF), providing insights into its background, formation, and recent activities. He touched on the IOF's origin, emphasizing its formation to address fragmented, incoherent industrial ontologies, especially in the engineering domain. IOF's primary goal is to develop a cohesive suite of ontologies for the entire manufacturing chain and provide a consistent structure and guidelines for community-led ontology development. A significant milestone was the release of IOF core version one in February 2023, accompanied by provisional supply chain and maintenance ontologies.

Boonserm introduced the main organs of the IOF:

- Governance Board: Manages administrative aspects, including laws and behaviour codes.
- Technical Oversight Board: Supervises the technical content of IOF, ensuring the content's quality and relevance.
- Working Groups: Primarily concerned with ontology development, working closely on specific segments or topics.

- Task Groups: Focus on technical specifications, ensuring infrastructure support for ontology development and publication.

As well as its three main "products":

- Best Practices: These include technical principles documents, IRI specifications, and governance workflows detailing the ontology development process.
- Infrastructure: This covers the technical backbone, including the GitHub repository, wiki pages, JIRA issue management, a validation engine, and publication automation tools.
- Reference Ontologies: Core ontologies developed and maintained by IOF to serve various industrial domains. The IOF core and related annotations and axioms form a vital part of this product.

The IOF core, highly axiomatized, has been piloted in industries like biopharmaceuticals, demonstrating its adaptability and relevance. Kulvatunyou also mentioned the transition towards a paid membership model and the establishment of industry council structures to cater to specific industrial extensions.

Dimitris Kiritsis offered a more detailed overview of the IOF Technical Oversight Board, where the IOF developments and the work done in the working groups and task groups are approved and discussed with the stakeholders. The Board meets every two weeks and ensures that there are no problems, and that the IOF principles and guidelines are respected

Barry Smith discussed the intricacies and challenges of representing abstract entities within the Basic Formal Ontology (BFO), particularly in the context of organizational structures and roles. He highlighted the limitations of BFO in articulating abstract relationships, like software, and mentioned the initiative to develop ontologies of mathematics and physics as extensions of BFO. The central theme of his talk was understanding human relationships in organizations, particularly authority relationships. He delved into the importance of roles and the concept of authority, emphasizing that functional organizations require authority structures to ensure coordinated activities. Dr Smith presented organizational charts, or "organigrams," as key tools for understanding the ontology of organizations, discussing their different types and complexities. He further elaborated on employment contracts as foundational elements of organizational authority in commercial settings. The session concluded by touching upon the challenge of representing normative relations within BFO and the need for a more nuanced representation of concepts like authority.

Jim Wilson's presentation delved into the current state and desired future state of IOF. Currently, IOF enjoys good name recognition and has numerous expert participants worldwide. The organization has released a core ontology and some domain-specific ones. They have a robust ontology development process and have many non-financial resources like Confluence, JIRA, Smartsheet, and GitHub. However, challenges include the lack of administrative support, especially post-COVID, and the need for better marketing, communication, and member onboarding processes. Some domains remain inactive and funding is an issue. The future vision for IOF entails being well-funded by the industry, hiring part-time and full-time staff, streamlining the onboarding process for members and experts, and having their work recognized more in academia and implemented in industries. They aim for better organizational management, a clearer strategic plan, a yearly business plan, marketing

strategies, and exploring funding opportunities. There's also an interest in establishing a legal presence in Europe to leverage potential EU funding opportunities and pursuing collaborations with organizations like Industry Commons.

The full session is available here: https://www.youtube.com/watch?v=tGw_zqEEVpU

Impact, Feedback and recommended actions

From the sessions presented during the workshop, several actionable takeaways emerge for stakeholders involved in the Industrial Ontology Foundry (IOF) and its affiliated domains. Firstly, to address the fragmentation in industrial ontologies, especially in engineering, there's an urgent need to rally around IOF's vision of developing a cohesive suite of ontologies for the entire manufacturing chain. Stakeholders should actively support and contribute to the IOF's core products, emphasizing Best Practices, Infrastructure, and Reference Ontologies. The adaptability and relevance of the IOF core, as seen in biopharmaceutical industries, suggests a broader application across other sectors. Additionally, addressing the challenges outlined by Jim Wilson, stakeholders should explore collaborative opportunities for better administrative support, enhanced communication, and diversified funding, especially from European avenues. Lastly, given the challenges in representing abstract entities in BFO, as noted by Barry Smith, the community should invest in refining the ontology's capability to articulate complex relationships, particularly concerning organizational authority and roles.

2.4 Day 4: Innovation (16 June 2023)

During the last day of the OntoCommons workshop, moderated by Michela Magas (ICF), the attendees delved into the transition from theoretical discussions to tangible real-world applications. After a week of hands-on prototyping (see Figure 3) with genuine data and use cases, the emphasis was on understanding the real-world impact of the OntoCommons ecosystem (OCES) on innovation and optimization in industrial applications. A key highlight was the unveiling of a legal ontology for intellectual property, developed in the scope of a project around manufacturing value networks, which involves 31 partners from European industry. This ontology was designed to streamline the tracking of intellectual property and industrial agreements within manufacturing value networks.

Agenda for the Innovative Prototyping session

Start	End	Duration	Date	Title of the session
TBC	TBC	30'	13 June 2023	Linked Open Terms (LOT) methodology and ontology engineering recipe from OntoCommons
16:15	15:15	60'	13 June 2023	Ontology requirement analysis using ORSD templates
09:30	10:00	30'	14 June 2023	Reusing existing ontology – introduction to top-level, middle-level, and domain-specific reference ontologies
10:00	10:30	30'	14 June 2023	How to find terms and select the most suitable ontologies to reuse (introduction to Industryportal)
TBC	TBC	TBC	TBC	How to map ontologies using bridge concepts
15:00	16:00	60'	14 June 2023	Introduction to SousLeSens – an online graph-based visualizer and editor for ontology development
16:15	17:00	45'	14 June 2023	Best practices for ontology development and technical principles
17:00	17:45	45'	14 June 2023	Data modelling techniques, including knowledge graph creation and update, using SPARQL query or RML (introduction to KGCreator)
14:00	15:00	60'	15 June 2023	How to publish ontology ensuring FAIR metadata and documentation in Industryportal
15:30	16:15	45'	15 June 2023	How to test your ontology and ensure its quality
16:15	16:45	30'	15 June 2023	Best practices for maintaining ontology for long-term sustainability
12 June - 15 June 2023				Prototyping of ontology applications by IKEA and Basajaun teams (OntoCommons Demonstrators)

Figure 3 - Agenda for the OntoCommons Innovative Prototyping session

Speakers:

- Tervel Bobev (KU Leuven),
- Andreas Rudenå, Basajaun use case
- Katariina Kari, IKEA use case
- Lan Yang, NUIG Galway
- Claude Fauconnet, SousLeSens

Presentations from students training:

- Nasreddin Bouchemel: Supporting complex intra- and cross ontology mapping in IndustryPortal
- Emna Lakani: Empowering Insights: KGCreator - Redefining Data Mapping for Semantic Excellence
- Amine Karoui: Supporting axioms and reasoning in SousLeSens

Additionally, a training session specific on SousLeSens was carried out by Claud Fauconnet during the Prototyping Lab sessions, on Day 2. The training session as part of the Prototyping Lab is available here: https://www.youtube.com/watch?v=aLgej0ZYTCo

2.4.1 Challenges in IP and Industry: Digesting a Datafied World with a Legal Ontology

Tervel Bobev, research fellow at KU Leuven, delved into the evolving relationship between data governance and intellectual property, discussing the shift in the European Union's perspective on the matter. He emphasized how data has evolved from conventional intellectual property norms to address the nuanced challenges of today's digital age. This includes understanding the European Union's recent initiatives like the "Digital Decade", which seeks to bolster the adoption of advanced

digital services such as AI and cloud computing. An integral part of the discussion was the EU's Data Governance Act, outlining the significant role of data intermediaries in a digitized economy. The act puts forth strict regulations to ensure these intermediaries' trustworthiness, focusing on aspects like operational transparency, neutrality, data security, and ensuring fair terms of service.

