Semantic Web 0 (0) 1
IOS Press

Special Issue on Semantic Web for Industrial Engineering: Research and Applications

Bahar Aameri [a], María Poveda-Villalón [b], Emilio M. Sanfilippo [c,*] and Walter Terkaj [d,**]
[a] *University of Toronto, Canada*
E-mail: bahar@cs.toronto.edu
[b] *Universidad Politécnica de Madrid, Spain*
E-mail: mpoveda@fi.upm.es
[c] *CNR-ISTC, Italy*
E-mail: emilio.sanfilippo@cnr.it
[d] *CNR-STIIMA, Italy*
E-mail: walter.terkaj@stiima.cnr.it

1. Introduction

Semantic Web languages, models, and technologies are increasingly finding widespread research and practical applications within the domain of Industrial Engineering. The key motivations behind applications of Semantic Web in industrial domains is twofold: On one hand, the extensive utilization of computer-based technologies in manufacturing organizations raises the need for rigorous approaches for managing and sharing data. On the other hand, achieving interoperability among different systems and stakeholders requires alignment between different terminologies. Specifically, in its current state, Semantic Web approaches within industrial domains address challenges that can be broadly classified into five categories:

***C1* Knowledge Representation and Management**
Semantic Web technologies are used to facilitate knowledge sharing and reusability effectively. This involves creating standardized and interoperable representations of information across various applications in areas such as manufacturing, logistics, maintenance, and supply chain management, and more [1–4].

***C2* Decision Support Systems**
Semantic Web technologies play a crucial role in developing decision support systems for engineers and practitioners. By utilizing automated reasoning along with other computational techniques, these systems help in design and optimization of processes, resource allocation, and managing complex workflows [5–7].

***C3* Semantic Interoperability**
Semantic Web languages provide explicit representations for intended semantic of data. This is essential for preventing the loss of crucial information when shared among multiple parties [8–10]. This enables the harmonization of heterogeneous data sources and allows seamless publication, exchange, and integration of data among different industrial processes, tools, and stakeholders [11–14].

---

[*] Corresponding author: E-mail: emilio.sanfilippo@cnr.it.
[**] Corresponding author: E-mail: walter.terkaj@stiima.cnr.it.

C4 **Smart Manufacturing and Industry 4.0**
In the context of Industry 4.0, Semantic Web contributes to the development of smart manufacturing systems by integrating data from various IoT devices, sensors, and cyber-physical systems, facilitating seamless interaction between machines and humans [8, 9, 15]. In particular, Semantic Web can help tackle several challenges related to the application of Digital Twin technologies in industry [16–18].

C5 **Human-Machine Interaction**
Semantic Web facilitates interaction between humans and machines, including robots, through creating common, formal terminologies and conceptual systems This standardization helps handle information within industrial contexts more effectively [19–21].

Various initiatives, by national and international organizations, have been commenced to disseminate and facilitate the utilization of the SW for industrial requirements. These initiatives aim to collect, enhance, and promote existing methodologies, best practices, ontologies and tools, and foster their further development and application. Examples of these initiatives are the European project OntoCommons[1] (part of the Horizon 2020 research and innovation program), the global endeavors of the Industrial Ontologies Foundry (IOF)[2], the W3C Linked Building Data Community Group[3], workshop series like FOMI (Formal Ontologies Meet Industry)[4] and LDAC (Linked Data in Architecture and Construction)[5] as well as digital twin-related initiatives like the UK National Digital Twin Programme (NDTP)[6] and the Building Digital Twin Association (BDTA)[7].

2. Special Issue topics

The purpose of this special issue, titled *"Semantic Web for Industrial Engineering: Research and Applications"*, is to collect contributions focusing on the application of Semantic Web in various industrial engineering settings such as discrete manufacturing (e.g., aerospace, automotive, machinery, electronics), continuous production (e.g., chemical engineering, oil and gas industry), product design, Architecture, Engineering and Construction (AEC). The topics we aimed to cover in this special issue include the following:

T1 Research and application challenges for the industrial exploitation of Semantic Web languages and technologies, including Industry 4.0 scenarios.

T2 Semantic Web as an enabler for Digital Twin applications in industry.

T3 Semantic Web frameworks (including frameworks adopting the FAIR principles) for knowledge-based industrial data management, covering tasks such as data modeling, sharing, integration, systems interoperability, reasoning about data and knowledge.

