Towards Pragmatic Explanations for Domain Ontologies

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Abstract. Ontologies have gained popularity in a wide range of research fields, in the domains where possible interpretations of terms have to be narrowed and there is a need for explicit inter-relations of concepts. Although reusability has always been claimed as one of the main characteristics of ontologies, it has been shown that reusing domain ontologies is not a common practice. Perhaps this is due to the fact that despite a large number of works towards complexity management of ontologies, popular systems do not incorporate enough functionality for ontology explanation. We analyse the state of the art and substantiate a minimal functionality that the system should provide in order to make domain ontologies better understandable for their users.

Keywords: Ontology Explanation · Pragmatic Explanation · Ontology engineering

1 Introduction

In the last few years, eXplainable AI has become a subject of intense study. Many efforts have been carried out towards an interpretation of how deep neural networks produce their results, and why we can trust them. At the same time, there is a common belief that ontologies (and other symbolic artefacts) do not suffer from the same problems and that current systems provide enough support to understand and reuse already existing artefacts. However, it has been shown that reusing ontologies is not a consolidated practice [5].

We claim that one reason for this could be the lack of support from software tools to make ontologies better understandable. Thus, the goal of this paper is to answer the following open questions: *(1)* What is an explanation in case of ontologies, and why we may be interested in it? *(2)* What is the minimal functionality a system should provide in order to make ontologies understandable?

The remainder of the paper is organized as follows. Section 2 determines relationships between ontologies and explanations and provides context for the rest of the paper. Section 3 describes a pragmatic approach to studying explanations of ontologies. Section 4 substantiates the functions a system should provide in

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order to provide explainability. Finally, Sect. 5 concludes the paper and points to open issues requiring further investigation.

2 Ontology and Explanation

2.1 Ontology as an Explanation

Since when they first appeared as "formal and explicit specification of shared conceptualizations" [9] in the beginning of the 90's, ontologies have gained popularity in a wide range of research fields. These range from knowledge engineering and knowledge representation to database design and information integration, in all those domains where possible interpretations of terms have to be constrained and there is a need for explicit inter-relations of concepts.

Fonseca and Martin [6] argue that ontologies should lead to explanation and understanding of the domain. Also, Cao [4] suggested an *ontological approach to explanation*: "whenever we have something important but difficult to understand, we should focus our attention on finding what the primary entities are in the domain under investigation. Discovering these entities and their intrinsic and structural properties [...] is the real work of science". Garcia and Vivacqua [8] concluded that "ontology explanation can be a valuable tool for semantic validation", where the latter term is defined as "human understanding of and agreement with the ontological representation".

Thus, it is generally accepted that *an ontology may serve as an explanation within the domain of interest.* And, according to this approach, ontology usage should result in an understanding of the domain (see [13,15] and [20, p.4]). However, does this imply that an ontology itself is such a clear, self-explained, and understandable artefact? Unfortunately, recent reports have shown, that despite existing well-accepted methods, "building an ontology is sometimes equated to an art" [8], and, even when ratified by experts, it may lead to unexpected results in trials. This brings us to the idea that *an ontology as an artefact also needs to be explained.*

2.2 Aspects of Ontology Explanation

The history of scientific explanations can be traced far back into antiquity, with numerous philosophical discussions in the second half of the 20th century (see [19]). This subsection is not intended to be an overview of existing theories in the philosophy of science but instead an attempt to find those that are applicable in the case of ontology explanation.

Hempel [12, p.334] formulated that "scientific explanation may be regarded as an answer to a why-question". According to his covering-law model, a scientific explanation takes the form of a syllogism consisting of a law, a statement of facts making up the initial conditions, and a statement of the event which occurred. He suggested two basic types of explanations, deductive-nomological and inductive-statistical, differing in how the conclusions are drawn. However, this approach resembles data provenance techniques or two ways of reasoning, where the ontology plays the role of a 'body of (domain) laws' within the domain of interest, while our goal is to explain the ontology itself.

It is worth noting that explanations differ depending on the traditions within the branch of science. For example, Baron [1] claims that psychology does not offer scientific explanations but rather "follows certain templates (schemata), basic forms with details to be filled in". In contrast to this approach, mathematicians explain their conclusions using formal proofs, e.g., in first-order logic.

Taking this into account, Weber et al. [20] suggest *a pragmatic approach to studying scientific explanation*. Here 'pragmatic' refers to an 'instrumentalist' approach towards constructing explanations, so as to consider a 'toolbox' that would help actors to reach their goals, instead of "describing the 'essence' of explanation or understanding" [20, p.33].

