Semantic lenses
to bring digital and semantic publishing together

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Abstract. Modern scholarly publishers are making steps towards *semantic publishing*, i.e. the use of Web and Semantic Web technologies to represent formally the meaning of a published document by specifying information about it as metadata and to publish them as Open Linked Data. In this paper we introduced a way to use a particular semantic publishing model, called *semantic lenses*, to semantically enhance a published journal article. In addition, we present the main features of *TAL*, a prototypical application that enables the navigation and understanding of a scholarly document through these semantic lenses, and we describe the outcomes of a user testing session that demonstrates the efficacy of TAL when addressing tasks requiring deeper understanding and fact-finding on the content of the document.

Keywords: Web interface, document semantics, semantic publishing

1   Introduction

Simultaneously to the evolution of the Web by means of Semantic Web technologies, modern publishers (and in particular scholarly publishers) are making steps towards the enhancing of digital publications with semantics, an approach that is known as *semantic publishing* [22]. In brief, semantic publishing is the use of Web and Semantic Web technologies to represent formally the meaning of a published document by specifying a large quantity of information about it as metadata and to publish them as Open Linked Data. As a confirmation of this trend, recently the Nature Publishing Group (publisher of *Nature*), the American Association for the Advancement of Science (publisher of *Science*) and the Oxford University Press have all announced initiatives to open their articles' reference lists and to publish them as Open Linked Data[3,4,5].

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[3] Nature.com Linked Data: http://data.nature.com.
[4] http://opencitations.wordpress.com/2012/06/16/science-joins-nature-in-opening-reference-citations
[5] http://opencitations.wordpress.com/2012/06/22/oxford-university-press-to-support-open-citations

However, the enhancement of a traditional scientific paper with semantic annotations is not a straightforward operation, since it involves much more than simply making semantically precise statements about named entities within the text. In [17], we have shown how several relevant points of view exist beyond the bare words of a scientific paper – such as the context of the publication, its structural components, its rhetorical structures (e.g. Introduction, Results, Discussion), or the network of citations that connects the publication to its wider context of scholarly works. These points of view are usually combined together to create an effective unit of scholarly communication so well integrated into the paper as a whole and into the rhetorical flow of the natural language of the text, so as to be scarcely discernible as separate entities by the reader. We also propose the separation of these aspects into eight different sets of machine-readable semantic assertions (called *semantic lenses*), where each set describes one of (from the most contextual to the most document-specific): research context, authors' contributions and roles, publication context, document structure, rhetoric organisation of discourse, citation network, argumentative characterisation of text, and textual semantics.

How can the theory of semantic lenses be used to extend effectively semantic publishing capabilities of publishers? In order to provide an answer to this question, in this paper we introduce a prototypical HTML interface to scholarly papers called *TAL* (*Through A Lens*), which enables the navigation of a text document on which semantic lenses have been applied to make explicit all the corresponding information. This HTML interface is meant to be a proof of concept of the semantic lenses in a real-case scenario. We performed a user testing session that demonstrates the efficacy of TAL when addressing tasks requiring deeper understanding and fact-finding on the content of the document.

The rest of the paper is organised as follows. In Section 2 we introduce some significant works related to semantic publishing experiences and models. In Section 3 we show an application of semantic lenses onto a particular scholarly article. In Section 4 we introduce TAL describing its main features, while in Section 5 we discuss the outcomes of a user testing session we performed to assess the usability and effectiveness of TAL. Finally (Section 6) we conclude the paper sketching out some future works.

2   Related works

Much current literature concerns both the proofs of concepts for semantic publishing applications and the models for the description of digital publishing from different perspective. Because of this richness, here we present just some of the most important and significant works on these topics.

In [22], Shotton *et al.* describe their experience in enriching and providing appropriate Web interfaces for scholarly papers enhanced with provenance informations, scientific data, bibliographic references, interactive maps and tables, with the intention to highlights the advantages of semantic publishing to a broader audience. Along the same lines, in their work [19] Pettifer *et al.* introduce pros

and cons of the various formats for the publication of scholarly articles and propose an application for the semantic enhancement of PDF documents according to established ontologies.

