Tool Facilitating Construction of Ontologies on the KIM Platform

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Abstract: During research based on experimental work vast amounts of data and associated metadata are usually produced. This is also the case of experimental work using the techniques of electroencephalography and event related potentials. The collected data and associated metadata have to be stored, analyzed, and eventually shared among research groups. Beside storing data and metadata from experiments, it is often beneficial to collect additional information from other sources related to the kind of experiment performed. These information sources are mostly scientific and technical publications, manuals describing the used infrastructure, and topical discussions appearing on the web. This article deals deals with selection and use of a semantic repository for such information sources. Development of a simple prototype ontology is shortly presented and a tool that facilitates construction of ontologies on the KIM platform is described. Sets of test documents are used to verify the functionality of the tool.

1 INTRODUCTION

During research based on experimental work vast amounts of data and associated metadata are usually produced. This is also the case of experimental work using the techniques of electroencephalography (EEG) and event related potentials (ERP). The collected data and associated metadata have to be stored, analyzed and eventually shared among research groups.

For performing electrophysiological experiments our research group (Neuroinformatics research group, 2014) uses the software and hardware infrastructure described in (Moucek et al., 2014). Experimental data and metadata are stored in EEG/ERP Portal (EEGbase) (Jezek and Moucek, 2012) that is available as an online tool (Neuroinformatics research group, University of West Bohemia, 2014) for storage, management, and sharing of electrophysiological data. These data and metadata, enriched by additional semantic constructions written as a part of code annotations, can be also published as dump files by using the languages of the Semantic Web. Through the use of these open standards for data exchange and subsequent integration of the EEG/ERP Portal into the Neuroscience Information Framework (NIF) (Gupta et al., 2008) the portal data are available to other researchers via both the EEG/ERP portal and NIF interfaces.

Beside storing data and metadata from experiments, it is often beneficial to collect additional information from other sources related to the kind of experiment performed. These information sources are scientific and technical publications, manuals describing the used infrastructure, and topical discussions appearing on the web. Search in these sources is not easy. Leaving aside the overall number of these information sources, other troubles come with different terminology used by individual authors. Individual facts can be even indicated by using different keywords. It often happens that it is necessary to reformulate the search query several times and enter different keywords to find desired information.

The aim of this work is to find a suitable solution for aggregating, storing and searching unstructured electrophysiological data (mostly in the form of text documents) that contain additional, supporting or explaining information related to the experimental work conducted. The secondary aim is to use up and/or extend the already existing description of the domain and use knowledge of the Semantic Web languages and technologies.

The article is organized in the following way. Sec-

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tion 2 shortly introduces the basic terminology, languages, and technologies of the Semantic Web to ensure that even the reader unfamiliar with the Semantic Web could follow the text. In the next section appropriate repositories for storing semantic data that enable users to use full-text search are compared. The basic features of the selected semantic repository are also described. Section 4 completes requirements on the documents stored in the selected semantic repository and introduces a part of the domain ontology that is used to describe domain knowledge. Section 5 describes a tool named KIM-OWLImport that was created to facilitate the ontology development. The next section presents the verification process and results of full-text search when using the domain ontology and the KIM-OWLIMport tool. The last section summarizes the whole work and outlines the possible further development of the implemented solution.

2 STATE OF THE ART

This section very briefly introduces the basic terminology used in the Semantic Web. At first, it is important to mention that the initial idea of the Semantic Web has been continuously changing from the very complex view of this phenomenon as an organized layered system of standards, languages, and technologies to the practical (and often separate) use of specific resources.

RDF (Miller and Manola, 2004) is a language for representation of knowledge about sources. These sources can be identified and referenced via their Uniform Resource Identifier (URI) in the WWW network. Knowledge is then organized as a graph structure and represented by triples (subject, predicate, object). RDF schema (RDFs) adds a type system to RDF; it is possible to define a hierarchy of classes. Classes and properties defined by RDFS can be found in (Guha and Brickley, 2004).

