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Development of Ontologies in Different Domains for a Test Generation Environment

Asya Stoyanova-Doycheva, Sebiha Madanska, Mariya Grancharova, Todorka Glushkova, Georgi Cholakov
Faculty of Mathematics and Informaticst, Plovdiv University "Paisii Hilendarski", Bulgaria.

Abstract

The purpose of the proposed article is to present the creation of ontologies for automatic generation of test questions from the Test Generation Environment, which was created as part of the Virtual Education Space. The ontologies presented in the article are in different fields and can be helpful to students in their exams or for self-study. The three ontologies are in the fields of botany, literature and history of Bulgaria, and architecture of Revival houses. The article presents examples of automatically generated questions for each of them.

Keywords: *ontology; VES; e-testing , e-learning, TGE.*

1. Introduction

One of the main tasks of e-learning environments is to provide e-testing services. They are needed to facilitate trainers and trainees in taking exams, preparing for exams, and self-assessment. There are a wide variety of systems offering similar services that are widely used. Such is the system Moodle (Moodle Community, 2022) (Modular Object-Oriented Dynamic Learning Environment), which is a modular, dynamic, object-oriented and free learning environment. The "Quiz" model in Moodle allows training to create different types of tests. Other examples of known test-supported systems are OLAT (Online Learning and Training) (OLAT, 2022) and OpenOLAT (Open Online Learning and Training) (OpenOLAT, 2022). Here again the tests can be automatic, but prior preparation is required, including inventing/ providing the parts of the test, the elements of the tasks, and the questions. In (Zeileis, 2014) is demonstrated the ability to automatically generate exams for the academic discipline of statistics with the environment R. Analysis of algorithms for compiling tests are presented in (Kostadinova, 2019). The authors offer information on various test systems. They focus on compiling the tests themselves, but providing the questions needed for these tests is still a task of the teacher.

The Virtual Education Space (VES) is being developed as a successor of the DeLC e-learning environment (Stoyanov, 2010, 2012, 2016) in the "Distributed eLearning Center" Lab of the University of Plovdiv “Paisii Hilendarski”. The space provides electronic teaching material and electronic services including support of the internationally accepted standards SCORM 2004 (SCORM 2004) and QTI 2.1 (QTI 2.1). One of the services offered by VES is the Test Generation Environment-TGE (Stancheva, 2017). The architecture of the environment is a multi-agent system that performs two main tasks generating and verifying tests. The specificity of the environment and the proposed architecture is that the questions in the tests are generated and checked automatically by two operational agents created for this purpose – Questioner Agent and Assessment Agent (Stancheva, 2016). For the purpose of automatically generating and checking questions, both agents use an ontology. The TGE environment was created to use the UMLOntology (Stoyanova-Doycheva, 2021), which contains knowledge of the UML language specification. One of the main tasks we set ourselves was to use the created architecture of the environment to automatically generate questions in other areas. For this purpose, we continued to create ontologies for the needs of this environment. The main goal of the article is to present three ontologies in three different areas, which we have created for the purpose of training in plant growing (botany), literature and history of Bulgaria, and architecture of Revival houses. On the one hand, ontologies are created with a structure that presents knowledge in the specific field, and on the other hand, they can be used to automatically generate questions. Learners will be able to use the question-generating environment, both to test their knowledge in these three areas and to do test-based self-study.

2. Structure of ontologies and test generation in TGE

2.1. Structure of GenBankOntology

GenBankOntology contains the classification of plants according to the taxonomy presented in (Stoyanov, 2019). Its main structure was developed under a project for maintenance of plant genetic resources in the gene bank of the IRGR in Sadovo (Stoyanova-Doycheva, 2020). The ontology can be used for training in botany. Some of the classes in the ontology hierarchy are presented in Figure 1. Owing to the strict hierarchy between the ontology classes, when adding an instance of a plant species, subspecies, or variety, the ontology immediately obtains all the other characteristics from the taxonomy such as genus, subfamily, family, and order. This makes it easier to maintain the ontology in the future, where these connections will be made automatically when new instances are added. The ontology currently has over 500 classes and over 2400 axioms.