A number of vocabularies for the description of research projects and related entities have been developed, e.g. the *VIVO Ontology*[6] – developed for describing the social networks of academics, their research and teaching activities, their expertise, and their relationships to information resources –, the *Description Of A Project*[7] – an ontology with multi-lingual definitions that contains terms specific for software development projects – and the *Research Object* suite of ontologies [1] – for linking together scientific workflows, the provenance of their executions, interconnections between workflows and related resources (datasets, publications, etc.), and social aspects related to such scientific experiments.

One of the most widely used ontology for describing bibliographic entities and their aggregations is BIBO, the *Bibliographic Ontology* [3]. FRBR, *Functional Requirements for Bibliographic Records* [10], is yet another more structured model for describing documents and their evolution in time. One of the most important aspects of FRBR is the fact that it is not tied to a particular metadata schema or implementation.

Several works have been proposed in the past to model the rhetoric and argumentation of papers. For instance, the SALT application [9] permits someone such as the author "to enrich the document with formal descriptions of claims, supports and rhetorical relation as part of their writing process". There are other works, based on [23], that offer an application of Toulmin's model within specific scholarly domains, for instance the legal and legislative domain [11]. A good review of all the others Semantic Web models for the description of arguments can be found in [21].

3   The Semantic Lenses

In [17], we claimed that the semantics of a document is definable from different perspectives, where each perspective is represented as a *semantic lens* that is *applied* to a document to reveal a particular semantic facet. In this section we briefly summarise our theory. A full example of the lenses applied to a well-known paper *Ontologies are us: A unified model of social networks and semantics* [14] is available at `http://www.essepuntato.it/lisc2014/lens-example`.

Lenses are formalised in the LAO ontology[8]. In addition, since the application of the semantic lenses to a document is an *authorial activity*, i.e. the action of a person (the original author as well as anyone else) taking responsibility for a semantic interpretation of the document, we also record the provenance of the semantic statements according to the *Provenance Ontology* (*PROV-O*) [12].

Figure 1 summarises the overall conceptual framework. The lenses are organised in two groups: *context*-related, which describe the elements contributing to

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[6] VIVO Ontology: http://vivoweb.org/ontology/core

[7] DOAP: http://usefulinc.com/ns/doap

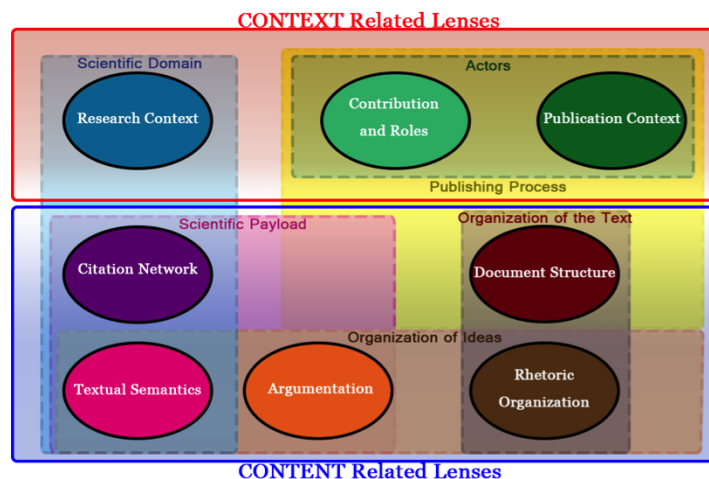[8] Lens Application Ontology (LAO): http://www.essepuntato.it/2011/03/lens.

Fig. 1. The layout of Semantic Lenses in relation to the facets of a scientific document.

the creation and development of a paper, and *content*-related, which describe the content itself of the paper from different angles.

