Report D6.5
"Report on the outcomes on the first OntoCommons Horizontal Workshop"

Grant Agreement: 958371

OntoCommons - Ontology-driven data documentation for Industry Commons, has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement no. 958371.

Project Title	Ontology-driven data documentation for Industry Commons
Project Acronym	OntoCommons
Project Number	958371
Type of project	CSA - Coordination and support action
Topics	DT-NMBP-39-2020 - Towards Standardised Documentation of Data through taxonomies and ontologies (CSA)
Starting date of Project	01 November 2020
Duration of the project	36 months
Website	www.OntoCommons

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"Report on the outcomes on the first OntoCommons Horizontal Workshop"

Work Package	WP6 | OntoCommons Dissemination, Exploitation & Sustainability
Task	T6.2 | OntoCommons horizontal workshops, synergies with wider stakeholder community, related projects and initiatives
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Peer reviewers	Nadja Adamovic (TU WIEN), Hedi Karray (ENIT)
Version	Final
Submission Date	14/01/2022

Versioning History

Revision	Date	Editors	Comments
0.1	19/10/2021	Cristina Mancarella (Trust-IT)	Table of Contents
0.2	10/11/2021	Cristina Mancarella, Luigi Colucci, Rita Giuffrida (Trust-IT)	Inputs in Chapter 2
0.3	16/10/2021	Rita Giuffrida (Trust-IT)	Chapter 3
0.4	22/11/2021	Cristina Mancarella (Trust-IT)	Chapter 1
0.5	25/11/2021	Cristina Mancarella (Trust-IT)	Chapter 4
0.6	29/11/2021	Cristina Mancarella (Trust-IT)	Executive Summary
0.7	06/12/2021	Luigi Colucci (Trust-IT)	Sections 2.5, 3.6, 3.2, 3.3
0.8	06/12/2021	Rita Giuffrida (Trust-IT)	Sections 2.6, 2.7
0.9	17/12/2021	Nicholas Ferguson (Trust-IT)	Internal Review
1.0	11/01/2022	Nadja Adamovic (TU-Wien)	Final Review

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

OntoCommons.eu has received funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement no. 958371.

Executive Summary

This deliverable reports on the **first Horizontal Workshop of OntoCommons** The four-day event provided the platform for engagement between 278 European and International stakeholders 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 OntoCommons Strategic Roadmap which will be delivered in M36.

High-level recommendations and inputs for OntoCommons Roadmap

The 1st Horizontal Workshop has helped identify some of the main challenges presented by ontologies:

- **Ontology Interoperability**: Difficulties in aligning ontologies and making them interoperable involve both semantic and semiotic aspects: developing a tool that helps solving semiotic level interoperability problems, or understanding how to process data between genuinely incompatible ontologies, could really contribute towards ontology interoperability. OntoCommons aims to facilitate the development of new links between present and future ontologies within the Ontology Commons EcoSystem, with the idea that the alignment between top level ontologies will facilitate alignments between middle level ontologies.
- Agreement on the use of certain concepts can help reaching stronger interoperability. A heavy ontology use can be, in some occasions, accompanied by a more lightweight approach, that, although unsupervised and not based on formal principles, can include a lot of variety. It is important to have open access material available too
- **Standardisation**: Dedicated efforts on developing SMART standards that are agile & market responsive need to be tackled with end-users through dedicated interoperability test-bed frameworks, and OntoCommons should have as an objective to find the right channels that can allow that, even more attention should be dedicated in the future to the connection between National and International Standards Bodies.
- **Top Reference Ontology**: The difference between top and middle ontologies is fuzzy. At the same time, Top Level Ontologies are more appropriate to be pluralistic, while Mid-Level Ontologies are more suitable to act as a bridge between the metaphysic and practical applications, so that the top level can make ontologies with lower complexity. The OntoCommons project aims to overcome this issue with the development of the OCES, which consists of ontologies and tools following specific standardisation rules, that can be effectively used as foundation for data documentation in the industrial domain, in order to facilitate data sharing and valorisation and overcome the existing interoperability bottlenecks
- A top-level ontology needs a certain top-level view, therefore, using domain experts for a top-level ontology might not work well.
- **Domain Ontologies**: A number of tools exist for the various steps of ontology engineering, often designed to be used by ontology engineers, but difficult to engage with for domain experts. The importance of the tools used is not to be underestimated, and it can impact the process of creating ontologies that fulfil the purpose of the end user.

- Regarding the design of ontology development environments, the coverage of the tasks by Ben Shneiderman to a satisfactory extent could be a success criterion; it is also recommended, regarding the terminology service, to broaden the scope of existing services to a wider range of domains in industry.
- **FAIRness:** An important gap emerged from the discussions is that no groups are currently working on the FAIRification of industrial data, although there are discussions in relation to Gaia-X and an existing project called FAIR Plus.
- Whereas the FAIR principles have a clear definition and the FAIRification path is fairly standard, there is no one-size-fits-all solution for their implementation. This is why it is important to adapt the implementation strategy to the specific contest and use clear FAIR data indicators to evaluate the correct implementation of the FAIRification process.
- **KExS**: A multi-stakeholder collaboration is necessary. Previously identified possibilities are the establishment of Task Forces as well as a Memorandum of Understanding (MoU). The creation of a FAIRness Clinic and an Ontology Clinic should and could also be taken into consideration, which could consult on what OntoCommons is producing and assess its course.
- **Ontologies in marketplaces:** Some important lessons learnt about ontologies in markeplaces can support OntoCommons' future work: it is fundamental to maximise the use of resources through a balance between new ontology developments and the reuse of existing resources, and between semantics and syntactics, as well as through the right tools to support annotation and mapping.
- **Human Factor:** The human factor has proved to be an extremely important component for the success of interoperable ontologies development, starting from the interfaces user-friendliness, but not limited to that. Human skills such as understanding, empathy and the ability to question assumption and also to transform implicit, tacit knowledge into explicit knowledge prove to be fundamental as well. The cross-domain challenges that are presented by ontology interoperability, and that OntoCommons is addressing with its work, reflect the challenges of human communication and culture blending.
- Ontologies applied to the way humans and systems communicate, can have a strong societal impact.
- **Demonstrators:** The work on the demonstrators should also allow creating links with marketplaces, sharing open-source documents and technologies, and through a convergence of underlying ontologies and taxonomies: the OntoCommons Demonstrators will provide the OntoCommons Ecosystem with prototypical needs
- **Ontology Adoption:** A way to influence industry's willingness to adopt ontologies, would be to understand what kind of operations the industry needs to run with the data schema: the better industry knows this, the more it is able to build a useful ontology. It is also fundamental to define, from the first steps of developing an ontology adoption strategy, a clear purpose for that ontology (what is that specific ontology needed for?). Finally, an incentive could be that of associating important stakeholders with the process and outcomes of ontology adoption, to lead by example.
- **Ontology Engineering:** Challenges to build good ontologies include: (a) improve the reliability of type memberships of entities in information processing, (b) finding types that provide sufficient distinctions for an algorithmic information processing and data granularity, (c) finding types that can be populated from existing data sources without reclassification tasks, and (d) finding conceptual distinctions that can be reliable.

- The challenges for ontology repositories include (a) ontology metadata evaluation and selection, (b) multilingualism, (c) ontology alignment, (d) generic ontology-based services, (e) annotations and linked data, and (f) scalability and interoperability.
- Ontologies can bring a strong **societal impact** by helping improve our systems understanding: in the case of the sound design for electric vehicles, for example, different sounds help different users identify the vehicle's intentions, resulting in increased security for citizens. Ontologies can support the mapping of sound's connotations to verify assumptions on the meaning conveyed by each sound, and help address ambiguity and create shared understanding.

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1. Introduction

This deliverable reports on the **first Horizontal Workshop of OntoCommons** which was held from 2 to 5 of November, 2021. The event aimed to provide the platform for engagement between different European and International stakeholders in order to discuss and identify priorities and recommendations on the future of standardized data documentation.

The event was the first of two Horizontal Workshops planned in the lifetime of the project with the second taking place in M30. A second, public, release of this deliverable will be issued following this event in M33, (D6.6 Report on the outcomes of the second OntoCommons Horizontal Workshop as well as with Synergies with related projects). The workshops are horizontal in name and also in nature, cutting across the results of each of the project's work packages. The principal takeaways of both events will feed into the OntoCommons Roadmap (D1.16, D1.17): a co-designed, community-oriented plan for the long-term, strategic development of developed ontology and data documentation to ensure long term relevance and implementation.

This document also accounts for the project's milestone **MS1 "Positive outcomes and interest from focused and horizontal Workshops"**, due in M12.

The inputs from each session of the workshop are collected in Chapter 2 (Ontology Commons addressing challenges of the transition to Industry 5.0): this chapter includes the main takeaways from each session and details on the target audience and how each stakeholder can benefit from the outcomes of the workshop. The high-level recommendations extracted from each session are included in the Executive Summary of this document. All Section 3 is dedicated to reporting on the organisation of the event and, communication and dissemination campaigns that were carried out before and during the event.

The event was held online due to the continuing COVID-19 pandemic and meant that 278 people attended the event, a higher number than would have been possible for a physical event with people not having to travel to join the event.

1.1 Background and purpose of the Horizontal Workshop

Objective 6.2 of Work Package 6 (OntoCommons Dissemination, Exploitation & Sustainability) is dedicated to the design and organisation of two Horizontal Workshops across domains and industrial sectors, which serve to **collect end-user requirements** and to provide **input and feedback** during the development and evolution phases of the OntoCommons Strategic Roadmap, due in M36. The second Horizontal Workshop to be organised in M30, in particular, will focus on collecting inputs for the delivery of the final version of the Roadmap, including a number of policy recommendations towards Data Sharing for the European Single Market, in support of the **digitalisation of industry**. This objective falls in the scope of Task 6.2 which focuses on synergies with the wider stakeholder community and related projects and initiatives. The workshop has gathered a number of key initiatives and projects related to OntoCommons and is also linked to specific activities carried out in the 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)

In order to represent each work package and the activities carried out, and to maximise the time and effort, the workshop was organised around plenary sessions dedicated to each objective, and specific, custom-designed, parallel sessions dedicated to different target audiences, combining open, topic-based discussions and impulse talks from invited speakers external to the projects. Each session was recorded and the recordings shared on the website immediately after the workshop, to allow each participant or stakeholder to watch the sessions they were unable to attend.

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: "**Global Workshop: Ontology Commons addressing challenges of the industry 5.0 transition**" (Global Workshop).

2. Ontology Commons addressing challenges of the transition to Industry 5.0

2.1 Day 1 (2 November 2021)

2.1.1 Plenary Sessions[1]

Nadja Adamovic, Senior Scientist at Technische Universität Wien and OntoCommons project coordinator, opened the first plenary session of the Horizontal Workshop. She welcomed all the participants with an exhaustive presentation of the main objectives of the OntoCommons project and its strategic Roadmap. She concluded her presentation by showing the main goals of the Workshop and introducing the speakers of the first day.

2.1.1.1 The International Association for Ontology and its Applications: 12 years of promoting Applied Ontology with an interdisciplinary approach

The first plenary session of the OntoCommons workshop was presented by *Laure Vieu: Senior Researcher at Institut de Recherche en Informatique de Toulouse (IRIT) and current President of the International Association for Ontology and its Applications (IAOA2).*

Objectives

Laure's talk presented the International Association for Ontology and its Applications (IAOA), a not-for-profit organization created in 2009 for promoting interdisciplinary research and international collaboration on applied ontology. After reviewing some historical background, she discussed the current activities the association is involved in and what are the ambitions for the future.

Impact

OntoCommons has already established collaborations with IAOA in several ways thanks to the fact that members of the project are also active players of IAOA (Nicola Guarino, Stefano Borgo, Claudio Masolo, Roberta Ferrario and Emilio Sanfilippo), who are involved in the OntoCommons Top Reference Ontology, Industrial Domain Ontologies, Ontology Commons Ecosystem Toolkit and Demonstrators.

The main collaborations established between IAOA and OntoCommons so far are:

- participation of IAOA members as partners in OntoCommons;
- participation of IAOA representatives in OntoCommons workshops across 2021;
- co-organization of the FOMI 2021 workshop in September 2021;

[1] https://www.youtube.com/watch?v=3T9y5Jj3pFk
[2] https://iaoa.org/

- discussion with co-chairs of the IAOA Industry and Standards Technical Committee for the organisation of events in the coming years.

Moreover, this collaboration aims to establish synergies also in the standardisation field, with the involvement of representatives of both initiatives in Technical Committee groups that can provide recommendations on standards applied to industry. These contributions are relevant to be included in the second release of the OntoCommons Report on Standardisation Impact (D1.7) and in the OntoCommons Roadmap.

2.1.2 Parallel Sessions

The following sections show more details on the objectives and impact of the parallel sessions conducted on the first day of the workshop.

2.1.2.1 Industry Commons Translator[3]

An Industry Commons Translator is an "ontologist" translator and coach with expertise spanning across the ICT, analytical philosophy and science/engineering domains, able to bridge gaps in the stakeholder value chain and ensure that end users can reap the benefits of ontology-based data documentation. This session represents a start to define the profile and role of such a Translator, establish best practices, and work globally with RTD stakeholders to provide Translator training resources to make this role truly an Industry Commons.

The session was moderated by *Gerhard Goldbeck: CEO and Founder at Goldbeck Consulting,* and Industry Commons Translator task leader of OntoCommons.

Objectives

The session had the main objectives of sharing:

- Experiences in different sectors: Materials Modelling Translator and Analytics Translator;
- The need and requirements for an Industry Commons translator;
- The role of the translator and the team of translators;
- The translator contribution to industries that adopt ontologies into their day-to-day work;
- The role played by the translator in enabling changes within an organisation to path the way for adopting ontologies.

Stakeholders involved and interested in defining the profile and role of an Industry Commons translator, and the potential steps involved in a translation task were invited to share their point of view.

[3] https://www.youtube.com/watch?v=vQrmnsLjVRM

Speakers and impulse talks

Advancing Translation in Materials Modelling

Peter Klein: *Senior Scientist at Fraunhofer ITWM currently working on multiscale models for materials, with a focus on surface and interface related phenomena and the leader of the Focus Area Impact in Industry of the EMMC ASBL*

- The genesis of the EMMC Translation concept and the EMMC Translators Guide documents how an EMMC group of scientists combined the translator concept with Business Decision Support Systems and developments of supporting ontologies.
- The translator, knowledgeable in ontologies, can support interoperability, correlate the industrial data lake with models and solvers thereof. This may be costly and a translator has to estimate the simulation costs for their customer.
- The role of the translator needs to evolve further, as tried in the new EU-H2020 project, VIPCOT, in which he will become a part of an Open Innovation Platform (OIP) and will take part in a co-creation process. In addition to modelling workflows, process workflows will find their way into this OIP and ontology compliance is key for interoperability. The OSMO ontology[4], developed in the ViMMP[5] project and PROMO will aid to accomplish this.
- The translator will become a part of a collective decision making/corporate innovation team. A new role of an innovation game master will be established to enable the innovation team to either win or lose (all or nothing). New protagonists could be politicians – who usually want/have to exert external controls or give boundary conditions. Hence, the translator will be confronted with the role of the rest of the world and become part of a global solution.

Translation of Innovation challenges

Michael Noeske*: Research associate in the department Adhesion and Interface Research at the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM.*

- The translator should aim for a high-level innovation that can fulfil superior aims, like the European Green Deal, and should appeal to future generations as much as the smaller ecosystem of a company. A good way for the translators to accomplish this is to follow the A-D-I triad: "Abduction" – give one's best shot to understand a problem, "Deduction" – become more specific about a problem, and "Inductive reasoning" – generalise a problem and capture its wider perspective.
- The reusability of the knowledge is currently one of the missing requirements in this area. In order to improve this aspect, the translator needs to look into ontologies and develop enough expertise to involve data scientists or ontologists. This requires some investment on the client side, which can bring the benefits of preserving knowledge.
- A translator needs to know more about ontologies in order to show how a translator can interface with other roles and highlight what global use a product might have.

[4] https://zenodo.org/record/5084394#.YbyNHizSJp8
[5] https://www.vimmp.eu/

Knowledge Engineering Translation - early experiences from the Biomedical Domain
Nicolas Matentzoglu: *Independent Consultant for semantic Technologies, specialised in biomedical ontologies and ontology mappings with an extensive experience as in the Semantic Web Developing field.*

- Examples of Knowledge Engineering Translator (KTE) problems, such as widely diverging "semantic technology" stacks, lack of expertise, complex "semantic trade-offs" and high up-front costs of implementation have been provided, together with some concrete examples of the Open Biomedical Ontology (OBO) knowledge engineering activities and semantic application development.
- Knowledge Engineering (KE) stacks which comprise standards, ontologies, knowledge graphs, database systems and tools. To find the right KE, an expert should have both software and KE skills. Software skills can be found in organisations, but KE takes time and cannot be introduced easily. This bottleneck increases the complexity of dealing with semantic technology and highlights the need of finding "semantic trade-offs".
- Experience and skills are needed to overcome this bottleneck, which increases the complexity of dealing with semantic technology and highlights the need of finding "semantic trade-offs". Moreover, KE technology should be cultivated within an organisation to also have higher experience and knowledge. Ideally, Continuous Professional Development should be offered to data scientists by purposefully invited speakers, collaboration with academics and global talent and expertise.

Impact

The inputs collected from the speakers' presentations and discussions during this session of the workshop will feed into the chapter dedicated to Industry Commons Translator of the OntoCommons Roadmap.

The session focused on presenting the role played by the Industry Commons Translator, which aims to bridge current community divides in the Industry Commons value chain and it supports potential (industrial) beneficiaries of OntoCommons in utilising the OCES for maximum impact. In particular, an Industry Commons Translator is an "ontologist" translator and coach with expertise spanning across the ICT, analytical philosophy and science/engineering domains, able to bridge gaps in the stakeholder value chain and ensure that end users can reap the benefits of ontology-based data documentation.

2.1.2.2 Ontology Interoperability[6]

Ontology interoperability focusses on the types of links that could be used to build the OntoCommons ecosystem. They can be obtained through ontology alignment, integration and conceptual heterogeneity.

[6] https://www.youtube.com/watch?v=OmCE4LciFyA

The session was moderated by ***Stefano Borgo:*** *Head of the Laboratory for Applied Ontology (LOA) at ISTC-CNR*, was the moderator of this session. Stefano is one of the OntoCommons members that supports the development of the Top Reference Ontology, Industrial Domain Ontologies and the Ontology Commons Ecosystem Toolkit.

Objectives

The Ontology Interoperability session aimed to:

- Present different types of links one can establish among formal ontologies;
- Clarify the purposes of these links and what kind of reasoning they allow;
- Discuss how to build networks of ontologies via different kinds of links.

Speakers and impulse talks

Introduction to ontology matching and alignment
Jérôme Euzenat: *Senior Research Scientist at INRIA & Université Grenoble Alpes with an interest in the relationships between different knowledge representations of the same domain.*

- The main goal of Ontological alignment is to reduce the heterogeneity among the diverse modelling, scopes and granularity levels that can be selected to represent the same domain.
- Alignments are sets of correspondences between terms used in different ontologies, that can be obtained through ontology matching. After the alignment is established, data can be merged and transferred to the ontologies.
- Alignments can be established in different ways:
    - using the content of ontologies through the study of the data and schemas and the deductions of eventual links. This can be obtained through the search of similar terms;
    - using the external context of ontologies. This is applicable when other resources mention ontologies or use them to make annotations of the same terms.
- There are challenges associated with alignments due to the fact that reasoning tasks are generally difficult to implement.

Ontology alignments: semantics, ontology integration, multiple logics
Till Mossakowski: *Professor at Otto-von-Guericke University of Magdeburg with a research interest in logic, semantics, and neural-symbolic integration, as well as applications in energy network simulation models.*

- Alignments can be used to check the joint consistency of a group (or network) of ontologies, in a semantically grounded way. In order to achieve this, it is crucial to build a semantic for the network: models of a network interpret each ontology using a model of that ontology, and, in addition, the alignments must be interpreted by some relations.
- There are three cases when building a model for an ontology network:

  - (1) If all the ontologies have the same quantification domain (simple semantic), then the above description suffices (but one could also use colimits and say that the model of the network is the model of the colimit ontology)
  - If the ontologies have different quantification domain, then those must be reconciled either:
    - (2) within a common domain or (integrated semantics) or
    - (3) by use of coherent relations between them (contextualized semantics),
- In ontology modelling many languages are used, thus, the need for multi-logic alignment. A way to do this is translation into a common language, like first order logic. DOL and Hets can be used to accomplish alignment between ontologies of different languages. DOL is a language supporting complete model-theoretic formal semantics for alignments. Instead Hets is a tool that uses DOL and can integrate ontologies, check joint consistency.

Conceptual heterogeneity: the case of time

Claudio Masolo: *Researcher at the Laboratory for Applied Ontology (LOA) ISTC-CNR. One of the main responsible for the development of the DOLCE ontology; co-founder and Membership Officer of the International Association of Ontology and its Applications (IAOA); member of the Editorial Board of the Applied Ontology Journal.*

- The two main problems encountered in the attempt of managing conceptual heterogeneity in the broad context of ontology integration are:
  1. to understand whether different ontologies genuinely disagree about the nature of the domain of interest;
  2. to understand whether theories with truly different ontological commitments can still be partially integrated and interlinked.
- The two problems have been addressed by taking into account the domain of time for which several ontologies have been developed in detail: given two formal temporal ontologies we can try to define the predicates of the first using the second. While doing so, it is possible to establish a mapping from the second to the first ontology and check if the axioms of the second ontology have correspondent ones in the first ontology.

Impact

The inputs collected from the speakers' presentations and discussions during this session of the workshop will feed into the chapter dedicated to Industrial Domain Ontology of the OntoCommons Roadmap.

This session highlighted the difficulties encountered in aligning ontologies, as making them interoperable, from semantic and semiotic viewpoints, finds obstacles at lexical and syntactical levels.

A big part of the focus of this parallel session was about how to manage ontologies that have semantic/semiotic interoperability problems. This task has no easy answer, especially if coupled with problems on the lexical/syntactical level. Alignment of ontologies is generally difficult. There

are open problems that could really help the field, if solved. For example, developing a tool that helps with solving semiotic level interoperability problems, or answering what to do with the data between genuinely incompatible ontologies. However, the OntoCommons project aims to facilitate the development of new links between present and future ontologies within the ecosystem that the project will realise, because the alignments between the top-level ontologies will facilitate alignments between lesser level ontologies.

2.1.2.3 Enabling intra-ontology interoperability through shared terminology[7]

This session presented how standardisation efforts have led to the emergence of conceptual models in many vertical industries. Simultaneously, there is such a high proliferation of digital information where decision-making is increasingly automated based on data coming from a myriad of sources, that this poses new challenges for efficient management and analysis of available data. Proposing ontologies helps map large data volumes through semantic queries using ontology vocabulary that helps simply analytics. In this context, OntoCommons can serve as a basis for developing a landscape analysis to assess standardisation efforts in ontologies.

This session was chaired by ***Silvana Muscella:*** *CEO at Trust-IT, Dissemination, Exploitation and Sustainability manager, and Leader of the Task dedicated to Specifications and Support to International Standardisation*.

