Towards a Knowledge Graph for a Research Group with Focus on Qualitative Analysis of Scholarly Papers

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Abstract. Support of scientific workflows by semantic technology gains increasing interest in recent years. Huge efforts are put on providing structured, standard-based meta data and on machine based qualitative analysis of unstructured content of scholarly papers. This helps researchers to stay oriented in an ever growing and gaining complexity field. Semantic technologies have also the potential to support the in-depth involvement in scholarly papers, like practiced in research seminars. The paper reports on the preliminary results of an undertaking to support the collaborative documentation and reuse of qualitative analysis of scholarly papers in an information systems research group. A vocabulary is developed and openly provided. The system is implemented as OntoWiki and can be accessed openly.

Keywords: Qualitative literature analysis, Scientific workflows, Research Group Knowledge Base, Collaborative annotation.

1 Introduction

Research groups form the smallest, often informal social entity in the scientific system. Their performance and their cohesion are mainly based on shared scientific interests and a common, high level of expertise in the research field. Even if this research field is narrowly specified, it remains a great challenge to keep in view the state of knowledge. Further elements of this expertise are the awareness of other research groups and influential researchers, the experience in methods and procedures applied to solve research questions, as well as the critical disputation of current research results. Undoubtedly, regular scientific seminars are a traditional and effective instrument for this, since they create a collective realm of experience and discussion.

The small, informal research group Business Modeling and Knowledge Engineering (BMaKE) at the Brandenburg University of Applied Sciences has established such a seminar recently. This group is anchored in the program of information systems. While the selection of the papers to be discussed and the analytical structure to be used were quickly agreed, the form of the knowledge base to be created led immediately to the following research question:

- How to build a sustainable infrastructure for storing the knowledge worked out in seminars in a systematic, structured and easy to re-use way?

The collaboration environments and systems successfully used so far in project work and teaching (Google Drive, GitHub, Confluence, Slack) are quite suitable for the exchange of data and information. They fall short in providing a systematic knowledge storage which can be queried flexibly.

At this point, the research question has not yet been definitively answered. The paper aims at presenting the initiated approach and at discussing the experiences so far. Therefore, the remainder of the paper is organized as follows: Section 2 provides an overview of relevant work on semantic analysis and structuring of scholarly papers content. The elaborated vocabulary to support the knowledge base is presented in Section 3, whereas Section 4 introduces the preliminary system design for the targeted knowledge base. Section 5 discusses the first implementation experiences. The paper closes with a short conclusion and an outlook on further work in Section 6.

2 Related Work

There are different lines of research dealing with semantic analysis and the deployment of structured data on scholarly papers and other relevant objects of scientific environments and workflows, like conferences, proceedings, people, and projects. Table 1 gives a brief overview mentioning exemplary work in the field as well as main research objectives and findings for each of these lines.

Table 1. Lines of research in scholarly papers analysis and structuring

Line of research	Exemplary work	Research Objectives	Main findings
Meta data extraction	Adding semantics to digital libraries [1]	Provide meta data in a standard-based, reusable and structured way	Linked open data publications framework
Collaborative annotation	OpenResearch collaborative management [2]	Enrich structured data about scholarly papers and/or related events	Data model, System architecture based on SMW, LOD services
Production of natively structured data	RASH framework enabling HTML+RDF submissions [3]	Establish standards, formats and frameworks for natively providing structured data	Specification for writing research articles in simplified HTML (RASH)
Text analysis, data mining and machine learning	Knowledge extraction from scientific publications [4]	Elicitation of inner semantics hidden in texts, figures and other unstructured data	Dr. Inventor Text Mining Framework for automated analysis of scientific publications

The results of meta data extraction projects like presented in Table 1 can be used as basic input for the research group knowledge base. The undertaking itself is a kind of collaborative annotation, but with a more specific focus. The increasing production of natively structured data will also support a basic input – as it looks today. However, it is not impossible that this form of publication will also support very specific, qualitative analysis questions in the future. The methods of text analysis and machine learning are the closest to the qualitative analysis of scholarly papers. Though, since a

qualitative analysis is very field-specific, a high-quality training set is required. Perhaps the knowledge base presented here can serve as a training set for automatic qualitative analysis for scholarly papers in the field of Business Modeling and Knowledge Engineering from the Information Systems' perspective.

3 Vocabulary for Qualitative Analysis of Scholarly Papers

Like stated above, the main objective of the required knowledge base is to support the qualitative work within a research group in the field of information systems. This implies the application of two structuring aspects: the general features of scholarly papers (comp. e.g. [5]) and the set of research methods in information systems. As characteristic aspects of a scholarly paper can be considered: (i) research objectives, (ii) research methods, (iii) research findings, (iv) future work, and (v) critical issues. The main research methods in information systems are described in [6].