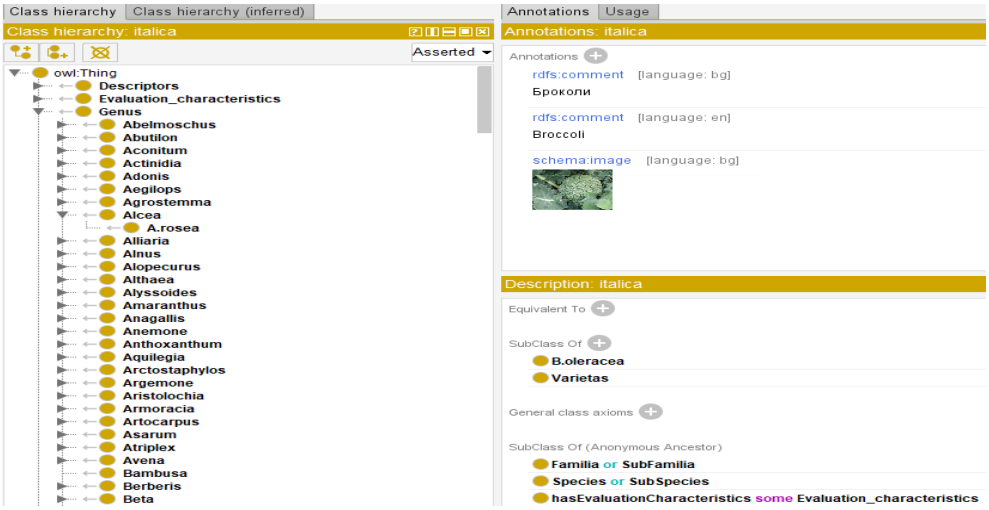

Figure 1. Part of the class hierarchy in GenBankOntology.

For the purposes of automated question generation, some additional annotations have been added to the created ontology. This is necessary because the questions in the TGE are generated on the basis of templates that use axioms in the ontology and annotations, which help to syntactically correct the generation of the questions. The additional annotations that have been added to the ontology are related to ObjectProperties – the connections between the concepts. In GenBankOntology, there are only two annotations (has evaluation characteristics and is evaluation characteristic) and they link an identity with its evaluation characteristics, such as where a plant can be found, where its seeds are stored, what its fruits are, what its resistance to diseases is, and others. Each identity of a species has its own evaluation characteristics, and each evaluation characteristic is determined by specific values

through DataProperties in the ontology. Figure 2 presents additional annotations for GenBankOntology's ObjectProperties.

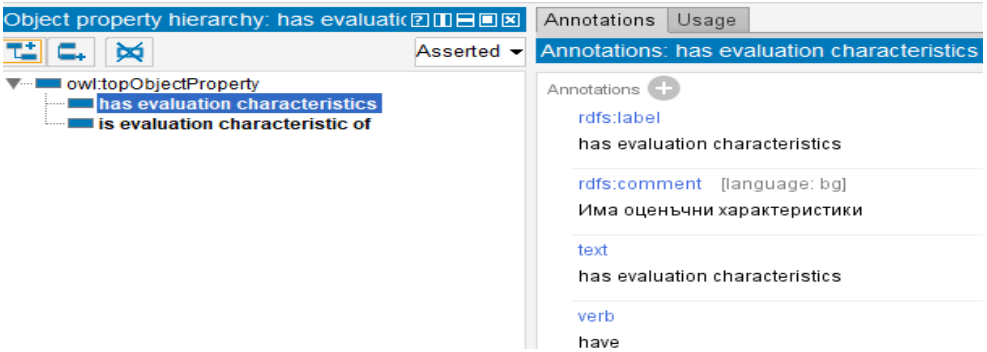

Figure 2. Anotation for ObjectProperties in GenBankOntology.