Additionally, Dr Bobev introduced the upcoming DATA Act, still in its developmental phase, which aims to regulate connected products, mainly IoT devices. The act also seeks to define key players in the data ecosystem while emphasizing the importance of data interoperability and smart contracts. Amidst these legal transformations, a recurring challenge is the complexity of intellectual property rights and data licensing. To address this, the EU is pioneering the development of an ontology—a structured framework for organizing and interpreting information. This ontology is particularly pivotal for the realm of intellectual property rights and data licensing. It has the objective to systematically map out the vast intricacies of IP rights, from the foundational elements of patent applications to the broader spectrum of actors within the IP ecosystem. Furthermore, the ontology's development plans to explore deeper into best practices, refine definitions of IP rights, and collaborate with partners like the Ready Project to enhance data interoperability across various domains.

The full session is available here: https://www.youtube.com/watch?v=qd5yrQO_nLM

Impact, Feedback and recommended actions

From the insightful session by Tervel Bobev, several proactive measures emerge as essential for businesses and individuals navigating this intricate domain. Recommended actions include:

- Monitoring the progress of the EU's DATA Act and its implications for connected products, particularly IoT devices.
- Organizations should invest in understanding the role of data intermediaries and the stipulations of the Data Governance Act to ensure compliance.
- Businesses should prioritize achieving interoperability in their digital operations to facilitate seamless data exchanges and collaborations.
- Periodically reviewing and updating data licensing agreements to reflect the evolving digital landscape and legal requirements.
- Engaging in discussions and debates on the challenges and solutions related to IP tracking, ensuring that solutions are robust and future-proof.
- IP instruments should focus not specifically on defining data itself, but rather attaching properties and qualities to it. Consider the implementation of sandboxing or safe harbour practices for research and other purposes to better understand and address data biases and quality issues. These practices can help in thoroughly understanding datasets, overcoming inherent challenges related to biases, and not just superficially complying with legal requirements.

2.4.2 OntoCommons Innovation Day Results from the OntoCommons Prototyping Lab

This session showcased several breakthroughs resulting from the work produced during the OntoCommons Innovative Prototyping Lab. Some of the work showcased was directly connected to the keynote talk (Session 2.4.1).

2.4.2.1 Innovation results from the OntoCommons Basajaun use case

Andreas Rudenå first demonstrated work that ported the OntoCommons EcoSystem (OCES) to industrial application use cases in the RE4DY Innovation Action (see 2.4.1). The resulting prototypes using data from the manufacturing flow of polycarbonate sheets, demonstrated vertical integration from data instances loaded live at application level, via domain ontologies for supply chains and for IP, all the way to BFO top reference documentation. This work inspired an innovative approach to the OntoCommons demonstrator Basajaun resulting in a prototypie developed during the week. He highlighted the unique collaborative setting where coding was intertwined with expert insights on ontology, emphasizing the benefits of such an integrative approach. The Basajaun project aims to digitalize the wood industry construction supply chains, enhancing environmental responsibility by tracing data flows between supply chain actors. This aids in monitoring various environmental indicators, like CO2 targets. Andreas showcased vertical integration directly from a CAD model of an actual building in France, illustrating its data connections to BIM and supply chain ontologies, and further connections to the BFO top level ontology. A distinct aspect of his presentation was the visualization of this data, depicting material batches, their semantic connections, and their integration into various ontologies. The seminar further introduced Woodlaunch, a live-streaming platform for node-based and semantic data designed for those unfamiliar with data management. This platform facilitates real-time collaboration and consensus on data-related terminology, aided by visualization, to ensure data integrity across domains in the wood industry value chain.

2.4.2.1 Innovation results from the OntoCommons IKEA use case

Katariina Kari, Lead Ontologies, IKEA Inter-Global Systems and her team including **Aparna Ashok**, IKEA's Digital Ethicist, and Tane Piper, IKEA's Software Engineering Leader, demonstrated breakthrough results from one week of hands-on prototyping in the OntoCommons Horizontal Workshops. The IKEA team was motivated by the need for ethical handling of digital data, and the need to replace weak signals with strong signals when interacting with customers. The team engaged in creating a front end of the live IKEA online catalogue and writing a new API that would connect anonymous customer requirements to the recently mapped IKEA Knowledge Graph. The resulting innovation solved ethics issues for customers but also resulted in a major optimisation breakthroughs, including:

- No cookies, no intrusion of privacy, no conjecture of what the customer wants
- The additional features that would previously take months were added in three days, with notable labour savings
- Substantially improved time to market allows for quick iterations and improvements

- No data migration, no training of large data sets over periods of months, no expense of running statistical models hosted in the cloud
- Substantial reduction of data carbon footprint

Aparna Ashok elaborated on IKEA's approach to using knowledge graphs to personalize shopping experiences while ensuring customers' privacy. The focus was on navigating a vast product range and offering personalized recommendations without compromising users' data. Aparna also touched upon the challenges posed by EU regulations like the Digital Services Act and the AI liability directive. The team's objective was to create a prototype integrating knowledge graphs and session data to improve user experiences without violating their privacy. Dr Ashok underscored the importance of transparency in their new prototype. The goal is to ensure that customer data is used openly, and customers are made aware of how their data influences product recommendations. This not only keeps profiling transparent but also leverages the strength of the knowledge graph, showcasing how customer inputs semantically connect to product suggestions.

Tane Piper demonstrated a Chrome extension they developed for Ikea.com, showing how customers could receive personalized product recommendations based on minimal input, ensuring privacy. The data used for this project is live and feeds from their core graph DB. It is worth noticing that while some customer questions, like those about living conditions, might be sensitive, answering them can enhance product relevance.

Katarina Kaari chimed in on the industry standards for data storage on sites. Using her experience at Zalando as a reference, she highlighted the traditional method of storing massive data sets in cookies and having data scientists find "weak signals" from them. In contrast, their new approach aims to capture strong, direct signals from customers. Drawing a parallel with physical stores, she expressed the discomfort of having someone with complete knowledge about a customer's preferences. The idea is that just as one wouldn't appreciate a stalker-like salesperson in a physical store, the same principle should apply online. The team's new strategy, thus, promotes direct and transparent interactions.

2.4.2.1 Prototyping using SousLeSens

Lan Yang and **Claude Fauconnet** engaged in an unplanned prototyping activity using SousLeSens, one tangible impact of the workshop that led to this collaborative development. The presentation focused on Lan Yang's personal experience with SousLeSens, emphasizing its value in providing visualized engineering support throughout the ontology lifecycle. As a company ontologist, Dr Yang noted that while SousLeSens caters primarily to those well-versed in ontologies, it also offers value from a data management perspective. They touched on the iterative nature of the ontology lifecycle, underscoring the importance of regular updates and maintenance. Discussing the ontology development process, it was pointed out the significance of the implementation phase, which encompasses conceptualization, encoding, reuse, and evaluation. Most ontology development initiatives begin from one of three sources: existing data sets, conceptual models, or pre-existing ontologies. SousLeSens has the ability to support all three starting points, and particularly for its visualization capabilities.

2.4.2.1 Student results using SousLeSens

Nasreddin Bouchemel presented his work on supporting complex intra and cross ontology mapping in Industry Portal, a platform for hosting and curating ontologies with many features, including the mapping feature. Mapping plays a vital role in order to establish meaningful relationships between ontologies. One of the outcomes of the work was the possibility to infer some complex relationships between classes and enrich the mapping to add more data.

Emna Lakani offered empowering Insights about KGCreator, a tool which has the potential of redefining Data Mapping for Semantic Excellence. The tool is part of SousLesensVocables (SLSV), it has been developed to simplify the process of data mapping and unlock the potential of semantic web technologies, empowering users to effortlessly transform their data into a more meaningful format. It also plays a vital role in constructing comprehensive knowledge graphs that facilitate deeper insights by mapping data to RDF triples. The presentation, in particular, was focused on the standardisation of data mapping using the RDF Mapping Language within KGCreator.

Amine Karoui talked about supporting axioms and reasoning in SousLeSens: Lineage is one of the different tools integrated with SousLesensVocables (SLSV), developed to Visualise, Edit and manage RDF Graph. The presentation showed some features of Lineage.