Because of the increasing importance of *Schema.org*, this vocabulary was first examined for suitable candidates for classes, relations and attributes. It was found that all rather formal, accompanying information on scholarly papers can be modeled adequately with elements of this vocabulary. The specific, qualitative aspects may reuse the relation *schema:about*, but no fitting elements were found there for the mentioned above five qualitative aspects. Ronzano and Saggion describe in [4] the *dri* vocabulary (Dr. Inventor), which semantically approximates these aspects. It is reasonable that the aspect "critical issues" is lacking, since this cannot be extracted from the text but needs a human, expert assessment. Therefore, these entities were modeled as new specific classes which nevertheless are semantically and structurally integrated in the *Schema.org* frame. Fig. 1 shows the high-level schema of the vocabulary. Red nodes are taken from *Schema.org*, green ones are specifically modeled, whereas the white nodes stand for abstract concepts implementable as blank nodes.

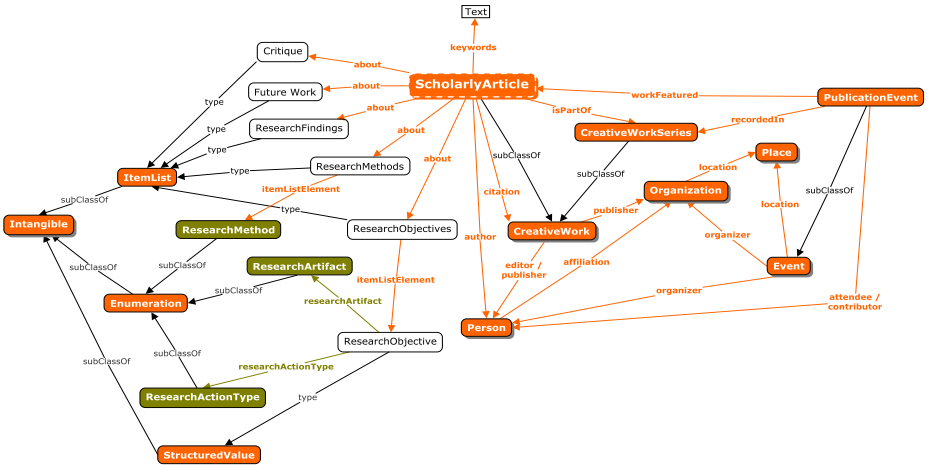

Fig. 1. High-level schema of the scholarly papers vocabulary

Research objectives and research methods were modeled as enumerated item lists, thereby differentiating research objectives in the two, multiply combinable aspects of research activity and research artifact. Table 2 lists the applied concepts. A documentation of the whole vocabulary is provided on GitHub[1].

Table 2. Field-specific enumerations for qualitative analysis of scholarly papers

Research objective		Research method
Research activity	Research artifact	
analyze	Application	Action Research
collect	Blueprint	Argumentative Deductive Analysis
conceptualize	Business Process	Case Study
construct	Development Framework	Conceptual Deductive Analysis
define	Documentation	Design Science (Hevner)
design	Infrastructure	Ethnography
develop	IT System	Field Experiment
elicit	Linked Data	Formal Deductive Analysis
enhance	Method	Grounded Theory
evaluate	Modeling Language	Laboratory Experiment
extend	NLP Artifact	Literature Analysis
extract	Ontology	Prototyping
implement	Policy	Qualitative Research
integrate	Requirements	Quantitative Research
prove	Standard	Reference Modeling
provide	System	Simulation
structure	Term Definition	
	Workflow	

4 Preliminary System Design of the Knowledge Graph

The target system can be described as a knowledge graph, like defined in [7] and further specified in [8]. Fig. 2 shows an abstract model of this knowledge graph where the characteristic elements, particularly the exploited knowledge sources and the provided knowledge services, are adapted to the underlying use case, like described in Section 1. The shaded items in the model represent already implemented, at least partly, elements.

Now, the system is implemented on the base of OntoWiki [9]. It is populated manually by researchers in parallel to the qualitative analysis of seminar papers. Particularly the effort for editing formal meta data is not acceptable. Therefore, knowledge sources for automatic input are now under evaluation. Manual editing is supported either by Turtle templates (which is acceptable only for Semantic Web experts, at least temporarily) or can be performed directly in the wiki. But, unfortunately, the wiki does not support a direct linking to external sources, like WikiData. Internal vocabulary information is provided by the wiki itself and by the documentation mentioned above.