Objectives

The main objectives of the session were to:

- show the OntoCommons efforts around standardisation and ontologies;
- collect input from our stakeholders that will support the contents of the Standardisation Impact Report delivered at the end of the project, and eventually feed into the OntoCommons Roadmap;

Speakers and impulse talks

Ontology Standards in ISO
Barry Smith: *Director at the National Center for Ontological Research. Barry Smith, prominent contributor to both theoretical and applied research in ontology.*

- The ISO/IEC 21838 is composed of several parts, two parts of which have already been approved and are currently in the publication stage. Part 1 of this standard specifies requirements needed for a top-level ontology (TLO) to be classified as such, with the underlying idea that the TLO should be domain-neutral and therefore applicable to all domains, without restrictions. Part 2 of the ISO/IEC 21838 standard specifies BFO as a TLO conforming to these requirements, and parts 3 and 4 will specify DOLCE and TUPPER in a similar manner.

[7] https://www.youtube.com/watch?v=nk8k21HoX0U

- BFO is the most widely used TLO in several applications:
  - it is used in biomedical domain (LOD cloud): 350 ontologies in bio-medical domain are using BFO;
  - it is adopted by IOF;
  - It is used in military and intelligence applications.

Improving the efficiency and effectiveness of systems integration and interoperability using ontology

Boonserm Kulvatunyou: *project manager for the infrastructure for data exchange standard development and use project in the Systems Integration Division at the National Institute of Standards and Technology (NIST). Currently he serves as chair of Semantic Refinement Method and Tools WG and in the Architecture Committee at the Open Applications Group, Inc. (OAGi) standard consortium among other WG participations.*

- This talk was focused on the challenge of developing a consistent enterprise-wide data model, and on the fact that, if this model is ontology-based, it may also be more tractable thanks to the possibility of using a reasoner to assist in model consistency checking. For this reason, the Industrial Ontology Foundry (IOF) is working to provide the basic building blocks to build a consistent enterprise-wide data model.
- Semantic ambiguity causes more than 80%-90% of the overall system integration, and other issues (for example, transport) cause only around 10%. Enterprise data models (UML, Relation model, XML schema) have limitations and are difficult to develop. Ontology-based enterprise data models are, instead, useful tools to overcome this issue.
- The benefits of adopting Ontology-based enterprise data model are multiple:
  - Ontology can inform traditional standards development and improve harmonization;
  - Run time-Ontology can complement data exchange standard;
  - Run time-Ontology can be used as the standard for system integration.

Standardisation in the IoT domain

Ulrike Parson: *current Steering Committee Chair of the iiRDS Consortium that develops and maintains a standard for the delivery of smart content. She is the CEO of parson AG, that provides both technical writing and consulting for content management and content delivery.*

- Both standards and ontologies bring benefits in the IoT domain:
  - Industrial standards in the internet of things enable interoperability and information exchange between components and services.
  - Ontologies help to create a shared understanding of and terminology for technical capabilities, product features, and service properties, as well as enabling efficient machine-to-machine and human-to-machine communication.

- The challenges encountered to adopt standards and ontologies in IoT are:
  - Establishing a common understanding takes time;
  - Many ontologies already exist but there is a need for alignments;
  - Ontology engineering skills are very often missing;
  - There is a limited number of ontology development frameworks and tools.

Ontology Standards in Industry 5.0

Nicolas Figay: *system architect at Airbus Defence and Space at Elancourt, France, and Airbus expert in the area of interoperability for PLM. International expert in the standardisation community (ISO SC4 TC184, ASD Strategic Standardization Group, liaison OSLC ISO TC184 SC4) and in research within the area of Product Data Exchange and Sharing (RISESTEP, SAVE), Interoperability of Technical Enterprise Application for Networked Collaborative Product Development (ATHENA), Model Driven Architecture/Model Driven Engineering (OpenDevFactory) or Dynamic Manufacturing Network (IMAGINE).*

- In the industrial context, ontologies and open standards are one of the identified interoperability enablers with Model Driven Architecture, Service Oriented Platform and Enterprise Architecture;
- Ontologies have been used for a very long time in industry but with too many alternative and/or competing approaches, languages, logics, paradigms and needs. Nowadays, ontologies go beyond the semantic web and focus on semantic preservation, cross domain collaboration, information consistency, effective decision making, silos preventions, and investment preservation.
- Airbus adopts the DDMS programme, that helps to define ontology capabilities, to establish a digital collaboration and develop a Business Ontology on top of Model Driven Architecture, Service Oriented Platform and Enterprise modelling. Moreover, the ontologies are used to analyse information and aggregation of data; and the standards are Machine Applicable, Readable and Transferable (SMART).
- In this context, some challenges linked to the Federation of Interoperability Frameworks, Semantic Preservation, Dynamic Networking, Interoperability Testbed, High performance reasoning and Ontology Engineering Practices and Training need to be addressed.

Impact

The inputs collected from the speakers' presentations and discussions during this session of the workshop will feed into the chapter dedicated to standardisation of the OntoCommons Roadmap.

The discussions have provided significant inputs that can guide the future efforts and can be summarised as follows:

- There is a lot going on in the standardisation landscape, and one of the current challenges is that of keeping track of the ongoing efforts. OntoCommons plays an important role as it can help aggregate the information and pool it together in the work related to Cooperation on Standardisation.

- The industrial domain values the endorsement from ISO, and ISO references are said to be available in open source & for public use;
- EU efforts & ESOs are working on SMART Standards, so it is useful to create a link with our initiative
- The OntoCommons Consortium is creating a connection with the EC DG GROW & DG Connect, in order to explore the possibility of setting up a dedicated chapter on Ontologies & Semantic interoperability within the 2022 edition of the ICT Rolling Plan of Standardisation.
- Dedicated efforts on developing SMART standards that are agile & market responsive need to be tackled with end-users through dedicated interoperability test-bed frameworks, and OntoCommons should have as an objective to find the right channels that can allow that.
- Even more attention should be dedicated in the future to the connection between National and International Standards Bodies.

2.1.2.4 Ontologies Stratification[8]

This session focussed on the vertical organisation of ontologies by top, mid, and domain level. Stratification of ontologies not only help in modular development and reuse but also provide semantic interoperability among domain level ontologies based on generalization, unification, and abstraction of concepts. In spite of several ontologies serving top-level and mid-level ontology, clear definition and characterization of top and mid-level ontologies still does not exist. Therefore, understanding different stratification strategies adopted in different ontology development projects is of paramount importance for OntoCommons members.

Dr. *Hedi Karray: Professor at ENIT and OntoCommons Technical Coordinator*, was the chair of this session.

Objectives

This session aimed to:

- Discuss potential criteria to identify a vertical ontology hierarchy, like by domain of interest and by internal structure.
- Understand benefits and drawbacks of using vertical stratifications to characterize ontologies.

Speakers and impulse talks

Layered patterns in design workflows
Aldo Gangemi: *Full Professor at University of Bologna and Director of the Institute for Cognitive Sciences and Technologies of the Italian National Research Council, co-founder of the Semantic Technology Lab (STLab) in 2008.*

- The traditional distinction into top, middle and domain ontologies is useful for general talk, but cannot be used as architectural principles, since the reasons why something is considered

[8] https://www.youtube.com/watch?v=OQOtmpDZz1o&t=11s

domain-(in)dependent can be very different. Very often the common sense is the driver of middle level or better core.
- Top-level predicates have a better trade-off, but they need to be strict in axiomatisation. However, too strict TLO may hamper interoperability because of lack of coverage. Fuzzy and relaxed intentions may encourage interoperability but they are difficult to model.
- Stratification can be seen from two different perspectives: vision and specificity. There are several tools that can be used for this purpose, like OntoPiA (it has a supporting level from vision dimension), ArCo (it is between vision and specificity), data.cnr.it (the modular stack is not necessarily stratified), Framester (there is no stratification).

Experience of ontology stratification strategy and Issues with TLO alignment in IOF
William Sobel: *Chief Architect at MTConnect Institute. He is most recently the co-founder of Metalogi, focusing on edge technology for standards platforms. Chief Technology Officer of VIMANA, providing a leading Industrial AI platform enabling predictive and prescriptive analytics for discrete manufacturing.*

- In this talk, William discussed his experiences leading the architecture group at the Industrial Ontologies Foundry (IOF) and lessons learned along the way which can be summarised as follow:
  - The choice of top-level-ontology (TLO) requires ontological commitments that necessitate design patterns for efficient operation of domain working groups due to the inherent complexity and learning curve of the TLO.
  - To engage domain experts, understand their concerns, and adapt the top and mid-levels to be accessible to participants. This delicate balance between ontological terminology and domain terminology is a continual struggle.

The EMMO Structure and Perspectives
Emanuele Ghedini: *Professor at University of Bologna and OntoCommons WP2 'Top Reference Ontology' Leader.*

- The Elementary Multiperspective Material Ontology (EMMO) uses a pluralistic approach to address the challenge of representing more than one single approach for the description of the domain of discourse.
- The EMMO is using an agnostic mereotopological approach for its Top Level, and provides different coexistent perspectives as its Middle Level, each one with its peculiar covering axiom, whose combinations can address very specific user needs without imposing a unique predefined view. In this way, instead of stratification it can be considered as a pluralistic parallelisation.
- Different perspectives let users describe an object in different ways leading to the fact that data may be described in different ways. These diverse views may be connected to an object by semiotics.

Impact

The inputs collected from the speakers' presentations and discussions during this session of the workshop will feed into the chapter dedicated to the Top Reference Ontology of the OntoCommons Roadmap.

The session highlighted the importance of creating ontologies stratifications and the difficulties encountered in establishing them as there are no defined standards. This is also caused by the fact that the difference between top and middle ontologies is fuzzy. At the same time, Top Level Ontologies are more appropriate to be pluralistic, while Mid-Level Ontologies are more suitable to act as a bridge between the metaphysic and practical applications, so that the top level can make ontologies with lower complexity. The OntoCommons project aims to overcome this issue with the development of the OCES, which consists of ontologies and tools following specific standardisation rules, that can be effectively used as foundation for data documentation in the industrial domain, in order to facilitate data sharing and valorisation and overcome the existing interoperability bottlenecks.

2.2 Day 2 (3 November 2021)

2.2.1 Plenary Sessions[9]

The plenary session of the second day of the OntoCommons workshop was opened by Hedi Karray (ENIT), project's technical coordinator. Hedi presented the agenda of the day and housekeeping information for the attendees.

2.2.1.1 Ontologies for everyone

The first plenary session of the day, entitled "Ontologies for everyone" was presented by ***Dr. Peter Murray-Rust:*** *(Yusuf Hamied Department of Chemistry, University of Cambridge), chemist involved in ontologies for over 20 years, also known for his support of open access and open data, as well as for his research on automated analysis of data in scientific applications, creation of virtual communities and the semantic web.*

Objectives

The presentation of Peter Murray-Rust explored ontologies in different domains, such as materials, chemistry, bioscience, medicine, geopolitics and more, enhancing their validity as tools which can support researchers, from secondary school onwards. A range of ontologies, demos and software was presented with some impactful suggestions for discussions. The starting assumption was that ontologies are very simple, and that they can be used by anybody: historically, creating ontologies has been considered as a hard task, but the ongoing growth of Wikidata, which is updated several times a minute, means that lightweight ontologies can be safely rooted there, and researchers can

[9] https://www.youtube.com/watch?v=mb6NWDxI8BI

make use of the over 100 million relationships which it contains. A group of undergraduate and master students in India's National Institute for Plant Genome Research, are working with this strategy, using tools to rapidly create personal distributed dynamic ontologies, usually of a few hundred entries. Although these may have several applications, he focused on multidisciplinary search and classification of the scientific literature, drawing examples from Lithium-ion batteries, crops and viral epidemics.

Impact

Thanks to the collaborative Open Python software (pygetpapers and py4ami) developed by Dr.Murray's group, early career researchers can easily start reviewing the literature and extracting Linked Open Data, thus being in control of their own analyses and not dependent on commercial gateways.

This also raises awareness on the importance of having Open Access material available, this being one of the main obstacles to this type of research.

The session was an opportunity to explore the possible balance between the **heavy ontology use** commonly experienced, and the **lightweight approach** proposed by Dr. Murray, and gather any views from the expert regarding advantages and disadvantages of one or the other approach, making sure that there is agreement among the use of certain concepts and reaching **stronger interoperability** by having a very strong ontological framework. One of the advantages of the lightweight approach, according to Dr.Murray, is the possibility of building unsupervised knowledge which is based on formal principles but **includes a lot of variety**, although this may not be an appropriately engineered ontology which could be proven to be correct and which was managed by an ontology committee.

2.2.1.2 Extraction of common conceptual components from multiple ontologies

The second plenary session of Day 2 was dedicated to "Extraction of common conceptual components from multiple ontologies", presented by ***Dr. Valentina Presutti:*** *associate professor at University of Bologna and associate researcher at the Institute of Cognitive Science and Technology of the CNR and coordinator of the Semantic Technology Lab. Dr. Presutti's research include AI, Semantic Web and Linked Data, Knowledge Extraction, Empirical Semantics, Social Robotics, Ontology and Knowledge Engineering*.

Objectives

Dr. Presutti's talk focussed on understanding large ontologies (both by humans or machines), a complex but crucially important task for performing ontology engineering tasks such as ontology reuse, ontology matching, ontology evaluation, and (federated) querying. Dr. Presutti described a **novel method for identifying and extracting conceptual components from domain ontologies**, which are used to understand and compare them. The term "conceptual component" in this scope was referred to complex structures expressing relational meaning e.g., membership, locating, interpreting, observing. Conceptual components are the intensional counterparts of OWL implementations in semantic web ontologies (sets of related predicates - classes and properties -

and axioms). Therefore, the conceptual components of an ontology indicate which types of facts, rather than which types of entities, an ontology can represent.

Impact

A number of tools exist for the various steps of ontology engineering, some very popular, others more obscure. Those tools are often designed to be used by ontology engineers and remain difficult to engage with for domain experts. This session was a chance to look at how important the experience of using such tools is, and how it impacts on the process of creating an ontology that fulfills the purpose of the end user.

The discussions following Dr. Presutti's presentations were focused on how to better define conceptual components of ontologies.

2.2.1.3 Ontology in the petroleum industry: conceptual models for knowledge discovery, interpretation and information search[10]

Mara Abel: UFRGS on behalf of ONTOBRAS, Brazil. Geologist and doctor in Computer Science, developing research on knowledge engineering applied to Petroleum Industry. In the last decades, she was dedicated to knowledge management and knowledge engineering research for building ontologies applied to Petroleum Geology, and to the entrepreneurship development. She is co-founder of the knowledge-based software company ENDEEPER and she has conceived several successful applications for reservoir characterization (description, interpretation, geochemical simulation).

Objectives

Ontology allows a non-ambiguous communication among professional people inside a corporate environment community. In the last decades, the Computer Systems for Petroleum Exploration & Production Group of Federal University of Rio Grande do Sul in Brazil have developed domain ontologies to support activities and applications for petroleum industry. The high level of expertise and knowledge in this industry require a multiplicity of technical people and software providers in diverse expertise areas, bringing extensive challenges for integration and interoperability of critical information. Ontology theory plays a relevant role in the challenge of documenting, modelling, integrating, organizing and process the geological and engineering knowledge that support decision taking. We describe here the several ontology-based successful projects developed for petroleum companies.

Impact

Ontology development effort is rewarded by the effective reusability of the model and supports tracing of reservoir properties through different data models, systems and interoperability standards, such as OSDU and RESQML. The precise semantic allows algorithm extraction of tendencies, correlations and patterns from data using IA.

[10] https://www.youtube.com/watch?v=4zaLpPJAU5U&t=222s

2.2.2 Parallel Sessions

Four parallel sessions took place on Day 2, the following paragraphs report on each of them:

2.2.2.1 Establishing a Knowledge Exchange Space[11]

In order to lay the foundation for interoperable, harmonized and standardised data documentation through ontologies, it is essential to draw on already existing networks of (European) bodies, projects and initiatives with the objective of establishing a shared data documentation framework. Members and representatives of OntoCommons-relevant projects, initiatives and communities, were invited to join this session, chaired by Yann Le Franc (e-SDF), with this purpose.

Objectives

The main objectives of this session were:

- to raise awareness of OntoCommons partners about projects related to FAIR implementation, EOSC infrastructure and data management good practices (Research Data Alliance)
- to build the basis for further cooperation between OntoCommons, one of the main goals of which is to leverage existing work in these areas and exchange knowledge by bringing together OntoCommons, Industry, FAIR initiatives and the EOSC landscape.

Three identified collaboration areas within the OntoCommons project were presented during the session, and discussions were carried out on specific topics for collaboration i.e., FAIR principles, cross domain semantic interoperability and services and infrastructure.

Speakers and impulse talks

Presentation of KeXS

***Florina Piroi**: Information Retrieval researcher with experience in domain speciÞc search, member of RDA Austria and member of the EOSC Association Task Force of Long-Term Data Preservation.*

- Introduction of the plans for establishing a "Knowledge Exchange Space for Data Management and Documentation" as a forum of collaboration, ontology alignment, FAIRness assessment, training and certification, in particular on three specific topics: FAIR Principles, Cross Domain Semantic Interoperability, and Services and Infrastructure.
- This responds to one of the main objectives of the OntoCommons project, namely Cooperation and Engagement with relevant stakeholders, in particular with RDA (aligning input to standards for data documentation and DMPs, EOSC (fostering European infrastructures) and FAIR initiatives (contributing to FAIR). To achieve this, OntoCommons has organised focused “exploratory” workshops in order to identify topics for future cooperation.

[11] https://www.youtube.com/watch?v=85bZHL8qcS0

GOing FAIR

***Barbara Magagna**: Landscape ecologist, working for Umweltbundesamt (Vienna) as knowledge facilitator. Previous collaboration with GO FAIR on two topics: FAIR Implementation Profiles (FIPs) and Metadata for Machine workshops (M4M). Co-chair of the RDA WG I-ADOPT.*

- Implementing the FAIR Principles is more about building social contracts than it is about building novel technologies. Aside from technical infrastructures, metadata is a fundamental component of making data FAIR, as well as domain relevant community standards, therefore it is very important to understand what metadata should look like. One of the requirements is that it should be machine-readable, not only human-readable, and it should consider interoperability, moreover it should have a registry of operations.
- The Three-Point FAIRification Framework, that has emerged in the GO FAIR initiative, is a pre-step for the FAIR digital object, with the primary goal of facilitating decision making among the numerous stakeholders required to achieve wide-spread FAIR data and Services.
- GO FAIR also offers FAIRification training so that from the beginning of a grant FAIRness of data is ensured; a FAIR implementation tool is foreseen as a next step for the GO FAIR initiative.

Overview of EOSC

***Karel Luyben**: Rector Magnificus Emeritus of the Delft University of Technology, National Coordinator for Open Science in the Netherlands; Chairman of the Task Force Open Science of CESAER, President of the EOSC Association.*

- Definitions of Open Science and Open/FAIR data (all data can be FAIR, not all data can be open, but they can be as open as possible).
- Presentation of the European Open Science Cloud (EOSC), its background, principles and development, and the vision for the EOSC ecosystem: the starting point of the EOSC Association is that of reducing the fragmentation in the European landscape and giving Europe a lead in the research management, thus developing a Web of FAIR data linking the e-infrastructures. These, in turn, form the backbone for storing data, computing with data and connections for transferring data, while EOSC forms the (research) data infrastructure for the re-use of data.
- Research is most often done in a global context. Thus, it is essential that EOSC is developed in conjunction with other regions in the world, leading to a global open science commons.
- The guiding principles of EOSC are: Multi-stakeholderism, Openness, FAIR principles, Federation of infrastructures and machine-actionability: in the context of the FAIR principles, interoperability is seen in relation to the fact that "research data usually need to be integrated with other data; in addition, the data need to interoperate with applications or workflows for analysis, storage, and processing". Multi-stakeholder approach means that the EOSC Association is expected to provide a single voice representing all stakeholders.

- The EOSC Association mission is to advance the European Open Science Cloud to accelerate the creation of knowledge, inspire education, spur innovation and promote accessibility and transparency.

Overview of RDA
Hilary Hanahoe: Secretary General, Research Data Alliance.

- The Research Data Alliance (RDA) is a global, consensus-based, community-driven organisation of over 12,000 individual and 65 institutional members from 145 countries whose mission is to provide a platform to drive innovation surrounding data sharing and interoperability. RDA enables data to be shared across geographical, technological and disciplinary boundaries through outputs developed by focused Working Groups and Interest Groups of volunteer experts from around the world and drawn from academia, the private sector and government. Established in 2013, RDA draws its membership from individuals and organizations across the data management ecosystem.
- When RDA was first conceived, the vision was to openly share and reuse data between disciplines and countries in order to meet the great challenges of society; the mission is thus to build the social and technical bridges to facilitate that vision; it is more of a road and it grows in terms of members, groups (99 active groups at the moment) and activities; RDA is still valid and as long as it is valid and valuable to the community, it is important to keep it going.
- Guiding principles: bottom-up/community driven; openness and consensus; inclusiveness; harmonization (also in terms of technology and ideas); non-profit —> technology neutral (e.g. try to avoid technology lock-in);
- Members are volunteers connecting and contributing to RDA in very many ways; many do not get active in groups; some are in the driving seat; all are welcome; affiliate members (such as codata and GO Fair): work together because there is a mutual benefit for these different communities;
- WGs —> there needs to be output (recommendations, tools etc.); they have a lifetime; IGs --> depend on the area on which they focus; they last as long as the discussions are on-going; often IGs result in WGs; Community of Practice —> much larger IGs; often result in IGs and WGs
- Bear in mind that one of the assets --> the large community that RDA brings with it: RDA has a ton of experts on global scale --> if you want to go fast, you go alone, if you want to go far you go together

Impact

The discussion points and questions of this session (derived from the session's objective) are to explore the best ways to organize a multi-stakeholder collaboration. Previously identified possibilities are the establishment of Task Forces as well as a Memorandum of Understanding (MoU). The creation of a FAIRness Clinic and an Ontology Clinic should and could also be taken into consideration, which could consult on what OntoCommons is producing and assess its course.

An important gap emerged from the discussion: no groups are currently working on the FAIRification of industrial data, although there are currently discussions in relation to GAIA-X and a project called FAIR Plus exists.
The session opened the discussion about different approaches: the SHARC/FDMM grid and the FIP profile/FAIR implementation profile and the FAIR data maturity Matrix: these are complementary approaches that should be combined together, since they deal with listing what communities are using and defining metrics as solutions that should be used.
Moreover, it was discussed if it is better to assess the validity (correctness) of user-entry in the FAIR metadata level or just to evaluate the presence of a value.
Some additional useful inputs concerning the State of the Art come from the RDA recommendations, the Metadata for Machine Workshops presented in one of the sessions and the I-Adopt Framework:

- Link to RDA recommendations might also be useful: https://www.rd-alliance.org/recommendations-and-outputs/
- Metadata for Machine Workshops: https://www.go-fair.org/resources/go-fair-workshop-series/metadata-for-machines-workshops/
- I-Adopt Framework: https://www.rd-alliance.org/group/interoperable-descriptions-observable-property-terminology-wg-i-adopt-wg/wiki/i-adopt

One of the KExS (Knowledge Exchange Spaces) objectives is to jointly identify gaps.

Input concerning Definition of success

- When planning activities, seek to understand the actual outcomes that can be achieved during the period of one project (with only 2 years left to go). Build the KExS Legacy on that and find ways to give it a longer lifetime (than that of a project) through that.