The full session is available here: https://www.youtube.com/watch?v=C4kDKiHEP0k

Impact, Feedback and recommended actions

- Encourage vertical integration of reference documentation from application level data instances via the relevant domain ontologies all the way to top-level reference.
- Emphasize research into digital ethics solutions, particularly focusing on the ethical handling of personal data. Investigate ways to combine knowledge graphs with session data, ensuring user experience enhancement without privacy breaches. Transparency should remain paramount.
- Consider Knowledge Graphs as technology solutions for managing big data for substantial optimisation of market deployment and savings on data carbon footprint.
- Considering SousLeSens for its support capabilities, especially its visualization features. Company ontologists could undergo training or sessions to leverage the full potential of SousLeSens, keeping in mind its iterative nature.
- Given the unexpected collaborative prototyping between Lan Yang and Claude Fauconnet, promote more unstructured collaboration opportunities in future workshops. Such collaborations may lead to unexpected yet valuable outcomes.

2.5 Posters Exhibition

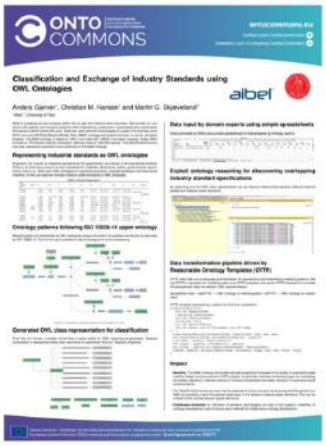
On the first day of the 2nd OntoCommons workshop, 28 posters were presented. These posters had been selected through an open call managed by Trust-IT. A dedicated networking and poster presentation session at the University of Oslo featured the chosen posters, each accompanied by a short description. All the chosen posters and their short descriptions are available below:

2.5.1 BLM Group – Ontology based Maintenance (Francesco Compagno CNR)

Description: Adige S.p.A., part of the enterprise group BLMGroup, manufactures laser-cutting machines. These machines are complex, their maintenance, in particular, requires advanced expertise. With the goal of reorganizing the knowledge management strategy of maintenance expertise, the company investigates semantic technologies in the OntoCommons project with the collaboration of the Laboratory for Applied Ontology (CNR-ISTC). The expected results are, among others, a decrease in the time required to solve previously encountered problems and an increment in the information that can be extracted from maintenance records. The resulting efforts produced ontologies containing domain terms, as well as methodological guidelines for functional and structural modeling of engineering systems, and failure analysis

DOI: https://doi.org/10.5281/zenodo.8316072

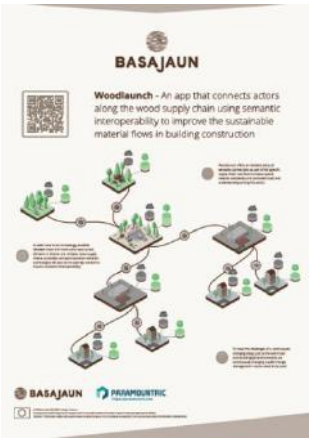
2.5.2 Aibel: Classification and Exchange of Industry Standards using OWL Ontologies (Anders Gjerver, Aibel)



Description: Aibel is a leading service company within the oil, gas and offshore wind industries. The company provides its customers with optimal and innovative solutions within engineering, construction, modifications and maintenance throughout a plant's entire life cycle. Aibel has used semantic technologies to support its business since 2013, and since 2015 the Material Master Data (MMD) ontology and system has been in use for all capital projects. The MMD ontology is based on OWL 2 and uses ISO 15926-14 as upper ontology. Today, MMD consists of 370 domain-specific ontologies, defining a total of 2000.000 classes. The Aibel use case represents a potential future extension of the MMD ontology

DOI: https://doi.org/10.5281/zenodo.8316142

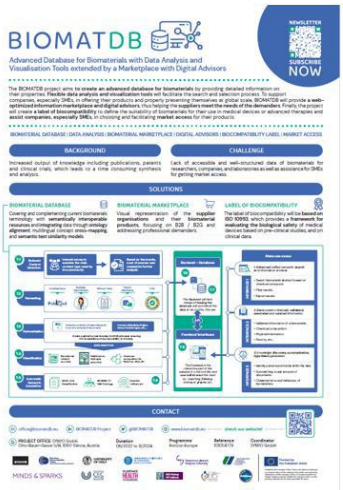
2.5.3 Basajaun Woodlaunch (Andreas Rudenå, Paramountric)



Description: The Basajaun project is building the Woodlaunch app, which connects actors along the wood supply chain using semantic interoperability to improve the sustainable materials flows in building construction.

DOI: https://doi.org/10.5281/zenodo.8318029

2.5.4 BiomatDB: Advanced Database for Biomaterials with Data Analysis and Visualisation Tools extended by a Marketplace with Digital Advisors (Celine Rabé, SYNYO GmbH)



Description: The BIOMATDB project aims to create an advanced database for biomaterials by providing detailed information on their properties. Flexible data analysis and visualization tools will facilitate the search and selection process. To support companies, especially SMEs, in offering their products and properly presenting themselves at global scale, BIOMATDB will provide a weboptimised information marketplace and digital advisors, thus helping the suppliers meet the needs of the demanders. Finally, the project will create a label of biocompatibility to define the suitability of biomaterials for their use in medical devices or advanced therapies and assist companies, especially SMEs, in choosing and facilitating market access for their products.

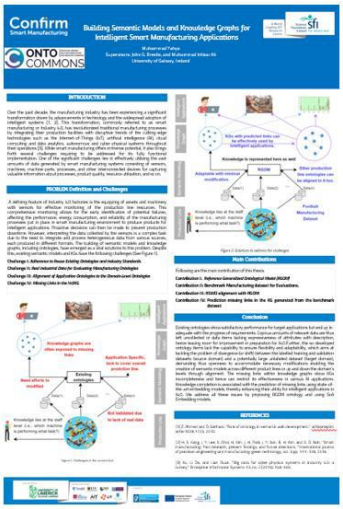
DOI: https://doi.org/10.5281/zenodo.8318108

2.5.5 CHAMEO: Characterisation Methodology Ontology (Pierluigi Del Nostro, Goldbeck Consulting Group)

Description: CHAMEO aims to create a common framework for the development of technique-specific ontologies.

DOI: https://doi.org/10.5281/zenodo.8318142

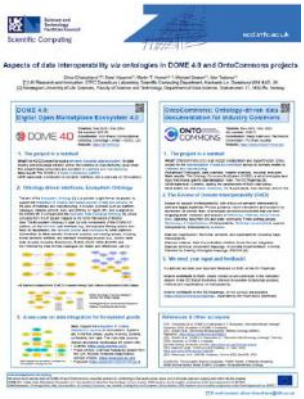
2.5.6 Confirm: Building Semantic Models and Knowledge Graphs for Intelligent Smart Manufacturing Applications (Muhammad Yahya, University of Galway)



Description: A defining feature of Industry 4.0 factories is the equipping of assets and machinery with sensors for effective monitoring of the production line resources. This comprehensive monitoring allows for the early identification of potential failures, affecting the performance, energy consumption, and reliability of the manufacturing processes put in place in smart manufacturing environment to produce products for intelligent applications. Proactive decisions can then be made to prevent production downtime. However, interpreting the data collected by the sensors is a complex task due to the need to integrate and process heterogeneous data from various sources, each produced in different formats. The building of semantic models and knowledge graphs, including ontologies, have emerged as a vital solution to this problem.

DOI: https://doi.org/10.5281/zenodo.8318169

2.5.7 Aspects of data interoperability via ontologies in DOME4.0 and OntoCommons projects (Silvia Chiacchiera: UK Research and Innovation)



Description: The aim of the Ecosystem Ontology is to provide a light formal vocabulary to support the integration of multiple web-based sources of data and services, in the area of materials and manufacturing. It includes concepts such as: platform, catalogue, dataset, service, topic, and offering, and is aligned to the EMMO. It complements the Semantic Data Exchange Ontology, where concepts from DCAT are mapped to the richer framework of EMMO. The Ecosystem Ontology is used by core components of the DOME 4.0 platform, as the front-end user interface (e.g., the available filtering options and fields for registration), the semantic broker, and connectors to other platforms. Whenever possible, preexisting assets, including formal semantic artefacts and standard knowledge sources (e.g., books) have been re used, including: EuroSciVoc , RoMM , DCAT, MSM, EVMPO and the FAIR sharing Data formats catalogue.