Web Ontology Language (OWL) is a language based on description logic that provides means for expressing richer semantic relationships. It is used for creating ontologies. Documents in RDF and OWL can be stored in various syntaxes, for example RDf/XML, OWL/XML or Turtle. While the RDF language was generally well adopted by a larger community, the OWL language due to its complexity is understandable to a substantially smaller community of experts.

Semantic repositories store Semantic Web data in RDF graphs. These data can be queried using specific query languages. The most used language is the SPARQL language (Harris and Seaborne, 2013) that is standardized by W3C.

3 SELECTION OF SEMANTIC REPOSITORY

This section describes the process of selecting semantic repository that would be appropriate for our aim. We defined the following criteria to select a semantic repository that are ordered by their importance to our task:

- possibility and quality of full-text search,
- performance,
- RDF and OWL support.

There are several benchmarks that deal with the comparison of performance of semantic repositories. We used the Berlin SPARQL Benchmark (BSBM) to compare the performance of a selected set of semantic repositories. There were used two data sets containing 100 000 748 triplets (100M) and 200 031 975 triplets (200M). The results (time to import the entire data set and the number of queries per time unit with the different number of simultaneously connected clients) are available in Tables 1 and 2.

Table 1: Time to import the entire data set.

Repository	100M dataset	200M dataset
4store	26min 42s	1h 12min 04s
BigData	1h 03min 47s	3h 24min 25s
BigOwlim	**17min 22s**	**38min 36s**
TDB	1h 14min 48s	2h 45min 13s
Virtuoso	1h 49min 26s	3h 59min 38s

Table 2: The number of queries per time unit.

Repository	100M dataset	200M dataset
4store	5589	4593
BigData	2428	1795
BigOwlim	3534	1795
TDB	2274	1443
Virtuoso	**7352**	**4669**

Finally we chose the semantic repository OWLIM with the KIM platform (named BigOwlim in Tables 1 and 2) that provided extended search and automated annotation of documents. This repository also provided good performance results as it can be seen in Tables 1 and 2.

The KIM platform is a product that enables users to upload documents in various formats (e.g. HTML, XML, RTF or PDF documents are supported) into a semantic repository. It also provides resources for automated annotation of repository documents according to prepared ontologies and resources for subsequent search in them. The principle of automated annotation and its implementation is available in (Kiryakov et al., 2003). The KIM platform works over the OWLIM repository. Processing and annotation of input documents is implemented using the tools of the GATE project. The functionality of the KIM platform is provided using the SOAP web services and JAVA RMI interface. The OWLIM repository is used for example for BBC Sport web (Rayfield, 2012) or the National Archives in Great Britain (Ontotext AD, 2012a).

The knowledge base used in the OWLIM repository is based on the PROTON ontology (Ontotext AD, 2012b). This ontology is divided into three modules and create a suitable cornerstone for the ontologies specific to elaborated domains. The KIM World Knowledge Base as a part of the KIM platform is also based on this ontology. Documents can be stored in three supported repositories: Apache Lucene, Semantic Annotation Repository, and Mimir.

To use the semantic repository for a specific domain thus means to define a domain ontology. All classes of this ontology have to be subclasses of the class Entity from the Proton ontology.

4 REQUIREMENTS AND DOMAIN ONTOLOGY

Before we started to create a domain ontology we had to decide what documents and in which formats would be stored in the selected semantic repository. Finally we decided to index two types of documents: scientific and other technical publications in pdf format and discussions in expert electrophysiology groups published in the social network LinkedIn. The typical domain information searched in these sources could be, for example, as the following one: ”I want to find a discussion about the matching pursuit method that is used to investigate the existence of the P3 component”. The aim of the proposed solution is to find the relevant information for this kind of query. It is also necessary to easily find the query results in original documents.

Beside necessary installation and configuration of the KIM platform the domain ontology that enables an advanced search has to be created. Since the ontology serves for the evaluation of functionality of the semantic repository, it was not proposed to be constructed using the best principles for creating ontologies like looking for terms in the ontologies covering similar domains. As a result a simple prototype of the domain ontology using the data model of the EEG/ERP Portal enriched by defining terms and relationships from specific parts of the domain was developed.

