Verification and Validation of Semantic Annotations

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Abstract. In this paper, we propose a framework to perform verification and validation of semantically annotated data. The annotations, extracted from websites, are verified against the schema.org vocabulary and Domain Specifications to ensure the syntactic correctness and completeness of the annotations. The Domain Specification allows checking of the compliance of annotations against corresponding domain-specific constraints. The validation mechanism will check for errors and inconsistencies in data between the content of analyzed schema.org annotations and the content of the web pages that were annotated.

Keywords: verification · validation · semantic annotation · schema.org.

1 Introduction

The introduction of the Semantic Web [4] changed the way data is published and consumed online fundamentally. For the first time, data in websites becomes not only machine readable, but also machine understand- and interpretable. The semantic description of data is driving the development of a new generation of applications, like intelligent personal assistants and chatbots, and the development of knowledge graphs and artificial intelligence applications fed by semantically annotated data. The use of semantic annotations was accelerated by the introduction of schema.org [11]. Schema.org was launched by the search engines Bing, Google, Yahoo! and Yandex in 2011. It has since become a de-facto standard for annotating data on the web [21]. The schema.org vocabulary, serialized with Microdata, RDFa, or JSON-LD, is used to markup website content. Schema.org is the most widespread vocabulary on the web, and is used by more than a quarter of web pages [12,20].

Even though studies have shown, that the amount of semantically annotated data is growing rapidly, there are still shortcomings when it comes to the quality of said annotations [17]. Also the analysis in [15] underline the inconsistencies and syntactic and semantic errors in semantic annotations. The lack of completeness and correctness of the semantically annotated data makes content unreachable for automated agents, causes an incorrect appearance in knowledge graphs and search results, or makes crawling and reasoning less effective for
building applications on top of semantic data. These errors may be caused by missing guidelines, insufficient expertise and technical or human errors. Data quality is a critical aspect for efficient knowledge representation and processing. Therefore, it is important to define methods and techniques for semantic data verification and validation, and to develop tools which will make this process efficient, tangible and understandable, also for non-technical users.

In this paper, we extend our previous work [27] and present an approach for verification and validation of semantic annotations. The semantify.it validator\footnote{https://semantify.it/validator/} is a tool that allows the verification of schema.org annotations which are collected from web pages or websites. Those annotations are verified against the schema.org vocabulary and Domain Specifications (DS), which were introduced in [27]. A DS is a design pattern for semantic data; an extended subset of types, properties, and ranges from schema.org. The verification against DSs allows for the checking of the compliance of annotations against corresponding domain-specific constraints. The validation approach will extend the functionality of the tool by detecting the consistency errors between semantic annotations and annotated content.

This remainder of this paper is structured as follows: Section \ref{verification} describes verification approach of semantic annotations. Section \ref{validation} describes the validation approach. Section \ref{conclusion} concludes our work and describes future work.

\section{Verification}

In this section we discuss the verification process of semantic annotation according to schema.org and domain specifications. The section is structured as follows: Section \ref{verification-definition} gives the definition of the semantic annotation validation, Section \ref{verification-related-work} describes some related work, Section \ref{verification-approach} discusses our approach, and Section \ref{verification-evaluation} describes the evaluation method.

\subsection{Definition}

The verification process of semantic annotations consists of two parts, namely, (I) the checking of the conformity with the schema.org vocabulary, and (II) the checking of the compliance with an appropriate Domain Specification. While the first verification step ensures that the validated annotation uses properly vocabulary terms defined in schema.org, the second step ensures that the annotation is in compliance with the domain-specific constraints defined in a corresponding Domain Specification.

\subsection{Related Work}

In this section, we refer to the existing approaches and tools for validating structured data. There are tools for validating schema.org annotations, such as the
Google Structured Data Testing tool\(^2\), the Google Email Markup Tester\(^3\), the Yandex Structured Data Validator\(^4\), and the Bing Markup Validator\(^5\). They validate annotations of web pages that use Microdata, Microformats, RDFa, or JSON-LD as markup formats. But they do not provide the check of completeness and correctness, such as allowing to have empty range values, redundancy of information, or semantic consistency issues (e.g. the end day of the event is earlier as the start day).

In \([10]\) SPARQL and SPIN are used for constraint formulation and validation. The use of SPARQL and SPIN query templates sets allows identifying data quality problem types.

The Shape Expression (ShEx) definition language \([26]\) allows RDF validation through the declaration of constraints. In \([5]\) authors define a schema formalism for describing the topology of an RDF graph that uses regular bag expressions (RBEs) to define constraints.

In \([6]\) authors described semantics and validation of Shapes Schemas for RDF, and presented two algorithms for the validation of an RDF graph against a shapes schema.