In order to apply this pragmatic approach to studying explanations, the authors suggest committing to three principles [20]:

1. *Make context-dependent normative claims and argue for them.* Here 'normative' refers to looking at how scientists actually explain in real-life scenarious, while 'context-dependent' means that we should work only in a certain discipline and within certain research traditions.
2. *Make context-dependent descriptive claims and argue for them.* The authors claim that when trying to 'describe' the existing practices, there is no need for a large sample of scientists to be interviewed or a large number of scientific writings to be analysed.
3. *Take into account the epistemic interests*[1] when trying to make context-dependent normative or descriptive claims about explanations.

Also, while applying the pragmatic approach, the following general considerations about explanations need to be taken into account. Miller [16] argues that there is a need to distinguish between "explanation" as *(1)* a cognitive process, including abductive reasoning and reduction to filling gaps, *(2)* a product, that can come in different forms[2], and *(3)* a social process of interaction.

The first process is what Lipton [15] refers to as closing the gap between knowledge and understanding. Since "the explained phenomenon is said to be reduced to the explaining phenomenon" [7], and the cognitive process of understanding and reduction happens in the human mind, it follows that the explanation of an ontology is *a user-centred process*[3].

According to Horne et al. [13], "an explanation is a statement that satisfies the request for information". However, as has been noted by Miller [16], this request for information often forms an interaction process. Lipton [15] suggested *a why regress* as one of the features of explanation, because "... explanation

[1] An epistemic interest is a reason scientists have for asking explanation-seeking questions.

[2] We come back to the discussion about forms of explanation later.

[3] Henceforward, by 'user' we mean a domain expert or a developer or simply anyone interested in getting an ontology explanation from the computer system.

can bring us to understand why what is explained is so even though we do not understand why the explanation itself is so".

Finally, *explanations are contrastive* (see [13,15,16]). In other words, people rarely ask "why P" but are more interested in "why P rather than Q". Horne et al. [13] even stated that "a contrast class of similar but non-observed states" should be incorporated within the structure of the explanation together with the explanandum (the observation to be explained) and "a request for information that differentiates the occurrence of the explanandum from the nonoccurrence of its contrast class".

3 A Pragmatic Approach to Ontology Explanation

As has been described before, a pragmatic approach to studying explanations suggests us to consider how scientists explain ontologies in real-life scenarios.

Garcia and Vivacqua [8] claimed that "the explanation played a fundamental role in the identification of problems" with the ontology. The main goal was to make the evaluation process more productive, and to help ontology users and developers to understand and audit the ontology. The authors reported about *visual inspection* as well as *text explanations* generated in a story-like format. They also noticed that using domain cases, i.e., *examples*, during the ontology development is a good way to elicit conflicts between experts' opinions [8].

A quite similar example of a storytelling approach was presented by Braga and Almeida [2], who used natural language narratives with the concepts that appear in the conceptual model for assessing and 'testing' the correctness of those models. That work was an extension of [3], which employed visual simulation for revealing the semantics of the ontology.

Horridge et al. [14] suggested a toolkit for working with *justifications for entailments* in ontologies, presented to the user as *a list of logical axioms*. Justifications are considered as a specific type of explanation, where a minimal sufficient subset of the ontology is selected to hold the entailment [18].

Nevertheless, despite all the efforts suggested in [8] towards ontology explanation, the first version of the developed artefact exhibited some critical problems. Taking into account how knowledge acquisition sessions were organised, we suppose that the explanation-as-a-process (both as a cognitive process as well as a social process) was properly supported. However, in contrast to the approach in [14], the authors were more focused on changing *the form of explanation* (visual and textual), rather than changing the explanation-as-a-product itself.

Overton [17] suggested considering five categories and relations between them (see Fig. 1). According to him, an explanation consists of an *explain-relation*, an *explanan*, i.e., an explaining category, and an *explanandum*, i.e., an explained category. Unlike Hempel, he does not restrict explanans and explanandum to propositions but considers a broader view. He argues that explanations of phenomena at one level could be relative to and refer to another level, so explanations between two levels should refer to all intermediate levels.