The base of this ontology is a collection of evoked potentials components (Figure 1) and methods used for EEG/ERP signal processing. The graph description of the components includes individual components, their polarity and their group membership. Some components also have their aliases which can be found in the literature. When creating these aliases we took into account some terminological customs, for example the component P3 is usually used as an alias to the component P3b and not as a superior term for all P3 components. That is why the component P3 is considered as an alias to the P3b component in the graph structure and not as a super class denoting the whole family of components. This graph as well as the graph representing the signal processing methods was expressed as an ontology in the OWL language.

The KIM platform imposes additional requirements on the form of ontologies, for example, all created terms have to be marked as trusted. However, when creating an ontology is better to focus on description of knowledge and extend the ontology by additional information later. A tool named KIM-OWLImport was proposed and developed to facilitate development of ontologies for the KIM platform and OWLIM repository. It enables users to focus on the ontology development itself while it automatically transforms it into/from the OWLIM repository in structures relevant to the Proton ontology.

5 KIM-OWLImport

The KIM-OWLImport is a tool that allows extending an existing ontology in a way that it can be used within the KIM platform (trusted resources have to be defined, all classes have a supeclass Entity or eventually a more specific class from a limited set, visibility in the web interface is ensured). Moreover, the tool is designed to be easily extensible by the possible future conditions defined within the KIM platform. The tool has a graphical user interface in which users can add, create and/or edit their ontologies. For each ontology it is possible to define a set of rules that are applied back to the ontology. The tool does not work with the basic RDF/XML syntax but works directly with triples using the Sesame library (Sesame developers, 2012). Sesame provides API that is used (in this case) to access a semantic repository OWLIM-Lite. Sesame also supports its query language SeRQL. The following query (Figure 2) shows the case when individual entities are extended with the property *generatedby*; the property value is a trusted resource.