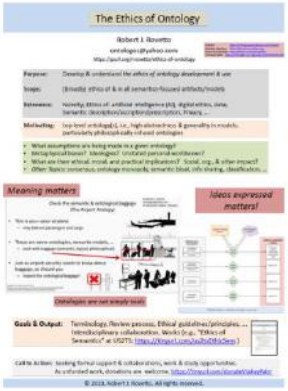
DOI: https://doi.org/10.5281/zenodo.8318196

2.5.8 EMMO's Theoretical Foundations (Francesco Zaccarini, University of Bologna)

Description: EMMO, the Elementary Multiperspective Material Ontology, is a foundational ontology expression of the common tenets and the general worldview at the core of applied sciences. It has been developed with the intent of providing a standard representational framework for materials modeling knowledge, while retaining a level of generality which makes it capable of being employed in any context to good results. EMMO is currently being formalized in First Order Logic with identity and W3C's OWL 2 DL; a Mereo-Causal theory was developed specifically for the ontology

DOI: https://doi.org/10.5281/zenodo.8318236

2.5.9 The Ethics of Ontologies (Robert Rovetto, University of Maryland)



Description: The main of this poster is develop and understand the ethics of ontology development in all semantics-focused artifacts and models.

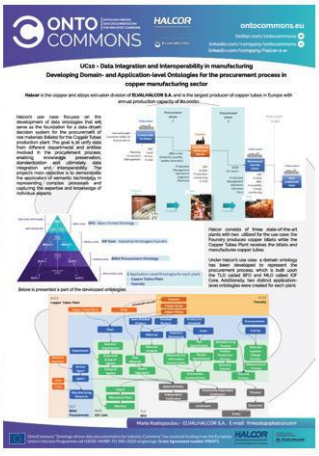
DOI: https://doi.org/10.5281/zenodo.8318243

2.5.10 Feedstock Quality Assurance (Janne Haack, Fraunhofer)

Description: Mixing different components is optimal performance of the final products. This process step is crucial for process engineering across various industries, ensuring homogeneity, consistency, and such as metal injection moulding (MIM), a manufacturing process that combines the advantages of plastic injection moulding and powder metallurgy to produce complex metal parts. Ontologies can capture domain-specific knowledge about the mixing process, including parameters, materials, and equipment. By integrating real-time data and process models, ontologies can assist in optimizing mixing conditions, ensuring consistent feedstock quality, and enabling real-time process control.

DOI: https://doi.org/10.5281/zenodo.8318270

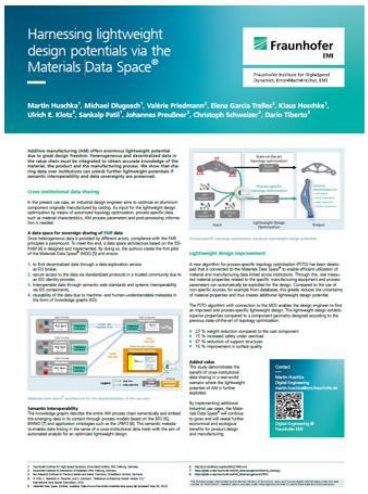
2.5.11 HALCOR: Data Integration and Interoperability in Manufacturing (Maria Kostopoulou, HALCOR)



Description: Halcor's use case focuses on the development of data ontologies that will serve as the foundation for a data-driven decision system for the procurement of raw materials (billets) for the Copper Tubes production plant. The goal is to unify data from different departments and entities involved in the procurement process, enabling knowledge preservation, standardization and ultimately, data integration and interoperability. The project's main objective is to demonstrate the application of semantic technology in representing complex processes and capturing the expertise and knowledge of individual experts.

DOI: https://doi.org/10.5281/zenodo.8318295

2.5.12 Harnessing lightweight design potentials via the Materials Data Space (Martin Huschka, Fraunhofer)



Description: Additive manufacturing (AM) offers enormous lightweight potential due to great design freedom. Heterogeneous and decentralised data in the value chain must be integrated to obtain accurate knowledge of the material, the product and the manufacturing process. This use case shows that sharing data over institutions can unlock further lightweight potentials if semantic interoperability and data sovereignty are preserved.

DOI: https://doi.org/10.5281/zenodo.8318309

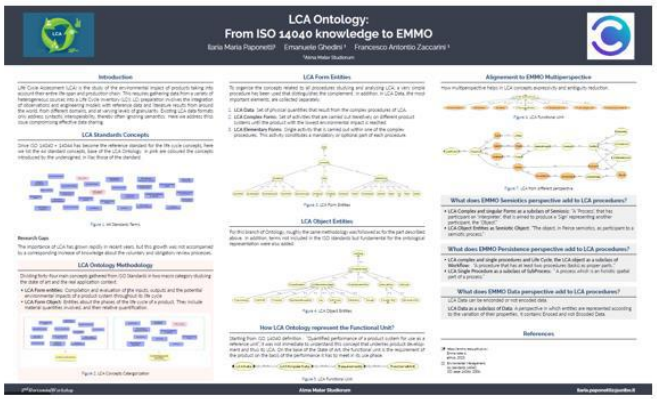
2.5.13 IRES: Nano-integrity in 3D printing (Vanessa Lislevand and Dimitris Karasavvas, IRES)

Description: IRES develops a series of filed measurements to characterize airborne particle number nitrationation (PNC) from Additive Manufacturing (AM) activities. Its goal is to develop an ontology describing the domain expertise involved and create a triple store databased based on the developed ontology with the data collected during the use case

DOI: https://doi.org/10.5281/zenodo.8318320

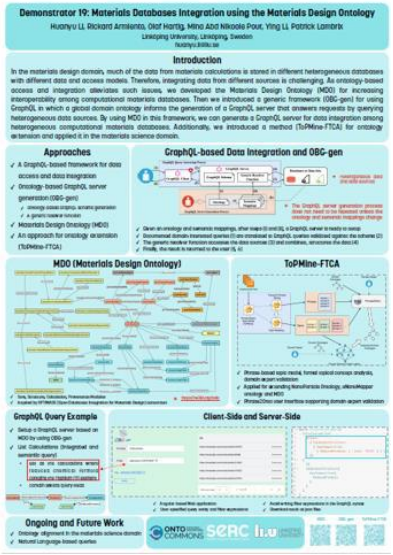
2.5.14 LCA Ontology: from ISO 14040 knowledge to EMMO (Ilaria Maria Paponetti, University of Bologna)

Description: Life Cycle Assessment (LCA) is the study of the environmental impact of products taking into account their entire life-span and production chain. This requires gathering data from a variety of heterogeneous sources into a Life Cycle Inventory (LCI). LCI preparation involves the integration of observations and engineering models with reference data and literature results from around the world, from different domains, and at varying levels of granularity. Existing LCA data formats only address syntactic interoperability, thereby often ignoring semantics. The LCA Ontology Methodology aims to overcome this issue.



DOI: https://doi.org/10.5281/zenodo.8318337

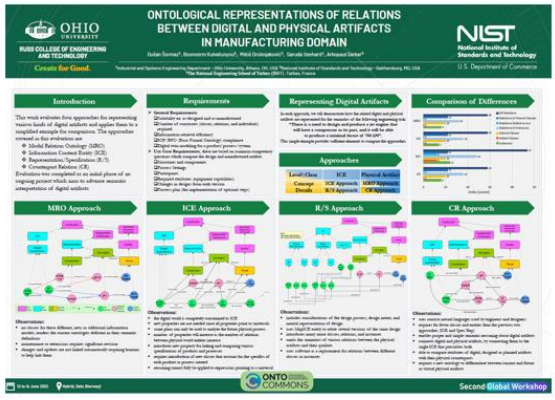
2.5.15 Materials Databases Integration using the Materials Design Ontology (Huanyu Li, Linköping University)



Description: In the materials design domain, much of the data from materials calculations is stored in different heterogeneous databases with different data and access models. Therefore, integrating data from different sources is challenging. As ontology-based access and integration alleviate such issues, we developed the Materials Design Ontology (MDO) for increasing interoperability among computational materials databases. Then, the team introduced a generic framework (OBG-gen) for using GraphQL in which a global domain ontology informs the generation of a GraphQL server that answers requests by querying heterogeneous data sources. By using MDO in this framework, it is possible to generate a GraphQL server for data integration among heterogeneous computational materials databases. Additionally, the team introduced a method (ToPMine-FTCA) for ontology extension and applied it in the materials science domain.