T4 Data analysis workflows supported by the Semantic Web.

T5 Novel technologies for Semantic Web applications in industry.

T6 Bridging methods between Machine Learning and the Semantic Web tuned to industrial engineering.

---

[1] https://ontocommons.eu/
[2] https://www.industrialontologies.org/
[3] https://www.w3.org/community/lbd/
[4] https://iaoa.org/index.php/faq/industry-and-standards-technical-committee/
[5] https://linkedbuildingdata.net/ldac/
[6] https://digitaltwinhub.co.uk/
[7] https://buildingdigitaltwin.org/

T7 Real cases of successful/unsuccessful use of the Semantic Web in industrial engineering applications

T8 Ontologies for knowledge representation and reasoning about topics relevant for industrial engineering (e.g., products, processes, manufacturing resources, requirements and capabilities, etc.).

T9 Ontology-based patterns for industrial engineering knowledge representation.

T10 Methodologies, methods, and techniques targeted to industrial contexts supporting the development, modularization, extension, and evolution of ontologies.

T11 Literature review of existing ontologies for industrial engineering, including structured comparisons.

T12 Experiences with the use of top-level ontologies (e.g. BFO, DOLCE, ISO 15926, among others) in industrial engineering.

T13 Experiences with research and application initiatives such as OntoCommons, the Industry Ontologies Foundry (IOF), and the UK National Digital Twins.

3. Contributions

Initially, 18 papers were submitted to the Special Issue, of which 12 have been accepted for publication. Herein, we present a brief summary of the accepted papers. Furthermore, Table 1 shows the mapping of the articles against the challenges (Sect.1) and topics (Sect.2).

Bareedu et al. [22] address challenges related to guidelines for data modeling provided in industrial standards but in unstructured formats. The use of informal specifications hinders the automated validation of data models reliant on these standards, potentially leading to costly interoperability errors. The paper proposes an approach to extract and represent modeling constraints from industrial standards as machine-actionable rules, particularly in the context of the OPC UA standard. The authors demonstrate the feasibility of this approach by formally representing modeling constraints using Semantic Web languages, successfully identifying constraints within specification documents and achieving the semiautomatic translation of the constraints into formal means.

Compagno and Borgo [23] aim to contribute to the establishment of a comprehensive ontological modeling of the engineering concepts of functionality, behavior, capability, and capacity, including the relationships between them. Using the foundational ontology DOLCE as top-level modeling framework, the paper conducts a conceptual analysis of these notions and formalizes the resulting logical theory in first-order logic and OWL. The study emphasizes differentiating functions from their implementation methods, distinguishing between capabilities and capacities of a product, and elucidating their relationships within engineering systems.

Donkers et al. [24] propose a scalable method for acquiring continuous occupant feedback, integrating it with building information using Semantic Web technologies. The Occupant Feedback Ontology (OFO) facilitates semantic description of feedback. The Mintal smartwatch app collects location, medical data, and survey responses, applying the ontology for integration with linked building data. A case study demonstrates the creation of a semantic digital twin, enhancing occupant-centric decision support tools and offering insights into perceived comfort levels.

Giustozzi et al. [25] introduce a semantic framework for evolving knowledge bases related to condition monitoring in the scope of Industry 4.0. The COInd4 ontology represents manufacturing domain resources, processes, and contextual information. Stream reasoning integrates sensor data with contextual knowledge, detecting situations leading to potential failures in real-time. A lattice structure organizes these situations by severity, providing a roadmap for decision support. The approach ensures adaptive process behavior without interrupting manufacturing processes.

Lambrix et al. [26] tackle the challenge of accessing and integrating heterogeneous data stored in various computational materials databases. The paper introduces the Materials Design Ontology, inspired by the OPTIMADE effort, aiming to enhance interoperability among multiple databases in computational materials science. The paper details the ontology and showcases its use in a proof-of-concept implementation for data access and information systems interoperability.

Stüber and Frey [27] explore the use of Semantic Web technologies to enhance the FAIRness of Modeling and Simulation (M&S) capabilities in industrial systems. In particular, it presents an open-source proof-of-concept implementation based on the Functional Mock-up Interface (FMI) standard. This implementation exposes models, instances, and simulation results through a hypermedia API, demonstrating increased FAIRness and support for use in loosely coupled systems.