The main axioms in GenBankOntology are SubClassOf, DisjointClass, and ObjectPropertyRange. The most widely used axiom is SubClassOf – 1142 axioms. With them, generating questions in TGE is easier because agents can use the concepts in the ontology directly. Let us consider such an axiom from the ontology and the question generated by it.

```
<SubClassOf>
    <Class IRI="#Poaceae"/>
    <Class IRI="#Familia"/>
</SubClassOf>
<DisjointClasses>
     <Class IRI="#Genus"/>
     <Class IRI="#Varietas"/>
    <Class IRI="#Ordo"/>
</DisjointClasses>
```

Figure 3. SubCalssOf and DisjointClass axioms.

The axiom represents that the class *Poaceae* is a subclass of the *Familia* class. The closed question generated by the system can be seen in Figure 4.

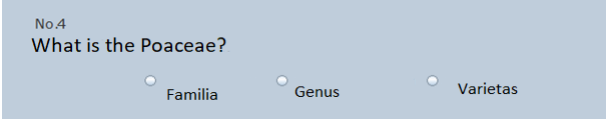

Figure 4. A multiple choice question generated in TGE.

To generate the wrong answers to the question, the Question Generation Agent uses the DisjointClass axiom for the *Familia* class. Each of the axioms in the ontology can be used to generate a question, and in GenBankOntology there are over 2400 axioms, which makes the variety of questions great.

2.2. Structure of BulgarianLiteratureAndHistoryOntology

BulgarianLiteratureAndHistoryOntology contains a classification of the notable personalities who have studied and worked at the First Bulgarian High School, established by Naiden Gerov in 1850. Its successor is today's Humanitarian High School "St. St. Cyril and Methodius" in Plovdiv. The created ontology (Figure 5) can be used in extracurricular forms of education in the field of Bulgarian literature and history.

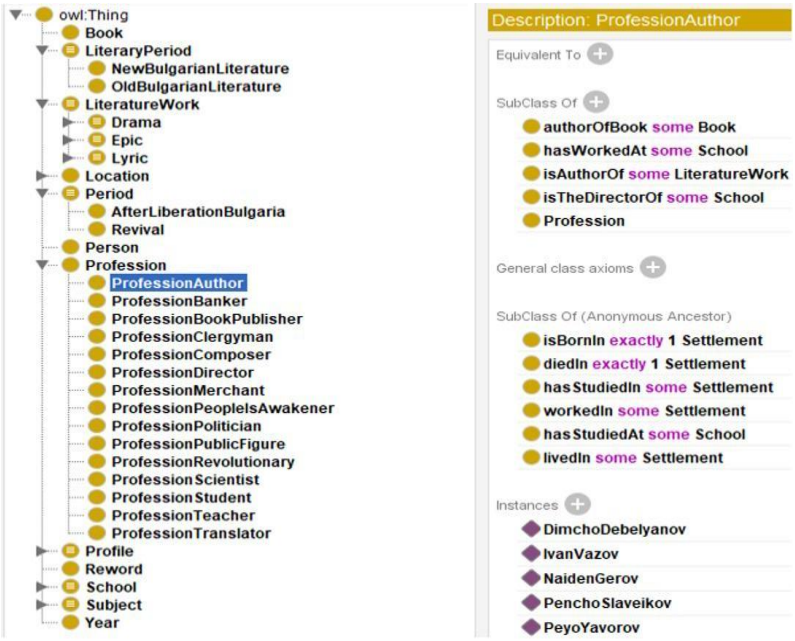

Figure 5. Part of the class hierarchy in BulgarianLiteratureAndHistoryOntology

By adding a new person as an individual, it can be concluded whether he is a graduate of the school or a teacher in it, whether he is a book author, revolutionary, politician, public figure, etc., according to the classes created and their limitations. If an individual is the author of a book, it is possible to find out during which literary period the book was created, which books were written by him and which of the literary genres the work belongs to.