DOI: https://doi.org/10.5281/zenodo.8318360

2.5.16 Ontological Representations of Relations Between Digital and Physical Artifacts in Manufacturing Domain (Dušan Šormaz, Ohio University)



Description: The poster evaluated four approaches for representing various kinds of digital artifacts and applies them to a simplified example for comparison. The approaches covered in this evaluation are:

- ❖ Modal Relation Ontology (MRO)
- ❖ Information Content Entity (ICE)
- ❖ Representation/Specification (R/S)
- ❖ Counterpart Relation (CR)

Evaluation was completed as an initial phase of an ongoing project which aims to advance semantic interpretation of digital artifacts

DOI: https://doi.org/10.5281/zenodo.8318375

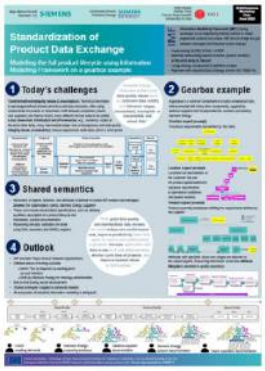
2.5.17 OAS – Ontology based yard management (Sebastian Scholze, ATB Bremen)

Description: This use case aims to improve the automation of yard management. The demonstrator, within OntoCommons, aims at improving effectiveness and responsiveness of decision0making in logistics control systems (yard management) based on data sharing built around data streams:

- Semantically describe the data streaming from yard management by dedicated PSS ontology.
- Ontology should support standardisation of yard management services; yard sites do differ from each other leading to very individual solution for each site.
- Defining rules for configuration and scheduling of yard system using ontology.

DOI: https://doi.org/10.5281/zenodo.8318398

2.5.18 Siemens Standardisation of Product Data Exchange (Maja Milicic Brandt, Siemens)



Description: This use case shares semantics of objects, relations, and attributes is defined in shared IMF models and ontologies, between the stakeholders: clients, Siemens Energy, suppliers. Thsee also include standardized specifications, such as attribute qualifiers, description of a product lifecycle and milestones, solution documentation. Reasoning and data validation are done using OWL reasoners and SHACL engines.

DOI: https://doi.org/10.5281/zenodo.8318402

2.5.19 SousLeSensVocables (Claude Fauconnet, Ontologist)

Description: SousLeSens Vocables is an extensible platform with tools designed to visually manipulate, compare, create and enrich OWL ontologies and knowledge graphs. It is under MIT license.

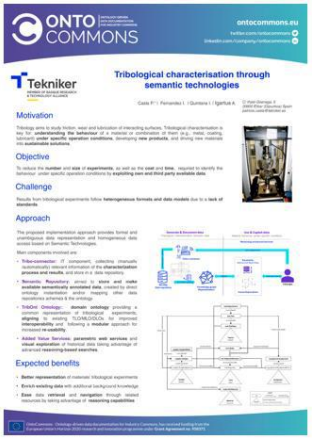
DOI: https://doi.org/10.5281/zenodo.8318414

2.5.20 A Space Industry Ontology Suite (Robert Rovetto, University of Maryland)

Description: This use case develops a set of ontologies (and related systems) for space industry: astronautics and astronomy related, with conceptual, philosophical and formal ontological exploration: spatiality and spatio-temporality, causality, discipline-specific questions. It develops top-level and mid-level space domain reference models.

DOI: https://doi.org/10.5281/zenodo.8318431

2.5.21 Tekniker: Tribological characterisation through semantic technologies (Patricia Casla, Tekniker)



Description: This use case aims to reduce the number and size of experiments, as well as the cost and time, required to identify the behaviour under specific operation conditions by exploiting own- and third-party available data. Results from tribological experiments follow heterogeneous formats and data models due to a lack of standards. The proposed implementation approach provides formal and unambiguous data representation and homogeneous data access based on Semantic Technologies. The components involved are: Tribo-connector, Semantic Repository, TribOnt Ontology, Added Value Services.

DOI: https://doi.org/10.5281/zenodo.8318438

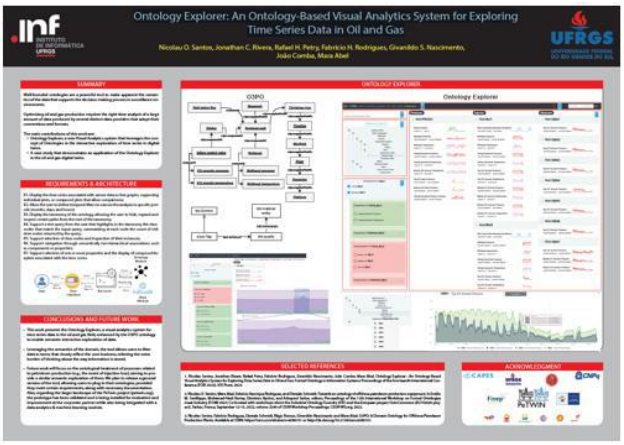
2.5.22 *Solution for Soilless Culture Nutrient (Edison Pignaton de Freitas and Pedro Henrique Morgan Pereira: UFRGS)*

Description: The use case aims to semantically represent heterogeneous IoT devices using unified IIoT ontology, based on well-established ontologies, in order to mitigate interoperability problems in industrial applications (data interoperability and interconnectivity).

DOI: https://doi.org/10.5281/zenodo.8318446

2.5.23 *Ontology Explorer: An Ontology-Based Visual Analytics System for Exploring Time Series Data in Oil and Gas (Nicolau Santos, UFRGS)*

Description: Well-founded ontologies are a powerful tool to make apparent the semantics of the data that supports the decision-making process in surveillance environments.



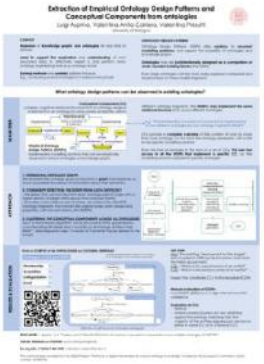
Optimising oil and gas production requires the right-time analysis of a large amount of data produced by several distinct data providers that adopt their conventions and formats.

The main contributions of this work are:

- Ontology Explorer, a new Visual Analytics system that leverages the concept of Ontologies in the interactive exploration of time series in digital twins.
- A case study that demonstrates an application of the Ontology Explorer in the oil and gas digital twins

DOI: https://doi.org/10.5281/zenodo.8318466

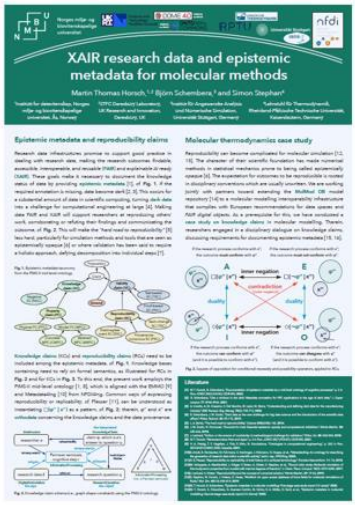
2.5.24 Extraction of Empirical Ontology Design Patterns (Luigi Asprino, University of Bologna)



Description: Ontology Design Patterns (ODPs) offer solutions to recurrent modelling problems, and support the reusability of ontologies and knowledge graphs. Ontologies may be (un)intentionally designed as a composition of small, reusable building blocks (the ODPs), thanks to which even large ontologies can be more easily explored, compared and reused based on these smaller fragments.

DOI: https://doi.org/10.5281/zenodo.8318478

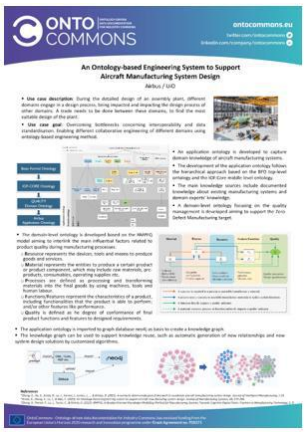
XAIR research data and epistemic metadata for molecular methods (Martin Thomas Horsch, NMBU)



Description: Research data infrastructures promise to support good practice in dealing with research data, making the research outcomes findable, accessible, interoperable, and reusable (FAIR) and explainable AI ready (XAIR). These goals make it necessary to document the knowledge status of data by providing epistemic metadata. If the required annotation is missing, data become dark. This occurs for a substantial amount of data in scientific computing, turning dark data into a challenge for computational engineering at large. Making data FAIR and XAIR will support researchers at reproducing others' work, corroborating or refuting their findings and communicating the outcome.

