ontoAGA:Ontology to Support Educational Systems Interoperability

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Abstract. Looking forward to promote the exchange and integration of information in order to build a unique reference model for the universities it is essencial to assure commom concepts of higher education institutions in Brazil. This paper proposes an University Support Management Ontology, named ontoAGA, to help the operation of legacy data in Semantic Web in a standardized manner and to allow the integration of databases with different technologies.To evaluate the research questions two usages cenarios were defined and the results point to the proposal viability.

Resumo. Para promover o intercâmbio e a integração de informações de forma a se construir um modelo de referência para as universidades há necessidade de se estruturar conceitos comuns às instituições de ensino superior no Brasil. Este artigo propõe uma ontologia, no domínio da gestão acadêmica nas universidades, denominada ontoAGA, para ajudar a exploração de dados legados na web Semântica de forma padronizada e para possibilitar a integração de bases de dados de diferentes tecnologias. Para avaliação das questões de pesquisa foram definidos dois cenários de uso, cujos resultados apontam para a viabilidade da proposta.

1. Introduction

A major Internet challenge is the organization of its information sets in a simple and efficient way focused on user's needs. Ontologies are integral part of the Semantic Web. They aim to capture the domain knowledge, providing a common understanding. Ontologies are independent of information systems themselves and as a result, they may contribute to the semantic interoperability among them.

According to Ameen et al. (2012), an ontology about the University generally portrays a particular institution, representing the local reality of the entire educational process. The understanding, information sharing and knowledge reuse from the domain of a higher education institution can contribute to the development of computer applications that incorporate the data that are not available in the current Web.

The proposal of ontology of the educational area, based on the reality of the Federal University of Juiz de Fora (UFJF), can be a first step to increase the standardization and clarity of domain concepts and properties, supporting interoperability between different educational systems. For example, students' mobility between institutions in Brazil requires equivalent curriculum. UFJF has about 20,000 students in undergraduate courses, 16,500 in regular classes and 3,500 in distance

learning, 1,500 students are in master degree and 800 in doctoral courses. It also has two campuses located in Juiz de Fora and Governador Valadares, state of Minas Gerais.

The main goal of this research is to propose a standard scope for the higher education institutions in Brazil, seeking for solutions to integrate legacy data using ontologies. So we highlight two research questions, considering the Brazilian Universities data exchange: The use of ontologies can help the generation of new information and relationships from legacy data in the Semantic Web, in a standardized manner? The data exposure in a standardized model enables the integration of legacy databases of different structures and technologies?

An additional motivation is to improve the researches related to the BROAD Project (Perreira; Campos; Stroele et al. 2014) (Perreira; Campos; Stroele et al. 2015) (Rezende, Pereira, Camposet al. 2015.) and (Palazzi; Matos; Campos et al. 2010), as this work integrates the framework semantic database, composed of ontologies.

This paper is organized as follows: in section 2 related works are described. Section 3 presents the design and development of Educational Support Management Ontology - ontoAGA using the QDAontology approach (Palazzi; Matos; Campos et al. 2010). The fourth section describes the proposal evaluation through two usage scenarious and in the last section the concluding remarks are presented.

2. Related Works

A systematic mapping was performed (Kitchenhamet al., 2010) to identify ontologies that, even emphasizing the development process, address the educational area of a higher education institution. First of all, the search expression was constructed and its execution returned 153 articles from Scopus (www.scopus.com), 9 from the IEEE Digital Library (ieeexplore.ieee.org), 12 from El Compendex (www.engineeringvillage.com) and 33 from Science Direct (www.sciencedirect.com).

The selected articles were originally evaluated by their titles and those that clearly did not fit the mapping objectives were excluded. As a result, it remained 146 articles, which were evaluated through the readings of their abstracts or the full paper in case of doubts about the inclusion or exclusion criteria. Finally, there were five papers describing ontologies related to universities, courses and subjects and twenty-one related to the state of the art of ontology applied to the educational domain. Four articles were especially important for the implementation of the ontology of the university scope (Borbásné et al, 2006), (Ameen et al, 2012), (Malviya et al, 2011), (Malik et al, 2010) and they are briefly described below.