Input concerning Recommended Actions

- There already is a lot of project-relevant knowledge out there. It would thus make sense to seek out this kind of knowledge, streamline it and connect it. That, however, is a long-term goal (not likely to be achieved within a project).
- Identify and on-board the key stakeholders and align activities as well as objectives with them - even if they are not contributing to KExS actively.
- RDA could help reaching out to the community once the time to do so has come.

The challenge that KExS is facing, is to extract all that is relevant for OntoCommons (and share it) from the many initaitves and projects and organizations that exist and are in one way or another contributing to (the development) of ontologies.

It is crucial to know where to find relevant information, to collect it and to connect it in the long run because usually there is a lot of knowledge out there already. However, since OntoCommons is limited in time (2 more years to go) converging all of that may not be possible. It is thus essential to define as tangibly and concretely as possible, the end goals and the legacy that should linger once the project ends. Questions to be answered therefore are:

- Do you hand your legacy over to others/share?
- How can the project be populated by the community?
- How can the key stakeholders be involved (even if they may not be contributing actively)?
- What is actually doable in the 2 years to go?

Key objectives and legacy should be aligned with key stakeholders; e.g. getting the relevant EOSC Task Forces on board is a reasonable approach in the short run. In addition, establishing guiding principles may support the KExS endeavour. Once the time has come RDA could help with reaching out to the community because there is mutual benefit in it.

2.2.2.2 Ontology-based digital marketplaces for Industry Commons[12]

Digital Marketplaces are multisided collaborative and trading platforms that facilitate materials innovation by easing access to otherwise disparate sources and deployments of information, expertise, software applications and data. There are multiple marketplace projects running at the moment, with only limited interaction between each other. OntoCommons aims to establish a cooperation with all the relevant stakeholders for data documentation and interoperability in industrial domains.

Objectives

The main objective of the session is to know about the previous experience and gaps in the ontology/taxonomy based standardized data documentation in the marketplace.

- Learn about the experience from VIMMP, MarketPlace, and Market 4.0 projects regarding ontology-based marketplaces.
- Discuss the application of the OntoCommons approach to supporting interoperability.
- Propose a practical way to have alignment and interoperability of data among different marketplaces.

Speakers and impulse talks

EC vision and recommendations
Laszlo Hetey: *Health and Digital Executive Agency (HaDEA), EC*

- The Health and Digital Executive Agency (HaDEA) is the new agency responsible for projects including the materials and manufacturing marketplaces. The cluster relevant to the OntoCommons stakeholders will be the Digital, Industry and Space Cluster, offering around €15 bn. A call of interest will be HORIZON-CL4-2022-DATA-01-04: Technologies and solutions for data trading, monetizing, exchange and interoperability (AI, Data and Robotics Partnership). AI will be pertinent as all existing e-commerce who work with AI are located elsewhere but Europe.

[12] https://www.youtube.com/watch?v=d2P4iWpaA0c

- Marketplaces are expected to have easy navigation, functionality, usability and competitiveness as they have to be viable besides other e-commerce ventures. Several projects in the area of new business models and marketplaces finished such as iBUS, FENIX, MANU-SQARE and still ongoing projects include OPEN-NEXT, INEDIT, iPRODUCE, as well as WeldGalaxy, Market 4.0 and DOME 4.0.

Experiences of marketplace projects
***Daniele Toti** (Marketplace), **Silvia Chiacchiera** (STFC UKRI on behalf of VIMMP), **Kosmas Alexopoulos** (University of Patras, on behalf of Market 4.0)*

- Daniele Toti introduced MAEO, the MarketPlace Agent/Expert Ontology which is compliant to the EMMO and is an application ontology, also using some concepts of FOAF. PROMO is an ontology-based simulation environment, where users provide variables and equations and can create building blocks which then create a workflow. The challenges were the alignment with EMMO, reusing ontologies, and also deploying and using triple stores where necessary.
- Silvia Chiacchiera (ViMMP) and her colleagues are responsible for the development of ontologies, interoperability and standards within their marketplace. A total of eight ontologies with alignment to the EMMO have been developed to enable semantic interoperability. Important are also interfaces that are human readable, if humans are expected to use them and good tools for annotation. Also, a good balance between expressivity and usability has to be found. If one goes towards inter-marketplaces interoperability a consensus between all entities has to be found. Hence, sharing of public deliverables or documents could aid herewith.
- Kosmas Alexopoulos (Market 4.0) was introducing the building blocks of their marketplace as an e-commerce portal, Industrial Data Space with several data models, APPs for collaboration between customers and suppliers, support for onboarding and integration of 3rd party APPs. Market 4.0 plans to enlarge via opening up to other marketplaces and seeks synergy/interoperability with them. Hence, they see the necessity of using ontologies to achieve this.

DOME 4.0 requirements
***Bjørn Tore Løvfall:** SINTEF*

- DOME 4.0 wants to provide FAIR data and knowledge and services around that. Data exists in abundance but interoperability is not a given. Thus, they plan a "digital collaborative" or "collective knowledge" provision assisted by ontologies. DOME sees themselves as a service broker who does not want to harvest or store data but provide them. They want to become a marketplace of marketplaces.

Marketplaces interoperability demonstrator
Silvia Chiacchiera: UKRI, UK

- ViMMP is not only a marketplace but also a Demonstrator in OntoCommons. Each individual marketplace has its different conceptual data models so a Top or Mid-level ontology will be key to query on high-level relations. Thus, a bespoke domain ontology can be aligned and mapped. The demonstrator case wants to prove that the OntoCommons approach can work for such complex entities as marketplaces are. Marketplaces are not publicly running as businesses yet, but would need to be open to prove true interoperability. The latter is expected to be reached by either agreeing on a common model (difficult) or by building a mediator/mapping (less difficult). The demonstrator will try to prove this on a small topic, i.e., materials modelling but not on the whole market place.

Impacts

The following questions summarise the issues for this session.

What have the experiences of the 'older' H2020 projects told us?

- A good Business model is required.
- Ontologies are key for interoperability and paving the way to AI.
- Ontologies in marketplaces are used for the following purposes:
  - Marketplace services and operation: Connect, Search, Test/Simulate, Tender/Bid, Compare. Feedback
  - Marketplace external: to facilitate integrating sources of information, experts, software, matchmaking, interoperability with other marketplaces, etc – widely agreed ontologies important
  - To support advanced functionalities e.g., modelling workflows offered in the marketplace

Lessons learnt:

- Balance between new ontology developments (that can take a long time on a project duration scale) and using existing resources (e.g., FOAF etc) must be struck
- **Interoperability**
  - Semantics is an important part of the solution, but not the whole story.
  - Syntactics does matter too (e.g., data model implementation/constraints).
  - The two can be entangled.
- **Annotation/Mapping**: This requires resources and can be time consuming and requireds tools to support it. Potentially annotation/tagging (as in publishing) could be enforced?
- **Human factor**: Interfaces need to be user friendly.

Challenges

- Alignment with still-in-progress TLO (EMMO). Also, many choices need to be made during ontology development. It is impossible to combine consensus with wider field and development time constraints.
- Balance between expressivity and usability.
- Reuse of ontologies, Integration/merging with other MarketPlace application ontologies.
- Links to databases – hopefully not in the long term.
- Triplestore deployment and usage.
- Using new technologies without missing out on existing previous approaches and a plethora of available tools.
- Identifying suitable levels of detail for the descriptions.
- Specific application challenges (e.g., different code for different orchestrators for workflows).

DOME 4.0 realated ontologies

- DOME 4.0 is strongly coordinating with OntoCommons. The project is aware how big and unstructured and multi-facetted the data lake is they would like to tap into.
- Needs and expectations
  - Each entity has their own data structure and DOME 4.0 is expected to come up with a universal adapter.
  - DOME 4.0 needs to Turn existing resources into knowledge assets.
  - Semantic data exchange ontology: aligned with EMMO.
  - Ecosystem Information model is required.
  - Data structures for data exchange that are capable of ontological mapping, enabling interoperability are required,
  - DOME 4.0 should enable users of every platform to search and find data and information, including how to exchange it and use it. Users are persona, entities, or other platforms
  - DOME 4.0 does not need/want to harvest the data nor be able to/have to search any "record"

What could a global ontology framework for marketplaces look like?

- Via ontologies, see e.g., graphics from Market 4.0
- European Virtual Marketplace Framework (EVMF), see Demonstrator

How can marketplace ontologies be aligned using a TRO?

- Shared fundamental concepts and small (mid-level) ontology that provides connection (taking the EVMPO that connects VIMMP ontologies to EMMO and other TLO concepts as an example)

How can Marketplaces interact and links be established?

- Sharing documents and technology which are OPEN.
- Further convergence of underlying ontologies/taxonomies

- OntoCommons Demonstrator will work on this and provide the OntoCommons Ecosystem with prototypical needs from digital marketplaces and similar NMBP platforms. Expected benefits include
    - Supporting federated queries on the high-level categories. For example, we could look for "agent" or "infrastructure" on multiple platforms
    - Supporting federated ingest

2.2.2.3 User Experience on Ontology Engineering Tools[13]

A number of tools exist for the various steps of ontology engineering, some very popular, others more obscure. Those tools are often designed to be used by ontology engineers and remain difficult to engage with for domain experts. The objective of this session was to look at how important the experience of using such a tool is, and how it impacts on the process of creating an ontology that fulfils the purpose of the end user.

The session discussed tools for different aspects of ontology engineering, from conceptualization and editing to alignment and finding of common terminology. State of the art ontology engineering tools have limited support for navigating ontologies effectively. Moreover, domain experts from industrial domains have difficulty working with those tools. In order to improve modern ontology engineering environments, the seven tasks[14] identified by Ben Shneiderman in HCI research should be supported. Ontologies are furthermore often designed from scratch, and terminology services can support the reuse and alignment of existing ontologies.

Objectives

- Understand how ontology engineering tools are perceived by their users, and how this perception affects the process of building an ontology.
- Identify opportunities for more meaningful engagement of users with ontology engineering tools.
- Identify where such engagement could better support methodologies for ontology engineering.

Speakers and impulse talks

HCI for ontologies

Enrico Motta: *Professor of Knowledge Technologies at the Knowledge Media Institute (KMi) of the UK's Open University*

Enrico Motta revisited the dimensions of visualisation described in 1996 in an influential paper by Ben Shneiderman, in the context of current ontology engineering environments. Starting from the seven tasks highlighted in the paper, that information visualisation systems ought to support to

[13] https://www.youtube.com/watch?v=w-8DBo35eKk

[14] See session on HCI for Ontologies (Enrico Motta), in 2.2.2.3. For more details about the paper by Shneiderman, see: https://www.cs.umd.edu/~ben/papers/Shneiderman1996eyes.pdf

enable effective browsing and sensemaking, the objective was to demonstrate the extent to which modern tools effectively support or fail to support these tasks.

- Much more work is required by the ontology engineering community before current tools will be able to provide adequate support for basic user tasks, such as browsing and making sense of ontologies.

Terminology Services for Community Driven Ontology Development

Felix Engel (TIB): *Coordinator for the TIB Terminology Service*

- Research data is of inestimable value; research is relying on previous research, which shall be reproducible. Thus, the data used and results must be available, described with metadata. Research involves a wide area of domains, each with its own terminology, which can be community-specific in a domain.
- Since Terminology is dynamic and constantly evolving over time, it shall be designed and maintained by a designated community. Ensuring wide uptake and use of a terminology requires continuous alignment with the needs of the designated community and further ontology developments.
- Terminology Service[15] is a Web portal that supports terminology standardization efforts, it is composed of an Entry Point allowing preparation of research data for effective later reuse, and a Community Hub fostering awareness and ontology alignment. The community can contribute ideas over an issue tracker and a REST API allows to query the collected terminology knowledge. The ontologies in the portal are indexed and classified based on abstraction levels.
- Terminology Service is currently being used by the SC3 project use case, which is working on vocabulary for semiconductors, which is integrated into the service. The ontology is aligned to other ontologies in the service. At the moment, the TIB platform is exchanging with EIB to discuss integration, in fact, open-source services are used in the backend, such as the ontology-lookup-service. The services could be also extended to other industrial domains.

Information Modelling Framework

Arild Waaler: *director of the SIRIUS Centre for Research-based Innovation and professor in computer science at the University of Oslo.*

- This session addressed gaps between the needs from engineering for principles, methods and tools for structuring of asset information, and the ones currently offered by ontology communities. The Asset Information Modelling Framework is proposed as a solution to mediate this gap, supported by an asset modelling editor currently under development by Equinor and scheduled for open-source release in 2022.
- Information in heavy industry needs tools capable of structuring it in a precise and simple way, and the "asset information modelling" is based on relations, and objects that are created

[15] https://terminology.nfdi4ing.de/ts4ing/index

and named through relations. Documentation of the engineering process and decisions are key: the ISO 81345 – Standard for life-cycle information divides life-cycle information in a function aspect, a location aspect, and a product aspect, with relations between them.

Impacts

The session allowed the OntoCommons Consortium to gather important input concerning current Industrial Need for Ontology Engineering tools:

- Abstraction of complex hierarchies of concepts facilitating browsing/navigation and sense-making in ontology engineering tools
- Collaborative editing of ontologies
- Standardization and alignment of metadata terminologies.

The current State of the Art includes a number of tools for ontology engineering such as Protégé and TopBraid, as well as emerging applications such as Gra.fo for collaborative ontology engineering. Ontology Lookup Service and OntoPortal were commented on as state of the art terminology services.

The following table summarises the existing gaps identified for Ontology Engineering Tools, that can be included in the OntoCommons Roadmap.

- Current ontology engineering environments provide very limited support for navigating ontologies effectively, in particular with respect to the tasks identified by Ben Shneiderman. Protégé for example doesn't support the task of zooming in and out on concept hierarchies to a satisfactory extent.
- Conventional ontology engineering tools are difficult to understand for engineers (domain experts).
- There is an existing gap in Ontology Engineering Tools for Heavy Industry, where the "asset information modelling" has potential to bridge this gap.
- There is also an existing market gap for HCI commercial tools (with a bigger market on the developer side, rather than the user side). The existing tools are quite limited and a barrier to entry.

The following inputs can help define success criteria for tool development:

- Regarding the design of ontology development environments, the coverage of the tasks by Ben Shneiderman[16] to a satisfactory extent could be a success criterion.
- Ontology engineering tools shall be designed with the tasks identified by Ben Shneiderman in mind.
- Regarding the terminology service, it is recommended to broaden the scope of existing services to a wider range of domains in industry

[16] See 2.2.2.3

2.2.2.4 Ontology Adoption[17]

This session looked into the critical, yet often overlooked step of adoption in the ontology engineering and application methodology. Discussions focused on approaches and ways to ensure the created ontologies are usable and supported by the intended users and developers in an industry context.

Objectives

- Understand what current practices exist in enabling adoption of ontologies, for specific use cases, or generally.
- Identify pitfalls that prevent or hamper adoption.
- Figure out how much good practice for adoption is supported by methodologies and tools.

Speakers and impulse talks

Ontology adoption in the aircraft industry
Gianmaria Bullegas: *founder and CEO of Perpetual Labs ltd. Perpetual Labs is a startup dedicated to creating DevOps tools for the collaborative design of Cyber-physical systems.*

- The presentation focussed on the experience of using ontologies to support the systems engineering process relevant to the design of a space mission, which is called semantic systems engineering.
- Traditional systems engineering is done in a document-based way. There is a transition to model-based and data-centric systems engineering. However, there is still a gap to capture the relationships between the data and make the knowledge explicit. Therefore, it is critical for the systems engineering community to overcome the challenge of digital continuity, which is the capability to capture the semantic links between different information models and artefacts about the system. These links need to be made apparent and traceable across the three dimensions of systems engineering, which are across disciplines, throughout the life cycle, and along the supply chain.
- An ontological framework is developed to support the systems engineering of the 'Large Aperture Space Telescope' Mission. The semantic systems engineering ontology consists of a process ontology, a domain lexicon, a modelling and simulation ontology and an organisation ontology. It also maps to a top-level ontology (BFO) and a mid-level ontology (CCO). It reuses well-established standards, ontologies and other resources.
- The ontological framework is tested in the use case of the 'Large Aperture Space Telescope' Mission, e.g., capturing different aspects of the system design and physical system architecture, enabling the traceability of requirements, etc.
- The tool that supports semantic systems engineering is called GraphSF. It is a web-based collaborative platform that allows large, distributed teams of engineers collaboratively designing complex systems. The platform not only shares data, but also captures the semantics of the data and manages the semantics in a formal way using ontologies and knowledge bases.

[17] https://www.youtube.com/watch?v=mLWoFK6QDF4

Adoption of GoodRelations

Martin Hepp: *Professor of Web Science and Digitalization at the Universität der Bundeswehr Munich and CEO and Chief Scientist of Hepp Research GmbH*

- Data interoperability benefits from shared conceptualizations of data. Based on the decade-long work on the GoodRelations ontology for e-commerce, this presentation discussed the interplay between the multiple design decisions that influence the overall effect of ontologies for data interchange. This impulse talk focused on the lessons learned from trying to build ontologies that span every industry in every economic system across the globe for any stage of the supply chain.
- Likelihood of people being able to consume data in an interoperable way depends on how they are 'stored' in the minds of users. Despite lots of axioms or examples, the resonance with the conceptual structure in the minds of users is very important.
- Any kind of computational operations over data can only be guaranteed to work if the type definitions of the origin and the destination of the data are compatible.
- Formal specifications would not always guarantee correct usage. Web ontologies would not always allow for the automated processing.
- Challenges to build good ontologies include: (a) improve the reliability of type memberships of entities in information processing, (b) finding types that provide sufficient distinctions for an algorithmic information processing and data granularity, (c) finding types that can be populated from existing data sources without reclassification tasks, and (d) finding conceptual distinctions that can be reliable.
- The key to GoodRelations' success is (a) making it as easy as possible for people to adopt, and (b) making it as rewarding as possible for people to use the ontology in an economic sense. Therefore, creating tangible, measurable incentives for publishing respected data according to the ontology is the easiest way to convince large relevant consumers to use it.

Experiences with ontology repositories

Clement Jonquet: *Dr. Clement Jonquet, PhD in Informatics, is associate research scientist at INRAE in the MISTEA research unit and associate professor at University of Montpellier, associated member of the LIRMM laboratory.*

- This presentation was focused on OntoPortal technology and partnership for co-developing ontology repositories. These include
  - NCBO BioPortal services: bioportal.bioontology.org
  - NCBO BioPortal part of the linked data cloud: lod-cloud.net
  - NCBO BioPortal French ontologies: bioportal.lirmm.fr
  - AgroPortal: agroportal.lirmm.fr
  - EcoPortal: ecoportal.lifewatch.eu
  - MatPortal: matportal.org
  - MedPortal: medpotal.bmicc.cn
- The importance to have ontology repositories is that (a) it makes ontologies known to others, (b) it offers others to reuse existing ones, (c) it verifies the usefulness of the ontology, (d) it helps finding data resources that are relevant to the domain of the ontology, (e) it leverages

ontologies to enable new science, and (f) it enables users to use the ontology without management.

- The challenges for ontology repositories include (a) ontology metadata evaluation and selection, (b) multilingualism, (c) ontology alignment, (d) generic ontology-based services, (e) annotations and linked data, and (f) scalability and interoperability.
- OntoPortal Alliance[18] is dedicated to synchronising and mutualising research and development efforts. It aims to maximise OntoPortal value, improve OntoPortal software while managing several parallel and different installations, increase semantic uptake in science communities and facilitate adoption of the FAIR principles, and increase the ecosystem's long term operational and financial health.

Impacts

This session has helped identifying some barriers to ontology adoption:
There is still a lot of confusion and different senses of the word "ontology", e.g., knowledge organisation systems ranging from terminology lists, to thesauri, to taxonomies, to ontologies. Apart from different senses, to identify a correct purpose and use cases to pick which tech platform/system is the most appropriate, is the biggest barrier and the key to successful adoption.

A way to influence industry's willingness to adopt ontologies, would be to understand what kind of operations the industry needs to run with the data schema: the better industry knows this, the more it is able to build a useful ontology. It is also fundamental to define, from the first steps of developing an ontology adoption strategy, a clear purpose for that ontology (what is that specific ontology needed for?). Finally, an incentive could be that of associating important stakeholders with the process and outcomes of ontology adoption, to lead by example.
Additional inputs of this session are summarised in the following table:

- The session has highlighted an existing gap in semantic systems engineering, which is the systems engineering process relevant to the design of a space mission: traditional systems engineering is done in a document-based way, there is a transition to model-based and data-centric systems engineering. However, there is still a gap to capture the relationships between the data and make the knowledge explicit.
- Digital continuity is a critical challenge that the systems engineering community has to overcome in order to capture the semantic links between different information models and artefacts about the system.
- TLO has proved to be one of the main challenges when mapping the Modelling and Simulation Ontology to BFO due to its realistic stance?
- Challenges to build good ontologies include: (a) improve the reliability of type memberships of entities in information processing, (b) finding types that provide sufficient distinctions for an algorithmic information processing and data granularity, (c) finding types that can be populated from existing data sources without reclassification tasks, and (d) finding conceptual distinctions that can be reliable.

[18] https://ontoportal.org/

- The challenges for ontology repositories include (a) ontology metadata evaluation and selection, (b) multilingualism, (c) ontology alignment, (d) generic ontology-based services, (e) annotations and linked data, and (f) scalability and interoperability.
- OntoPortal-type sites allow FAIR access to the domain-specific ontologies: it is worth investigating its usage for Materials with OntoCommons and Manufacturing.
- A top-level ontology needs a certain top-level view, therefore, using domain experts for a top-level ontology might not work well.
- An incentive for ontology adoption could be that of having "big names" associated with the process and outcomes.

2.3 Day 3 (4 November 2021)

2.3.1 Plenary Sessions[19]

The plenary session of the third day of the OntoCommons workshop was opened by Gerhard Goldbeck, CEO and Founder of Goldbeck Consulting, and Industry Commons Translator task leader of OntoCommons. During the welcome speech Gerhard shared the agenda of the day to give a detailed introduction of the various talks and their purpose.

2.3.1.1 Use of ontologies in the manufacturing and production sector

Jorge Martinez-Gil: senior researcher and project manager at the Data Science Software Competence Center Hagenberg in Austria.

Objectives

Jorge's talk presented an overview of how the manufacturing and production industry can benefit from ontology-driven tools that allow the identification, understanding, and correction of faults root causes, due to the cost of handling such situations.

To make his case, Jorge introduces a case study on power transformers, an artifact very common to find in factories and production facilities that create various problems in occasion of downtime from a time and cost perspective.

Given the fact that ontologies-like techniques have not been studied in this domain and the great need of tools for predictive maintenance, Jorge shared how ontologies could be used to perform "cause recommendation, failure classification and advanced querying".

Impact

This talk shows that ontologies are a systematic way to document industrial processes and build tools for fault root cause analysis with powerful inference and reasoning mechanisms that do not require large training dataset and guarantee full replicability and reproducibility of the results.

[19] https://www.youtube.com/watch?v=aFNFfocPSBw

2.3.2 Parallel Sessions

The following sections show more details on the objectives and impact of the parallel sessions conducted on the third day of the workshop.

2.3.2.1 Fair Technology Adoption in Demonstrators[20]

This session was moderated by Umutcan Simsek, postdoctoral researcher at Semantic Technology Institute research group at University of Innsbruck.