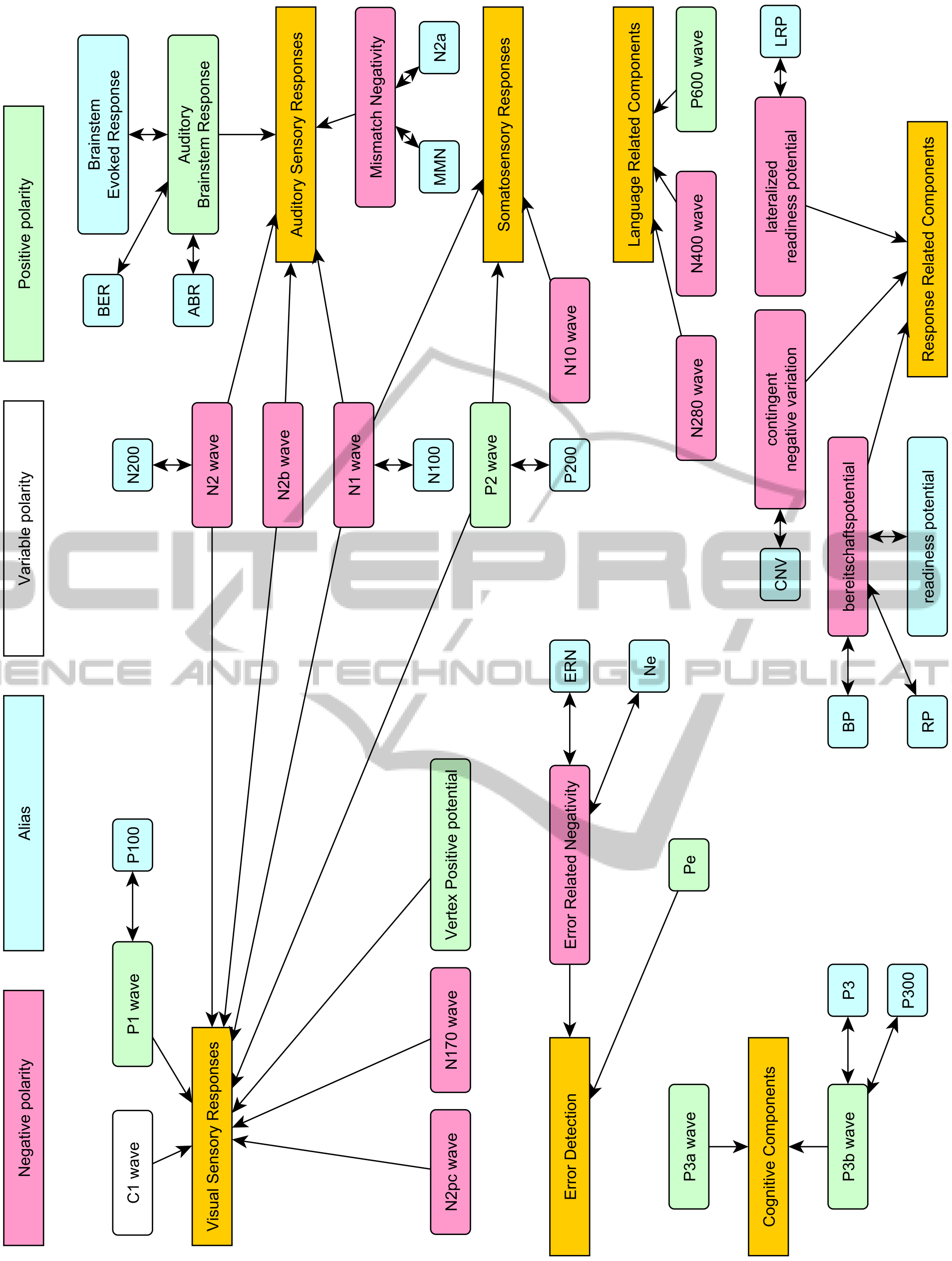


Figure 1: Ontology of ERP Components.

The query finds all the entities which type is a direct instance of the owl:Class type. For the entities which are found the triplet appearing in the CONSTRUCT part is generated. The parameter _sourceUri has to be completed with the URI of a trusted resource. The outputs from all queries are stored using the Sesame API that provides classes for storing triplets in various formats.

The UML diagram of the most important classes and interfaces of the KIM-OWLImport is shown in Figure 3.

The files containing ontologies are uploaded into semantic repositories. The class RepositoryManager ensures the management of these repositories. Each created repository has its own configuration and it is accessed using the RepositoryWrapper class. An ontology is represented by the class AbstractSource. Ontology construction is ensured by the implementation of the ISourceFactory interface. The parameters necessary for creating a specific resource (URL, file path) are passed by the class implementing the ISourceParams interface. All resources and their factories

```
CONSTRUCT DISTINCT {Entity} protons:generatedBy {_sourceUri}
FROM {Entity} rdf:type {Type}, {Type} sesame:directType {ClassType}
WHERE ClassType = owl:Class
USING NAMESPACE
          protons = <http://proton.semanticweb.org/2006/05/protons#>
```

Figure 2: Entities extended with the property generatedby.

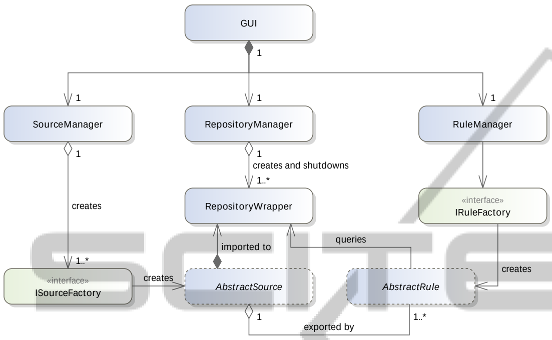


Figure 3: KIW-OWLImport - UML diagram of the most important classes and interfaces.

are managed by the SourceManager class.

A number of rules, which ensure construction of triplets, can be assigned to each resource. The architecture is very similar to the management of ontologies. Specific rules that implement the AbstractRule class are created by the factories implementing the IRuleFactory interface. Rules parameters are represented by the classes implementing the IRuleParams interface. Individual factories are managed by the class RuleManager, the rules are aggregated in a collection belonging to the resource. Rules parameters are configured after the construction of the rule, while ontology resources are configured at the construction time.

The rules method getStatements() performs queries on the semantic repository and returns a result. Individual triplets are then stored in the collection implementing the interface Iteration that is provided by Sesame.