DOI: https://doi.org/10.5281/zenodo.8318493

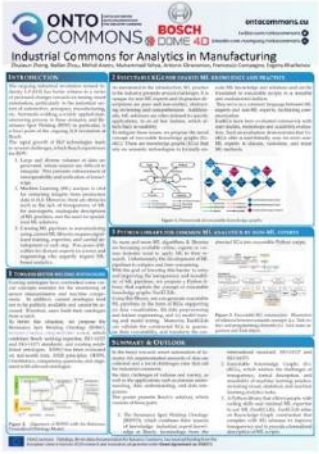
2.5.25 An Ontology based Engineering System to Support Aircraft Manufacturing System Design (Rebecca Arista, Airbus)



Description: The use case aims to overcome bottlenecks concerning interoperability and data standardisation. It aims to enable different collaborative engineering of different domains using an ontology-based engineering method.

DOI: https://doi.org/10.5281/zenodo.8318636

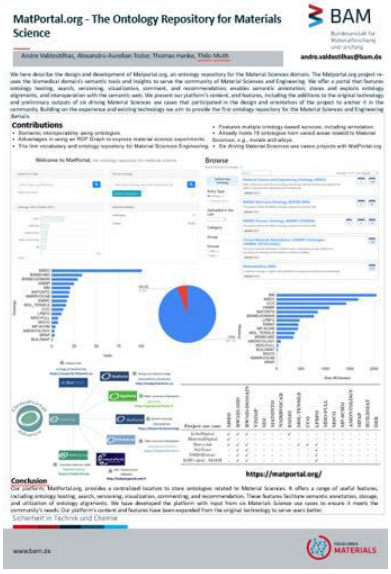
2.5.26 BOSCH: Industrial Commons for Analytics in Manufacturing (Evgeny Kharlamov, BOSCH)



Description: Existing ontologies have overlooked some crucial concepts essential for the monitoring of sensor measurements and machine components. In addition, current ontologies tend not to be publicly available and cannot be accessed. Therefore, users build their ontologies from scratch. To better this situation, the BOSCH team proposes the Resistance Spot Welding Ontology which combines Bosch welding expertise, ISO-14327 and ISO-14373 standards; and existing established ontologies. RSWO has been evaluatedon real-world data, FAIR principles, OOPS!, OntoMetrics, competency questions, and alignment with relevant ontologies.

DOI: https://doi.org/10.5281/zenodo.8318517

2.5.27 MatPortal.org: The Ontology Repository for Materials Science (Andre Valdestilhas, BAM)



Description: The poster describes the design and development of Matportal.org, an ontology repository for the Material Sciences domain. The Matportal.org project re-uses the biomedical domain's semantic tools and insights to serve the community of Material Sciences and Engineering. Matportal.org offers a portal that features ontology hosting, search, versioning, visualization, comment, and recommendation; enables semantic annotation; stores and exploits ontology alignments, and interoperation with the semantic web. The poster shows the platform's content, and features, including the additions to the original technology and preliminary outputs of six driving Material Sciences use cases that participated in the design and orientation of the project to anchor it in the community. Building on the experience and existing technology Matportal.org aims to provide the first ontology repository for the Material Sciences and Engineering domain.

DOI: https://doi.org/10.5281/zenodo.8318532

2.6 A Snapshot of Attendees and Participants

The workshop welcomed a diverse group of 400 experts hailing from 39 different countries around the world. While the majority of participants originated from Europe (comprising 85% of the attendees), there was also notable representation from non-European countries, primarily from the USA, Brazil, and Argentina. In terms of gender, men accounted for the majority, comprising 69% of the participants.

These participants brought with them a wealth of expertise in the field of ontology, with specialisations spanning various domains. The largest contingent consisted of researchers, making up 48% of the attendees, followed by ontologists at 33%, and a presence of industrial professionals at 9%, complemented by engineers at 11%. It's noteworthy that standards development organizations (SDOs) and standardisation bodies were not explicitly categorised in the data presentation, as many individuals engaged in research and academia frequently collaborate with these stakeholders. Consequently, individuals affiliated with universities often bring expertise in standardisation to the workshop sessions. In essence, every workshop session benefitted from the inclusion of experts in the realm of standardization.

The figures below provide a concise overview of the composition of participants at the OntoCommons workshop.

