

4.4 Merry hMAS and Happy New Web: A Wish for Standardizing an AI-Friendly Web Architecture for Hypermedia Multi-Agent Systems

Fabien Gandon (INRIA – Sophia Antipolis, FR)

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- Main reference** Andrei Ciortea, Simon Mayer, Fabien Gandon, Olivier Boissier, Alessandro Ricci, Antoine Zimmermann: “A Decade in Hindsight: The Missing Bridge Between Multi-Agent Systems and the World Wide Web”, in Proc. of the 18th International Conference on Autonomous Agents and MultiAgent Systems, AAMAS '19, Montreal, QC, Canada, May 13-17, 2019, pp. 1659–1663, International Foundation for Autonomous Agents and Multiagent Systems, 2019.
- URL** <http://dl.acm.org/citation.cfm?id=3331893>
- Main reference** Simon Bienz, Andrei Ciortea, Simon Mayer, Fabien Gandon, Olivier Corby: “Escaping the Streetlight Effect: Semantic Hypermedia Search Enhances Autonomous Behavior in the Web of Things”, in Proc. of the 9th International Conference on the Internet of Things, IoT 2019, Bilbao, Spain, October 22-25, 2019, pp. 28:1–28:8, ACM, 2019.
- URL** <http://dx.doi.org/10.1145/3365871.3365901>
- Main reference** Fabien Gandon: “The Web We Mix: Benevolent AIs for a Resilient Web”, in Proc. of the 11th ACM Conference on Web Science, WebSci 2019, Boston, MA, USA, June 30 – July 03, 2019, pp. 115–116, ACM, 2019.
- URL** <http://dx.doi.org/10.1145/3292522.3329406>
- Main reference** Fabien Gandon: “A survey of the first 20 years of research on semantic Web and linked data”, *Ingénierie des Systèmes d Inf.*, Vol. 23(3-4), pp. 11–38, 2018.
- URL** <http://dx.doi.org/10.3166/isi.23.3-4.11-38>
- Main reference** Olivier Corby, Catherine Faron-Zucker, Fabien Gandon: “LDScript: A Linked Data Script Language”, in Proc. of the The Semantic Web – ISWC 2017 – 16th International Semantic Web Conference, Vienna, Austria, October 21-25, 2017, Proceedings, Part I, Lecture Notes in Computer Science, Vol. 10587, pp. 208–224, Springer, 2017.
- URL** http://dx.doi.org/10.1007/978-3-319-68288-4_13
- Main reference** Fabien Gandon: “The Three ‘W’ of the World Wide Web Call for the Three ‘M’ of a Massively Multidisciplinary Methodology”, in Proc. of the Web Information Systems and Technologies – 10th International Conference, WEBIST 2014, Barcelona, Spain, April 3-5, 2014, Revised Selected Papers, Lecture Notes in Business Information Processing, Vol. 226, pp. 3–15, Springer, 2014.
- URL** http://dx.doi.org/10.1007/978-3-319-27030-2_1
- Main reference** Fabien Gandon, Michel Buffa, Elena Cabrio, Catherine Faron-Zucker, Alain Giboin, Nhan Le Thanh, Isabelle Mirbel, Peter Sander, Andrea G. B. Tettamanzi, Serena Villata: “Challenges in Bridging Social Semantics and Formal Semantics on the Web”, *CoRR*, Vol. abs/1408.7092, 2014.
- URL** <http://arxiv.org/abs/1408.7092>

Although it was initially an “Information management proposal” [1] the Web really is a successful « application integration platform » [2]. More importantly, it is both. It is a self-documenting hypermedia system for application and information integration, and that makes the Web very special. Just like it is important to propose a Web of linked data and distributed RDF knowledge graphs as an alternative to data silos [3], the Web must also support an alternative to intelligence silos and thrive to host a wealth of distributed artificial and natural intelligence forming hybrid communities [6] and managing distributed resources [10]. This is a call for hMAS: Hypermedia Multi-Agent Systems [4] [5].

Among the success factors of the Web are a number of non-functional properties purposefully enforced at design time including: simplicity, generality, portability, extensibility and the systematic search for compatibility [8]. For instance, the simplicity meant, at the time, accepting to simplify solutions (e.g. SGML vs. HTML, HTTP vs other protocols) but also proposing viral approaches for adoption to learn to “weave by weaving” including copy-paste facilities of Web pages codes to start to contribute and what will later become the wiki-way too. The fact the Web proposal was put in the public domain by CERN in 1993 was also critical in reaching the threshold in volume of attractive resources and trigger the network effects and Metcalfe’s law. All these lessons learnt should be kept in mind when specifying hMAS.

Making autonomous agents a first class abstraction of the Web architecture requires importing important MAS concepts (environment, workspace, platform, situatedness, observability, organizations, norms, regulation, interactions). But to maintain extensibility

and forward compatibility hMAS must be a friendly architecture for all types of agents [9]: reactive vs cognitive, knowledge reasoning vs connectionist, stygmergy-oriented vs contractual protocol ones,... In this picture, semantic Web and linked data [7] have a key role to play both in weaving the hypermedia fabric for the agents' environment and in providing the semantics to capture the key concepts of hMAS in ontologies to ensure interoperability. Extensible top ontologies are needed to setup the architecture and support extension by domain-dependent and task-dependent ontologies needed for practical concrete applications.