3.1 Describing the context

Writing a scientific paper is usually the final stage of an often complex collaborative and multi-domain activity of undertaking the research investigation from which the paper arises. The organizations involved, the people affiliated to these organizations and their roles and contributions, the grants provided by funding agencies, the research projects funded by such grants, the social context in which a scientific paper is written, the venue within which a paper appears: all these provide the research *context* that leads, directly or indirectly, to the genesis of the paper, and awareness of these may have a strong impact on the credibility and authoritativeness of its scientific content.

Three lenses are designed to cover these aspects:

- *Research context*: the background from which the paper emerged (the research described, the institutions involved, the sources of funding, etc.). To describe such *contextual environment* we use *FRAPO*, the *Funding, Research Administration and Projects Ontology*[9].
- *Contributions and roles*: the individuals claiming authorship on the paper and what specific contributions each made. We use *SCoRO* (the *Scholarly Contributions and Roles Ontology*[10]) and its imported ontology *PRO* (the *Publishing Roles Ontology*[11]) [18] to describe these aspects.

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[9] FRAPO: http://purl.org/cerif/frapo
[10] SCoRO: http://purl.org/spar/scoro
[11] PRO: http://purl.org/spar/pro

– *Publication context*: any information about the event (e.g., a conference) and publication venue of the paper (such as the proceedings or the journal), as well as connections to the other papers sharing the same event or venue. This part is described by using FaBiO, the *FRBR-aligned Bibliographic Ontology*[12] [16] and BiRO, the *Bibliographic Reference Ontology*[13][5].

Note that all the ontologies used or suggested in this paper to describe "lenses" statements have been chosen as an appropriate and convincing example of an ontology that fulfils the requirements for the lens, since they allow us to fully describe all the document aspects we are interested in. However, their use is not mandatory, so as to leave people to use other models (such as those described in Section 2) instead of them.

3.2 Describing the content

The semantics of *the content* of a document, i.e. such a semantics that is implicitly defined in and inferable from the text, can be described from different points of view. For example, the semantical *structure* of the text – i.e. the organization of the document as structured containers, blocks of text, inline elements – is often expressed by means of markup languages such as XML and LaTeX, that have constructs for describing content hierarchically.

In a Semantic Web context, we would rather use an ontology that describes the markup structures in OWL. For this reason, we use *EARMARK* [8], an ontology[14] of a markup metalanguage, to describe the structure of the document as a set of OWL assertions to associate formal and explicit semantics [15]. Through the *Pattern Ontology* (*PO*)[15] [6] in combination with EARMARK we can associate a particular structural semantics to markup elements, such an element *h1 expressing* the concept of being a block of text, or the *div* element containing it being a container. This is covered by the *document structure* lens.

Close to that, we place the identification and organization of the *rhetorical components* of the text, such as a section being an *Introduction*, some paragraphs describing the *Methods* of the research, or the presented *Results* or the paper's *Conclusion*), in order to label all the meaningful aspects of the scientific discourse. Such rhetoric characterization of markup structures can be specified through *DoCO*, the *Document Components Ontology*[16], and *DEO*, the *Discourse Elements Ontology*[17].

In addition, strictly correlated with the rhetorical aspects of a document, we can detail the organization of the claims and the arguments of the paper (providing evidences to a claim). The argumentative organisation of discourse is

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[12] FaBiO: http://purl.org/spar/fabio

[13] BiRO: http://purl.org/spar/biro

[14] EARMARK: http://www.essepuntato.it/2008/12/earmark

[15] PO: http://www.essepuntato.it/2008/12/pattern

[16] DoCO: http://purl.org/spar/doco

[17] DEO: http://purl.org/spar/deo

described using *AMO*, the *Argument Model Ontology*[18], that implements Toulmin's model of argumentation [23][19] in OWL.

The *textual semantics*, i.e. the very message contained in a piece of text, is the final step in the definition of the semantics of a piece of text. For instance, the formal description of a claim needs to be expressed in such a way as to represent as faithfully as possible the meaning of the claim itself. Since each document expresses content in domains that are specific of the topic of the paper, we cannot provide an encompassing ontology to express claims. In some cases, the claim of an argument can be encoded through using a simple model, e.g. DBPedia.