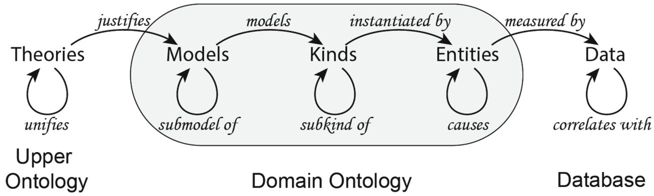

Fig. 1. Overton's five categories with some relations between them.

Following this approach, we can consider upper-level ontologies, such as DOLCE[4], or UFO [11], in the category of 'theories', and domain ontologies or ontology-driven conceptual models based on them at the lower levels. Thus, we can partially explain a domain ontology by *(1)* grounding it on an upper-level one, *(2)* increasing its comprehensibility and semantic transparency by leveraging on foundational techniques for complexity management[5], or *(3)* justifying it by providing data evidence. Aspects (1) and (3) are exemplified in Sect. 4.

The last question is whether an ontology as a way to provide explanation to an ontology is reasonable and valid. Actually, this form of explanations is known as *self-evidencing explanations*: "... explanations where what is explained provides an essential part of our reason for believing that the explanation itself is correct" [15]. So while an upper-level ontology partially explains (grounds) a domain ontology, the domain ontology justifies the upper-level one.

Therefore, when providing an ontology explanation, the following ideas need to be taken into account. First, the ultimate goal of the user is rarely on understanding the ontology per se, but rather on understanding it such that its quality can be assessed, and so that it can be safely reused and integrated with other ontologies. Second, the explanation of a domain ontology should be provided at different levels, by explicitly referencing (grounding it on) a foundational ontology, by increasing its comprehensibility and transparency via complexity management, and also justifying it with entailments or examples from real data. Third, the explanations can be given in different forms (visual, text, logic), but the form of explanation can be considered as a user's preference of presenting an explanation-as-a-product. Finally, the system should be ready for explanation-as-a-process in the sense that a user may ask to explain the explanation.

4 Functionality of an Ontology Explanation System

An Explanation System should provide an opportunity for a potential regress of explanation, i.e., the possibility to explain the explanation. In case of ontology explanation, this interaction may happen between the system and the user, so it is a human-computer interaction process, which is dependent on the user's goal.

[4] http://www.loa.istc.cnr.it/dolce/overview.html.

[5] For examples of complexity management techniques based on foundational ontologies one could refer to [10].

Imagine we have developed a domain ontology that includes the following piece of information: "Spouses can be exclusively married to one another".

– What makes this relation true for a given pair (if true): this would be done by explicitly representing the *truthmaker* of that relation, i.e., the Marriage relator [11]. In other words, e.g., John is married to Mary iff there is a particular Marriage relator binding them. Moreover, the model could explain that 'spouse' is a *role* played by adult individuals of the *kind* Person when bound by a marriage relator.
– What is the semantics of that relation and what does it entail: by representing a relator as a bundle of legal dispositions (e.g., commitments, claims, liabilities, powers, etc.), we would be able to explain exactly what it means to be 'married with', i.e., what it means in terms of its (legal) consequences to be a spouse in that context.
– Improving comprehensibility by abstracting legal dispositions, as well as a marriage relator and the events in its life cycle, into a direct (but further explainable) 'married with' relation with the proper cardinality constraints.
– Exemplify that 'John and Mary are married' in a given timespan as an example from the data.
– Demonstrate that 'John cannot also be married to Clara in a timespan intersecting that one', because the notion of marriage in that model is of a monogamous one (as a negative example or contrastive explanation).

Ideally, these explanations should be provided in different forms. Actually, algorithms for producing such explanations already exist, but techniques for complexity management of ontologies, e.g., modularization and abstraction [10], can be considered as explanation techniques if and only if they take into account the user's goals.

5 Final Considerations

One of the primary functions of explanation is to facilitate learning [16]. Before reusing an already existing domain ontology one needs to understand it, thus, making ontology explanation an important feature of any ontology management system. However, ontology comprehension is a complex process that happens in the human mind, and which needs a proper support from the software side. Unfortunately, when talking about ontology explanation researches are mostly focused on considering different forms, instead of providing connections to different levels. Currently, there are already existing algorithms that can provide support to some of the explanation requirements outlined here, but to the best of our knowledge, there is no tool that would cover all required functionality. Also, it would be interesting to understand whether such a tool will be able to have a positive effect on ontology reuse.