Borbásné et al. (2006) describe an educational ontology for students transfer and mobility between universities. This paper presents the ontology development process and describes the prototype implementation using Protégé. The knowledge areas were highlighted in the conceptual model to ensure the comparison among different curriculum contents. To the evaluation process the authors describe the set of courses of information system development area.

Ameen et al. (2012) present the university ontology construction process, the steps and details of the activities using the Protégé tool. Seven steps were defined in the creation of the ontology: a survey of the detailed university operation, identification of classes and their properties, definition of restrictions, ontology creation and how to save and export it. They identified many subclasses as course, student, qualifying

examination, library, teacher, non teching people, management staff, laboratory and so on. Furthermore, they present object properties, data propertiers and annotation properties. In data properties the restrictions were defined and the annotation properties were used to add metadata or information for classes, individuals and objects. The authors highlight as advantages of working with ontologies the use of reasonner to check their consistency, discovery of new information through inferences, ontology reuse and efficient access, and information retrieval.

Malviya et al. (2011) present the development of the university ontology using the Protégé tool, highlighting the superclasses and the subclasses hierarchy, the instances of subclasses and the steps for their development. This ontology focuses on the details of university community and some important elements such as one student relation to a specific teacher, subject or year. The steps for the development of ontology about the University refer to the following definitions: classes and class hierarchy, properties, data properties, relationships, axioms, instances and ontology reasoning to verify consistency and find implicit logical contradictions in terms definitions.

Malik et al. (2010) present the development process of the university ontology considering various items and steps: superclasses, subclasses hierarchy, subclass creation, class instances illustration and query process. For the authors the basic steps for an ontology development are: obtain domain knowledge, identify the key concepts, build the taxonomy, identify relationships between classes, consistency checking and implementation of ontology.

Considering the articles survey about university ontology and educational domain the main terms were identified. It is important to state that Borbásné et al. (2006) emphasized the knowledge areas, curriculum and skills, which are important data for mobility between universities. Ameen et al. (2012), considered classes related to the university domain, such as: library, student, teacher, qualifying examination, laboratory and doctorate degree. Malviya et al. (2011) highlighted the class course, department, management, student, institute, people, paper publication and thesis. Malik et al. (2010) create the ontology classes with emphasis on management and institute classes of the university domain. Course, teacher and student were common classes that appeared in the works of Ameen et al. (2012) and Malviya et al. (2011). The proposed ontoAGA ontology aims to develop a semantic model, which wishes to represent the common concepts of higher education institutions in Brazil.

3. ontoAGA: Ontology to Support Educational Management

Every higher education institution has some sort of computational support for the management of educational activities. These information systems are built with different technologies, using a variety of programming languages, user interfaces and database systems. Hence from this diversity, the data integration from a range of institutions (carried out, for example, when the Ministry of Education realizes the University Census) is a complex task.

The use of ontologies can support this implementation process. Although there are several ontologies about the university domain, most of them either are considered reference ontologies or are created to a specific application. Besides that, most of them do not portray the educational structures of the Brazilian universities.

OntoAGA ontology aims to structure common concepts of higher education institutions in Brazil based on the Federal University of Juiz de Fora context. The proposal is an on going project that wants to walk forward to enrich the current educational information systems, allowing not only the registration and discovery of knowledge, but also promoting the exchange and integration of information between institutions. OntoAGA can be classified as intermediate application and domain ontology, and in the future a "language pattern" for the universities.

The ontology development process, also known as ontological engineering, was the QDAontology approach (Palazzi, 2010). The use of this approach is justified not only by the fact that this approach proposes a well-defined process - specifying steps, activities, artifacts and participants, but also as it was developed in the context of NEnC Research Group to which this work it is related. Next we present some of the main steps and the documents generated.

Specification: in ontoAGA, the scope is the university domain, specifically the educational management processes.