Finally, a document takes also part to a *citation network* with its cited documents, in particular taking into account the *reasons* for particular citations – e.g. to express qualification of or disagreement with the ideas presented in the cited paper – which may effect the evaluation of a citation network itself. Using CiTO, the *Citation Typing Ontology*[20] [16], we provide descriptions of the nature of the citations.

4   Application of the theory

In this section we provide an answer to the question we introduced in Section 1 – how can the theory of semantic lenses be used to extend effectively semantic publishing capabilities of publishers?

We look at this issue from two orthogonal points of view: (i) identifying the actors involved in the process and (ii) presenting a tool to help readers to focus on distinct aspects of the same document so as to benefit from 'lenses-based' semantic annotations.

4.1   Authoring Semantic Lenses

The application of any particular lens to a document is an authorial operation in the sense that is an act involving individuals acting as agents, responsible for the choice of determined semantic interpretations on a document or its content. Although it seems to be necessary to have authors involved in the application of semantic lenses, thus tracking the provenance of semantic assertions of an enriched document, it may be more difficult and even unclear to understand the possible relationship between the authorship of semantic lenses and the actors involved in that authorship. Semantic Publishing involves different actors of

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[18] AMO: http://www.essepuntato.it/2011/02/argumentmodel

[19] Toulmin proposed that arguments are composed of statements having specific argumentative roles: the *claim* (a fact that must be asserted), the *evidence* (a foundation for the claim), the *warrant* (a statement bridging from the evidence to the claim), the *backing* (credentials that certifies the warrant), the *qualifier* (words or phrases expressing the degree of certainty of the claim) and the *rebuttal* (restrictions that may be applied to the claim).

[20] CiTO: http://purl.org/spar/cito

the publication chain [22] – such as authors, reviewers, editors and publishers – who may be responsible for the application of particular kinds of metadata rather than others. Within the semantic lenses domain, it is quite important to identify how all these actors are involved in the application of semantic lenses. Of course, there is no clear-cut answer to this question, but based on our own experience in field-testing the application of lenses, we find reasonable to suggest some guidelines, beginning by considering how much the original authors of the document might be involved in the generation of semantic lenses. In Table 1 we summarise our own findings and recommendations about the involvement of the authors or other possible actors that might intervene on each semantic lens.

Table 1. Summary of suggested involvement in the authoring of lenses.

Semantic lens	Author involvement	Other actors usually involved
Semantics	Highly recommended	Publisher: can specify additional semantics to text (e.g., the abstract). Proof reader: detects errors prior to final publication and can propose appropriate changes. Reader: can provide a semantic interpretation of author's text such as in form of nanopublication.
Argumentation	Highly recommended	Reviewer: can suggest different way of presenting and defending a claim.
Citation	Recommended	Publisher: can expand the citation network of the document according to implicit and/or inferable relations, e.g., links to related papers and so on. Reader: can link the article in unpredictable way according to his/her own interests, also with auxiliary application such as CiteULike Reviewer: can propose additional citation links between the document in consideration and related materials according to particular reasons
Rhetoric	Recommended	Editor: can provide semantics of the particular rhetoric organisation of sections so as to conform the document in consideration to the proposed organisation of a particular journal. Reader: can enhance particular blocks of text so as to make explicit the perceived rhetoric of such a text, e.g. for future searches.
Structure	Limited	Publisher: can suggest and/or apply a different structural organisation of the text according to publishing formats and needs.
Publication context	Not required	Editor and publisher: provide contextual information about the actual venue where the document was published and how it appears within bibliographic reference lists of other papers.
Contributions and roles	Recommended	Publisher: can complete the information provided by authors about their contributions and roles within the document in consideration.
Research context	Highly recommended	Funding agency and institution: can provide additional metadata to describe their involvement related to the document and, thus, to increase their visibility within the Web of Data.