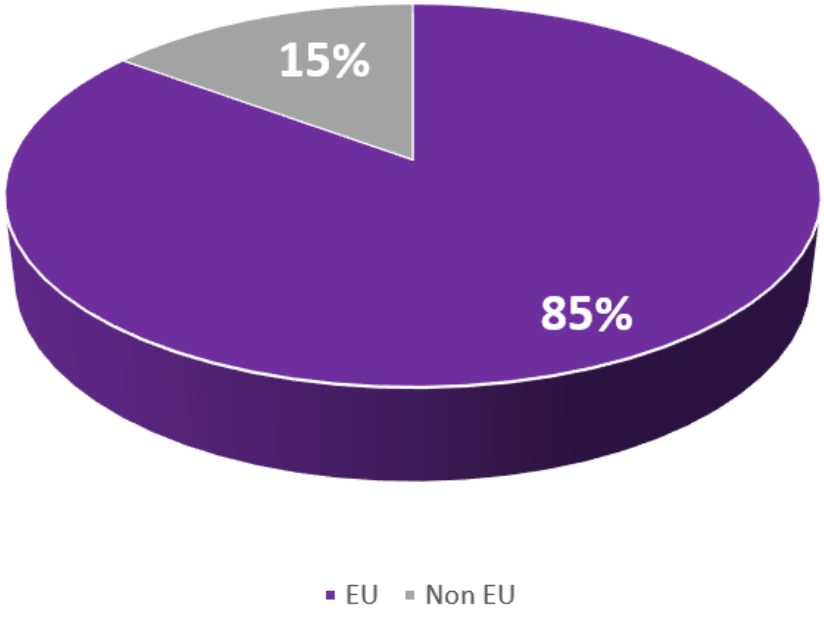


Figure 4 - Percentage of EU and Non-EU attendees

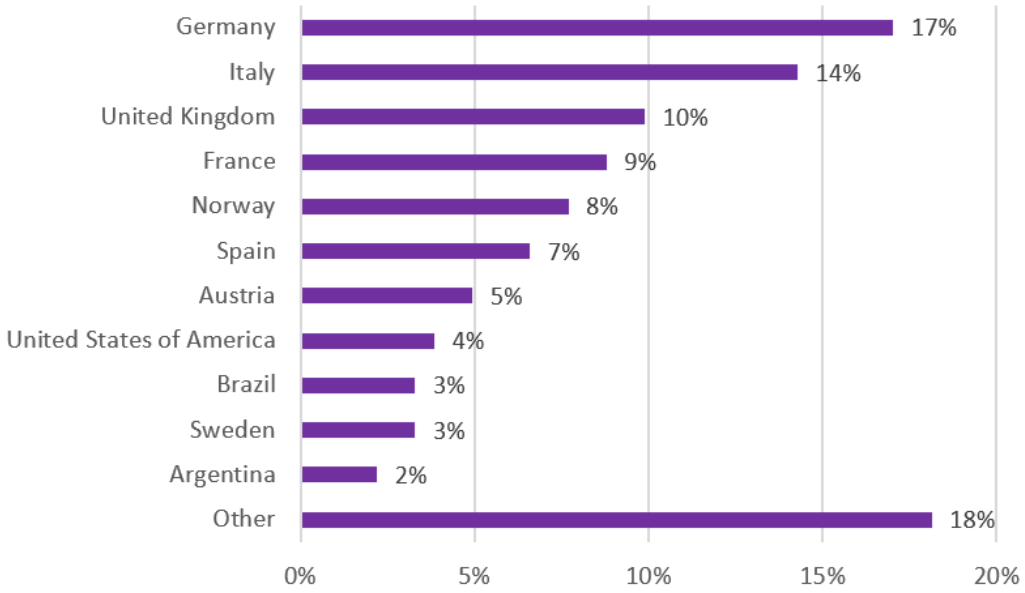


Figure 5 - Country breakdown of the attendees

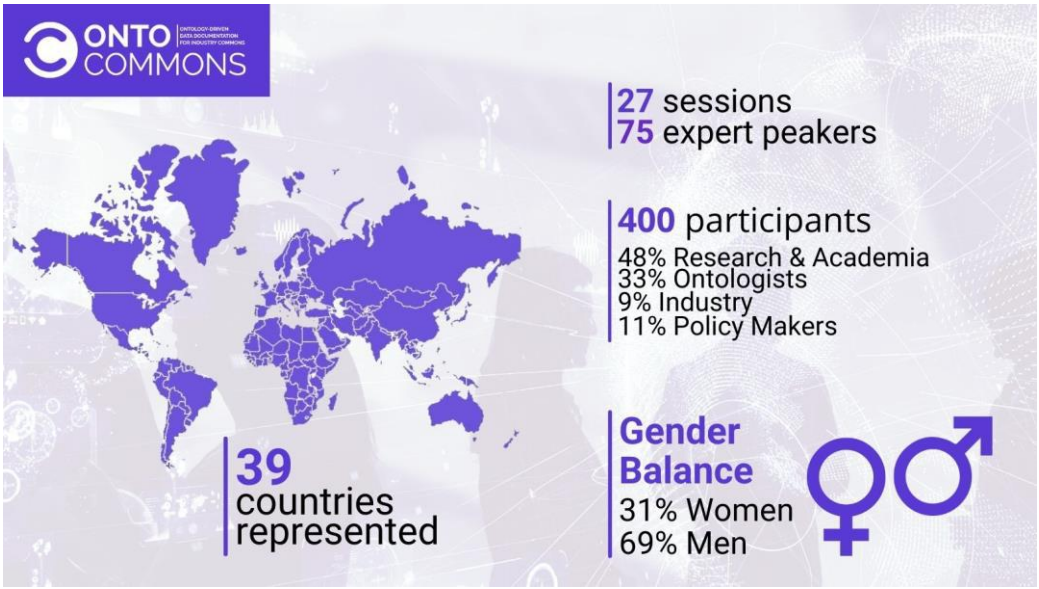


Figure 6 - Participants' statistics

3. Conclusions & next steps

The OntoCommons Second Horizontal Workshop stood as a crucial platform, enhancing collaborations and facilitating interactions among ontology experts. The emphasis was clearly on the significance of stakeholder involvement and the imperative need for sustained communication across diverse ontology-related initiatives, spanning both the EU and international dimensions.

The workshop resonated with an unexpected momentum, manifested through extensive training sessions, a plethora of recommendations, and dedicated work towards shaping project deliverables and roadmaps. Maintaining this momentum is essential, and fostering further collaborations within the broader community and the specific sectors identified during this initiative remains a priority.

Engaging conversations led by workshop speakers spotlighted the importance of community-based discussions and the collective achievements that encompassed more than just the direct project participants. The intent is to harness insights from a spectrum of stakeholders, transforming them into meaningful outcomes. The immediate future holds the release of an updated roadmap, incorporating feedback from the workshop, to cater to the broader community and decision-makers. Addressing challenges, particularly the interoperability issues, is essential for the thriving European common data market. Two upcoming events in September, hosted by the University of Bologna and ENIT respectively, further highlight the commitment to ongoing dialogue and collective progress.

Annex 1 – Speakers of the 2nd Global Workshop

Name	Surname	Affiliation
Nadja	Adamovic	TU-Wien
Umutcan	Serles	STI Innsbruck
Hedi	Karray	ENIT
Martin Thomas	Horsch	NMBU
Silvia	Chiacchiera	UKRI
Pablo	de Andres	Fraunhofer IWM
Amit	Bhave	CMCL
Dimitris	Kiritsis	UiO
Arild	Waaler	UiO
Michela	Magas	ICF
Emanuele	Ghedini	University of Bologna
Barry	Smith	University of Buffalo
Gerhard	Goldbeck	GCL
Francesco Antonio	Zaccarini	University of Bologna
Stefano	Borgo	CNR
Arkopaul	Sarkar	ENIT
Alexandru	Todor	DIN Software GmbH
Jim	Wilson	OAGI
Johan Wilhelm	Klüwer	DNV
Chris	Partridge	BORO Solutions
Paul	Harvey	University of Glasgow
Ivana	Mijatović	University of Belgrade

Anders	Gjerver	Aibel
Cristina	Mancarella	Trust-IT
Florina	Piroi	TU-Wien
Henriette	Harmse	EMBL-EBI
Nicole	Vasilevsky	Critical Path Institute
Claire	Johnson	SciBite Limited
David	Cameron	UiO
Francesca	Bleken	SINTEF
Oystein	Linnebo	UiO
Ilaria	Paponetti	University of Bologna
Alberto	Olivares Alarcos	Technical University of Catalonia
Alessandro	Oltramari	BOSCH
Lan	Yang	NUIG
Clement	Jonquet	LIRMM
Holger	Knublauch	Top Quadrant
Jinzhi	Lu	BUAA
Guoxin	Wang	BIT
Maria	Poveda	UPM
Claude	Fauconnet	TotalEnergies
Andrea	Cimmino	UPM
Dermot	Doyle	Dynaccurate
Serm	Kulvatunyou	NIST
Tervel	Bobev	KU Leuven
Andreas	Rudenå	Paramountric
Katariina	Kari	IKEA
Nasreddin	Bouchemel	ENIT
Emna	Lakani	ENIT
Amine	Karoui	ENIT
Francesco	Compagno	CNR

Celine	Rabé	SYNYO GmbH
Pierluigi	Del Nostro	Goldbeck Consulting Group
Muhammad	Yahya	University of Galway
Robert	Rovetto	University of Maryland
Janne	Haack	Fraunhofer
Maria	Kostopoulou	HALCOR
Martin	Huschka	Fraunhofer
Vanessa	Lislevand	IRES
Dimitris	Karasavvas	IRES
Huanyu	Li	Linköping University
Dušan	Šormaz	Ohio University
Sebastian	Scholze	ATB Bremen
Maja	Milicic Brandt	Siemens
Patricia	Casla	Tekniker
Edison	Pignaton de Freitas	UFRGS
Pedro Henrique	Morgan Pereira	UFRGS
Nicolau	Santos	UFRGS
Luigi	Asprino	University of Bologna
Rebecca	Arista	Airbus
Evgeny	Kharlamov	BOSCH
Andre	Valdestilhas	BAM

Annex 2 – Organisations and countries of the attendees of the 2nd Global Workshop

This annex provides details on the attendees' countries of origin and affiliations. However, to comply with GDPR, individual details such as name, surname, and email address are not included in this list.

Although the total number of participants was 400, it is noteworthy that many originated from the same organization. This data was collated by combining the registration form on the OntoCommons.eu website and the attendee list from the Airmeet Platform, where the online event was held. For those participating in person, confirmation of attendance was required a few days prior, and a list of registrants was created to welcome attendees with a badge at the event entrance. Hence, both physical and online attendees are incorporated into the same reports.

The OntoCommons.eu report encompasses all users who registered for the event in advance. However, many users joined during the event, likely after receiving an invitation link from other participants. The Airmeet Platform mandates users to provide their names and surnames but does not require information such as the organization. Consequently, not all attendees have included this information.

By merging the two forms (Airmeet and the website) and eliminating duplicates, we arrived at the number 400. Nonetheless, it is essential to distinguish between the number of registrations and the actual attendance in each session, which averaged 60 people, both online and in person. Among the 400 registered, some may have attended only one session or may not have participated at all, a common occurrence with early registrations.

Despite these variations, the number of registrations indicates a high level of interest in the workshop and, more broadly, in the OntoCommons activities.