References

1. Baron, J.: Forms of explanation and why they may matter. Cogn. Res. Principles and Implications **3**(1), 1–9 (2018). https://doi.org/10.1186/s41235-018-0143-2
2. Braga, B.F.B., Almeida, J.P.A.: Modeling stories for conceptual model assessment. In: Jeusfeld, M., Karlapalem, K. (eds.) ER 2015. LNCS, vol. 9382, pp. 293–303. Springer, Cham (2015). https://doi.org/10.1007/978-3-319-25747-1_29
3. Braga, B.F.B., Almeida, J.P.A., Guizzardi, G., Benevides, A.B.: Transforming OntoUML into Alloy: towards conceptual model validation using a lightweight formal method. Innovations Syst. Softw. Eng. **6**(1), 55–63 (2010). https://doi.org/10.1007/s11334-009-0120-5
4. Cao, T.Y.: Ontology and scientific explanation. In: Cornwell, J. (ed.) Explanations: Styles of Explanation in Science, pp. 173–196. Oxford University Press (2004)
5. Fernández-López, M., et al.: Why are ontologies not reused across the same domain? J. of Web Semantics **57**, 100492 (2019). https://doi.org/10.1016/j.websem.2018.12.010
6. Fonseca, F., Martin, J.: Learning the differences between ontologies and conceptual schemas through ontology-driven information systems. J. of the Association for Information Systems 8(2), 129–142 (2007). https://doi.org/10.17705/1jais.00114
7. Friedman, M.: Explanation and scientific understanding. The J. of Philosophy **71**(1), 5–19 (1974). https://doi.org/10.2307/2024924
8. Garcia, A.C.B., Vivacqua, A.S.: Grounding knowledge acquisition with ontology explanation:a case study. J. of Web Semantics **57**, 100487 (2019). https://doi.org/10.1016/j.websem.2018.12.005
9. Guarino, N., Oberle, D., Staab, S.: What Is an Ontology? In: Staab, S., Studer, R. (eds.) Handbook on Ontologies. IHIS, pp. 1–17. Springer, Heidelberg (2009). https://doi.org/10.1007/978-3-540-92673-3_0
10. Guizzardi, G., Prince Sales, T., Almeida, J.P.A., Poels, G.: Automated conceptual model clustering: a relator-centric approach. Software and Systems Modeling pp. 1–25 (2021). https://doi.org/10.1007/s10270-021-00919-5
11. Guizzardi, G., et al.: UFO: Unified Foundational Ontology. Appl. Ontol. **17**(1), 167–210 (2022). https://doi.org/10.3233/AO-210256
12. Hempel, C.G.: Aspects of scientific explanation. In: Aspects of scientific explanation and other essays in the philosophy of science, pp. 331–496. Free press Collier-Macmillan, 2nd printed edn. (1966)
13. Horne, Z., Muradoglu, M., Cimpian, A.: Explanation as a cognitive process. Trends Cogn. Sci. **23**(3), 187–199 (2019). https://doi.org/10.1016/j.tics.2018.12.004
14. Horridge, M., Parsia, B., Sattler, U.: Explanation of OWL entailments in Protege 4. In: Proc. of the Poster and Demonstration Session at the 7th Int. Semantic Web Conf. (ISWC). CEUR Workshop Proceedings, vol. 401. CEUR-WS.org (2008), http://ceur-ws.org/Vol-401/iswc2008pd_submission_47.pdf
15. Lipton, P.: What good is an explanation? In: Cornwell, J. (ed.) Explanations: Styles of Explanation in Science, pp. 1–22. Oxford University Press (2004)
16. Miller, T.: Explanation in artificial intelligence: Insights from the social sciences. Artif. Intell. **267**, 1–38 (2019). https://doi.org/10.1016/j.artint.2018.07.007
17. Overton, J.A.: Explanation in Science. Ph.D. thesis, The University of Western Ontario (2012), https://ir.lib.uwo.ca/etd/594
18. Peñaloza, R., Sertkaya, B.: Understanding the complexity of axiom pinpointing in lightweight description logics. Artif. Intell. **250**, 80–104 (2017). https://doi.org/10.1016/j.artint.2017.06.002

19. Salmon, W.C.: Four Decades of Scientific Explanation. University of Pittsburgh Press (1990), http://www.jstor.org/stable/j.ctt5vkdm7
20. Weber, E., Bouwel, J.V., Vreese, L.D.: Scientific Explanation. SpringerBriefs in Philosophy, Springer (2013). https://doi.org/10.1007/978-94-007-6446-0