Even if we have broadly identified author's involvement and other actors in semantic lenses applications, the time when one can apply these lenses can vary. On the one hand, the timeframe for the application of the context-specific lenses relates to several aspects that may be gathered only after the document publication (e.g., the publication venue, the DOI, etc.). On the other hand,

according to the other content-specific lenses, there is the possibility to apply them within the same timeframe of the document creation, since the author's involvement would be more straightforward. As a result the information would arguably be far more accurate than a post-hoc application.

However, the above ideal approach does not address some fundamental technical issues. First, it supposes that authors already know how to apply semantic lenses, or could become quickly familiar with semantic lenses, their definitions, and concepts and meanings encoded by the ontologies used. In addition, the application of semantic lenses requires a good amount of technical knowledge, which is an unreasonable expectation for non-experts. In the next section we propose a solution for helping users understanding semantic lenses.

4.2 Through A Lens

The knowledge of the languages used to represent lens-related semantic data is crucial to understand and use semantic lenses appropriately. This knowledge seems to be the most significant obstacle to a wide adoption of semantic lenses, since several actors (e.g. publishers, readers, authors) may not be experts of such semantic technologies. A common solution is to hide the intrinsic complexities of such technologies behind an interface that allows anyone (even the non-expert) to use a tool like semantic lenses in an easy way. To this end, we developed a prototypical HTML interface to scholarly papers called *TAL* (*Through A Lens*), which enables the navigation of a text document on which semantic lenses have been applied to make explicit all the corresponding information. As input, TAL takes an EARMARK representation [8] of a document – we use an HTML version of [14] in the online-available prototype[21] – properly enriched with lens-related semantic assertions as shown in Section 3. The production of annotated documents is not simple. EARMARK includes a Java API on top of which we are developing sophisticated editors. At this stage, we used that API to annotate the sample document. Further developments on the authoring of semantic-lenses-enabled documents are still needed. TAL generates an HTML page with the article and some tools enabling a quick and smart navigation.

Argumentation index. This index is generated from semantic data related to the *argumentation* lens. It lists all the argumentations of the document, making possible to click on each claim within this index to scroll the document down to where the sentence of the claim is written and to show up the related argumentative components (*evidences*, *warrants*, *backings*, *qualifiers* and *rebuttals*). Figure 2.A shows a TAL screenshot with this summary. Claim seven is expanded, others are left unexpanded. Each type of component of a claim (e.g. Evidence, Warrant, Backing, etc.) is explicitly labeled, and coloured in a way to be immediately distinguishable from other types.

Rhetoric Denotation. Labels are placed at the beginning of each paragraph to mean its rhetoric function according to data related to the *rhetoric* lens. Figure 2.B contains the rhetoric denotation of a paragraph.

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[21] http://www.essepuntato.it/lisc2014/LensedMika.html

Fig. 2. Three TAL screenshots showing: (A) the argumentation index, (B) a rhetoric denotation of a paragraph, and (C) the citation index with the tooltip box.

Citation index. This index is the counterpart of the argumentation index, but realised over the citation lens. The purpose is to give an interactive table of content for the whole set of citations made by the document, and to offer a level of readability and interactivity similar to the one seen in the argumentation index, by explicitly showing all the citations within the text, grouped by their related CiTO properties and ordered by frequency in the document, together with pointers to their occurrences within the text. An example is shown in Figure 2.C. The position and the way to open the citation index is the same of the argumentation one. Once it expands, the summary reveals a first list of CiTO properties. This list is ordered by frequency of use within the document. Clicking on a property, a nested sub-list is unfolded with the references to all citation items exhibiting that property. To each item is associated a summary of the bibliographic reference information originally contained within the text, together with pointers to both the complete bibliographic reference, as well as anchor links to each occurrence of the citation within the document.