Umbrico et al. [28] present an extension of the Sharework Ontology for Human-Robot Collaboration (SOHO) to enhance the characterization of behavioral constraints in collaborative tasks. The work introduces a knowledge extraction procedure for automating the synthesis of Artificial Intelligence plan-based controllers. The generality of the ontological model and the synthesized planning domains are validated in real industrial scenarios with collaborative robots.

Werbrouck et al. [29] introduce ConSolid, a decentralized ecosystem designed for multi-stakeholder collaborations dealing with heterogeneous data in industries like construction. Leveraging Solid specifications for Web decentralization, ConSolid extends these specifications to facilitate semantic interoperability among diverse subdomains. The ecosystem employs metadata-generated virtual views via SPARQL interfaces, enabling data aggregation and alignment across multiple vaults in a scalable manner.

Woods et al. [30] study maintenance for asset-intensive organizations by focusing on data quality of Maintenance Work Order (MWO) records. The authors present a reference ontology for maintenance activity terms derived from natural language processing of MWOs, and an application-level ontology demonstrating the use of the reference ontology in an industrial use case. The end-to-end NLP-ontology pipeline identifies data quality issues and infers relevant activity classes, offering a practical approach for organizations to enhance maintenance work management processes through ontological workflows.

Yahya et al. [31] focus on developing a benchmark dataset for generating Knowledge Graphs (KGs) in Industry 4.0 production lines. It highlights the benefits of utilizing ontologies and semantic annotations to demonstrate the advantages of KGs in the Industry 4.0 domain. Collaboration with industry professionals has resulted in a KG based on the Reference Generalized Ontological Model (RGOM), showcasing adaptability and usefulness in supporting decision-making processes within production lines.

Yaman et al. [32] apply semantic web standards to enhance data quality governance in the architectural, engineering, and construction (AEC) domain, focusing on Ordnance Survey Ireland (OSi). The approach establishes a unified knowledge graph for data quality measurements across a complex, heterogeneous data production pipeline. It formalizes mappings between semantic models of data quality dimensions from ISO and W3C standards, enabling end-to-end data quality reporting and analysis. The use of a knowledge graph and semantic web standards unifies distributed data quality monitoring, offering a standards-agnostic end-to-end data dashboard for OSi's data publishing pipeline.

Zhao et al. [33] address the need for seamless information exchange when dealing with dynamically changing 3D environments in shopfloor and warehouse robotics. The authors propose an ontology model integrating contextual, topologic, and geometric information for both rigid bodies and free space. The evolvable knowledge model supports simulated task-related information, improving interoperability for path planning systems. The ontology allows for updating contextual semantics related to specific applications while maintaining geometric and topological models through semantic links.

4. Remarks

The papers featured in this special issue, along with the mentioned international research and application works, showcase the significant interest of the industrial engineering community in ontologies and Semantic Web technologies. These are recognized as key enablers to foster data management practices within organizations and to support experts and stakeholders in effectively handling large and heterogeneous datasets in a robust and intelligent manner in their daily routines.

Table 1

Mapping of special issue article against challenges and topics

Article	**Challenges**					**Topics**												
	C1	**C2**	**C3**	**C4**	**C5**	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**T9**	**T10**	**T11**	**T12**	**T13**
Bareedu et al. [22]	X		X					X	X		X							
Compagno and Borgo [23]	X												X	X			X	
Donkers et al. [24]	X		X			X	X	X				X	X					
Giustozzi et al. [25]	X		X	X		X	X	X								X		
Lambrix et al. [26]	X		X					X					X					
Stüber and Frey [27]			X	X			X	X										
Umbrico et al. [28]	X	X		X	X	X	X						X					
Werbrouck et al. [29]			X					X	X									
Woods et al. [30]	X		X					X	X			X	X	X			X	X
Yahya et al. [31]			X	X				X				X						
Yaman et al. [32]			X					X	X							X		
Zhao et al. [33]	X	X	X	X			X	X					X					

At the same time, as researchers in ontology engineering, we often face criticism asserting that the efforts invested in the development of ontology-based models and technologies may not be justified, with alternative approaches being deemed more readily exploitable and maintainable. Additionally, despite the initial introduction of ontologies as a common “interlingua” across systems to address knowledge portability and counteract the proliferation of data model, we constantly witness the emergence of new ontologies. Another prevalent critique centers around the challenge of determining when one has created a “good” ontology, given the absence of standardized benchmarks in the ontology evaluation process.