The Shapes Constraint Language\(^6\) (SHACL) is a language for validating RDF graphs against a set of conditions. SHACL allows us to define constraints targeting specific nodes in a data graph based on their type, identifier, or a SPARQL query.

### 2.3 Our approach

To enable the verification of semantic annotations, according to the schema.org vocabulary and to Domain Specifications, we propose a tool that executes a corresponding verification algorithm. This tool takes as inputs the schema.org annotation to verify and a DS that corresponds to the domain of the annotation. The outcome of this verification process is provided in a formalized, structured format, in order to enable the further machine processing of the verification result.

The verification algorithm consists of two parts, the first checks the general compliance of the input annotation with the schema.org vocabulary, while the latter checks the domain-specific compliance of the input annotation with the given Domain Specification. The following objectives are given for the conformity verification of the input annotation according to the schema.org vocabulary:

1. The correct usage of serialization formats allowed by schema.org, hence RDFa, Microdata, or JSON-LD.
2. The correct usage of vocabulary terms from schema.org in the annotations, including types, properties, enumerations, and literals (data types).

\(^2\) [https://search.google.com/structured-data/testing-tool/](https://search.google.com/structured-data/testing-tool/)

\(^3\) [https://www.google.com/webmasters/markup-tester/](https://www.google.com/webmasters/markup-tester/)

\(^4\) [https://webmaster.yandex.com/tools/microtest/](https://webmaster.yandex.com/tools/microtest/)

\(^5\) [https://www.bing.com/toolbox/markup-validator](https://www.bing.com/toolbox/markup-validator)

\(^6\) [https://www.w3.org/TR/shacl-ucr/](https://www.w3.org/TR/shacl-ucr/)
3. The correct usage of vocabulary relationships from schema.org in the annotations, hence, the compliance with domain and range definitions for properties.

The domain-specific verification of the input annotation is enabled through the use of Domain Specifications\(^7\), e.g. DS for annotation of tourism domain and geodata \[^23,24\]. Domain Specifications have a standardized data model. This data model consists of the possible specification nodes with corresponding attributes that can be used to create a Domain Specification document (e.g. specification nodes for types, properties, ranges, etc.). A Domain Specification document is constructed by the recursive selection of these grammar nodes, which, as a result, form a specific syntax (structure) that has to be satisfied by the verified annotations \[^16\]. Keywords in these specification nodes allow the definition of additional constraints (e.g. "multipleValuesAllowed" or "isOptional" for property nodes). In our approach, the verification algorithm has to ensure that the input annotation is in compliance with the domain-specific constraints defined by the input Domain Specification. In order to achieve this, the verification tool has to be able to understand the Domain Specification data model, the possible constraint definitions, and to check if verified annotations are in compliance with them.

2.4 Evaluation

We implement our approach in the semantify.it Validator\(^8\). The tool provides a verification report with detailed information about detected errors according to the schema.org (see Fig.\(^1\)), Domain Specifications (see Fig.\(^2\)), and in the list of web pages of the same domain (see Fig.\(^3\)).

| Nr. | Type         | Markup | View           | SDO-Valid                  |
|-----|--------------|--------|----------------|----------------------------|
| 1   | MusicEvent   | jsonld | ![valid](checkmark) | Valid with Warnings ![error](error) |
| 2   | WebSite      | jsonld | ![valid](checkmark) | Valid with Warnings ![error](error) |
| 3   | BreadcrumbList | jsonld | ![valid](checkmark) | Not Valid ![error](error) |
| 4   | BreadcrumbList | microdata | ![valid](checkmark) | Valid ![checkmark](checkmark) |
| 5   | PostalAddress | microdata | ![valid](checkmark) | Valid ![checkmark](checkmark) |

Fig. 1. Schema.org Verification

\(^7\) List of available Domain Specifications: [https://semantify.it/domainSpecifications/public](https://semantify.it/domainSpecifications/public)

\(^8\) [https://semantify.it/validator/](https://semantify.it/validator/)
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The report includes error codes (ID of the error type), error titles, error severity, error paths (where within the annotation the error occurred), and textual descriptions of the errors. The validator implementation itself can be evaluated in terms of correct functionality through unit tests. This can be done by comparing the structured representation of a validation report, namely the JSON file produced by the validator with the validation report specified in the test case for a specific annotation-domain specification pair.

3 Validation

In this section we discuss the validation process of semantic annotations and proposed approach. The section is structured as follows: Section 3.1 gives the definition of the semantic annotation validation, Section 3.2 describes some related work, Section 3.3 discusses our approach, and Section 3.4 describes the evaluation method.

3.1 Definition

The validation of semantic annotations is the process of checking whether a semantic annotation corresponds to the content of the web page that it represents,
and is consistent with it. Semantic annotation should include the actual information of the web page, correct links, images and literal values without overlapping and redundancy.