6 RESULTS

The functionality of the KIM-OWLImport tool was verified using two following approaches. The first approach involved the semantic annotation according to created ontology, while in the second approach a specific query was tested. Both tests were performed using the test documents in which the results had been known in advance and using the real documents stored in the semantic repository.

For the verification of the functionality of the semantic annotation the test document containing all the terms (including aliases) from the ontology was created. Each term was placed in a simple sentence that simulates the neighbourhood of the term. The whole text was uploaded to the KIM platform. The annotated document is available in Figure 4.

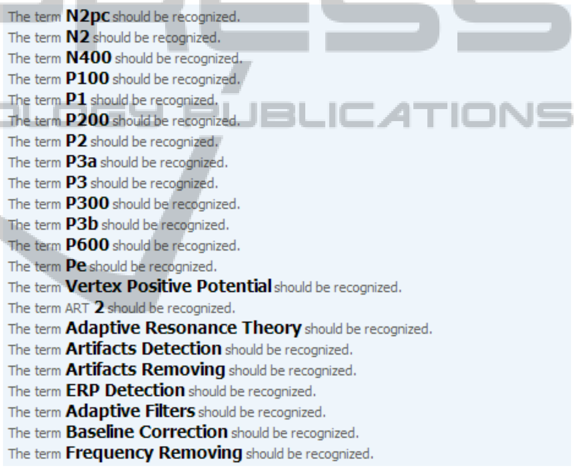
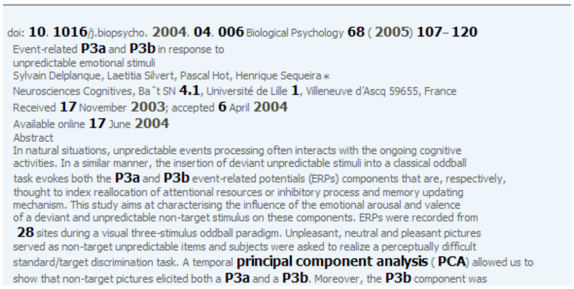

The term **N2pc** should be recognized.
The term **N2** should be recognized.
The term **N400** should be recognized.
The term **P100** should be recognized.
The term **P1** should be recognized.
The term **P200** should be recognized.
The term **P2** should be recognized.
The term **P3a** should be recognized.
The term **P3** should be recognized.
The term **P300** should be recognized.
The term **P3b** should be recognized.
The term **P600** should be recognized.
The term **Pe** should be recognized.
The term **Vertex Positive Potential** should be recognized.
The term ART **2** should be recognized.
The term **Adaptive Resonance Theory** should be recognized.
The term **Artifacts Detection** should be recognized.
The term **Artifacts Removing** should be recognized.
The term **ERP Detection** should be recognized.
The term **Adaptive Filters** should be recognized.
The term **Baseline Correction** should be recognized.
The term **Frequency Removing** should be recognized.

Figure 4: A part of the annotated document shown in the KIM user interface. Annotated terms are highlighted in bold.

Except for one single term all keywords were correctly recognized. The difficulty was with the term ART2 , which contains letters and numerals. Only the number identified as a numeral was recognized in this term, the rest of the term was not recognized. The terms containing one letter followed by one or more digits were recognized correctly.

Then 76 documents from public sources were uploaded to the semantic repository and annotated. An example of annotated document is available in Figure 5.

The search in the semantic repository was verified using the search scenario: "I want to find a discussion about the matching pursuit method that is used to investigate the existence of the P3 component." The query contains the following keywords: "matching pursuit", "P3", and "existence". For testing a set of