[1] https://github.com/bmake/scholarlygraph/

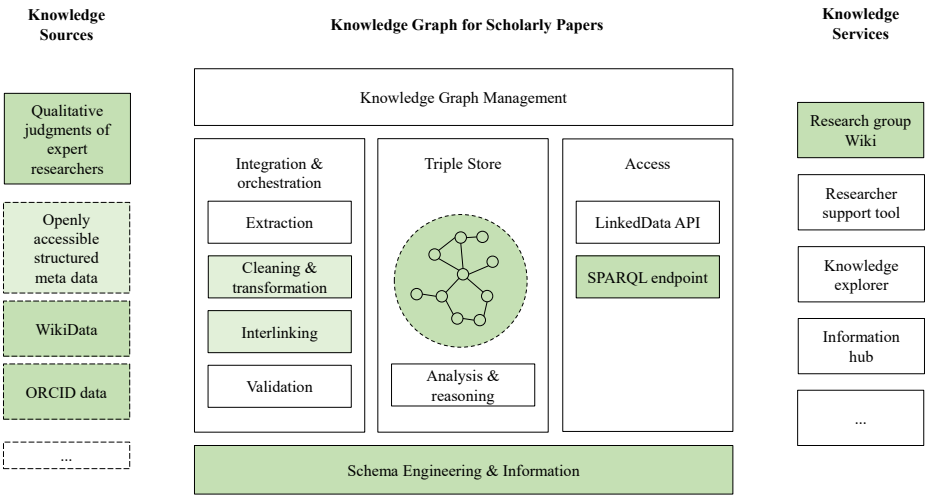

Fig. 2. Abstract model of the knowledge graph for scholarly papers

5 First Implementation Experience

The actual preliminary implementation of the knowledge support system as an out of the box OntoWiki, populated by RDF dump import and direct editing, can be considered as a research prototype. The immediate support of the research group's work allows an in-process evaluation of the support quality and a deeper elicitation of needs and requirements. Fig. 3 shows the user interface with structured data on papers.

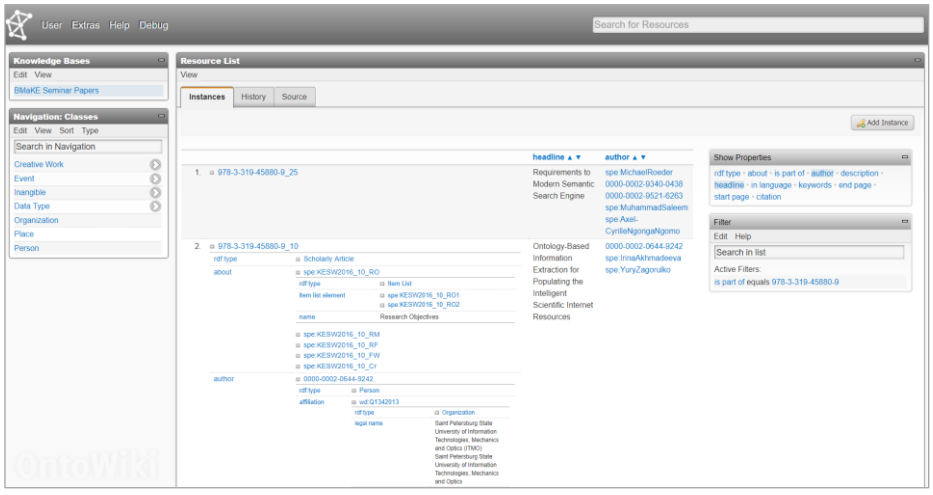

Fig. 3. Faceted list view on scholarly papers data in BMaKE wiki[2]

[2] https://bmakewiki.th-brandenburg.de

The first experiences in using the system in the context of scientific seminars shows the following informal results:

1. Pure consumers of the system assessed it as very helpful in gathering deeper knowledge in the research field.
2. Active editors reported very clearly the necessity of implementing automated bulk import for the formal metadata of scholarly papers.
3. Overall, it becomes obvious, that the system does not support natively a range of required views and analyses. Hence, the system shall be replaced or modified by custom application development, e.g. by means of the OntoWiki framework.

6 Conclusion and Further Work

According to preliminary assessment, a knowledge graph can be considered as a sustainable infrastructure for storing and reusing the results of qualitative analyses of scholarly papers. Even the preliminary implementation presented in this paper was evaluated as an effective (even if up to now not efficient) measure to support the work of a research group. There are three main lines of further development of the system: (i) Formal meta data which are not object of qualitative analysis must be integrated in an automatic way reusing structured data provided by open sources. (ii) A well-usable template-based form should be developed for capturing the results of the qualitative analysis. (iii) The use cases for the support of the research work must be elicited systematically and on this basis the research group wiki should be adapted.

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