It is essential to acknowledge that ontology engineering, as a scientific endeavor, is not a magical solution. The research community must enhance its practices, consistently evolve methodologies to (a) aid stakeholders in developing ontology-based systems for their businesses; (b) build and maintain Knowledge Graphs in sync with the ontology evolution; (c) establish standardized benchmarks for systematic ontology testing; and (d) define ontology governance models for different types of organizations. Moreover, there is a duty to educate future generations of computer scientists and engineers, providing them with the interdisciplinary skills needed for ontology design, usage, and maintenance. Given that ontologies are knowledge-based models, it is unavoidable that their representation will entail some complexity when the human knowledge they aim to represent exhibits a certain degree of functional complexity for the intended application. Finally, despite encountering scenarios where various ontologies coexist, even within specific application domains, a straightforward solution, in our opinion, remains elusive. Efforts like OntoCommons or the IOF, mentioned earlier, rely either on formal *mappings* to align ontologies to ensure a certain level of interoperability among the data modeled on their basis, or develop *reference* ontologies for data management practices. The first approach promotes a *plurality* of perspectives about the engineering domain, while the second one relies on *single*, *monolithic* models to be widely adopted within communities.

While acknowledging that ontologies may not guarantee a complete information systems interoperability, they can, at the very least, be systematically used to discern semantic convergences and divergences in data. In a nutshell, the maturity of the discipline and the business exploitation of ontology-based tools in the (near) future hinge on the research community’s efforts and its ability to meet the evolving requirements of society.

Acknowledgements: We are thankful to the Guest Editorial Board for their support throughout the review process: João Paulo A. Almeida, Farhad Ameri, Toshihiro Ashino, Daniel Beßler, Jürgen Bock, Stefano Borgo, Carlos Buil-Aranda, David Chaves-Fraga, Hyunmin Cheong, Silvia Chiacchiera, Gonçal Costa, Iker Esnaola-Gonzalez, Emanuele Ghedini, Franco Giustozzi, Gerhard Goldbeck, Michael Gruninger, Melinda Hodkiewicz, Boonserm Kulvatunyou, Kyoung-Yun Kim, Davide Lanti, Maxime Lefrançois, Francesco Mercuri, Nandana Mihindukulasooriya, Gianfranco Modoni, Alessandro Mosca, Elisa Negri, Andrea Orlandini, Romana Pernischova, Mihai Pomarlan, Luis Ramos, Mohamed Ragab, Julian Rojas, Ana Roxin, Marta Sabou, Arkopaul Sarkar, Georg Schneider, Umutcan Serles, Daniele Spoladore, Markus Stumptner, Seppo Törmä, Alessandro Umbrico, Dylan Van Assche, Marcela Vegetti, Sven P. Voigt, Jeroen Werbrouck, Beyza Yaman, Robert I.M. Young, Cecilia Zanni-Merk, Baifan Zhou.

In addition, we would like to thanks the current (Krzysztof Janowicz) and past (Pascal Hitzler) Editors-in-Chief for the opportunity to organize this special issue.

References

[1] M. Drobnjakovic, B.S. Kulvatunyou, F. Ameri, C. Will, B. Smith and A. Jones, The Industrial Ontologies Foundry (IOF) Core Ontology, in: *Proceedings of the 12th International Workshop on Formal Ontologies Meet Industry (FOMI 2022)*, E.M. Sanfilippo, M.-H. Karray, D. Kyritsis and A. Sarkar, eds, CEUR Workshop Proceedings, Vol. 3240, CEUR, Tarbes, France, 2022. ISSN 1613-0073.

[2] J. Zenkert, C. Weber, M. Dornhöfer, H. Abu-Rasheed and M. Fathi, Knowledge integration in smart factories, *Encyclopedia* **1**(3) (2021), 792–811.

[3] N. Shilov, A. Smirnov and F. Ansari, Ontologies in smart manufacturing: approaches and research framework, in: *2020 26th Conference of Open Innovations Association (FRUCT)*, IEEE, 2020, pp. 408–414.