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Event-related **P3a** and **P3b** in response to
unpredictable emotional stimuli
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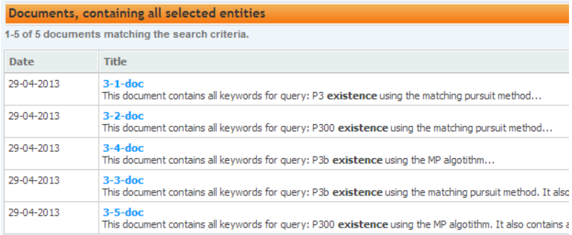
Available online **17** June **2004**
Abstract
In natural situations, unpredictable events processing often interacts with the ongoing cognitive
activities. In a similar manner, the insertion of deviant unpredictable stimuli into a classical oddball
task evokes both the **P3a** and **P3b** event-related potentials (ERPs) components that are, respectively,
thought to index reallocation of attentional resources or inhibitory process and memory updating
mechanism. This study aims at characterising the influence of the emotional arousal and valence
of a deviant and unpredictable non-target stimulus on these components. ERPs were recorded from
28 sites during a visual three-stimulus oddball paradigm. Unpleasant, neutral and pleasant pictures
served as non-target unpredictable items and subjects were asked to realize a perceptually difficult
standard/target discrimination task. A temporal **principal component analysis** (**PCA**) allowed us to
show that non-target pictures elicited both a **P3a** and a **P3b**. Moreover, the **P3b** component was

Figure 5: Annotated document dealing with P3a and P3b components shown in the KIM Platform user interface.

15 documents was created. These documents were divided into three groups:

- Documents containing none of the keywords in the query.
- Documents containing any subset of the keywords in the query, eventually the aliases of the entities ”P3” and ”matching pursuit”.
- Documents containing all the keywords from the query and aliases of the entities ”P3” and ”matching pursuit”.

The set of documents was uploaded to the KIM platform and the query described above was applied. The results are shown in Figure 6. As it was expected the search results included only documents that contained all the keywords.



Documents, containing all selected entities

1-5 of 5 documents matching the search criteria.

Date	Title
29-04-2013	3-1-doc This document contains all keywords for query: P3 **existence** using the matching pursuit method...
29-04-2013	3-2-doc This document contains all keywords for query: P300 **existence** using the matching pursuit method...
29-04-2013	3-4-doc This document contains all keywords for query: P3b **existence** using the MP algotithm...
29-04-2013	3-3-doc This document contains all keywords for query: P3b **existence** using the matching pursuit method. It alsc
29-04-2013	3-5-doc This document contains all keywords for query: P300 **existence** using the MP algotithm. It also contains a

Figure 6: Results of searching entities ”P3b”, ”matching pursuit”, and the keyword ”existence”.

When forming a query any alias for the selected entity can be entered. Apart from ontology entities it is also possible to enter any keyword, which will be subsequently used for full-text search.

7 CONCLUSIONS

This article at first briefly deals with the principles and technologies of the Semantic Web. It is followed by a short overview of the widespread semantic repositories, which are compared in performance tests. Based on the features and the use in real projects the semantic repository OWLIM and the KIM Platform were selected for storing documents in the electrophysiology domain.

The KIM Platform allows semantic annotation of documents based on ontology, which is stored in the semantic repository. The annotated documents can be searched and by using ontology terms it is possible to get more relevant results than in the case of common full-text search. The used ontology must be based on the PROTON ontology and has to meet additional conditions for the full functionality of the platform.

Semantic annotation thus requires an ontology, which contains definitions and classification of domain terms. Since the ontology fully covering the electrophysiology domain does not exist yet, a prototype ontology containing a part of domain knowledge was developed.

To facilitate the development of the ontology, which meets the requirements of the KIM Platform, a tool named KIM-OWLImport was designed and implemented. This tool is able to load the selected ontology in the semantic repository in memory and extend it according to defined rules in a way so that it can be used for semantic annotation of documents (in our case scientific and technical documents and discussions from the social network LinkedIn).

Downloaded documents are annotated and indexed within the KIM Platform. Subsequent search is made possible through the web interface, which is the part of the KIM platform. Search functionality was verified on a set of test documents and on scientific publications dealing with research in event related potentials domain.

The tool KIM-OWLImport thus can be used for automated transfer to any ontology structure, which corresponds to the PROTON ontology required by the KIM Platform. The tool is easily extensible by additional rules and may become a full-fledged transformation tool.

Within the further development it is necessary to replace the prototype ontology with the complex ontology, which will include a larger number of the key terms from the electrophysiological domain. This ontology is currently being developed within Ontology for Experimental Neurophysiology (OEN) group.

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