Conceptualization: in this step the glossary of terms was generated, as a way to organize and structure the acquired knowledge from the specification stage.

Formalization: ontoAGA consists of three domain ontologies, organized as a network, that together define the global ontology:

- Base ontology: contains the basic classes, considered as a "top ontology", but only with the necessary concepts for the ontoAGA scope;
- Educational ontology: contains classes that represent the concepts associated with educational activities at the university (Figure 1);
- Management ontology: includes classes that represent the concepts associated with the management support at the university.

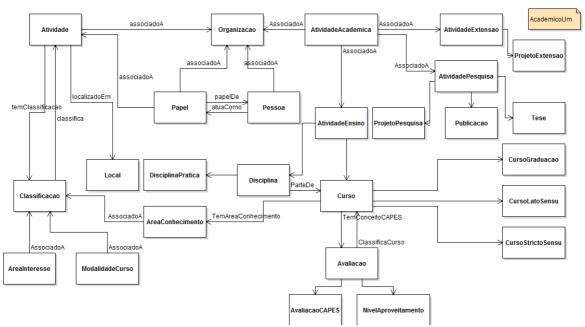


Figure 1 – Part of the ontoAGA Educational Ontology

The network of ontologies allows the creation and evolution of concepts in an independen way, even if each of the ontologies be used in a specific application. The generated artifacts at this stage are the classification of concepts tree, the alignment of the concepts and the classes relationships diagram.

Implementation: as a development tool, we used Protégé 4.3 (Protégé, 2010) and the OWL2 language. Annotations were also made on the ontology itself. Figure 2 is example of classes and properties of object definitions.

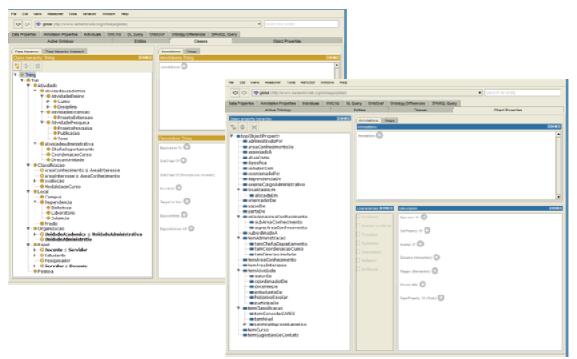


Figure 2 – ontoAGA – Classes and Properties in Protégé

Some examples of <u>defined classes</u> in ontoAGA ontology are presented below to illustrate the implementation step.

• **Course**: the classification of the course is specified according to the property value "temClassificacao".

```
CursoGraduacao ≡ temClassificacao value Graduacao
CursoLatoSensu ≡ temClassificacao value LatoSensu
CursoStrictoSensu ≡ temClassificacao value StrictoSensu
```

• **Roles**: some of the people's roles associated with the university, are also recorded as defined classes inferred by the reasoner. It is thruth that a class can be defined based on another class.

Estudante ≡ estudanteDe some Curso			
EstudanteGraduacao ≡ estudanteDe some CursoGraduacao			
EstudanteLatoSensu ≡ estudanteDe some CursoLatoSensu			
EstudanteStrictoSensu ≡ estudanteDe some CursoStrictoSensu			
Pesquisador ≡ temAtividade some AtividadePesquisa			
DocenteLaboratorio ≡ docenteDe some DisciplinaPratica			
Orientador ≡ orientadorDe some Estudante			

Now, some examples of <u>rules</u> defined in ontoAGA ontology are presented below in order to illustrate the implementation step.