Objectives

This session provided an introduction to FAIR principles and shared an overview of their implementation in the industry via the OntoCommons demonstrators highlighting best practices and challenges of FAIR adoption in the industrial use cases.

Speakers and impulse talks

FAIR Principles and GOFAIR

Barbara Magagna: is a landscape ecologist working for Umweltbundesamt (Vienna) where she undertakes the function of a knowledge facilitator. Collaborating with GO FAIR.

- In this session, Barbara gave an introduction of the FAIR principles, their purpose to make data and services findable, accessible, interoperable and re-usable for both machines and people and the importance of metadata to make data and services FAIR.
- Metadata is crucial to make data FAIR, therefore focusing on FAIR metadata is a great strategy to go towards the implementation of FAIR data. This is why GOFAIR has developed the FAIR Implementation Profiles (FIPs) to guide the implementation of the 15 FAIR principles.

An industrial demonstrator: FAIRness at OAS

Sebastian Scholze: Studied Computer Science at the University of Bremen. Since 2000, he has been working as a scientific staff member at ATB. He has excellent IT skills in programming lan-guages (java, c/c++, perl, python), database systems, and development methodologies (RAD, XP, RUP, OOP). Active in researching context awareness.
Ana Correia: Researcher at ATB, involved in diverse CEC funded RTD projects, has long project experience in the development of context aware systems, user driven telematics solutions for automotive industry, industrial KM systems and platforms for the introduction of Collaborative Working Environments in manufacturing industry, design and deployment of Product Service Systems, ontology development and application, among others.

- Sebastian Scholze and Ana Correia (ATB Bremen) presented the FAIR principles implementation in the OAS yard management OntoCommons demonstrators.

[20] https://www.youtube.com/watch?v=SXDTEbb9aWQ

- Given the fact that their yard management system was not flexible enough to address customers' requirements, OAS aims to create a next generation yard management solution to improve the effectiveness and responsiveness of decision-making in logistics control systems based on sharing built around data streams semantically described by dedicated PSS ontologies.
- Status of OAS's FAIR principles implementation. While findability and accessibility principles are fully implemented, interoperability and reusability principles are in a less advanced state:
    - Findability: Metadata and data are fully identified by a persistent identifier and rich metadata is provided to allow data discovery.
    - Accessibility: The metadata contains information to enable the user to get access to the data. Metadata and data are accessed through a standardised protocol that can be accessed automatically.
    - Interoperability: Metadata and data uses knowledge representation expressed in standardised format and machine-understandable knowledge representation.
    - Reusability: There are plans to have metadata and data comply with machine-understandable community standards (an ontology).
- Becoming an OntoCommons demonstrator, OAS will use the project's best practices and methodology to achieve a higher FAIRness level and improve the interoperability and reusability of data outside of the OAS ecosystem.

The FAIR cookbook, by the IMI FAIRplus project: a brief tour

Philippe Rocca-Serra: Associate Member of Faculty at the University of Oxford e-Research Centre. His primary interests revolve around making data more open, accessible and interoperable.

- The FAIRplus and ELIXIR FAIR Cookbook are an online combinations of guidance and technical hands-on resources that cover the operational steps of FAIR data management for the life sciences created for researchers, data scientists, policymakers, data managers and software developers in need of practical assistance in their FAIRifaction journey.
- Philippe shared a practical example of how researchers could use the FAIR cookbook, by showing how a team of researchers used the cookbook to find open source tools, discover guidelines and references that they then used to integrate a few datasets into a knowledge graph to support a specific analysis.

Impact

The input collected will feed into the chapter dedicated to Industrial Domain Ontology of the OntoCommons Roadmap.

The recent increase in awareness regarding what FAIR data means and what are their benefits, has shifted the focus towards the actual implementation and evaluation of FAIR data. This session has highlighted some valuable resources (FAIR Implementation Profiles and FAIR cookbook) that researchers could use to make their data FAIR and the importance of FAIR data indicators to

evaluate the correct implementation of the FAIR principles and understand the skills required to address the challenges and shortcomings of the FAIRifaction process.

In fact, whereas the FAIR principles have a clear definition and the FAIRifacation path is fairly standard, there is no one-size-fits-all solution for their implementation. This is why it is important to adapt the implementation strategy to the specific contest and use clear FAIR data indicators to evaluate the correct implementation of the FAIRifaction process.

2.3.2.2 Domain Ontology for manufacturing and supply chain[21]

This session was moderated by Dimitri Kiritsis, leader of the ICT for Sustainable Manufacturing group at the Institute of Mechanical Engineering of EPFL.

Objectives

This session introduced the requirements and specifications of ontology models in industrial maintenance, the position of systems engineering in the landscape of industrial engineering and manufacturing of industrial domain ontologies and the challenges in developing a reference supply-chain ontology.

Speakers and impulse talks

Ontology engineering for Industrial Maintenance

Melinda Hodkiewicz: *Industrial Ontology Foundry, coordinates the Maintenance Working Group. She leads the NLP-TLP program in the Australian Government and Industry funded Centre for Transforming Maintenance through Data Science. Chartered Engineer registered in the UK, member of IEEE and the IOM.*

- modular ontologies for maintenance texts: Maintenance work orders, equipment rebuild reports, failure investigations, maintenance procedures, and equipment manuals are a valuable but hidden resource of unstructured and semi-structured maintenance-related engineering text data for equipment manufacturers and asset operators.
- This is why the NLP-TLP group at UWA seeks to apply modular ontologies (aligned with the BFO ISO/IEC 21838-2 and ISO 15926-14 top-level ontologies) to these raw data to unlock the information captured in these texts and standardise different areas of maintenance management processes and practices.
- A practical example of the benefits of applying modular ontologies for maintenance texts show how from work order raw data it has been possible to infer that a specific engine participated in an end-of-life event, thus extracting crucial information for the failure calculation and maintenance strategy development.

Systems Engineering as the foundation for industrial domain ontologies

Jinzhi Lu: *Research Scientist at EPFL. Vice head of the China Council on Systems Engineering (CCOSE), China Council on Systems Engineering.*

[21] https://www.youtube.com/watch?v=pV7pui3TrVU

- Model-based systems engineering (MBSE) is a solution to integrate system development models (CAD, testing models, property models, performance models, etc.) and manage the complexities of system development.
- It is important to use ontologies to represent the models to increase data interoperability, since the modeling languages are heterogeneous even within the same organisation system.
- Two ontologies were used for this purpose: the Industrial Ontologies Foundry (IoF) Systems Engineering (focused on the system architecture, life cycle and requirement) and MBSE (focused on the GOPPRRE ontology and two use cases to support the ontology) ontologies.

Ontology engineering for supply chain, procurement, and logistics

Farhad Ameri: Professor of Manufacturing Engineering and Technology at Texas State University and the Director of the Engineering Informatics (INFONEER) Research Group. Chair of the Supply Chain WG in Industrial Ontology Foundry (IOF).

- The current state and procedure used to create the IOF Supply Chain Reference Ontology (SCRO) still under development.
- Ontology in the supply chain domain is very important to achieve human and machine interoperability between information systems (CRM applications, ERP solutions, etc.) of business needs and vendor offers.
- To make the ontology relevant across the entire supply chain lifecycle, IOF defined the requirements of the ontology by using three use cases (supply chain discovery, traceability and logistics) each defining specific notions.
- To develop this ontology, IOF used BFO as the top-level ontology and some mid-level ontology (among which IOF Core).

Impact

Ontology often is often able to unlock innovation in various domains. In the maintenance domain, for example, ontology can help inferring failure root cause analysis, state of systems and other valuable knowledge hidden in the current volume of unstructured maintenance text documents.

This session showed how ontologies could be the "behind the scene" trigger for various innovation mechanisms in the maintenance and manufacturing domain that every organisation should consider adopting, as they proved to be able to unlock previously unstructured information, enable information systems interoperability and help standardisation efforts.

2.3.2.3 OntoCommons Demonstrators[22]

This session was moderated by Anna Fensel, Associate Professor at the Wageningen University and Research.

[22] https://www.youtube.com/watch?v=6VUOlB1a-qk

Objectives

This session aimed to address the developments of new and existing OntoCommons demonstrators, their impact on the project and how they can benefit from the project's solutions and best practices.

Speakers and impulse talks

Measuring the impact of industrial ontology application

Evgeny Kharlamov: *Evgeny Kharlamov does AI-centered R&D on Semantic Technologies, Digital Twins, Ontologies, Knowledge Graphs and on their combination with Machine Learning methods.*

- During the "measuring the impact of industrial ontology application" presentation, Evgeny Kharlamov (BOSCH) described the impact that ontologies can have on an industrial organisation. Evgeny shared various practical use case examples, such as:
  - Equinor, an oil company that, thanks to the application of ontologies, simplified and reduced the data access time from days to hours.
  - Siemens used semantic technologies to improve the remote diagnostics of complex turbines by reducing the time needed for the diagnostic from hours to minutes.
  - Festo, developed semantic solutions to reduce the configuration time of complex technical systems made of thousands basic components and thus billions of combinations, from hours to minutes.
- Evgeny then analysed how the time decrease resulting with the application of industrial ontologies could turn into a positive financial impact for the organisation, especially when the time savings are scaled up across various operations in different factories.

Characterising Tribological Experiments: Current Status and Impact of OntoCommons on TEKNIKER Demonstrator

Iker Esnaola-Gonzalez: *Coordinator of Artificial Intelligence in Tekniker and researcher in the Intelligent Systems Unit.*

- Tribology is the science that deals with the design, friction, wear, and lubrication of interacting surfaces in relative motion and with the discovery of how a specific material will behave in specific contests.
- The lack of experiments documenting standards, produces heterogeneous information that is difficult to access for researchers.
- Tekniker's OntoCommons demonstrator is therefore using ontologies to create a common representation of tribological experiments and enrich the data with additional information to help tribologists have an ontology-based homogeneous access to the data and shorten the time, number and size of experiments required to identify the behaviour of a material or combination of them with respect to specific operating conditions.

Demonstrating the FAIR Data Station for managing metadata in the life sciences

Jasper Koehorst: Doctoral researcher combining Semantic Web technologies, big data analytics and Life Sciences at the Laboratory of Systems and Synthetic Biology.

- Ontologies can have an important impact on the microbial life science community, given the huge amount of data produced in this domain.
- Setting up an experiment, sample collection and processing requires human involvement.
- To support researchers in improving the FAIRness of their research, the Unlock WUR microbial facility developed the FAIR Data Station, a four-step process metadata management open-source web tool (excel metadata form generation for data collection, data registration, data validation and semantic resource availability) that makes sure that the metadata associated with these four steps can then easily be captured and integrated into the research workflows by allowing researchers to register and continuously update their data before their validation.
- The FAIR Data Station's metadata structure contains information such as what is the project doing the research, the information about what is being researched, who can access the data, what is the subject of the observation and the dataset related to a specific piece of data.

Impact

This session showed how the OntoCommons demonstrators highlight the benefits of ontology-based industrial data access to help organizations save time and money, since there is no standardised way to gather data within different industries and organisations. The more complex and larger the dataset, the greater the benefits for the organisations that apply the ontologies to research workflows.

All use cases presented in this session showed how further progress on FAIR data, metadata management and industrial domain ontologies development and implementation best practices, will turn into technological and societal innovation thanks to greater cross-domain data interoperability and easier complex data access.

2.3.2.4 Industrial Engineering[23]

This session was moderated by Stefano Borgo, researcher at the Laboratory for Applied Ontology ISTC-CNR.

Objectives

This session aimed to provide an overview on how to formally present competency questions and their role for ontology development. The presentations also explored the practical role of ontologies in industrial applications and the impact of the transition to ontology-driven information systems.

[23] https://www.youtube.com/watch?v=2qq8lnur4KI

Speakers and impulse talks

How to use competency questions in ontology requirement analysis?

Michael Grüninger: Has been working in the area of formal ontology and its applications to industrial problems for the past twenty-five years. He has published over 130 peer-reviewed papers, including a seminal paper in the methodology of ontology design and evaluation. His current research focuses on the design and formal characterization of theories in mathematical logic and their application to problems in manufacturing and enterprise engineering.

- Michael Grüninger (University of Toronto) introduced the role of competency questions (such as "What axioms do I need in my ontology?" or "How do I know when I am finished?") as a way to guide ontology development through the specification of the semantic requirements needed to create and evaluate the ontology by testing and understanding the intended meaning of its vocabulary.
- Ontology verification is concerned with the match between the intended models of an ontology (clean dataset without errors consistent with the ontology) and the models following from its axiomatization. Ontology verification is supported by using theorem provers, such as the "entailment of competency questions".
- Ontology validation is concerned with checking whether the intended models are the correct models for the ontology. This can be verified by engaging in discussions with the domain experts who specified the intended models to understand whether the competency questions asked really match their knowledge.

Ontologies for manufacturing

Walter Terkaj: Walter Terkaj is senior researcher at STIIMA institute of the National Research Council of Italy. His main research interests are related to the study and modelling of production systems in the scope of digital factory applications. He employed semantic web and VR technologies in research projects and academic teaching.

- Ontology-based Digital Twin has been applied to factories and related products, processes and to increase the interoperability of these digital technologies along the factory lifecycle, the coherence of evolving models and the synchronisation between real and digital factories.
- In application contexts related to factory and manufacturing engineering, ontology experts work with highly heterogeneous knowledge and data regarding different entity types (machines, resources, components, events, production systems, maintenance, etc.) and with ontologies that alone cannot manage this heterogeneity.
- To overcome this challenge, an integrated architecture of ontology modules has been used called Factory Data Model (FDM).
- The FDM is based on the Industry Foundation Classes (IFC), its OWL formal representation called ifcOWL, and other models, including various ISO standards and ontologies (such as ssn, sosa).

- Walter then concluded with a use case for the FDM architecture, by showing how it could be used to overcome data heterogeneous data in the case of an assembly line producing self-closing cabinet hinges with 19 workstations (building, product, process, production resources, product/process/resource relations).

Experience with SAREF for Industry

Mauro Dragoni: Research Scientist at Fondazione Bruno Kessler within the Digital Health Research Center. His main research topics concern knowledge management, information retrieval, and machine learning by focusing on the development of real-world prototypes as outcome of his research activities. He has been involved in a number of international and industrial research projects.

- The Smart Appliances REFerence ontology (SAREF) core ontology has 11 ontology extensions in different domains. This is a series of user-friendly technical specifications published by the European Telecommunication Standardization Institute (ETSI) in a repository available for developers.
- The SAREF framework was an explicit request from the industry that got the support of the standardisation world at an early stage and that is now maintained and evolved by experts from several European organisations that successfully collaborate with each other and can count on the continuous support from ETSI and the European Commission.
- Mauro concluded by sharing some of the expected impact of the SAREF core ontology, such as the support to the standardisation of some IOT, IEEE and other technical recommendations, increase the adoption of the SAREF conceptual model in various domains for the realisation of applications, services and connected devices and appliances.

Impact

This session highlighted the importance that the interaction with domain experts and competency questions play during the ontology development life-cycle, not only for the technical development of the ontology, but also to make ontologies useful for the targeted domain and interoperable. The importance of domain experts' interaction and competency questions increases with the complexity of the use of the ontology, such as ontology-based digital twin for industrial domains. To conclude, one of the biggest challenges of industrial domains is the huge amount of data and its heterogeneity, which sometimes requires the interoperable use of more than one ontology to be overcame, but that then could unlock cross-domain innovations.

2.3.2.5 Community-based Ontology Development: Lessons Learned from the Financial Industry Business Ontology (FIBO) [24]

Elisa F. Kendall: Partner in Thematix Partners LLC and graduate-level lecturer in computer science, focused on data management, data governance, knowledge representation, and decisioning systems.

[24] https://www.youtube.com/watch?v=goR2NYo5pQU

Objectives

During the "Community-based Ontology Development: Lessons Learned from the Financial Industry Business Ontology (FIBO)" presentation, Elisa started her presentation highlighting how ontologies for industrial data, enterprise data and application data need to be different due to the different data challenges and target user. Following this concept, Elisa shared the example of a financial company and the government, showing that their information and data needs are often not aligned and provided as a solution, the creation of a reference model that both organisations can use to align and demonstrate how they relate to one another. To create such reference model, it will be necessary to anticipate what the models in the industry will look like, combine features that we see in multiple models that are contributing to the work, design a model that cover these features, and finally, evaluate the model by ensuring that the core elements are consistent with the vertical domains in which it will be used. Elisa then introduced the Financial Instrument Business Ontology (FIBO), an industry-level ontology that provides standard terminology, relationships, and logic designed to help reconcile disparate language defining financial instruments and related knowledge. It was first released as a joint Object Management Group (OMG) and EDM Council international standard in 2015 and is now updated quarterly and published on the EDM Council site by domain experts and professional ontologists. Elisa concluded her presentation with an example showing how in the financial sector, to develop an ontology it is necessary to associate parties (people and organisations) with the roles they play, understand when an identifier applies to a party or a role and link parties and roles to complex situational patterns that are time bound (ownership, control, authorisations, membership, etc.).

Impact

This session highlighted how it is important to improve data FAIRness and ontology interoperability, but it is also crucial to tailor the ontology development effort to the custom needs of the domain where it will be used. Industry-level ontologies must address a wide variety of domain applications that may not be known at the time of development, further complicating the development effort, such as agreeing on intellectual property rights and documenting them. The provided practical examples and lessons learned in the financial domain with the FIBO ontology will also hopefully guide and be useful for the industrial ontology development effort underway in the Industrial Ontology Foundry (IOF).

2.4 Day 4 (5 November 2021)

2.4.1 Plenary Sessions[25]

The last day of the workshop included a plenary session, a poster presentation and two parallel sessions, as well as a final summary of the day.

[25] https://www.youtube.com/watch?v=uakhAnIrAr0

Michela Magas (OntoCommons Sustainability Manager, ICF), presented day 4 and introduced the speaker.

2.4.1.1 Enterprise Knowledge Graphs as a Basis for Company-Lead Innovation

Katariina Kari outlined how enterprise knowledge graphs are built, what competencies they involve inside the company, and how they are made available internally to the company to democratise the knowledge. What needs and requirements does an enterprise have for public external ontologies? This session concluded with an assessment on how the availability of an enterprise knowledge graph and useful links to public external ontologies create a fruitful basis for innovation with the possibilities to expand all the way to the customer experience of the enterprise.

2.4.2 Parallel Sessions

Two parallel sessions took place in the final day of the workshop

2.4.2.1 Use Cases for innovative ontology applications[26]

The OntoCommons Innovation Session's objective was to incentivise the creation and use of ontologies in various domains where this approach can add value.

The session, chaired by Michela Magas, explored novel and potentially innovative use cases by engaging representatives from a wider community spanning diverse domains including global furniture distribution, sound for self-driving vehicles, skills and competence frameworks, and accessible musical instruments: a whole new set of domains that are affected by digitalisation and that are presenting challenges of creating new systems of understanding, with the result of having to reconsider and design whole new systems and create new vocabularies.

This session was not organised around impulse talks, but it was organised as a panel discussion.

Objectives

- reinstate the use of ontologies in commercial enterprise scenarios
- incentivise adoption of ontologies in various domains where they can add value
- explore novel and potentially innovative use cases by engaging representatives from a wider community spanning diverse domains
- add more ontology use cases to the OntoCommons pool
- add more domains to the Industry Commons and OntoCommons ecosystem
- open up new research directions
- identify novel application areas for ontologies

Panellists

- ***Fredrik Folkestad:*** *Senior Sound Design Lead, Skania/VW Group and CEO, Folkestad Sino-Skandinavien, Sweden (clients are Volvo Cars, Miele, Netflix).*
- ***Simon Grant:*** *P2P Foundation, Belgium and Netherlands*
- ***Tim Yates****: Accessibility designer and Founder, the Hackoustic platform*
- ***Katariina Kari****: Lead Ontologist, Inter-IKEA Systems*

[26] https://www.youtube.com/watch?v=A4PLVQlrTyI&t=3965s

Main Takeaways:

- Friederik Folkestad presented his use case in sound design, in particular for electric vehicles, and the huge challenge this field presents in terms of our understanding. Having to create a completely new vocabulary is a paradigm shift, where we're forced to renegotiate and rethink what a vehicle is, how it should sound and to whom it is relevant. Vehicles are extreme products and there is a high number of deaths every year related to traffic noise. The sound of the vehicle is important to communicate its intention (above all in particular situations such as visual impairment).
- The approach is to map out the sound connotations: what is the sound that communicates something? This is done by focusing on **frequencies** (an assumption could be that bigger sound waves produced by bigger masses of energy could be used to "describe" an object's bigger mass and force), **intervals** (the less used intervals could convey a meaning of uncertainty and be used to alert the user in a particular situation), and **pulse** (which is good to convey information about the pace). These three aspects can be combined together to design the more appropriate sound for a vehicle.
- Simon Grant talked about Exploring Consensus, and understanding how information can help human connection. Simon Grant leads a team which is producing an interoperability specification for frameworks called "InLOC": for the conceptual modelling activity it is useful to have a reference to ontologies and in particular to the levels of ability, which are a key feature to make things understandable to people.
- People tend to see complexity in various way (due to an infinity of reasons, such as mental predisposition in what one finds easier, the way our mental structure is built up): the result of this in ontologies, is that each ontology is designed by a different team, of people that see complexity in their own way, therefore each ontology is very different from the other. The key question in this session was: how to build ontologies that can relate to everybody?
- Ontology experts are often on the engineering side, but ontologies also involve a big part of human science (relating, collaborating skills, listening, questioning, empathy, dialogue, insights into why other people organise their concepts in different ways, ability to question assumptions), above all if we want to build an ontology that is common.
- Tim Yates discussed accessibility, in particular for what concerns musical insturments: Inclusion, representation and co-design has to be the starting point & none of the implicit knowledge can be addressed unless this is the starting point: cultural diversity and inclusion is the key
- Designing culture to designing ontologies can be compared to designing information systems for companies
- Learning through Dialogue is the way to a commons!
- New paradigm of the Industry5.0 that is very human-centric, radically inclusive of all other systems & species

Impact:

- This session has highlighted the strong **societal impact** that ontologies can have by helping improve our systems understanding: in the case of the sound design for electric vehicles, for example, different sounds help different users identify the vehicle's intentions, resulting

in increased security for citizens. Ontologies can support the mapping of sound's connotations to verify assumptions on the meaning conveyed by each sound, and help address ambiguity and create shared understanding.
- In ontologies and in enterprise knowledge graphs, it is important to look at what others develop human skills such as understanding, empathy and the ability to question assumptions, and to transform implicit, tacit knowledge into explicit knowledge. The same challenges that apply to culture blending, also apply to cross-domain challenges that we face in OntoCommons, where a balance has to be found between a total blending, that would erase the individual aspects of a domain, and the complete lack of understanding and inclusion.

2.4.2.2 Ontology Engineering in Material Science[27]

The field of materials science and engineering is using ontologies and semantic technologies more and more in order to support interoperability and provide solutions to the need of ever richer integration of information to support the design and development of materials and processes. Practitioners are however faced with a huge task of building and maintaining ontologies that cover all relevant aspects. The concept of domain ontologies is to agree on common areas of interest for which joint, pre-competitive developments can take place. These efforts require a framework to ensure FAIRness of ontologies, avoid duplication of efforts, and improve ways of harmonizing domain ontologies for intra- and cross-domain interoperability.