3.2 Related Work

The incorrect representation of the structured data can make data unreachable for automated engines, cause an incorrect appearance in the search results, or make crawling and reasoning less effective for building applications on top of semantic data. The errors may be caused by not following recommended guidelines, e.g. structured data guidelines, insufficient expertise, technical or human errors (some of the issues can be detected by Google search console), and/or annotations are not in accordance with the content of web pages so-called "spammy structured markup". The checking algorithms may penalize the publisher of structured data if their annotations include content that is invisible to users, and/or markup irrelevant or misleading content. These penalties may have negative effects on the usage of the annotations (e.g. bad position of the website in search results) or even lead to a non-integration of the structured data (e.g. no generation of rich snippets). There is no direct literature related to the methods of detecting inconsistency between semantic annotations and content of web pages, but the problem of the content conformity restriction also mentioned in.

3.3 Our approach

Since semantic annotations are created and published by different data providers or agencies in varying quantity and quality and using different assumptions, the validity of data should be prioritized to increase the quality of structured data. To solve the problem of detecting errors caused by inconsistencies in data between analyzed schema.org annotations and the content of the web pages where the annotations were found, we propose a validation framework. The framework will consist of the following objectives:

1. Detect the main inconsistencies between the content of schema.org annotations and web pages.
2. Develop an algorithm for the consistency check between a web page and semantic annotations. The information from web pages can be extracted from the source of a web page by tracking the appropriate HTML tags, keywords, lists, images, URLs, paragraph tags and the associated full text. Some natural language processing and machine learning techniques can be applied to extract important information from the textual description, e.g. price, email, telephone number and etc. There exist some approaches, such as
as named entity recognition [22] to locate and categorize important nouns and proper nouns in a text, web information extraction systems [8], text mining techniques [2].

3. Define metrics to evaluate the consistencies of the semantic annotations according to the annotated content. There are different metrics which can be applied to the validation process. They were formulated in the literature review of quality methodologies [3,29], models and metrics for big data and linked open data quality assessment [7,19,25], ontology foundation and evaluation [28,14], ontology design patterns [13], knowledge graphs [9], and semantic description of web services [30]. In this step, we will analyze existing data quality metrics that can be applied on the structured data and define metrics that can be useful to evaluate the consistency between a web page content and semantic annotation.

4. Provide a validation tool to check the consistencies and perform the overall score for the web page.

3.4 Evaluation

To ensure the validity of the report results, we will organize a user study of semantic annotations and web pages, which were annotated, to prove the performance of our framework. The questionnaire will be structured in a way to get quantitative and qualitative feedback about the consistencies between a web page and annotation content (see Fig. 3) according to the results provided by the framework.

4 Conclusion and Future Work

Semantic annotations may be used for improved search results by search engines or as building blocks of knowledge graphs. Therefore, the quality issues in
terms of structure and consistency can have impact on where the annotations are utilized and lead, for instance, false representation in the search results or low quality knowledge graphs. In this paper, we described our ongoing work for an approach to verify and validate semantic annotations and the tool that is evolving as the implementation of this approach. The current state of the approach can verify annotations in terms of structure and syntax based on Domain Specifications. In our ongoing we are extending our approach and the tool with validation, which means to check whether the annotation is consistent with the content that it describes. This is especially important for search engine results, since inconsistency between content and annotation may be perceived as spam and harm the search result rankings.

For the future work, we will define Domain Specifications with SHACL in order to comply with the recent W3C Recommendation for RDF validation. We will develop an abstract syntax and formal semantics for DSs and map it to SHACL notions, for instance by aligning the concept of domain specification with SHACL node shape.