• **Management**: an educational activitiy (or course) is associated with a management job (not to a specific person), and this individual performs this work. The following rules are the association of Educational Activity (or course) with a Person.

```
UnidadeAcademica(?x),exerceCargoAdministrativo(?z, ?y),
temAdministracao(?x, ?y) -> administradoPor(?x, ?z)
Curso(?x), exerceCargoAdministrativo(?z, ?y),
temCoordenacaoCurso(?x, ?y) -> coordenadoPor(?x, ?z)
```

The next rule defines that if a course is associated to a certain knowledge area, the Course Adviser can also be associated with the same Knowledge Area.

```
Curso(?x), temAreaConhecimento(?x, ?w),
exerceCargoAdministrativo(?z, ?y), temCoordenacaoCurso(?x, ?y)
-> temAreaConhecimento(?z, ?w)
```

Some rules were implemented through the use of property chains, as the ones to recommend people contact (associating people with interest in some knowledge area with the people related to the same knowledge domain).

```
temAreaInteresse o areaConhecimentoDe o
papelDe→temSugestaoDeContato
temAreaInteresse o superAreaConhecimento o areaConhecimentoDe o
papelDe→temSugestaoDeContato
```

Integration: this activity considers the reuse and compatibility with other ontologies in the same domain. To carry out this phase we selected the HERO ontology (Zemmouchi-Ghomari & Ghomari, 2013). We chose the mapping technique between ontologies (Souza Junior, H. C., 2008), made by OWL statements, using the OWL property equivalentClass. This property associates a class description with the description of another class. This axiom implies that both classes have the same length (i.e., their extensions contain the same set of individuals). The equivalence statements were recorded in OWL file that imports the ontoAGA and HERO ontologies. The object properties are presented in the ontology, but not the properties data, since they are retrieved from the original databases.

4. ontoAGA Evaluation

In order to structure the evaluation process we used the GQM method (Basili 1994). Thus, the scope of this evaluation was structured as follows:

"Analyze the use of semantic web technologies, mainly ontologies, in order to propose a reference model, related to data and processes of educational management systems, from the point of view of users and software applications that need these data and processes and in the context of exposition and integration of available data in legacy systems."

The research method for ontoAGA evaluation was the usage scenarios, based on the formalization of case studies (Dresch, A. et al. 2015), in order to validate the research questions. The following steps were followed, adapted from Wholin et al. (2012): definition, goal formulation, planning, execution/observation and results. Considering space limitation, we describe only two scenarios. The first one aims at observing the kind of knowledge generated from the use of data and the application of inference mechanisms from the ontoAGA and the UFJF information System. The second scenario explores the possibility of integrating semantic database with relational databases, considering that the lattest does not allows semantic search.

4.1. Scenario I

For the first scenario an ontology instance with individuals for each class of ontoAGA was created. The inference engine was executed over this ontology and the generated results were validated comparing the defined classes and rules. The running queries were focused on the question: "Considering an student individual interest area (for exemplo to start a research program or to recommend some educational resources), which are the suggestions of teachers to contact?". The inference was performed within the Protégé development environment, using the Pellet Reasoner. Figure 3 shows the results after the inference process for the defined classes *CursoGraduacao*, *Pesquisador* and *Orientador*.

escription: Orientador	08
juivalent To 🛨	
orientadorDe some Estudante	?@×0
ib Class Of 🛨	
Docente	<u>?@×0</u>
🖨 Servidor	
ub Class Of (Anonymous Ancestor)	
e associadoA some Atividade	?@XO
associadoA some Papel	?@×0
9 Servidor	
Docente	?@×0
subordinadoA some Servidor	<u>?@×0</u>
eassociadoA some Organizacao	?@×0
temAreaConhecimento some AreaConhecimento	?@ ×0
docenteDe some Disciplina	?@×0
lembers	? @ ×
Docente2	2@X
Docente3	201
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Figure 3 – Some Inference Results

Figure 4 shows the inference results for the individual *Docente2*, presenting the axioms that were established *a priori*. It stands out the automatic classification of the individual in different classes, as the *Docente* class, as well as the results of applying the rules in *subordinadoA* and *coAutorCom*.