Objectives

- Identify gaps
- Improve FAIRness in the domain
- Exploitation aspects of the domain ontologies

Speakers and impulse talks

Collaborative Ontology Development in Materials Science (with T Hanke)
Alexandru Tudor: Fraunhofer, Germany

- Developing materials science ontologies can be a challenging task, especially in the area of materials characterization which requires a detailed representation of the process by which a value was determined in order to make data compatible and reproducible, thereby enabling FAIRness.
- Accurate ontological representation of characterization methods requires the collaboration and agreement of multiple domain experts, creating new kinds of requirements that traditional ontology development approaches and tools struggle to fulfil.
- Once a domain ontology has been developed, new challenges arise regarding ontology repositories and versioning, data mapping, conversion, validation etc. This talk discussed

[27] https://www.youtube.com/watch?v=aDz66P3CkAY

challenges faced in over 4 years of team-based ontology development, as well as presenting a unified collaborative ontology development approach and tool pipeline.

Development of the Battery Interface Ontology (BattINFO) for battery data interoperability
Simon Clark (SINTEF): *Coordinator for the TIB Terminology Service*

- The development and "gigascale" production of batteries is one of the most widely pursued technical research topics in the world today. Battery development generates an immense number of different kinds of data, which could provide a valuable resource for artificial intelligence methods directed to discover new materials or optimize performance. However, there are currently no standard vocabularies for generating consistent battery metadata. The Battery Interface Ontology (BattINFO) is an initiative from the EU H2020 project Battery Interface Genome and Materials Acceleration Platform (BIG-MAP)[28]. The goal is to develop an EMMO-based domain ontology for electrochemistry and batteries to support the interoperability of data in the battery discovery and design process. In this talk, Dr. Simon Clark also discussed the development of BattINFO and potential use cases in BIG-MAP and beyond.

Ontology Development in Process Engineering and Catalysis – Current Status in NFDI4Cat
Alexander Behr*: Research associate in the NFDI4Cat project for Prof. Norbert Kockmann of the Faculty of Biochemical and Chemical engineering TU Dortmund focusing on ontology design*

- Ontologies are the base for data structures and their accessibility since they are used to represent relations among terms readable for humans and machines. Thus, an ontology can describe conceptual knowledge in an explicit way. The presentation gives examples from process engineering and biocatalysis, how ontologies are applied therein to ease the exchange and reuse of knowledge. An equipment and process ontology is presented based on existing ontologies to build a knowledge graph of own biocatalytic experiments. Further applications are discussed with the aim of improved user access and acceptance.

[28] https://battery2030.eu/battery2030/projects/big-map/

Impacts

The session was very useful in terms of learning from the experience of people who are developing material science ontologies in different contexts and the tools around them.

In terms of collaborative ontology development in material sciences, the Mat-O-Lab presentation helped capture the entire process of development and understand the existing challenges in terms of existing tools (enabling collaborative ontology development for non-experts).

Moreover, some important inputs might help address the current needs:

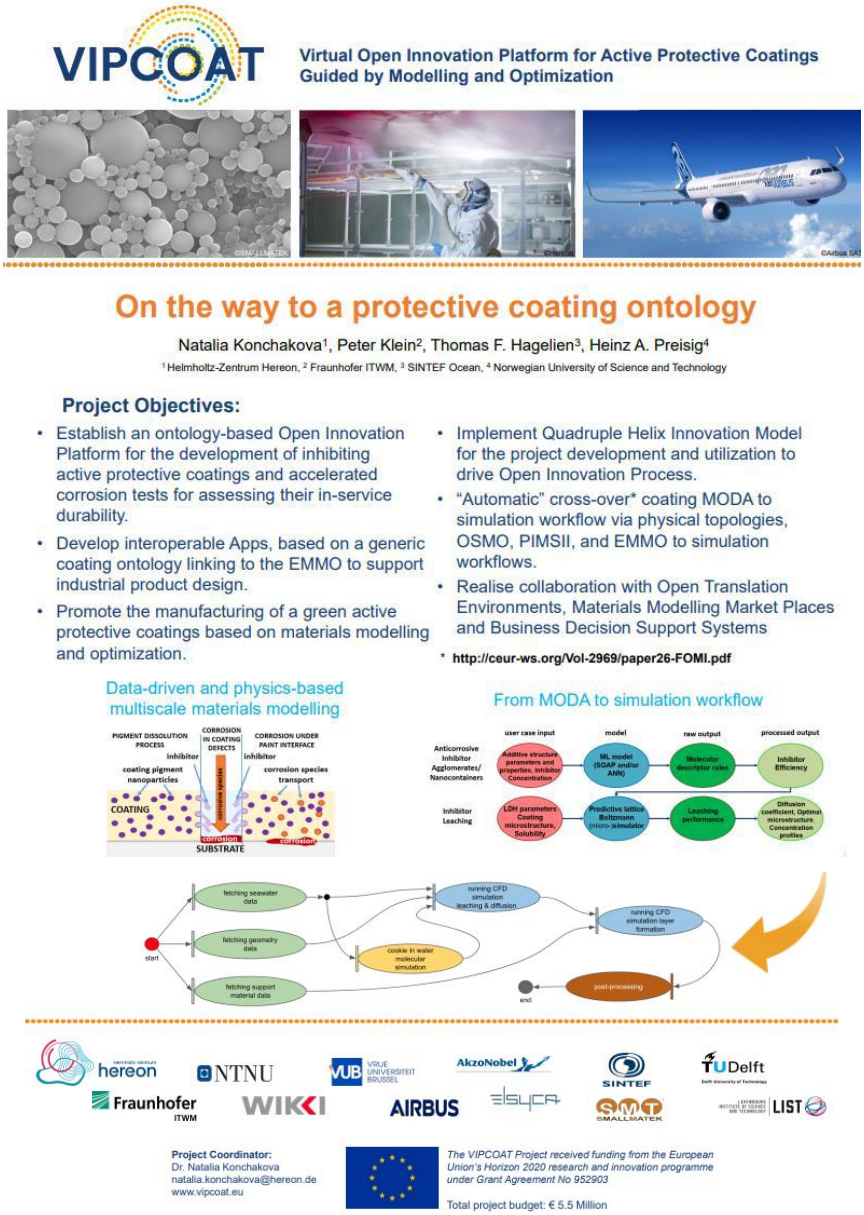
- Terminology Provider:
  - MatPortal.org, features?
- Collaborative/Visual Ontology dev tool
  - Onto dev vs Draw.io etc. Now using Draw.io plus Chowlk (or Visio but closed)
- Common ontology architecture / ecosystem (ODP etc)
  - IOF style: Materials Science and Engineering Ontology as a Core
- Data conversion and mapping tools
  - Pipeline for data transformation of CSV files
- Pipeline Glue to combine all tools

The examples of BattINFO (for battery interoperability) highlighted the need for collaboration across communities.

2.5 Posters Presentations

Six posters, selected through a dedicated open call managed by Trust-IT, have been dedicated 5 minutes slots on each day of the workshop, to present their organisation or project, the posters and short descriptions of the presentations are available below:

2.5.1 Virtual Open Innovation Platform for Active Protective Coatings Guided by Modelling and Optimisation[29]



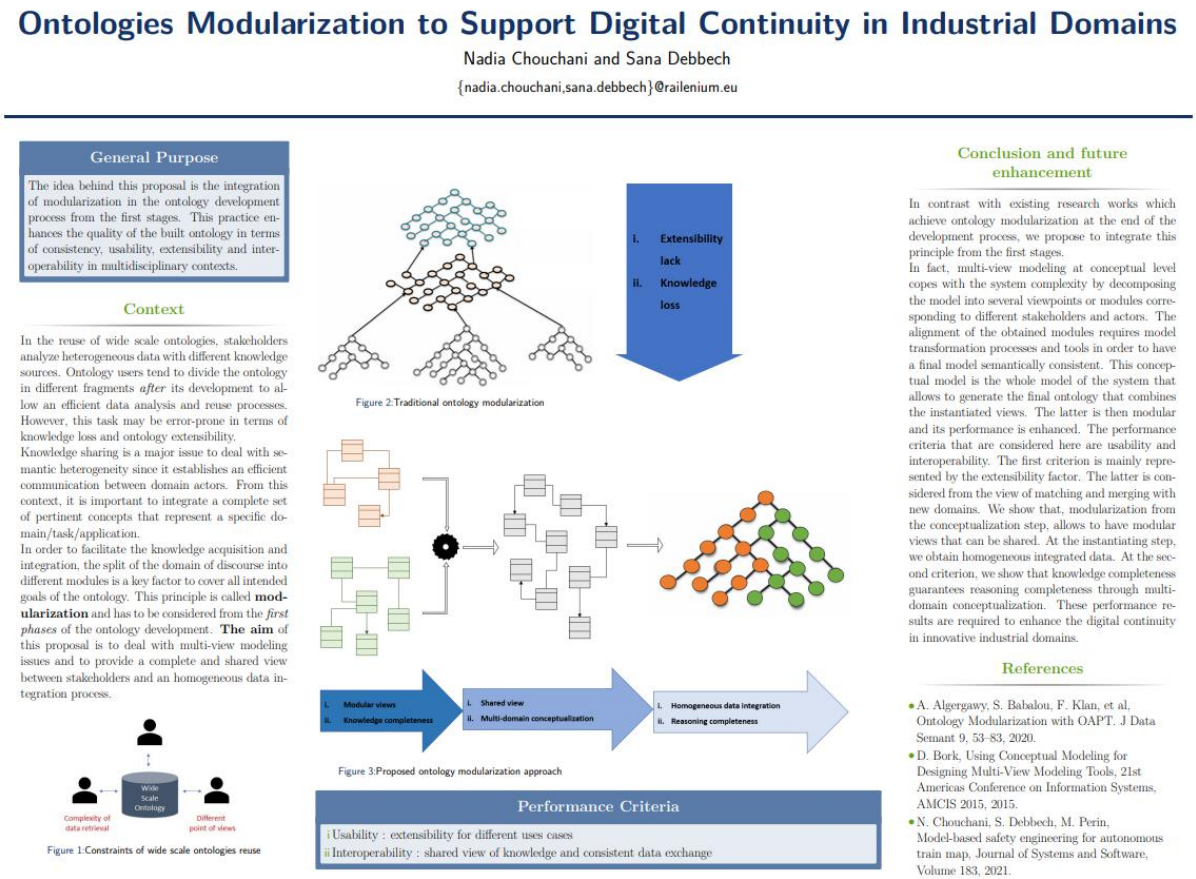
Natalia Konchakova: Helmholtz-Zentrum Hereon.

Objectives

This poster presented the effort to establish an ontology-based open innovation platform for the development of inhibiting active protective coating and promote the manufacturing of a green active protective coating based on materials modelling and optimisation.

[29] https://youtu.be/3T9y5Jj3pFk?t=3460

2.5.2 Ontologies Modularisation to Support Digital Continuity in Industrial Domain[30]



Ontologies Modularization to Support Digital Continuity in Industrial Domains

Nadia Chouchani and Sana Debbech

{nadia.chouchani,sana.debbech}@railenium.eu

General Purpose

The idea behind this proposal is the integration of modularization in the ontology development process from the first stages. This practice enhances the quality of the built ontology in terms of consistency, usability, extensibility and interoperability in multidisciplinary contexts.

Context

In the reuse of wide scale ontologies, stakeholders analyze heterogeneous data with different knowledge sources. Ontology users tend to divide the ontology in different fragments *after* its development to allow an efficient data analysis and reuse processes. However, this task may be error-prone in terms of knowledge loss and ontology extensibility.
Knowledge sharing is a major issue to deal with semantic heterogeneity since it establishes an efficient communication between domain actors. From this context, it is important to integrate a complete set of pertinent concepts that represent a specific domain/task/application.
In order to facilitate the knowledge acquisition and integration, the split of the domain of discourse into different modules is a key factor to cover all intended goals of the ontology. This principle is called **modularization** and has to be considered from the *first phases* of the ontology development. **The aim** of this proposal is to deal with multi-view modeling issues and to provide a complete and shared view between stakeholders and an homogeneous data integration process.

Figure 1:Constraints of wide scale ontologies reuse

Figure 2:Traditional ontology modularization

Figure 3:Proposed ontology modularization approach

Performance Criteria

i Usability : extensibility for different uses cases
ii Interoperability : shared view of knowledge and consistent data exchange

Conclusion and future enhancement

In contrast with existing research works which achieve ontology modularization at the end of the development process, we propose to integrate this principle from the first stages.
In fact, multi-view modeling at conceptual level copes with the system complexity by decomposing the model into several viewpoints or modules corresponding to different stakeholders and actors. The alignment of the obtained modules requires model transformation processes and tools in order to have a final model semantically consistent. This conceptual model is the whole model of the system that allows to generate the final ontology that combines the instantiated views. The latter is then modular and its performance is enhanced. The performance criteria that are considered here are usability and interoperability. The first criterion is mainly represented by the extensibility factor. The latter is considered from the view of matching and merging with new domains. We show that, modularization from the conceptualization step, allows to have modular views that can be shared. At the instantiating step, we obtain homogeneous integrated data. At the second criterion, we show that knowledge completeness guarantees reasoning completeness through multi-domain conceptualization. These performance results are required to enhance the digital continuity in innovative industrial domains.

References

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- D. Bork, Using Conceptual Modeling for Designing Multi-View Modeling Tools, 21st Americas Conference on Information Systems, AMCIS 2015, 2015.
- N. Chouchani, S. Debbech, M. Perin, Model-based safety engineering for autonomous train map, Journal of Systems and Software, Volume 183, 2021.

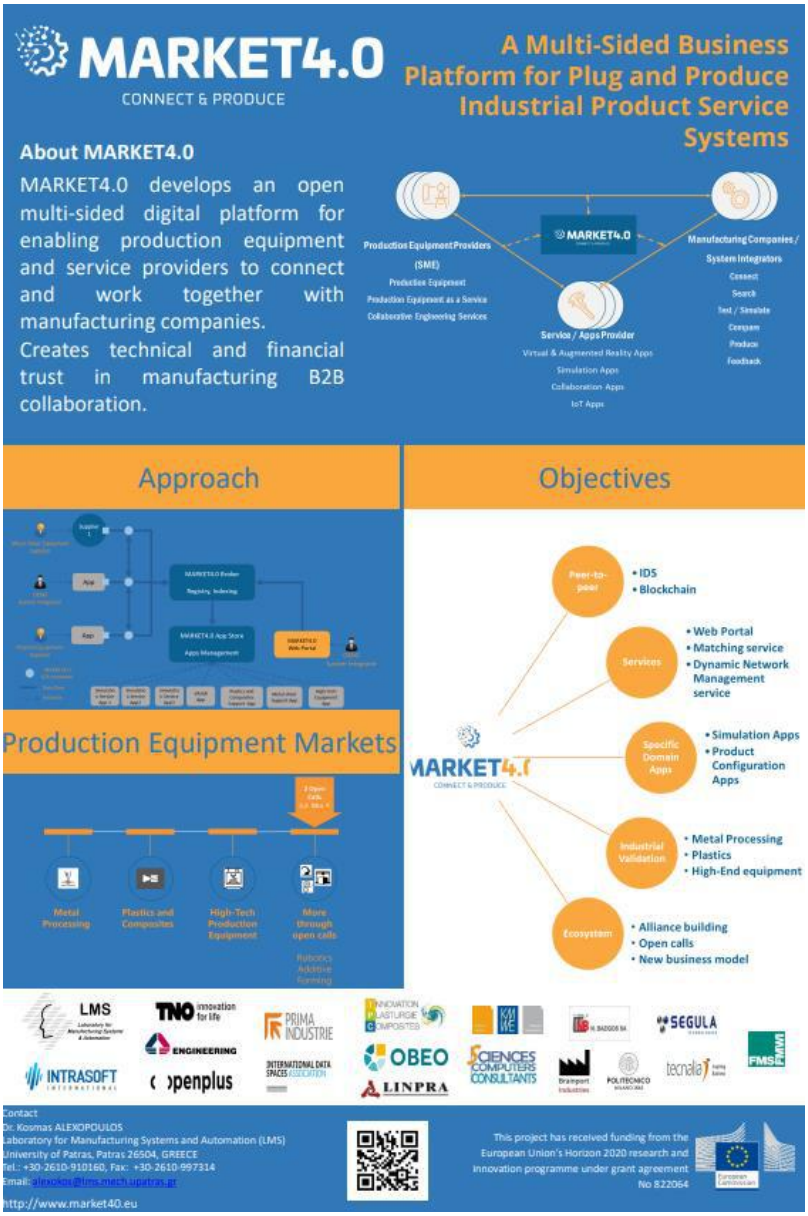
Nadia Chouchani: Railenium.

Objectives

This poster presented the benefits of integrating ontology modularization from the first stages of the development process to enhance the quality of the built ontology in terms of consistency, usability, extensibility and interoperability in multidisciplinary contexts.

[30] https://youtu.be/mb6NWDxl8BI?t=5670

2.5.3 A Multi Sided Business Platform for Plug and Produce Industrial Product Service Systems[31]



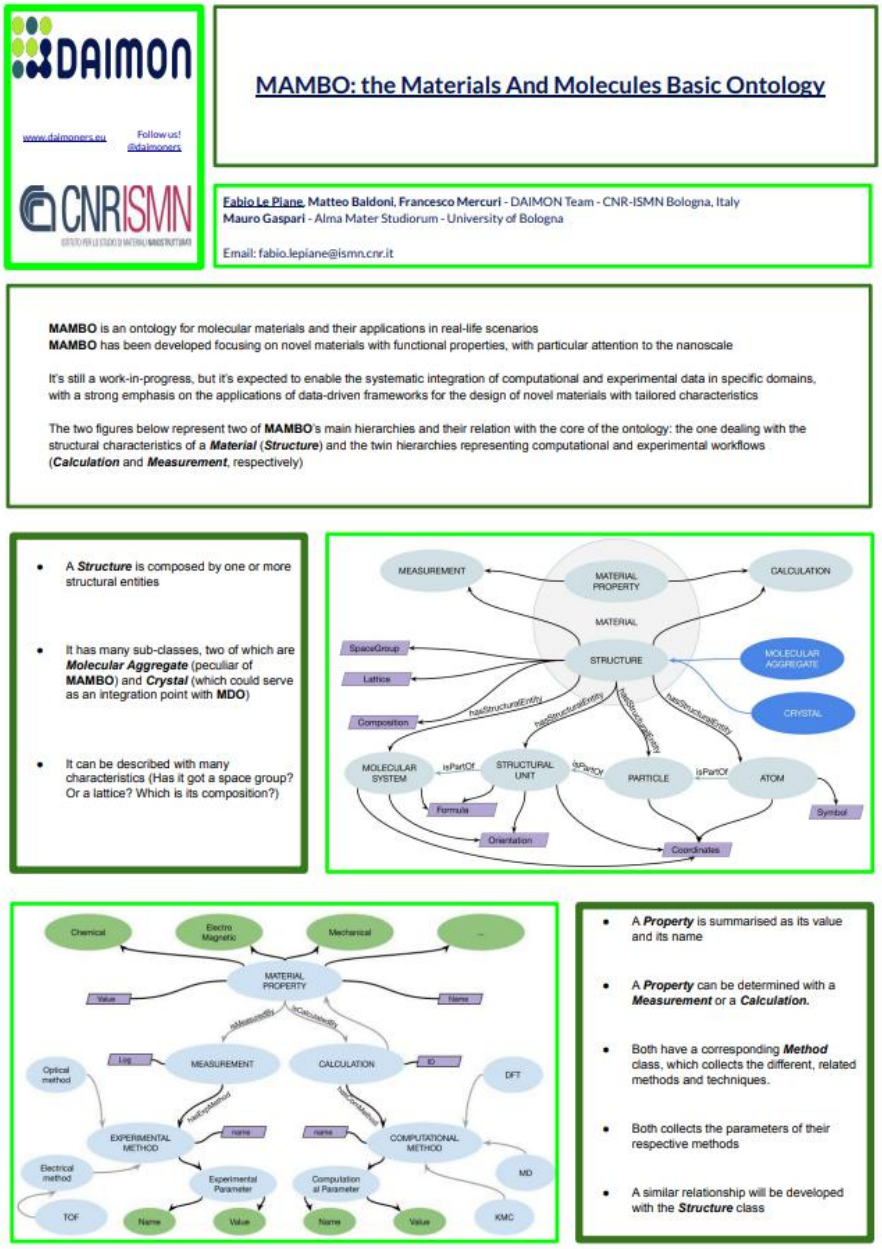
Kosmas Alexokos: University of Patras.

Objectives

This poster shared an overview of the MARKET4.0 project and its approach to develop an open multi-sided digital platform that will allow production equipment and service providers to connect and work together with manufacturing companies.

[31] https://youtu.be/sorSCYsx6Co?t=1390

2.5.4 MAMBO: the Materials And Molecules Basic Ontology[32]



Fabio Le Piane: CNR-ISMN.

Objectives

This poster presented MAMBO an ontology for molecular materials and their applications in real-life scenarios that is expected to enable the systematics integration of computational and experimental data in specific domains for the design of novel materials with tailored characteristics.

[32] https://youtu.be/aFNFfocPSBw?t=3076

MAMBO aims to define standards for the represantation of materials and molecules and their related domains in the realm of computational science and to integrate computational and experimental research data workflow to gather as musch data as possible to empower deep learning and neural networks.