This annex includes a list of the participants' organizations and the percentage representation of the countries they hailed from:

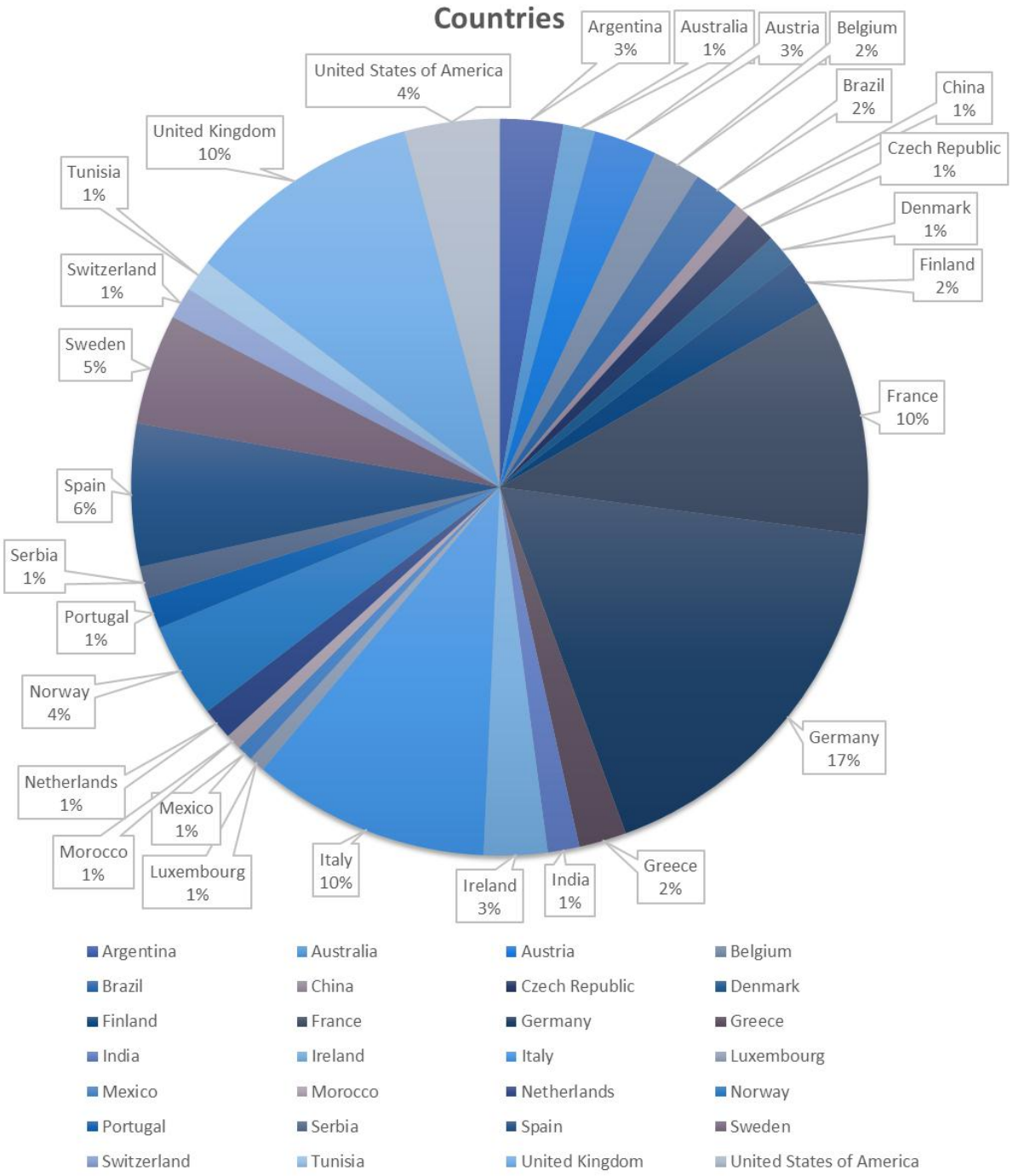
Organisations:

1. Aibel Field Development
2. Airbus
3. Akkodis
4. Alma Mater Studiorum
5. AnneFdeBaasMaterialsResearch
6. Arkema
7. ATB-Bremen
8. BAM
9. Basajaun use case
10. Basque Center for Climate Change -BC3
11. Beihang Univerisity

12. BIOMATDB project
13. BORO Solutions
14. Bosch
15. Bundesanstalt für Materialforschung und -prüfung (BAM)
16. CirQulor
17. CMCL
18. CMCL Innovations
19. CNR
20. CNR-ISTC
21. Cranfield University
22. Critcal Path Institute
23. Czech Technical University in Prague
24. Danish Agency for Digital Government
25. Data Science Institute, University of Galway
26. DIN Software GmbH (part of DIN - German Institute of Standards Group)
27. DNV
28. Dynaccurate SARL
29. EC
30. ecoinvent
31. ElvalHalcor S.A.
32. EMBL-EBI
33. Eni
34. eni s.p.a.
35. ENIT
36. EOSC Association, Semantic Interoperability Task Force
37. EPFL
38. e-Science Data Factory
39. e-SDF
40. Federal University of Rio Grande do Sul (UFRGS)
41. Fraunhofer
42. Fraunhofer EMI
43. Fraunhofer IFAM
44. Fraunhofer ISC
45. Fraunhofer-Institut für Werkstoffmechanik IWM
46. Free University of Bozen-Bolzano
47. German Aerospace Center (DLR)
48. Goldbeck Consulting Ltd (GCL)
49. Graphifi
50. Grundfos
51. Helmholtz-Zentrum Berlin
52. IAM-MMS, Karlsruhe Institute of Technology

53. IBM Research
54. IDENER
55. Ikea
56. Independant consultant (SousLeSens)
57. Independent consultant
58. Indian Institute of Science, Bangalore, India
59. Industry Commons Foundation
60. InfAI
61. INGAR (CONICET/UTN)
62. INRAE/Univ of Montpellier
63. INSEA
64. Institut de Robòtica i Informàtica Industrial, CSIC-UPC
65. Institute of Chemical Research of Catalonia
66. Inter IKEA Group
67. Inter IKEA Systems B.V.
68. International Association for Ontology & its Applications. Independent
69. IRES
70. IRT Railenium
71. IRT systemX
72. ITAINNOVA
73. KU Leuven Center for IT & IP Law
74. Laboratory for Applied Ontology ISTC-CNR
75. LGP
76. Linköping University
77. Loughborough University
78. Lumoin
79. MFPA Weimar
80. Michelin
81. National Engineering School of Tarbes (ENIT)
82. National Research Council (CNR)
83. National University of Ireland Galway
84. NBIS - National Bioinformatics Infrastructure Sweden
85. Netcompany-Intrasoft
86. Norwegian University of Life Sciences
87. NuoroForestrySchool-DipAGR-UniSS.it
88. Ohio University
89. Ontology Engineering Group
90. OPE
91. Other
92. Paramountric AB
93. Physikalisch-Technische Bundesanstalt (PTB)

94. Posgrados CIATEQ, A.C.
95. professor
96. Railenium
97. Raytheon
98. Sap
99. SciBite Limited
100. Science and Technology Facilities Council, UK Research and Innovation (STFC/UKRI)
101. Siemens AG
102. SINTEF
103. SINTEF Digital
104. SLSV/LGP
105. STFC/UKRI
106. TECNALIA
107. TEKNIKER
108. Texas State Univerisy
109. TopQuadrant
110. TotalEnergies
111. Trust-IT
112. TU Wien
113. UFRGS
114. UNCo
115. Unibo
116. Universidad Nacional del Litoral
117. Universidad Politécnica de Madrid
118. Universität Bremen
119. University College Dublin
120. University of Belgrade, Faculty of Organisational Sciences
121. University of Bologna
122. University of Buffalo
123. University of Galway, Ireland
124. University of Glasgow
125. University of Innsbruck
126. University of Nis, Faculty of Electronic Engineering
127. University of Oslo
128. University of South Australia
129. US GAO
130. Vienna University/ Aliya GG freelance
131. VisuaLynk


Countries
Argentina 3%
Australia 1%
Austria 3%
Belgium 2%
Brazil 2%
China 1%
Czech Republic 1%
Denmark 1%
Finland 2%
France 10%
Germany 17%
Greece 2%
India 1%
Ireland 3%
Italy 10%
Luxembourg 1%
Mexico 1%
Morocco 1%
Netherlands 1%
Norway 4%
Portugal 1%
Serbia 1%
Spain 6%
Sweden 5%
Switzerland 1%
Tunisia 1%
United Kingdom 10%
United States of America 4%
Argentina
Australia
Austria
Belgium
Brazil
China
Czech Republic
Denmark
Finland
France
Germany
Greece
India
Ireland
Italy
Luxembourg
Mexico
Morocco
Netherlands
Norway
Portugal
Serbia
Spain
Sweden
Switzerland
Tunisia
United Kingdom
United States of America