[4] E.M. Sanfilippo, W. Terkaj and S. Borgo, Ontological modeling of manufacturing resources
16(1), 87–109, Publisher: IOS Press. doi:10.3233/AO-210242. https://content.iospress.com/articles/applied-ontology/ao210242.

[5] S. Cisneros-Cabrera, G. Pishchulov, P. Sampaio, N. Mehandjiev, Z. Liu and S. Kununka, An approach and decision support tool for forming Industry 4.0 supply chain collaborations, *Computers in Industry* **125** (2021), 103391.

[6] M.M. Mabkhot, A.M. Al-Samhan and L. Hidri, An ontology-enabled case-based reasoning decision support system for manufacturing process selection, *Advances in Materials Science and Engineering* **2019** (2019).

[7] J.J. Montero Jiménez, R. Vingerhoeds, B. Grabot and S. Schwartz, An ontology model for maintenance strategy selection and assessment, *Journal of Intelligent Manufacturing* **34**(3) (2023), 1369–1387.

[8] M.M. Hafidi, M. Djezzar, M. Hemam, F.Z. Amara and M. Maimour, Semantic web and machine learning techniques addressing semantic interoperability in Industry 4.0, *International Journal of Web Information Systems* (2023).

[9] M. Yahya, J.G. Breslin and M.I. Ali, Semantic web and knowledge graphs for industry 4.0, *Applied Sciences* **11**(11) (2021), 5110.

[10] M. Urgo and W. Terkaj, Formal modelling of release control policies as a plug-in for performance evaluation of manufacturing systems
69(1), 377–380. doi:10.1016/j.cirp.2020.04.007. https://www.sciencedirect.com/science/article/pii/S0007850620300287.

[11] P. Pauwels, S. Zhang and Y.-C. Lee, Semantic Web Technologies in AEC Industry: A Literature Overview, *Automation in Construction* **73** (2017), 145–165. doi:10.1016/j.autcon.2016.10.003.

[12] A.L. Szejka, O. Canciglieri Jr., H. Panetto, E. Rocha Loures and A. Aubry, Semantic Interoperability for an Integrated Product Development Process: A Systematic Literature Review, *International Journal of Production Research* **55**(22) (2017), 6691–6709. doi:10.1080/00207543.2017.1346314.

[13] F. Ameri, D. Sormaz, F. Psarommatis and D. Kiritsis, Industrial Ontologies for Interoperability in Agile and Resilient Manufacturing, *International Journal of Production Research* **60**(2) (2022), 420–441. doi:10.1080/00207543.2021.1987553.

[14] W. Terkaj, P. Gaboardi, C. Trevisan, T. Tolio and M. Urgo, A digital factory platform for the design of roll shop plants
26, 88–93. doi:10.1016/j.cirpj.2019.04.007. https://www.sciencedirect.com/science/article/pii/S1755581719300264.

[15] C. Yang, Y. Zheng, X. Tu, R. Ala-Laurinaho, J. Autiosalo, O. Seppänen and K. Tammi, Ontology-based knowledge representation of industrial production workflow, *Advanced Engineering Informatics* **58** (2023), 102185.

[16] S. Dai, G. Zhao, Y. Yu, P. Zheng, Q. Bao and W. Wang, Ontology-based information modeling method for digital twin creation of as-fabricated machining parts, *Robotics and Computer-Integrated Manufacturing* **72** (2021), 102173.

[17] M. Rico, M.L. Taverna, M.R. Galli and M.L. Caliusco, Context-aware representation of digital twins' data: The ontology network role, *Computers in Industry* **146** (2023), 103856.

[18] W. Terkaj, M. Annoni, B.O. Martinez, E. Pessot, M. Sortino and M. Urgo, Digital Twin for Factories: Challenges and Industrial Applications, in: *Selected Topics in Manufacturing: Emerging Trends from the Perspective of AITeM's Young Researchers*, L. Carrino, L.M. Galantucci and L. Settineri, eds, Lecture Notes in Mechanical Engineering, Springer Nature Switzerland, pp. 255–274. ISBN 978-3-031-41163-2. doi:10.1007/978-3-031-41163-2$_1$3.

[19] S. Borgo, A. Cesta, A. Orlandini and A. Umbrico, Knowledge-based adaptive agents for manufacturing domains, *Engineering with Computers* **35** (2019), 755–779.