2.5.5 SSHOC Reference Ontology[33]

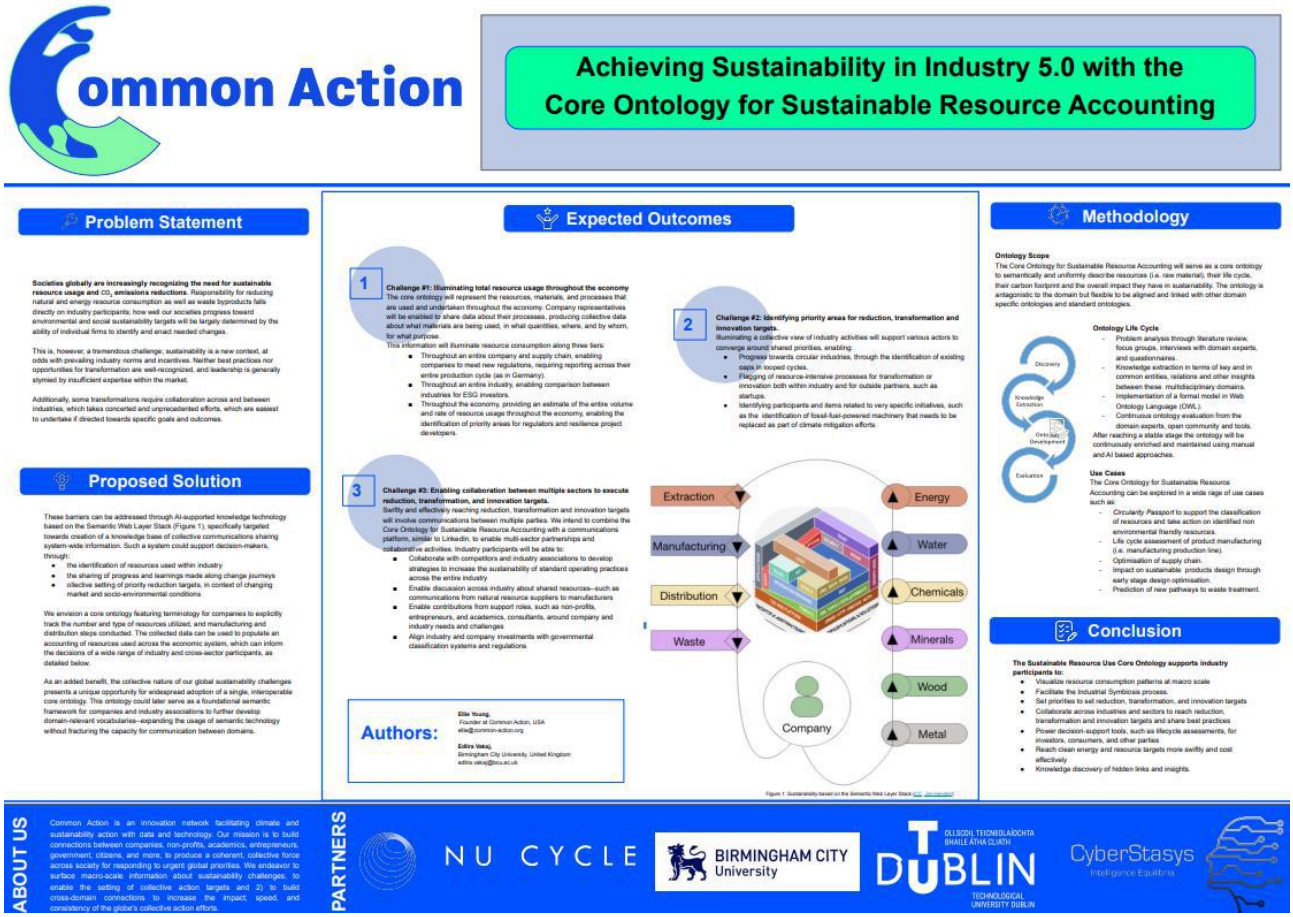
Athina Kritsotaki: *department of Archaeology and Art History of the National and Kapodistrian University of Athens.*

Objectives

This poster presented the SSHOC Reference Ontology (SSHOCro) developed by the Social Sciences and Humanities Open Cloud (SSHOC). SSHOCro is a common meta-level schema used as a top-level ontolgies to organise knowledge and information in the social sciences and humanities open cloud that aims to provide a semantic interoperability framework to be used in the step of devising and implementing metadata for the SSHOC data life cycle in individual projects, institutions and disciplines of social science and humanities domains.

[33] https://youtu.be/aFNFfocPSBw?t=2680

2.5.6 *Common Action: Achieving Sustainability in Industry 5.0 with the Core Ontology for Sustainable Resource Accounting*[34]



Ellie Young: founder of Common Action.

Objectives

This poster presented the core ontology for sustainable resource accounting. Being the use of sustainable resources a rather new topic and market, there is not enough domain expertise and cross industry collaboration yet to transition to sustainabel resources use at a global scale. To overcome this challenge, in her poster Ellie shows how AI-supported semantic technologies could create a knowledge base of collective communications sharing system-wide information to support decision-makers to:

- Identify the resources used within an industry.
- Share the progress and learnings made along the sustainable resources transition journey.
- Specification of priority market and socio-environmental conditions reduction targets.

[34] https://youtu.be/TGvsB_WYvEc?t=2666

This will be achieved through the widespread adoption of a single, interoperable core ontology featuring terminology for companies to track the number and type of resources utilised, optimise the supply-chain and the manufacturing and distribution steps conducted that will help to visualise resource consumption patterns at macro scale, collaborate across industries and to achieve the set clean energy and resources innovation targets

2.6 Target Groups

The workshop was designed to serve five main stakeholder groups, who represent a group of experts that can provide feedback, contributions and strategy for the development of the OntoCommons Roadmap. The identified target groups are composed of experts in the ontological domains, who are interested in getting updates about the OntoCommons project main achievements. Joining events organised by the project helps them to interact with experts in the area and exchange opinions on the latest studies in the ontology and industrial fields.

2.6.1 Industrial ecosystem

This target group is composed of all industrial players who are interested in adopting ontologies to improve the intra- and cross-domain interoperability and reusability of the data used in their ecosystems. Cooperating with industries is relevant for the OntoCommons project given its industry-oriented nature, which is proved by the development of 11 initial industrial demonstrators. 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.

For this reason, creating strong connections with this group can contribute to better defining the development of 10 new industrial demonstrators, which can show how possible it is to strengthen data harmonisation, and alignment on standards in an ontology-based system that supports innovation.

2.6.2 Ontologists

This group is composed of philosophers, logicians, semantic web experts, ontology developers, and reasoning experts. This community of experts benefits from the OntoCommons activities of collection and formalisation of requirements, in terms of ontology development and exploitation: based on these, OntoCommons is identifying gaps (with respect to pre-existing ontologies) and encouraging and facilitating the development efforts from the community aiming at closing these gaps. These analyses and recommendations provided by this target group represent useful insights to develop the OntoCommons Roadmap and contribute to the advancement of the OCES.

2.6.3 Policy makers

The OntoCommons team will develop a Roadmap with strategic recommendations in the areas of Top reference ontologies, industrial domain ontologies, the ecosystem toolkit, industrial applications, standardisation, industry commons translators, digital marketplaces and innovation in ontologies

applied to industry. A first release of the Roadmap will be released in a first version by M18 and a final version by M36.

The Policy makers benefit from the project's activities by addressing specific policies based on the recommendations highlighted in the Roadmap.

During the finalisation of the workshop organisation, representatives from OntoCommons have had exchanges with European Commission officials of DG GROW, DG CONNECT, who lead the ICT Rolling of Standardisation. They have offered an opportunity to the project to provide contributions around ontologies and semantic interoperability to a new chapter, entitled "the Data Economy", in its final phases of revision for introduction to the 2022 Rolling Plan for ICT Standardisation. The content provided by OntoCommons partners UiO and ICF is now undergoing peer review acceptance, nevertheless, the opportunity to have this dialogue was extremely positive and put the project in a good position to have a continued dialogue with the Multi Stakeholder Platform contributors in the following months.

2.6.4 Research and Academia

Research and Academia are represented by domain experts in the area of ontologies, interoperability and standardisation. The OntoCommons outputs are relevant to these stakeholders as they can exchange ideas and discuss the latest advancements in this sector with project members and experts in the field. Moreover, the work conducted by OntoCommons is particularly interesting to them as it demonstrates how theoretical concepts can be applied in a practical way to industries and can facilitate the advancement of research.

2.6.5 Standardisation ecosystem

This group is composed of SDOs and standardisation organisations interested in adopting ontologies to better establish and define standards. This stakeholders group shows interest towards OntoCommons, as the project ensures that standardised documentation based on ontologies is represented and fed into the main OntoCommons outcomes, like the industrial demonstrators, the OCES and its strategic Roadmap. Moreover, OntoCommons team partners are members of Technical Working Groups in the standardisation area, such IOF, ISO, and StandICT.eu, just to mention a few. This cooperation strengthens the collaboration with standardisation institutions and makes the OntoCommons project attractive to them.

The benefits encountered by each target group in joining the OntoCommons 1st Horizontal Workshop, are summarized in the figure below.

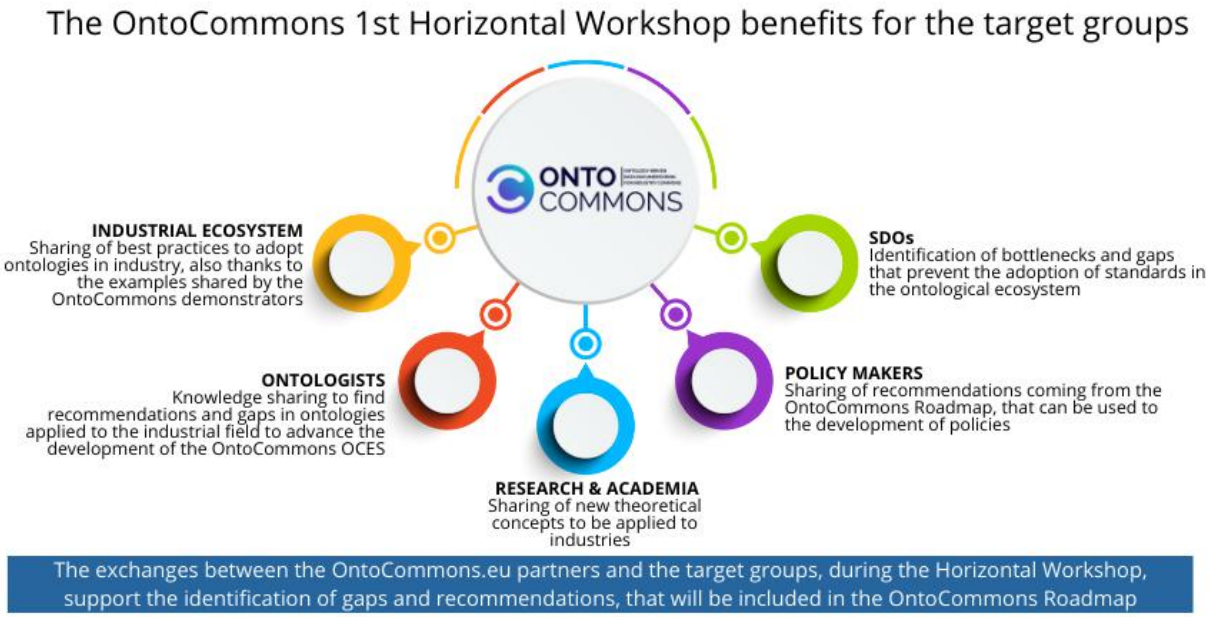


Figure 1 – Benefits for the target groups taking part to the 1st Horizontal Workshop

278 experts joined the OntoCommons 1st Horizontal Workshop. The majority of them are coming from Research and Academia (49%), and the Industrial ecosystem (34%), followed by Ontologists (10%) and Policy Makers (7%). The Standardisation ecosystem is not represented in experts who joined the workshop. However, the majority of research and academia stakeholders who joined the workshop demonstrated to be experts also in the standardisation area and, in order to advance their research, they closely cooperate with SDOs.

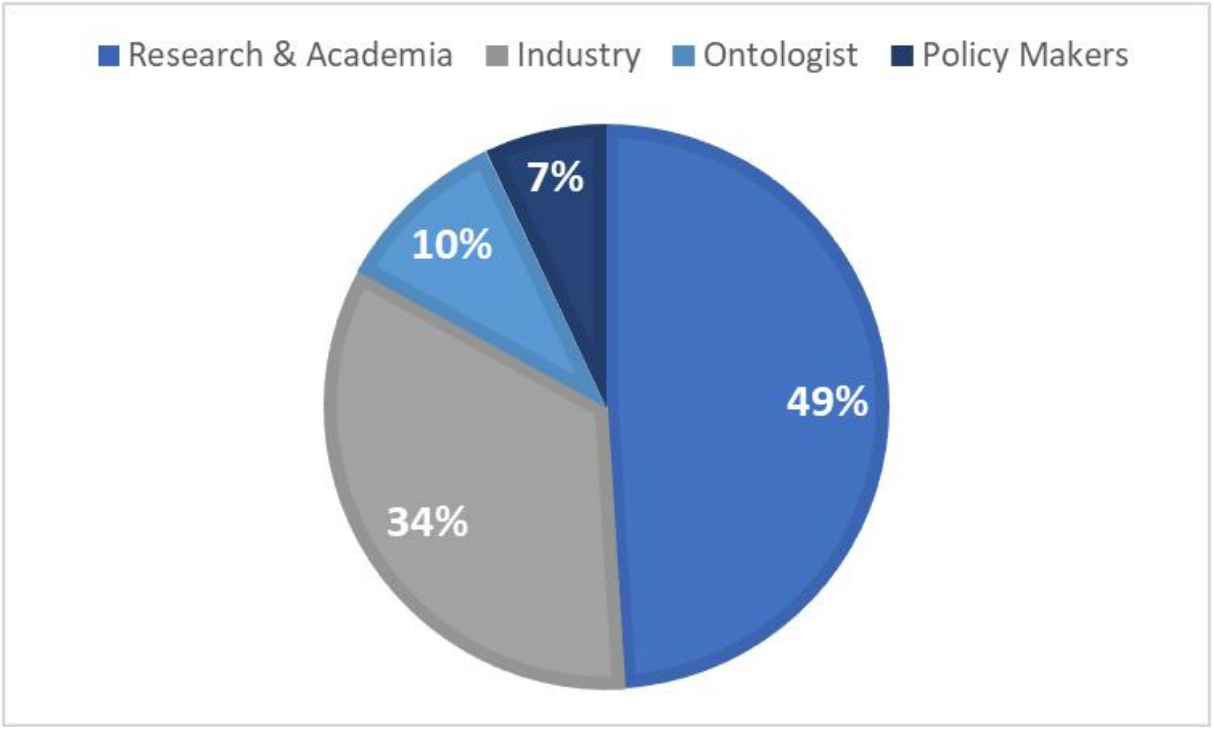


Figure 2 - Type of target groups participating in the workshop

2.6.6 Strength of clustering with other projects

The 1st Horizontal Workshop offered a platform for all stakeholders to interact and exchange information and updates. The workshop has been organised in close cooperation with related projects and initiatives to maximise the synergies between the initiatives. A total of 67 initiatives have been involved during the 4 days of the workshop, either to support the organisation of the event or to help with the content preparation of the several sessions.

All the involved initiatives share similarities with the OntoCommons project in terms of focus, research field or target stakeholders. These similitudes facilitate the exchange of information, and support joint dissemination activities and strengthen synergies.

Given the CSA-nature of OntoCommons, for the project it is crucial to establish strong partnerships with a variety of actors, that aim to create long-lasting relationships both for attaining the OntoCommons long-term objectives and for contributing to shaping the strategic Roadmap. The established synergies are in the area of ontologies stratification, industrial domain ontologies, industrial applications, standardisation, industry commons translators, digital marketplaces and innovation in ontologies applied to industry.

This approach shows how it is relevant to create connections with similar projects operating in the same research field due to the opportunity to share joint results to a wider community, paving the way towards the exploitation of the OntoCommons results in the medium run.

2.7 Workshop Participants

The workshop was attended by 278 experts coming from 39 countries in the world, with a participation rate of 92%. The majority of people were coming from Europe (82%), but there were also attendees from extra-European countries, mainly from the USA, Argentina and Australia, with a predominance of men (71%).

As already mentioned in the Section 2 of this deliverable, the participants were all experts in the ontology area and are specialised in different areas: the majority of attendees were researchers (49%), followed by industrial players (34%), and ontologists (10%) and Policy makers (7%). SDOs and standardisation organisations have been not included in the graph, as the majority of people involved in research and academia deal with this stakeholder category very often, and therefore can be considered as part of it. This means that in every session of the workshop the team got there were experts in standardisation, even though they are affiliated to universities. The figures below summarise the participants' composition of the OntoCommons workshop.

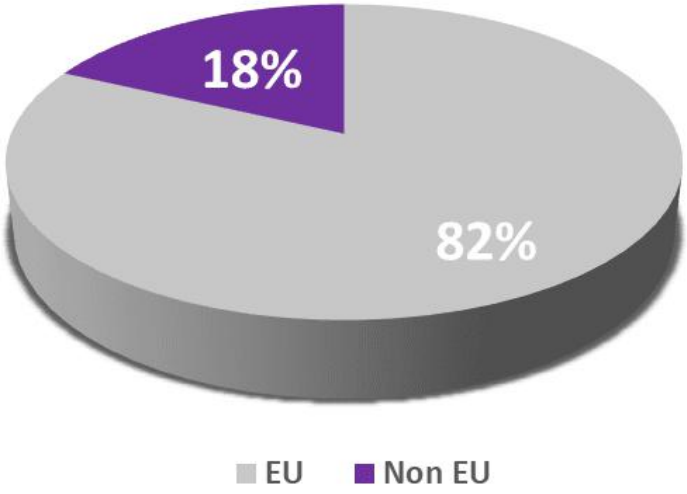


Figure 3 – Percentage of EU and Non-EU attendees

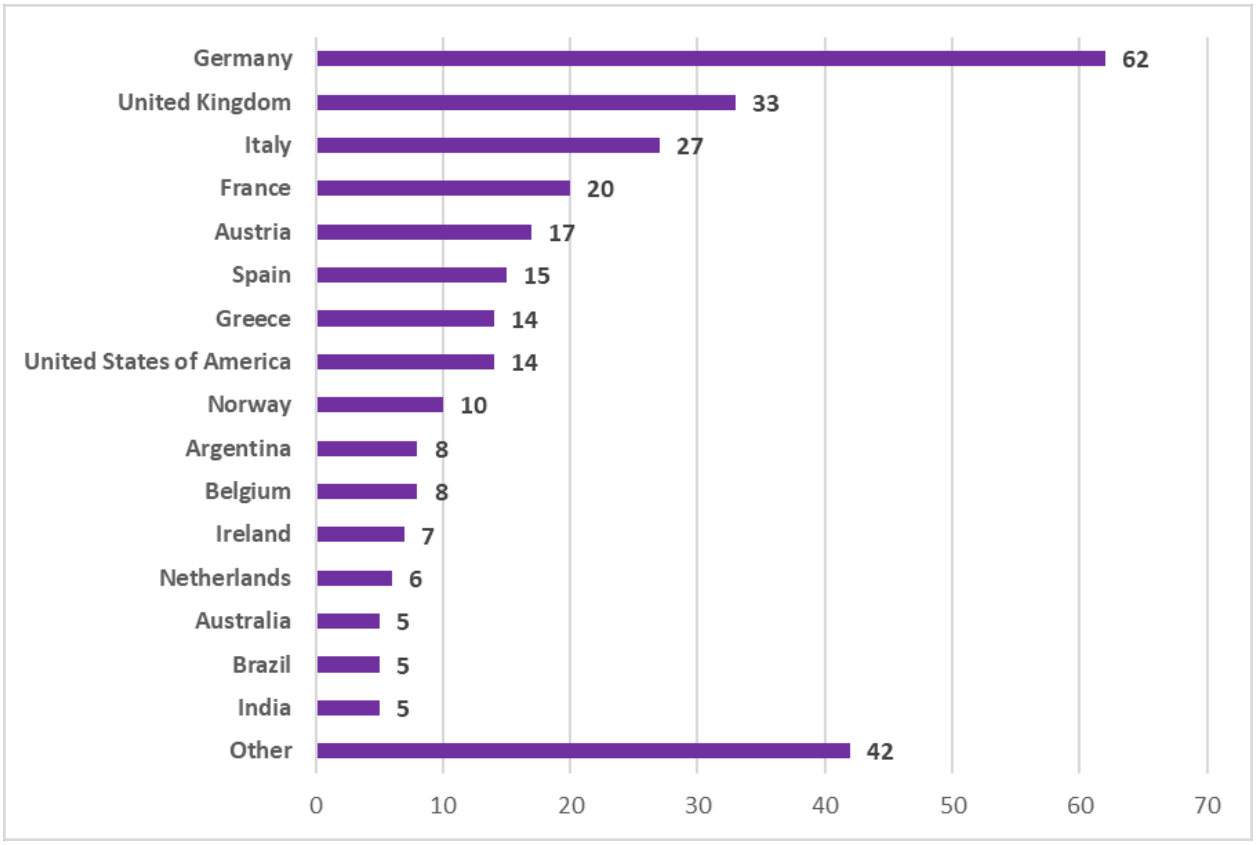


Figure 4 - Country breakdown of the attendees

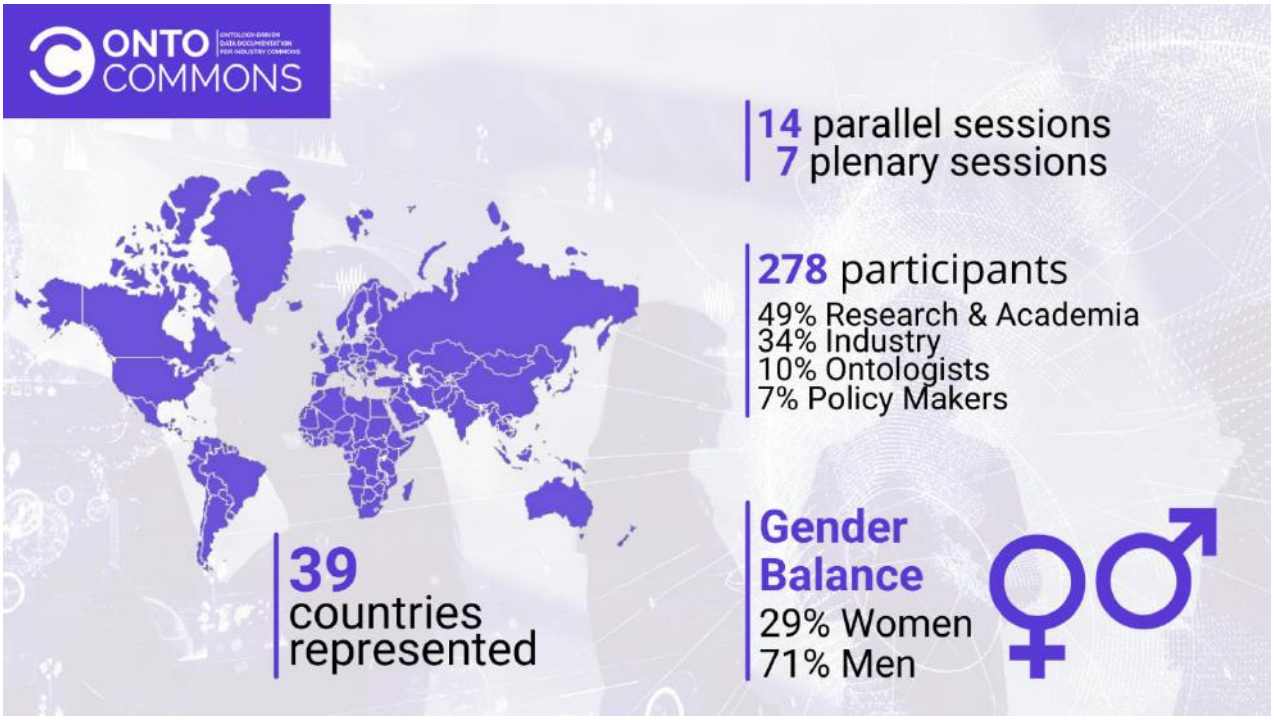


Figure 5 - Participants' statistics

3. Communication and Dissemination activities around the workshop

Communication and dissemination activities were carried out to promote the workshop and engage with relevant stakeholders from August 2021 to beginning of November 2021. The next sections explain in more detail the different strategies and operation activities that have been implemented to increase the visibility and engagement of relevant stakeholders around the OntoCommons Horizontal Workshop.

3.1 Organisation

The organisation of the workshop started in M8, kick-starting the discussions on this topic on occasion of the Executive Board meeting, although a draft plan was circulated in the beginning of the project. The Consortium partners worked together and in close cooperation with the related projects in order to maximise the synergies between the initiatives.

The **discussion notes** were prepared and circulated in advance to the session chairs and rapporteurs, following a template provided by TU-WIEN which included the session title and introduction, objectives of the session and name of the organisers, designated chair and impulse speakers, background information and documents, and final discussion points and questions to drive the panel discussion.