Linked data also come with solutions and concepts to be used and aligned with hMAS for instance LDP [11] principles and containers or languages such as SPARQL to manipulate RDF data, SHACL to validate and exchange constraints, and extensions such as LDScript to program on top of linked data [12], a language that could be a candidate to align with agent programming languages. For instance, the notion of norms in MAS could be positioned w.r.t. rule languages and validation languages like SHACL which use cases already include both the validation of outputs and inputs of a software and the validation of interactions with a human like we would have in hybrid communities.

In parallel, Web of things, thin servers [13] and Digital Twins [14] are giving more and more substance to the Web resources that shadow physical resources. The URI could lead to more and more informed Web resources and put in touch a variety of digital twins and autonomous agents with the potential of supporting multi-model approaches at an unprecedented scale. Here again, the linked data framework holds the potential for deeply linking all these models [15].

To conclude, one of the hardest tasks for Tim Berners-Lee in the early 90s was to make people imagine a world with a fully deploy Web. Years later, it is hard to imagine a world without the Web. We have the same cold-start problem with the hMAS and we need to find incentives for this change to happen and to reach the threshold in terms of usage that will trigger the network effect and make it go viral. Therefore, together with a proposal of a standard architecture, we need to find incentives and added values for hMAS to be taken on by industry and developers.

References

- 1 Tim Berners-Lee. *Information Management: a proposal*. CERN, 1989.
- 2 Roy Fielding, Richard Taylor, Rohit Khare . *Reflections on the REST Architectural Style and "Principled Design of the Modern Web Architecture"*, FSE'17 Keynote, Proceedings of the 2017 11th Joint Meeting on Foundations of Software Engineering (ESEC/FSE 2017), pp. 4-11
- 3 Mansour, Essam, Andrei Vlad Sambra, Sandro Hawke, Maged Zereba, Sarven Capadisli, Abdurrahman Ghanem, Ashraf Abounaga, and Tim Berners-Lee. *A demonstration of the solid platform for social web applications*. In Proceedings of the 25th International Conference Companion on World Wide Web, pp. 223-226. 2016.
- 4 Ciortea A., Boissier O., and Ricci A., 2019. *Engineering World-Wide Multi-Agent Systems with Hypermedia*. In: Weyns D., Mascardi V., Ricci A. (eds) *Engineering Multi-Agent Systems*. EMAS 2018. Lecture Notes in Computer Science, vol 11375. Springer, Cham. https://doi.org/10.1007/978-3-030-25693-7_15
- 5 Andrei Ciortea, Simon Mayer, Fabien Gandon, Olivier Boissier, Alessandro Ricci, and Antoine Zimmermann. 2019. *A Decade in Hindsight: The Missing Bridge Between Multi-Agent Systems and the World Wide Web*. In Proceedings of the 18th International Conference on Autonomous Agents and MultiAgent Systems (AAMAS '19). International Foundation for Autonomous Agents and Multiagent Systems, Richland, SC, 1659–1663.
- 6 Gandon, F., Buffa, M., Cabrio, E., Corby, O., Faron-Zucker, C., Giboin, A., Le Thanh, N., Mirbel, I., Sander, P., Tettamanzi, A. and Villata, S., 2013, July. *Challenges in bridging*

- social semantics and formal semantics on the web*. In International Conference on Enterprise Information Systems (pp. 3-15). Springer, Cham.
- 7 Fabien Gandon. *A Survey of the First 20 Years of Research on Semantic Web and Linked Data*. Revue des Sciences et Technologies de l'Information – Série ISI : Ingénierie des Systèmes d'Information, Lavoisier, 2018
 - 8 Fabien Gandon. *For everything: Tim Berners-Lee, winner of the 2016 Turing award for having invented... the Web*. 1024 : Bulletin de la Société Informatique de France, Société Informatique de France, 2017, pp.21
 - 9 Fabien Gandon. *Combining reactive and deliberative agents for complete ecosystems in infospheres*. IEEE/WIC International Conference on Intelligent Agent Technology (IAT), Oct 2003, Halifax, Canada.
 - 10 Fabien Gandon, Laurent Berthelot, Rose Dieng-Kuntz. *A multi-agent platform for a corporate semantic web*. AAMAS 2002, 6th International Conference on Autonomous Agents, 5th International Conference on Multi-Agents Systems, 9th International Workshop on Agent Theories Architectures and Languages, Jul 2002, Bologna, Italy.
 - 11 Le Hors, Arnaud J., and Steve Speicher. *The linked data platform (LDP)*. Proceedings of the 22nd International Conference on World Wide Web. 2013
 - 12 Olivier Corby, Catherine Faron Zucker, Fabien Gandon. *LDScript: a Linked Data Script Language*. International Semantic Web Conference, Oct 2017, Vienne, Austria.
 - 13 M. Kovatsch, S. Mayer, and B. Ostermaier. *Moving Application Logic from the Firmware to the Cloud: Towards the Thin Server Architecture for the Internet of Things*. In Proc. IMIS, pages 751–756, 2012
 - 14 Ricci, A. *A Challenge for “Autonomous Agents on the Web” & Friends: Shaping & Designing “National Digital Twins”*, University of Bologna, position paper in this seminar, Dagstuhl Seminar, February 2021
 - 15 Fabien Gandon. *From linked data & knowledge graphs to linked intelligence & intelligence graphs or the potential of the semantic Web to break the walls between semantic networks and computational networks*, ISWC 2020 Vision Track Talk <https://www.youtube.com/watch?v=b9GPOOu2PTM>