Another way to evaluate the scope of the ontology is to check the kind of queries available. For this step, the ontology has been used as a database (dataset) and published as a SPARQL endpoint, enabling the data query via HTTP protocol. For this test SPARQL Fuseki server was used (Fusekii, 2015). Figure 5 shows the execution of some SPARQL queries (indicated as a remark), using Fuseki server.

scription: Docente2		Property assertions: Docente2	
pes 🕂		Object property assertions 🛨	
Docente	<u> </u>	associadoA	?@
CoordenadorCurso	?@	orientadorDe Estudante14	? @
Orientador Pesquisador	?0	temAreaConhecimento 1.05.00.00-6-FISICA	?@
		exerceCargoAdministrativo Coordenação_Curso_Bachar	?@
ime Individual As 🛨		autorDe Publicação2	20
fferent Individuals 🕂		coordenadorDe Curso_Bacharelado_Física	
Docente1, Docente10, Docente3, Docente4,	?@XO	coAutorCom Estudante14	
Docente5, Docente4, Docente5, Docente6,		temAtividade Publicação2	
Docente7, Docente8, Docente9		temAtividade Curso_Bacharelado_Física	
		papelDe Pessoa2	
		subordinadoA Docente1	
		associadoA Instituto_de_Ciências_Exatas	
		Data property assertions 💮 Negative object property assertions 🕀 Negative data property assertions 🔁	

Figure 4 – Infered Results - Individuo

10	## Dada a AreaInteresse da Pess	oa, qual a sugestão	< 🖸 🗋 🗎		
11	## de Docente para contato?				
12	##				
13					
14					
15	where {				
16					
17					
18					
19	<pre>?pessoa acad:temSugestaoDeContato ?contato.</pre>				
20					
21	4 4				
22					
23			~		
	Raw Response Table		Show 50 v entries		
	Berry Berry and Table	1	Show 50 v entries		
		docente	Show 50		
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1	Raw Response Table pessoa ind:PessoaA ind:PessoaA	ind:Docente1 ind:Docente10	Show <mark>50 ∨</mark> entries		
1 2 3	Raw Response Table pessoa Ind:PessoaA Ind:PessoaA Ind:PessoaA	ind:Docente1 ind:Docente10 ind:Docente2	Show 50 v entries		
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1 2 3 4 5	Raw Response Table pessoa ind:PessoaA ind:PessoaA ind:PessoaA ind:PessoaA ind:PessoaA	ind:Docente1 ind:Docente10 ind:Docente2 ind:Docente3 ind:Docente4	Show 50 v entries		
1 2 3 4 5 6	Raw Response Table pessoa ind:PessoaA ind:PessoaA ind:PessoaA ind:PessoaA ind:PessoaA ind:PessoaA	ind:Docente1 ind:Docente10 ind:Docente2 ind:Docente3 ind:Docente4 ind:Docente5	Show <u>50</u> ∨ entries		

Figure 5 – SPARQL Query

4.2. Scenario II

This scenario was created to evaluate the effectiveness of using the ontoAGA ontology as an integration mechanism between two environments: the ontology and the relational database. In this context we can apply the ontology inference mechanisms to access large volumes of data available in legacy databases creating a semantic integration when searching related databases. For these application systems MySQL database was created (MySQL, 2015).

In order to promote the integration of these two environments and enable publishing legacy data on the Semantic Web, we used the D2RQ platform (D2RQ, 2015). D2RQ is a system for accessing a relational database as a virtual RDF graph, allowing data access without requiring their replication on a RDF base. The D2RQ system also allows database dump as a triple-store RDF. To evaluate ontoAGA, together with D2RQ system, an example of database (named DB1) was created, using the DBMS MySQL. The scheme of this database is presented in Figure 6.