The organisational committee was composed of Trust-IT, TU-WIEN and ENIT, supported by a scientific committee including the Executive Board members. The roles were defined as follow:

- Scientific Committee: Agreement on workshop date, session topics and titles, list of invited stakeholders, selection of Plenary and Impulse Speakers and definition of title and content for plenary and impulse talks, selection of session chairs and rapporteurs.
- Organisational Committee: Technical implementation of the workshop, organisation of poster sessions, invitation of stakeholders and speakers.

The agenda was developed taking into account the session topics and availability of speakers coming from different time zones: an internal, shared, GDPR compliant document was used as a base to monitor the creation of the sessions and the availability of speakers, their registration, and collection of speakers' abstracts and bios:

	A	B	C	E	F	G	H	I	K	L	M	N	O
1		Day 1	02-nov							Session			
3		10:30	10:50			Welcome	Introduction of OntoCommons and scope of the workshop				Nadja Adamovic, TU-WIEN, Project Coordinator		done
4		10:50	11:25			PWP2	The International Association for Ontology and its Applications: 12 years o				Laure Vieu (President of the IAOA, Toulouse, France)		done
5		11:25	11:30			Poster presentation		VIPCOAT			Natalia Konchakova, Helmholtz-Zentrum Hereon		done
6		11:30	11:45							Break 1			
7				Room 1					Room 2				
8						SWP1_1					SWP2_1		
9				**Industry Commons Translator**					**Ontology Interoperability**				
10				**Chair: Gerhard Goldbeck (GCL, UK)**			done		**Chair: Stefano Borgo CNR, Italy**				done
11				**Rapporteur: Alexandra Simperler (GCL, UK)**					**Rapporteur: Francesco Compagno (CNR, Italy)**				
12	1st Break out			11:45	11:55	Advancing Translation in Mate	Peter Klein | Fra	done	11:45	11:55	Introduction to ontology ma	Jérôme Euzenat (INRIA and Université Grenoble Alpes,	done
13		11:45	13:15	11:55	12:00	Q&A			11:55	12:00	Q&A		
14				12:00	12:10	Translation of Innovation chal	Michael Noeske	done	12:00	12:10	Ontology alignments: seman	Till Mossakowski (Otto-von-Gueri	done
15				12:10	12:15	Q&A			12:10	12:15	Q&A		
16				12:15	12:25	Knowledge Engineering Transl	Nicolas Matentz	done	12:15	12:25	Conceptual heterogeneity: tl	Claudio Masolo (Laboratory for Ap	done
17				12:25	12:30	Q&A			12:25	12:30	Q&A		
18				12:30	13:15	Discussions	Gerhard Goldbeck		12:30	13:15	Discussions	Stefano Borgo	
19		13:15	14:15							Lunch Break			
20						SWP1_2					SWP2_2		
21				**Enabling intra-ontology interoperability through shared terminology**					**Ontologies Stratification**				
22				**Chair: Silvana Muscella, Trust-IT Services, Italy**					**Chair: Hedi Karray - ENIT**				
23				**Rapporteur: Dimitris Kiritsis, University of Oslo, Norway**					**Rapporteur: Arkopaul Sarkar, ENIT**				
24	2nd Break out			14:15	14:25	Ontology Standards in ISO	Barry Smith | Di	done	14:15	14:25	Experience of ontology strati	Will Sobel	done
25				14:25	14:30	Q&A			14:25	14:30	Q&A		
26		14:15	15:45	14:30	14:40	Improving the efficiency and e	Boonserm Kulva	done	14:30	14:40	The EMMO Structure and Pe	Emanuele Ghedini & Jesper Friis (E	done
27				14:40	14:45	Q&A			14:40	14:45	Q&A		
28				14:45	14:55	Standardisation in the IoT dor	Ulrike Parson (P	done	14:45	14:55	Layered patterns in design w	Aldo Gangemi (MAC, Italy)	done
29				14:55	15:00	Q&A			14:55	15:00	Q&A		
30				15:00	15:10	Ontology Standards in Industr	Nicolas Figay - A	done	15:00	15:45	Discussions	Hedi Karray	done
31				15:10	15:15	Q&A							
32				15:15	15:45	Discussions	Silvana Muscell	done					
33	Plenary	15:45	16:00							Break 2			
34		16:00	16:25							Session Summary - Nadja Adamovic, TU-WIEN + Rapporteurs/Chairs			
35		16:25	16:30							PS3+PS4			

Figure 6 - A snapshot of the workshop internal agenda

This agenda was then published on the event website with a branded look, and made available for the external users:

Ontology Commons addressing challenges of the Industry 5.0 transition

Standardised data documentation and data sharing valorisation to foster data-driven innovation

Follow us on

Agenda

2 November 2021

	Time (CET)	Sessions			
Plenary	10:30 - 10:50	Welcome, introduction of OntoCommons.eu and scope of the workshop	Nadja Adamovic, TU-WIEN, Project Coordinator		
	10:50 - 11:25	The International Association for Ontology and its Applications: 12 years of promoting Applied Ontology with an interdisciplinary approach	Laure Vieu (President of the IAOA)		
	11:25 - 11:30	Poster presentation: VIPCOAT - Natalia Konchakova, Helmholtz-Zentrum Hereon			
	11:30 - 11:45	Coffee Break			
		Room 1		**Room 2**	
Parallel sessions		**Industry commons translator**	Chair: Gerhard Goldbeck (GCL)	**Ontology Interoperability**	Chair: Stefano Borgo (Laboratory for Applied Ontology ISTC-CNR)
	11:45 - 11:55	Advancing Translation in Materials Modelling	Peter Klein (Fraunhofer ITWM)	Introduction to ontology matching and alignment	Jérôme Euzenat (INRIA and Université Grenoble Alpes)
	11:55 - 12:00	Q&A		Q&A	
	12:00 - 12:10	Translation of Innovation challenges	Michael Noeske (Fraunhofer IFAM)	Ontology alignments: semantics, ontlogy integration, multiple logics	Till Mossakowski (Otto-von-Guericke University of Magdeburg)
	12:10 - 12:15	Q&A		Q&A	
	12:15 - 12:25	Knowledge Engineering Translation - early experiences from the Biomedical Domain	Nicolas Matentzoglu (Independent Contractor)	Conceptual heterogeneity: the case of time	Claudio Masolo (Laboratory for Applied Ontology ISTC-CNR)
	12:25 - 12:30	Q&A		Q&A	
	12:30 - 13:15	Discussions	Chair: Gerhard Goldbeck (GCL)	Discussions	Chair: Stefano Borgo (Laboratory for Applied Ontology ISTC-CNR)
	13:15 - 14:15	Lunch Break			

Figure 7 - A snapshot of the branded agenda published on the webpage

Based on the defined agenda, and after an initial contact with each session organiser and speaker short training sessions were organised. Each chair was provided with a set of slides including a short introduction and house-keeping information, and each rapporteur was provided with the speakers' abstracts and bios.

3.2 Workshop format

The Global Workshop, initially planned as a physical event, took place in a **virtual form** due to the ongoing Covid-19 pandemic (this is explained in detail in session 3.3, dedicated to Risk Mitigation). The event lasted three and a half days, from 2 until 5 November, 2021, and was held on the AirMeet platform. This tool had been already used in the focused Top-Level and Mid-Level Ontologies Multi-Disciplinary Workshop, and was chosen again to host the Global Workshop due to its versatility and to its high number of functionalities that help create connections between the audience, and between the audience and the speakers, and give the "human feel" which may be difficult to achieve in virtual events. Some examples of these functionalities are: the possibility to

bring forward a discussion in private, using one of the free "tables" available in the lounge room, the message board where each participant can send a private message to other participants and speakers (only in the event environment, to remain GDPR compliant), the possibility to read a speakers' short bio by hovering on their contact, and the possibility to send out notifications to all participants even when they are in any lounge or breakout room, in order to announce the starting of a session and guide the attendees in the right room.

The workshop format was discussed and agreed upon by the OntoCommons Executive Board members based on the formats previously used in the EMMC workshops, which have proven to be very successful. The objective was to ensure that all Work Package topics with appropriate results were covered.

Each Work Package (and consequently each project's Focused Area) was introduced by a high-level plenary speaker, and looked at in more detail during parallel sessions with guided discussions and short impulse presentations to animate the discussions. The number of participants foreseen for each session was 35 to 50, in order to ensure sufficient opportunities for each delegate to participate actively and ask questions.

3.2.1 Morning Sessions

Each day of the event was organised following the same structure, starting with a short **welcome plenary session** presented by the Coordinator Nadja Adamovic (TU-WIEN, on Day 1), by the Technical Manager Hedi Karray (ENIT, on Day 2), Consortium Partner Gerhard Goldbeck (GCL, on Day 3), and the Innovation and Sustainability Manager Michela Magas (ICF, on Day 4). The welcome session on Day 1 included a presentation of OntoCommons and of the objective of the workshop, to frame the event and drive the following discussions towards the objective of collecting inputs from the stakeholders' community.

Each morning, after the welcome session, the participants were presented with a 35-minute **plenary session** dedicated to a specific topic related to one of the project's main objectives, and usually followed by one of the **poster presentations** selected for the event, held by the coordinator of the selected related initiative or project. The posters presented in these sessions were selected through an Open Call for Posters, published on the OntoCommons website and described in this document in session 3.4.1.2. The posters were also made accessible to the public on the OntoCommons website and in dedicated **booths** in the virtual event venue on Airmeet.

At the end of the plenary sessions in the morning, after a 15 minutes break, the audience was invited to join one of the **morning parallel sessions** taking place in dedicated breakout rooms. Each breakout room was managed by a dedicated **host** in order to ensure a smooth running of the session and address any technical need. A **chair** and a **rapporteur** from the project's Consortium were assigned to each session, with the respective roles of presenting the session and the speakers, and taking minutes. The parallel sessions lasted 90 minutes and included three to four **impulse talks** with presentations by invited speakers, and a final **panel discussion** between the speakers, which was the most interactive part of the session and the most relevant one for the collection of feedback from the experts. During the panel discussions the audience had the possibility to use the **chat and the Q&A panel** to raise questions and to be invited on stage if any stimulating dialogue was brought forward following a question.

The image below represents the Airmeet Dashboard from the users' perspective, where guests could select the sessions to join and get information about the content and speakers of each session.

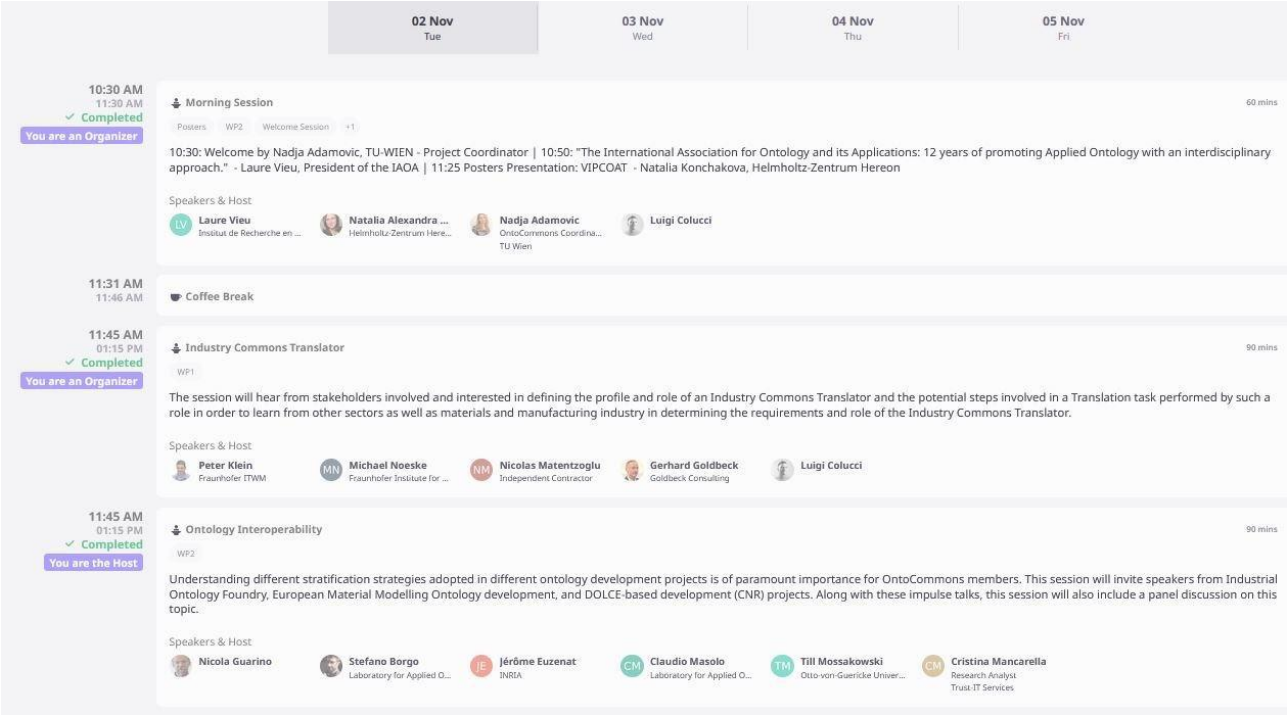


Figure 8 - The event dashboard, where users join different sessions

3.2.2 Afternoon Sessions

The same structure was repeated for the **afternoon sessions**, after the lunch break of one hour, and including a second break in the afternoon (several breaks have been included in the daily schedule, in order to avoid screen fatigue and keep the audience engaged).

Both in the morning and afternoon sessions, the topics selected for each parallel session have been organised so as to not overlap two sessions related to the same work package, and therefore to the same topic of the workshop, in order to give the possibility to participants to follow all the sessions related to their topic of interest.

At the end of the afternoon parallel sessions, and following a short break, each day of the workshop was concluded with an additional poster presentation and a **summary session**: the summary sessions were presented by the presenter of the morning's welcome session, and each rapporteur provided an overview of the session and the main outcomes.

Day 4 of the workshop followed the same structure, but only with the morning sessions, and it ended at 13:30.

3.3 Covid-19 and risks mitigation

This section explains how OntoCommons Horizontal Workshop strategy coped with the restrictions imposed by the COVID-19 crisis and reports on specific creative activities that have been developed

to mitigate the negative effects of the pandemic in terms of event organisation and community engagement.

Lockdowns, social distancing and other COVID-19 restrictions have had a significant impact on OntoCommons, since all project's events were organised remotely in digital format, decreasing the engagement and interaction quality that comes with face-to-face events.

To address the lower engagement characteristic of virtual events, the OntoCommons project started very early the promotion of the Horizontal Workshop, by mentioning it during its Focused Workshops, such as the Workshop 'DORIC-MM 2021' co-located with the 18th ESWC, the Industry Commons Marketplaces workshop and the Top-Level and Mid-Level Ontologies Multi-Disciplinary Workshop.

Given the overload of October and November's digital events due to the Covid-19 restrictions, we wanted to keep the audience constantly engaged and interested in our Horizontal Workshop to increase the registrations number, by creating and promoting various catchy graphic material (such as event banner, speakers twitter cards and sessions twitter cards), content-rich newsletters (August 2021, October 2021, November 2021) and tailored direct messages to our community.

Figure 9 - Speaker card for live twitting during the event

To address the Covid-19 Zoom fatigue, we decided to host the event on the popular Airmeet platform, which allowed us to engage with the audience in various dynamic ways through the Airmeet tabs:

- Reception: Where users would land once joining the event to find the upcoming session about to start.
- Schedule: Where users could browse the event agenda, speakers and read the session abstract.
- Lounge: Where users could join video discussion tables.
- Messages: Where users could write to each other through a written chat.

Figure 10 - Airmeet Reception room

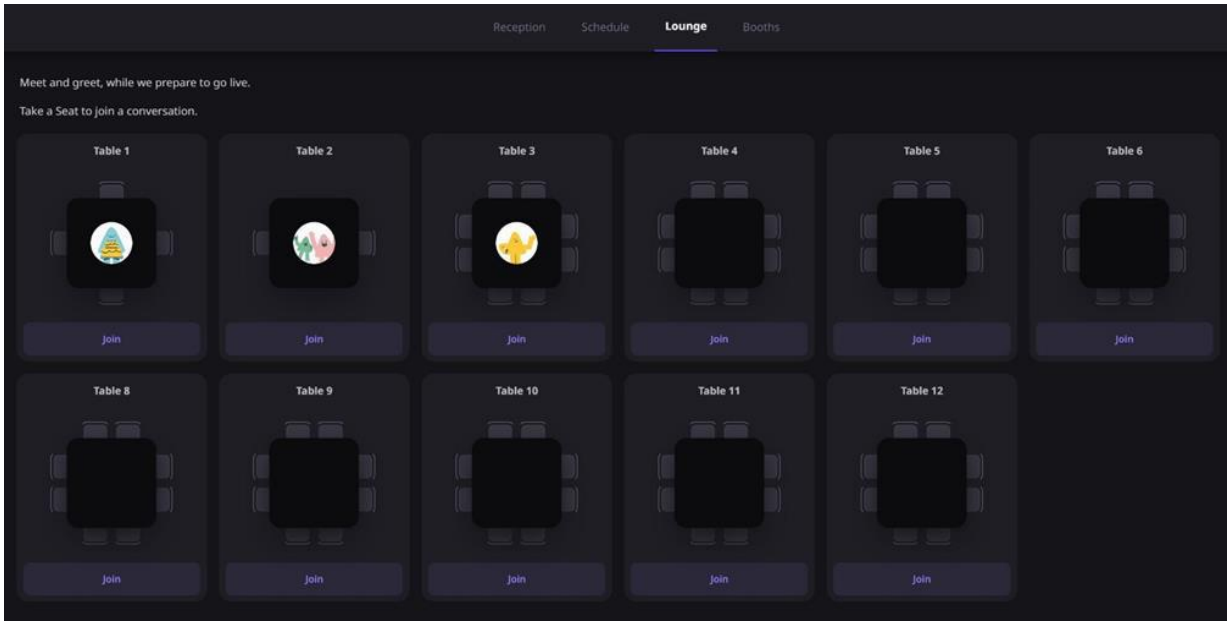


Figure 11 - Airmeet Lounge room

3.4 Horizontal Workshop webpage

The OntoCommons website is the main reference tool used for the promotion of events and general communication about the project's objectives and results. For this reason, a dedicated page has been created to inform the OntoCommons community about the 1st Horizontal Workshop. The page is composed by three main sections:

- In the top, there is the graphic banner that contains the main information about the workshop (title, date, time) followed by a brief description of the event.

- In the middle there is the agenda, the registration link and a 1-minute video, created to explain in a simple way the main purpose of the workshop and invite people to register for it.
- At the bottom of the page, instead, the website users could learn more about the content of each session.

Currently, at the workshop page, the registration link has been removed and substituted by the recorded videos from the workshop, as shown in the picture below.

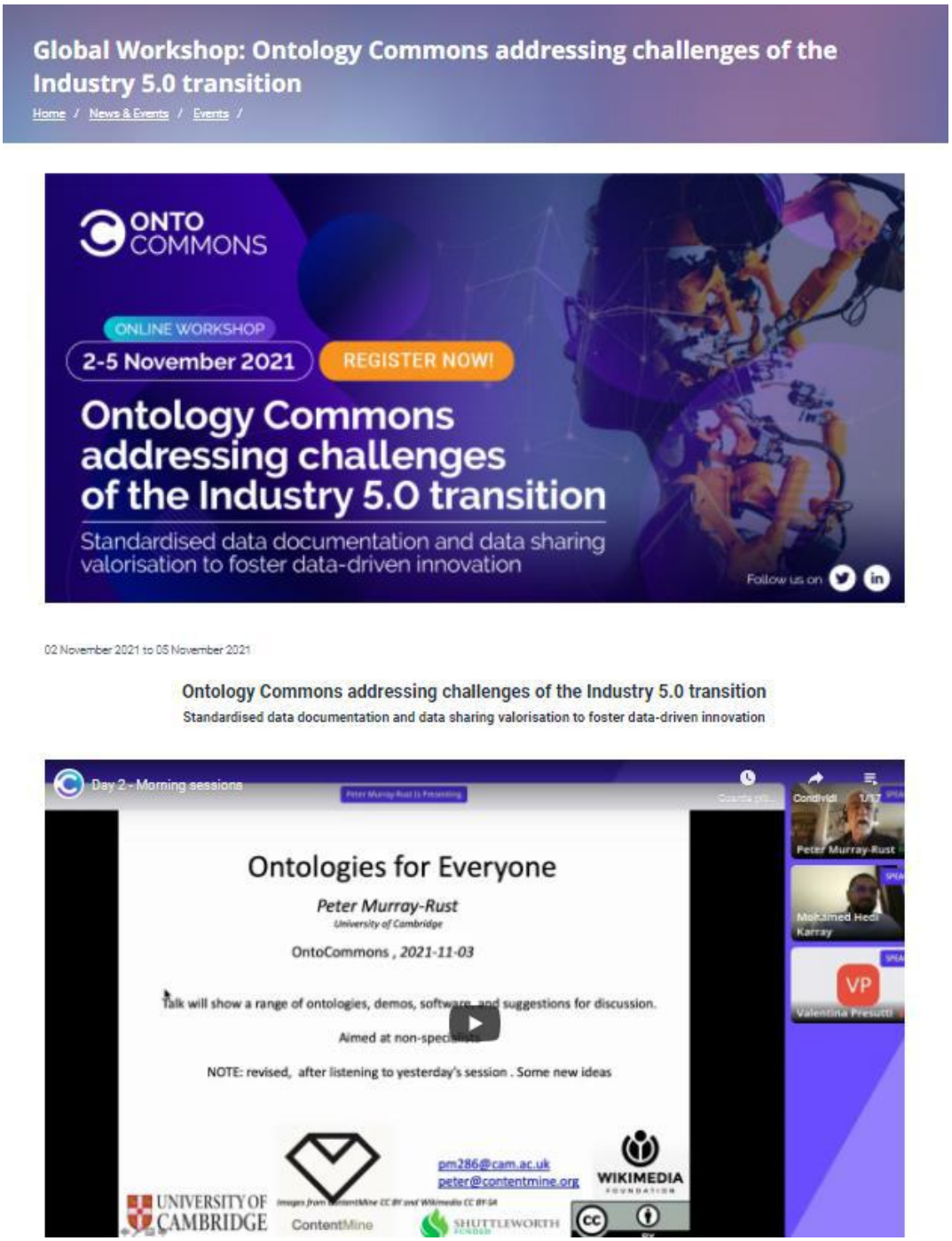


Figure 12 - Snapshot of the 1st Horizontal Workshop webpage

3.4.1.1 Experts' registration form

Moreover, as the main outcomes from the different sessions of the workshop will contribute to the content of the OntoCommons Roadmap, the participants to the workshop were asked to register for the event with an expert account. The participants were asked to register an expert stakeholder's account on the OntoCommons website in which the users were asked to fill in information related to its ontology experience, in a specific webform.

3.4.1.2 Open calls for posters webpage

An additional page to promote the open call for posters was prepared and displayed on the website. In this page, relevant stakeholders in the fields of ontologies, interoperability, material science, manufacturing, FAIR data and standards applied to the industrial ecosystem had the opportunity to submit a graphical poster that summarises the main outcomes and impacts of the research they are performing. The OntoCommons team received 6 applications for the posters that have been presented over the course of the workshop and published on a dedicated page on the website.

3.5 Graphic material

Branding images to promote and ensure a consistent and distinctive look and feel of the workshop across various communication channels (social media, website, newsletter, video, registration webform) were prepared.