[20] S. Manzoor, Y.G. Rocha, S.-H. Joo, S.-H. Bae, E.-J. Kim, K.-J. Joo and T.-Y. Kuc, Ontology-based knowledge representation in robotic systems: A survey oriented toward applications, *Applied Sciences* **11**(10) (2021), 4324.

[21] K. Ryabinin, S. Chuprina and K. Belousov, Ontology-driven automation of IoT-based human-machine interfaces development, in: *International Conference on computational science*, Springer, 2019, pp. 110–124.

[22] Y.S. Bareedu, T. Frühwirth, C. Niedermeier, M. Sabou, G. Steindl, A.S. Thuluva, S. Tsaneva and N. Tufek Ozkaya, Deriving semantic validation rules from industrial standards: An OPC UA study
Preprint, 1–38, Publisher: IOS Press. doi:10.3233/SW-233342. https://content.iospress.com/articles/semantic-web/sw233342.

[23] F. Compagno and S. Borgo, Towards a formal ontology of engineering functions, behaviours, and capabilities
Preprint, 1–34, Publisher: IOS Press. doi:10.3233/SW-223188. https://content.iospress.com/articles/semantic-web/sw223188.

[24] A. Donkers, B. de Vries and D. Yang, Creating occupant-centered digital twins using the Occupant Feedback Ontology implemented in a smartwatch app
Preprint, 1–26, Publisher: IOS Press. doi:10.3233/SW-223254. https://content.iospress.com/articles/semantic-web/sw223254.

[25] F. Giustozzi, J. Saunier and C. Zanni-Merk, A semantic framework for condition monitoring in Industry 4.0 based on evolving knowledge bases
Preprint, 1–29, Publisher: IOS Press. doi:10.3233/SW-233481. https://content.iospress.com/articles/semantic-web/sw233481.

[26] P. Lambrix, R. Armiento, H. Li, O. Hartig, M. Abd Nikooie Pour and Y. Li, The materials design ontology
Preprint, 1–35, Publisher: IOS Press. doi:10.3233/SW-233340. https://content.iospress.com/articles/semantic-web/sw233340.

[27] M. Stüber and G. Frey, Dynamic system models and their simulation in the Semantic Web
Preprint, 1–36, Publisher: IOS Press. doi:10.3233/SW-233359. https://content.iospress.com/articles/semantic-web/sw233359.

[28] A. Umbrico, A. Cesta and A. Orlandini, Enhancing awareness of industrial robots in collaborative manufacturing
Preprint, 1–40, Publisher: IOS Press. doi:10.3233/SW-233394. https://content.iospress.com/articles/semantic-web/sw233394.

[29] J. Werbrouck, P. Pauwels, J. Beetz, R. Verborgh and E. Mannens, ConSolid: A federated ecosystem for heterogeneous multi-stakeholder projects
Preprint, 1–32, Publisher: IOS Press. doi:10.3233/SW-233396. https://content.iospress.com/articles/semantic-web/sw233396.

[30] C. Woods, M. Selway, T. Bikaun, M. Stumptner and M. Hodkiewicz, An ontology for maintenance activities and its application to data quality
Preprint, 1–34, Publisher: IOS Press. doi:10.3233/SW-233299. https://content.iospress.com/articles/semantic-web/sw233299.

[31] M. Yahya, A. Ali, Q. Mehmood, L. Yang, J.G. Breslin and M.I. Ali, A benchmark dataset with Knowledge Graph generation for Industry 4.0 production lines
Preprint, 1–19, Publisher: IOS Press. doi:10.3233/SW-233431. https://content.iospress.com/articles/semantic-web/sw233431.

[32] B. Yaman, K. Thompson, F. Fahey and R. Brennan, LinkedDataOps:quality oriented end-to-end geospatial linked data production governance
Preprint, 1–27, Publisher: IOS Press. doi:10.3233/SW-233293. https://content.iospress.com/articles/semantic-web/sw233293.

[33] Y. Zhao, A. Sarkar, L. Elmhadhbi, M.H. Karray, P. Fillatreau and B. Archimède, An ontology of 3D environment where a simulated manipulation task takes place (ENVON) **Preprint** (2023), 1–28, Publisher: IOS Press. doi:10.3233/SW-233460. https://content.iospress.com/articles/semantic-web/sw233460.