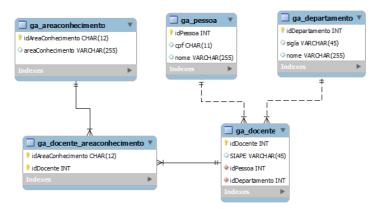


Figure 6 – DB1 Database Scheme

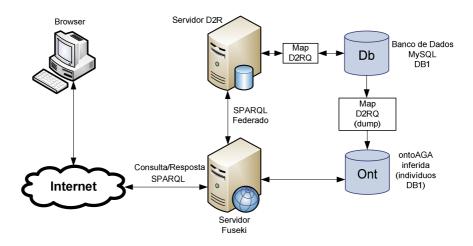
Following the proposal of working ontoAGA only with individuals (no data properties), two mappings have been created:

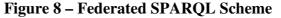
- A mapping to dump the identifiers of each entity. In this case, we decided to use as an identifier not the primary key for each table, but the fields that can be more readable in the ontology. Thus, the Person entity was identified by CPF number, the Department entity by SIGLA and the Faculty entity by SIAPE number. The ontology generated from this mapping is used for application of the inference engine.
- A mapping to access the data from the database used by D2RQ server.

For the evaluation step an individual *PessoaA* was created with interest in Mathematics area. After the inference execution two persons were selected as contacts candidates (Figure 7).

Property assertions: PessoaA	
Object property assertions 🛨	
temAreaInteresse 1.01.00.00-8-MATEMATICA	?@×0
temSugestaoDeContato 12345678901	?@
temSugestaoDeContato 23456789012	?@
Data property assertions 🛨 Negative object property assertions 🛨	
Negative data property assertions 🕂	

Figure 7 – Inference Results





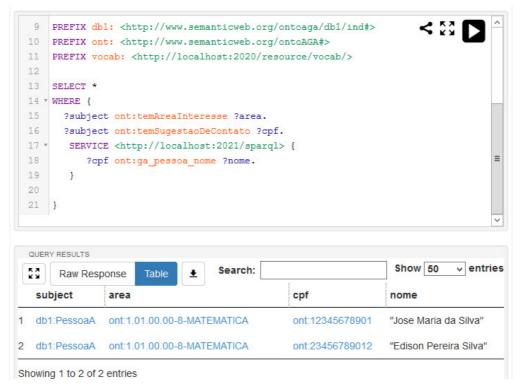


Figure 9 – Federated SPARQL Query

5. Results Analysis

Usage scenarios showed the feasibility of using ontologies for data integration based on diverse technologies and as integration mechanism between two different environments, ontology and relational databases. Thus, there is evidence that the ontoAGA ontology can allow different semantically enriched queries and help the exposure of legacy data in the Semantic Web, in a standardized way.

The first scenario evaluated the generation of information and knowledge using ontologies through two mechanisms: automatic classification of individuals/classes (using defined classes, appling restrictions on the primitive classes) and the application of rules (discovery mechanisms and new relationships generation based on existing relationships). The second scenario evaluated the effectiveness of the use of ontoAGA as integration mechanism between two different environments: ontology and relational databases. Thus, we could apply the ontology inference mechanisms and access large volumes of data from legacy database systems.

6. Final Remarks

This paper presented the development of ontoAGA ontology not only using concepts of primitive and defined classes, rules, through formulas and properties chains, which are available in OWL2, i.e. *propertychain*, but also extracting new knowledge from the ontology; queries using FUSEKI system, which is a server that supports the SPARQL HTTP protocol, the SPARQL query language and SPARQL update language. The queries can be federated, which means access to more than one data source through the use of SERVICE operation.

There has been evidence that the research questions can be reached, since the ontoAGA ontology is able to support legacy data from the Semantic Web in a standardized manner and can enable the integration of legacy databases of different structures and technologies besides generating new relationships among classes.

Due to the large volume of data in the databases from the Univerity information systems only the primary keys were included in the ontology. Access to other data was done through SPARQL queries, which can result a delayed response, in case of queries with many returning data. A study on what data would be more accessed (and therefore able to be migrated to the ontology) could reduce this problem. The development of this work can also contribute to management decision support.

Considering that, UFJF and all the Universities in Brazil have to deal with many government educational systems and technologies as future work we consider their integration with ontoAGA, which will extent the educational ontology network.

Acknowledgement: This research is partially supported by UFJF, FAPEMIG, CAPES and CNPq.

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