References

1. Akbar, Z., Kärle, E., Panasiuk, O., Şimşek, U., Toma, I., Fensel, D.: Complete semantics to empower touristic service providers. In: OTM Confederated International Conferences. On the Move to Meaningful Internet Systems”. pp. 353–370. Springer (2017)
2. Allahyari, M., Pouriyeh, S., Assefi, M., Safaei, S., Trippe, E.D., Gutierrez, J.B., Kochut, K.: A brief survey of text mining: Classification, clustering and extraction techniques. arXiv preprint arXiv:1707.02919 (2017)
3. Batini, C., Cappiello, C., Francalanci, C., Maurino, A.: Methodologies for data quality assessment and improvement. ACM computing surveys (CSUR) 41(3), 16 (2009)
4. Berners-Lee, T., Hendler, J., Lassila, O.: The semantic web. Scientific american 284(5), 34–43 (2001)
5. Boneva, I., Gayo, J.E.L., Hym, S., Prudhommeaux, E.G., Solbrig, H.R., Staworko, S.: Validating rdf with shape expressions. CoRR, abs/1404.1270 (2014)
6. Boneva, I., Gayo, J.E.L., Prudhommeaux, E.G.: Semantics and validation of shapes schemas for rdf. In: International Semantic Web Conference. pp. 104–120. Springer (2017)
7. Cai, L., Zhu, Y.: The challenges of data quality and data quality assessment in the big data era. Data Science Journal 14 (2015)
8. Chang, C.H., Kayed, M., Girgis, M.R., Shaalan, K.F.: A survey of web information extraction systems. IEEE transactions on knowledge and data engineering 18(10), 1411–1428 (2006)
9. Färber, M., Bartscherer, F., Menne, C., Rettinger, A.: Linked data quality of dbpedia, freebase, opencyc, wikidata, and yago. Semantic Web 9(1), 77–129 (2018)
10. Färber, C., Hepp, M.: Using sparql and spin for data quality management on the semantic web. In: International Conference on Business Information Systems. pp. 35–46. Springer (2010)
11. Guha, R.: Introducing schema. org: Search engines come together for a richer web. Google Official Blog (2011)
12. Guha, R.V., Brickley, D., Macbeth, S.: Schema.org: Evolution of structured data on the web. Communications of the ACM 59(2), 44–51 (2016)
13. Hammar, K.: Content Ontology Design Patterns: Qualities, Methods, and Tools, vol. 1879. Linköping University Electronic Press (2017)
14. Hlomani, H., Stacey, D.: Approaches, methods, metrics, measures, and subjectivity in ontology evaluation: A survey. Semantic Web Journal 1(5), 1–11 (2014)
15. Hollenstein, N., Schneider, N., Webber, B.L.: Inconsistency detection in semantic annotation. In: LREC (2016)
16. Holzknecht, O.: Enabling Domain-Specific Validation of Schema.org Annotations. Master’s thesis, Innsbruck University, Innrain 52, 6020 Innsbruck, Austria (Nov 2018)
17. Kärle, E., Fensel, A., Toma, I., Fensel, D.: Why are there more hotels in tyrol than in austria? analyzing schema.org usage in the hotel domain. In: Information and Communication Technologies in Tourism 2016, pp. 99–112. Springer (2016)
18. Kärle, E., Fensel, D.: Heuristics for publishing dynamic content as structured data with schema.org. arXiv preprint arXiv:1808.06012 (2018)
19. Knight, S.A., Burn, J.: Developing a framework for assessing information quality on the world wide web. Informing Science 8 (2005)
20. Meusel, R., Petrovski, P., Bizer, C.: The webdatacommons microdata, rdfa and microformat dataset series. In: International Semantic Web Conference. pp. 277–292. Springer (2014)
21. Mika, P.: On schema.org and why it matters for the web. IEEE Internet Computing 19(4), 52–55 (2015)
22. Mohit, B.: Named entity recognition. In: Natural language processing of semitic languages, pp. 221–245. Springer (2014)
23. Panasiuk, O., Kärle, E., Şimşek, U., Fensel, D.: Defining tourism domains for semantic annotation of web content. e-Review of Tourism Research 9 (Jan 2018), research notes from the ENTER 2018 Conference on ICT in Tourism
24. Panasiuk, O., Akbar, Z., Gerrier, T., Fensel, D.: Representing geodata for tourism with schema.org. In: Proceedings of the 4th International Conference on Geographical Information Systems Theory, Applications and Management - Volume 1: GIS-TAM,. pp. 239–246. INSTICC, SciTePress (2018)
25. Pipino, L.L., Lee, Y.W., Wang, R.Y.: Data quality assessment. Communications of the ACM 45(4), 211–218 (2002)
26. Prud’hommeaux, E., Labra Gayo, J.E., Solbrig, H.: Shape expressions: an rdf validation and transformation language. In: Proceedings of the 10th International Conference on Semantic Systems. pp. 32–40. ACM (2014)
27. Şimşek, U., Kärle, E., Holzknecht, O., Fensel, D.: Domain specific semantic validation of schema.org annotations. In: International Andrei Ershov Memorial Conference on Perspectives of System Informatics. pp. 417–429. Springer (2017)
28. Wand, Y., Wang, R.Y.: Anchoring data quality dimensions in ontological foundations. Communications of the ACM 39(11), 86–95 (1996)
29. Zaveri, A., Rula, A., Maurino, A., Pietrobon, R., Lehmann, J., Auer, S.: Quality assessment methodologies for linked open data: A systematic literature review and conceptual framework. Journal of Semantic Web pp. 1–33 (2012)
30. Zhu, H., Liu, D., Bayley, I., Aldea, A., Yang, Y., Chen, Y.: Quality model and metrics of ontology for semantic descriptions of web services. Tsinghua Science and Technology 22(3), 254–272 (2017)