Tooltip box. A yellow box, shown in Figure 2.C, is placed on the right side of the document content. It will be used to show additional information about in-line references (such as the factual or rhetoric reason of citations) and claims (such as the rhetoric denotation of paragraphs containing them) when hovering them with the mouse pointer. All the information visualised in the box

are generated starting from semantic data related to the lenses *argumentation*, *citation* and *rhetoric*.

5   Experiment and evaluation

At this stage of the development of the TAL prototype, we undertook user testing on it, not solely to gather data about its usability and effectiveness, but mostly to probe if the road we had undertaken in order to make available our set of lens browsing features might be potentially promising. We asked 9 subjects with different backgrounds (Ph. D. students and people working in publishing houses) to perform three unsupervised tasks (max. 5 minutes per task), involving navigation of Mika's paper [14] through TAL. There were no "administrators" observing the subjects while they were undertaking these tasks. All the subjects were volunteers who responded to personal e-mails. When prototype development will be over, we plan to execute further user tests, including comparative ones, and with a larger user base.

The tasks given to the subjects are shown in Table 2. This set of tasks was designed to exploring the TAL capabilities in enabling an intuitive and useful navigation of papers. The test session was structured as follows. Firstly, as a warm-up task, we asked subjects to use TAL to find the paragraph containing the second claim and to write down all the citations in that paragraph, explaining also the reason for the citation (max. 5 minutes). Then, as the real test, we asked subjects to complete the three tasks listed in Table 2 using TAL (max. 5 minutes per task). Finally, we asked subjects to fill in two short questionnaires, one multiple choice and the other textual, to report their experience of using TAL to complete these tasks (max. 10 minutes). All the questionaries and all the outcomes of the experiments are available online[22].

Table 2. The three tasks subjects performed in the user testing session.

Task 1	Write down all the reasons why the document cites the reference [8]
Task 2	Write down the evidences of the claim "It is important to note that in terms of knowledge representation, the set of these keywords cannot even be considered as vocabularies, the simplest possible form of an ontology on the continuous scale of Smith and Welty [5]"
Task 3	Write down the (first words of the) paragraphs containing statements of the problems discussed in the paper

Out of 27 tasks in total (3 tasks given to each of 9 subjects), 20 were completed successfully (i.e., the right answers were given), while 7 had incorrect or incomplete answers, giving an overall success rate of 74%. The 20 successes were distributed as follows: 5 in Task1, 9 in Task2 and 6 in Task3.

The usability score for TAL was computed using the *System Usability Scale* (*SUS*) [2], a well-known questionnaire used for the perception of the usability of a

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system. In addition to the main SUS scale, we also were interested in examining the sub-scales of pure *Usability* and pure *Learnability* of the system, as proposed recently by Lewis and Sauro [13]. As shown in Table 3, the mean SUS score for TAL was 70 (in a 0 to 100 range), surpassing the target score of 68 to demonstrate a good level of usability [20]. The mean values for the SUS sub-scales Usability and Learnability were 69.44 and 72.22 respectively.

Table 3. SUS values and related sub-measures.

Measure	Mean	Max. value	Min. value	S. deviation
SUS value	70	95	50	13.58
Usability	69.44	93.5	53.13	12.18
Learnability	72.22	100	37.5	24.83

6   Conclusions

Modern publishers are now approaching digital publishing from a semantic perspective, making steps towards *semantic publishing*. In this paper we introduce a way to use *semantic lenses* [17] to semantically enhance a published journal article. In addition, we also introduced *TAL*, a prototypical application we developed as proof of concept of the use of semantic lenses in a real-case scenario, that enables the navigation and understanding of a scholarly document through these semantic lenses. Although TAL is still a prototype rather than a complete application, the outcomes reported from the user testing session were positive and very encouraging. In the future we plan to extend TAL so as to handle additional ways of navigation according to all the eight lenses introduced, as well as to produce semantic assertions according to each lens through automatic or semi-automatic approaches, as already proposed for the structural lens [6, 7] and the citation lens [4].

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