The graphic materials include the development of workshop banners that were posted on the website and on social media; session cards to promote and better explain the content of the workshop; speaker cards to show the various speakers and the topic they covered during the event and the agenda.

Figure 13 - Workshop promotional banner

Figure 14 - Open call for posters promotional banner

Figure 15 - Examples of promotional cards for the workshop sessions

Figure 16 - Examples of speaker cards for the promotion on social media

Figure 17 - Partial snapshot of the branded workshop agenda

3.5.1 Promotional Video

Videos are becoming one of the most essential tools when creating multimedia content. According to a survey shown on the TechSmith website, 68% of users prefer to watch short videos when learning about new topics[35]. This is driven by the fact that videos represent an engaging and direct way to connect with stakeholders and explain topics in an easy way. For this reason, the OntoCommons team has prepared a 1-minute video to promote the workshop, explaining the main objectives of the event and its added value.

The video, uploaded on the OntoCommons YouTube and website pages, achieved the astounding number of 6,299 visualisations in just one month, since the 7th October when it was published until the beginning of November, which is significantly higher than the industry standard, mainly driven by the PPC Campaign launched in October, as explained in more details in section 3.8.

[35] https://www.techsmith.com/blog/why-video-is-important/

Figure 18 - Screenshot from the promotional video

3.6 Social media management

A continuous promotion on the OntoCommons social media channels (LinkedIn and Twitter) has been carried out to increase the awareness and registrations for the workshop. Social media is an instant form of communication with community members and potentially interested people or organisations who do not belong to the OntoCommons consortium. Hence, social media channels help ensure continual visibility of the project's efforts to targeted stakeholders.

The next two paragraphs show in more detail the activities performed on LinkedIn and Twitter.

3.6.1 LinkedIn

LinkedIn is the most recognised social media channel for building professional networking. The OntoCommons community is mainly composed of ontologists, research and academia and industrial stakeholders interested in the usage of ontologies.

Starting from August 2021 until beginning of November, the OntoCommons team has regularly posted content that incentivised people to register for the workshop.

Posts included general information about the workshop, testimonial cards with the speakers and session cards that explained in more detail the content of the workshop. Visual examples of LinkedIn posts can be found in the figure below.

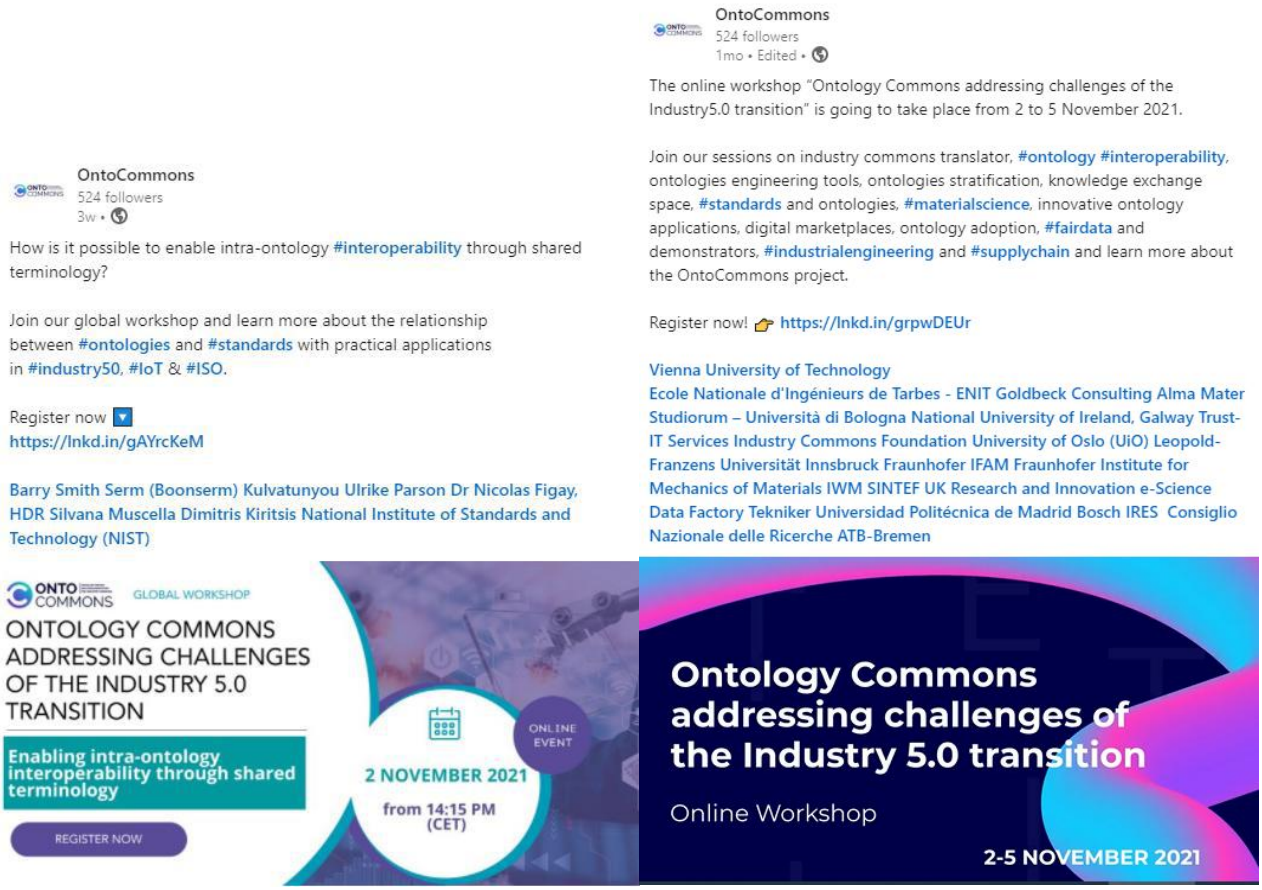


Figure 19 - Examples of LinkedIn posts promoting the workshop

Moreover, a dedicated event page was created on LinkedIn to increase the visibility and engagement around the workshop. Indeed, on LinkedIn event pages, it is possible to invite the community to the event and have private chats with the attendees before and during the workshop. Creating the event represented an easy way to get in touch with interested stakeholders and keep them updated about the latest information on the workshop.

Figure 20 - Partial snapshot of the LinkedIn event page

The activities run on LinkedIn over the last months and during the workshop, helped to increase the number of followers on this social media channel. As a matter of fact, in August the OntoCommons community counted 370 followers. But, thanks to the higher number of posts, higher engagement created during the workshop and PPC Campaigns, as better explained in the section 3.7.1, the LinkedIn community increased by 154 members (+ 42% in a month), counting 524 followers by mid-November.

3.6.2 Twitter

Twitter is a social media channel that provides news and brief real time information. It is mainly used for posting instantaneous updates and advertising upcoming OntoCommons activities. This characteristic made Twitter the ideal social media to promote the workshop to relevant stakeholders and launch live tweets while the workshop was live (2-5 November 2021).

Examples of tweets launched before and during the workshop are available below:

Figure 21 - Examples of Twitter posts promoting the workshop

Figure 22 - Examples of live-twitting activities during the event

The engagement created during the workshop increased, as well as the visits and followers of the OntoCommons twitter account in the period from mid-October to mid-November 2021, compared to the same interval in the previous month.

As shown in the picture below, the number of tweets during the workshop was increased by almost 115% (58 live tweets), bringing higher posts impressions (27000, +193.7% versus the previous month) and visits to the OntoCommons twitter profile (5737, +97.9% versus the previous month). Moreover, the account has gained 39 followers and has been mentioned by external accounts almost 167% times (24) more than in the previous month.

Figure 23 - Statistics from the OntoCommons Twitter Profile

3.7 Newsletters

Sending newsletters can create or increase awareness, provide basic information such as details of upcoming events and insights from the past ones, or create a sense of stability and commitment for the project by sharing its achievements and relevant messages to the stakeholder's community.

In the workshop context, the OntoCommons team has sent three newsletters to invite the subscribers (549 at the time of writing) to the Horizontal Workshop and to apply for the posters open call. The newsletters have been sent in August, October and November and drove registrations to the workshop as shown in the Table below. The numbers show that sending newsletters is a profitable way to engage with the OntoCommons community and keep them updated on the latest news, since we always achieve on average an open rate higher than the industry standard (30%). Newsletter subscribers is also a metric that we saw increase at a rate above industry standard. In fact, during the event, we gained 44 new newsletter subscribers, plus additional 84 newsletter subscribers gained since the start of the promotion. For this reason, it is essential to increase the engagement level for these kinds of events.

Newsletter issue	Open Rate	Promoted content	Acquisitions
nr. 6 (August 2021)	38.6%	Horizontal Workshop webpage	44%
nr. 8 (October 2021)	38.4%	Horizontal Workshop webpage	17%
		Call for posters	22%
nr. 9 (November 2021)	40%	Horizontal Workshop webpage	49%
		Call for posters	2%

Table 1 – Newsletter Results

3.8 Pay-Per-Click Campaigns

Pay-Per-Click Campaigns are becoming a popular advertising strategic element that use a dedicated paid tool to draw attention to specific online content through keyword searches. They can therefore be used to highlight specific content and videos with the aim of increasing their visibility among priority stakeholder groups, including interested users of the OntoCommons project. Moreover, targeting can be optimised by including all relevant keywords, such as the video/content topic, demographic data and audience interests. As the campaigns can be sponsored only to selected target customers, the costs associated with them can be reduced.

In order to increase the number of registrants to the OntoCommons Horizontal Workshop, three PPC Campaigns have been launched in October 2021, including two campaigns on LinkedIn and one on Google. The campaigns have been continuously monitored and adjusted on a case-by-case basis, according to their performances.

3.8.1 PPC Campaigns on LinkedIn

LinkedIn is 227% more effective for lead generation than Twitter and Facebook, as the number of contents posted is lower and the platform, being a professional network, targets mainly business-oriented users. For this reason, a post has a higher probability to be displayed and read by relevant stakeholders[36]. This is the main reason why two PPC campaigns have been launched on LinkedIn to increase the number of registrants to the workshop and promote the call for posters. The PPC Campaigns on LinkedIn have supported the increase in number of followers of this social media channel by 154 in just a month, as shown in the paragraph 3.6.1.

The type of campaign chosen to increase the number of registrations is the Lead Generation as this is the one that helps target and reach relevant stakeholders. The Lead Generation allows to promote a post that contains a text with an image or video. In this case, it was used to promote the one-minute video teaser prepared to attract more participants to the workshop, as this is the video that explains in an easy and compelling way what the workshop is about and how to register for the event.

36 https://blog.hubspot.com/blog/tabid/6307/bid/30030/LinkedIn-277-More-Effective-for-Lead-Generation-Than-Facebook-Twitter-New-Data.aspx

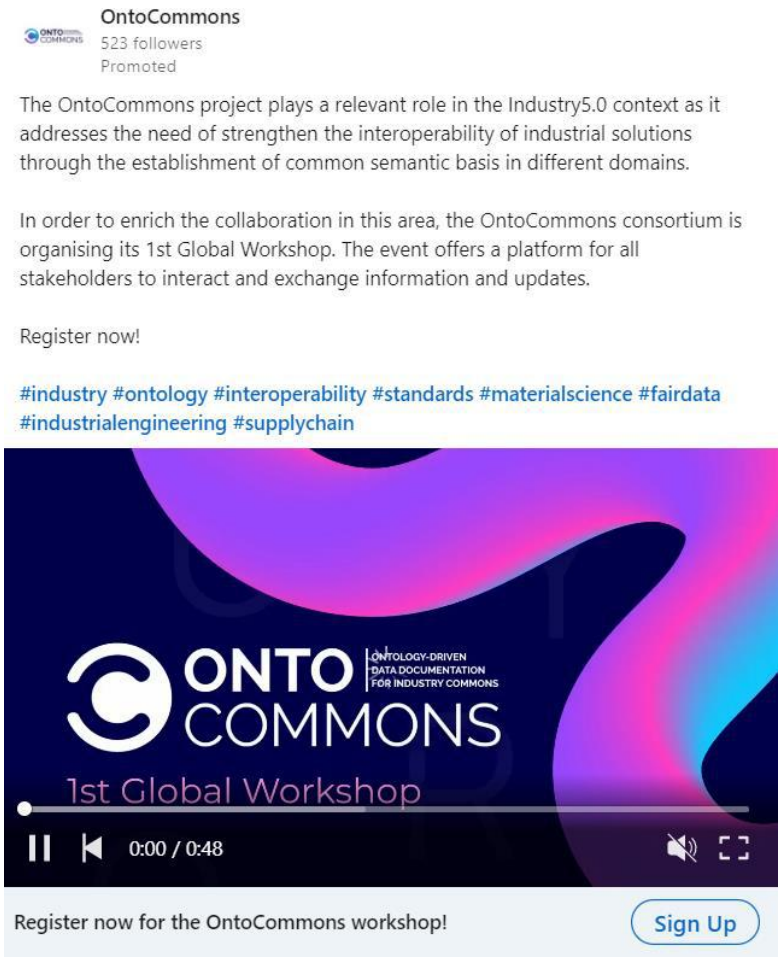


Figure 24 - Print screen of the Lead Generation PPC Campaign

The Lead Generation campaign has been carried out for a period of three weeks, starting from 11 October, and has contributed to bring very positive results with 31,786 impressions and 84 clicks of the post.

The call for papers, instead, has been promoted through **a sponsored content PPC Campaign**, which is ideal to increase traffic on posts published on a LinkedIn page and, in only a week, has gained 13,135 impressions and 91 clicks, which are extremely good results, considering that the average number of impressions of LinkedIn post on the project page is 200, with about 15 likes.

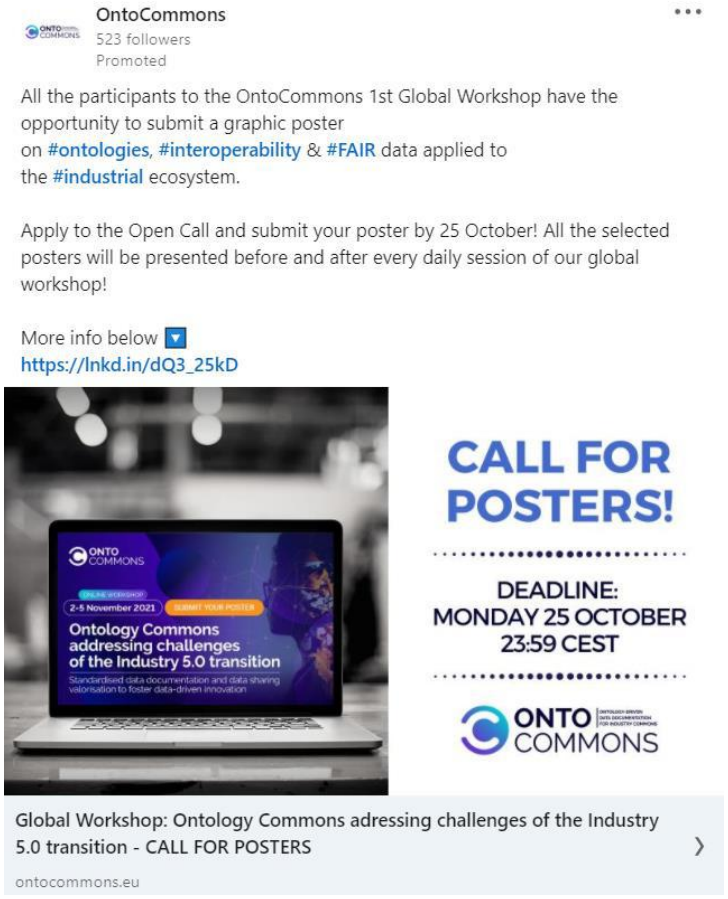


Figure 25 - LinkedIn PPC Campaign - Sponsored content for the call for posters

3.8.2 PPC Campaign on Youtube

The PPC Campaign on YouTube has been launched for the entire month of October to increase the views of the workshop promotional video. The selected PPC campaign has been the **Discovery** one, which shows the video on the YouTube search results, as well as among other YouTube videos.

The campaign gained outstanding results with 197,533 impressions and 6,106 visualisations. The video PPC campaign helped the OntoCommons team also to understand what are the most searched keywords while people navigate on Google platforms. These keywords (engineering tools, industry commons, manufacturing, material science) have been reused with hashtags while posting on other social media, given the relevance for the specific sector.

The average number of visualisations of a Research & Innovation video is 150, which shows the very positive impact the video PPC Campaign has brought in terms of engagement.

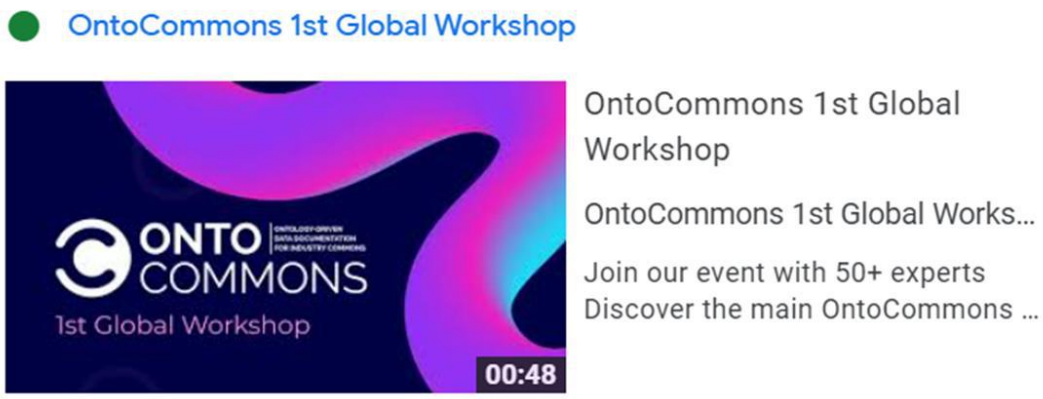


Figure 26 - Video PPC Campaign on YouTube

3.9 Post-workshop activities

Post-workshop activities are extremely important to engage with the audience and maintain high interest in the project, because they provide the opportunity to communicate "what is going to happen next and why they should care" to a highly engaged audience that has just proved extremely interested in the project's activities by joining the event.

After the workshop's conclusion, we immediately thanked all the speakers and chairs for their availability to join the various sessions and contribution to the event with their content-rich inputs and presentations.

We also thanked and shared with all the Horizontal Workshop attendees the event statistics, presentations and the session recordings link in the main event page.

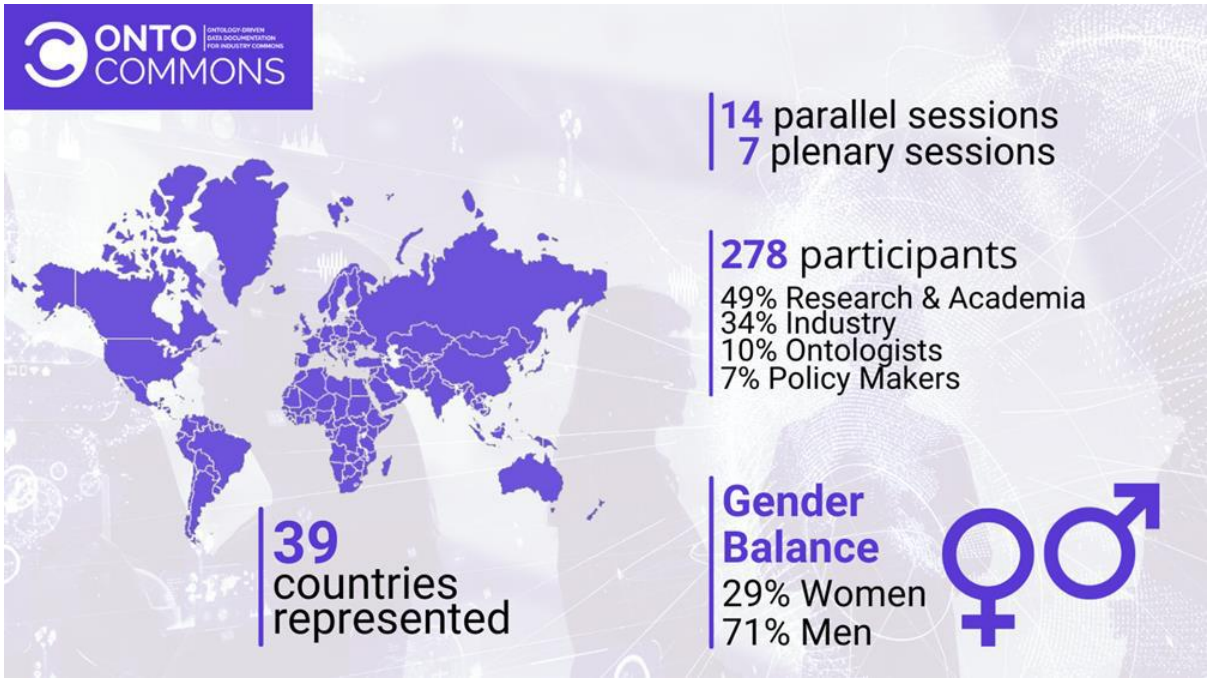


Figure 27 - OntoCommons Horizontal Workshop participants statistics

As a results of the event, various new content will be created and disseminated to the community to provide additional insights on the project's activities and impact, such as the External Advisory Board members interviews on their standardisation effort or the OntoCommons demonstrators video on their impact and benefits for joining the project as demonstrator use cases.

4. Conclusions

The first Horizontal Workshop of OntoCommons has been a fundamental step in order to engage the stakeholders and it has proved the need for communications around the different initiatives and projects, at EU and international level, working around the ontologies' domain.

Some User's needs have emerged during the workshop, that are collected in the following paragraphs.

4.1 Lessons Learnt & Future Plans

The engaging four-day workshop has allowed different stakeholders from very different contexts to engage together and initiate discussions on the topics presented so far. During the organisation of the workshop, the schedule has been set up in order to fit all the topics in the four days (three days and a half, considering the length of Day 4), but at the same time in order to avoid computer fatigue to the users, vary the types and topics of the sessions, make regular breaks and directing the target users where they were the most interested, leaving the possibility to watch the recordings of the other sessions.

Despite that, many users have expressed their interest in carrying out the discussions outside of the stage, when some interesting and engaging topic was introduced by the speakers.

- The second (and last) Horizontal Workshop (scheduled for M30) will be set up with a lounge room, to give the audience the possibility to engage in offline discussions and create more opportunities for dialogue, which, as emerged from the impacts of the sessions, is a fundamental component for the success of ontology interoperability.

- Dedicated poster booths will be set up for the same reasons, instead of the simple on-stage presentation. In this way, the poster presenter can remain available to give more information in a dedicated room.

- More Policy Intervention talks will be introduced, if possible, in the following iteration of the workshop.

- Dedicated online surveys provided by the Work Package Leaders could be allocated to each specific session in order to collect additional inputs from external experts.

- The External Advisory Board members will be involved with more specific roles in the activities of the second year of project and invited to take part more actively in the second Horizontal Workshop

At the moment of writing, it is still uncertain whether there will be the possibility to have a physical Horizontal Workshop, instead of a Virtual or Hybrid one.

The OntoCommons Consortium will integrate the inputs collected in this report, with the outcomes of the Second Horizontal Workshop, and use them to contribute to the final version of the Roadmap, helping the ontology community defining the path towards better cross-domain interoperability.