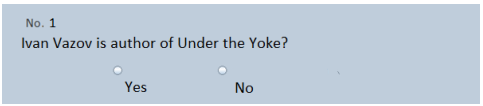

Figure 6. A question generated for isAuthorOf

The ObjectProperties isAuthorOf connects the classes ProfessionAuthor and LiteratureWork. A question generated for this ObjectProperty is presented in Figure 6.

2.3. Structure of RevivalHousesOntology

RevivalHousesOntology contains information about the Bulgarian residential architecture in and around the period of the Bulgarian Revival (Madanska, S., Bilyanov, S., Stoyanova-Doycheva, A., Stoyanov, S., 2021). The development describing the houses consists of seven ontologies. The division of the ontology into subsets is according to the CCO standard (Baca, M., Harpring, P., Lanzi E., McRae, L., Whiteside, A., 2006) and in view of scalability. *Agents.owl* includes information about the personalities who played a role in the buildings – owners (past and present), builders, restorers, organizations, as well as the registration as a cultural value in the relevant institutions. *Locations.owl* contains location - geographical, administrative, cadastral, and coordinate. *Ontology Subjects* includes data for the period. *Ontology Objects* contains the characteristics of a standard house, and *Materials* describes building materials and techniques. *Functionalities.owl* contains rooms according to different geographical and dialectal features. *The OldHouses ontology* includes IRI of elements from the above-mentioned ontologies and characteristic features of the Revival house – the typological groups of houses on the territory of Bulgaria are discussed in it; they are described in detail and their individuals are added, for example, the "Pangalova house" (Figure 7).

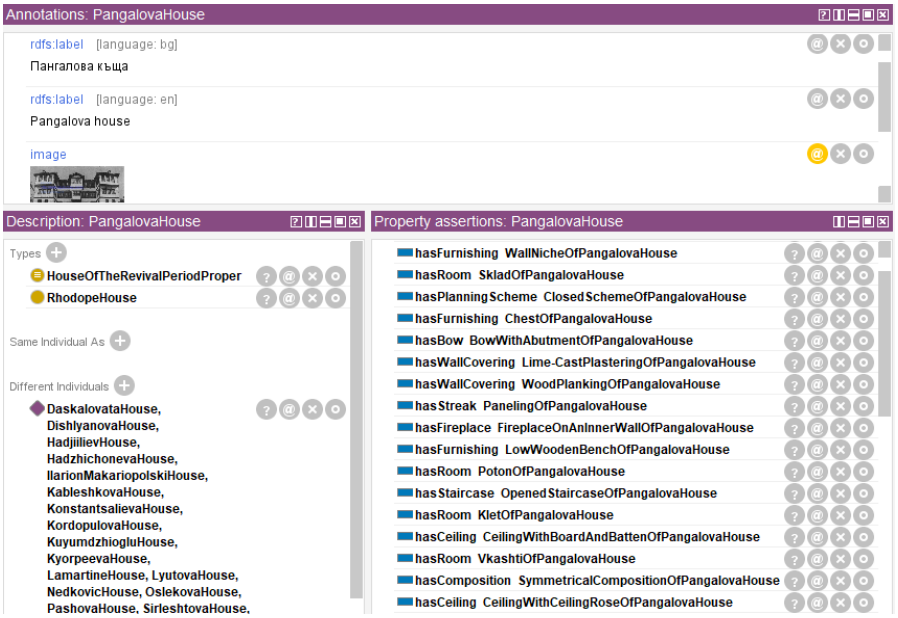

Figure 7. Individual description of the "Pangalova house"

The ontology can be used for training in schools and universities in the field of architecture and art, for tests related to the determination of a Revival house to a specific Typological group of houses and the period of its construction; architectural features and varieties of bearing and non-bearing elements, and others.

Figure 8 presents a segment of axioms: for the subclasses of the class BulgarianRevivalHouse, which are "disjoint" with each other in order to unambiguously define and identify a house afterwards, and a characteristic of the class HouseOfTheRevivalPeriodProper, that there is a closed or opened scheme.

```
<ObjectUnionOf>
  <ObjectSomeValuesFrom>
      <ObjectProperty IRI="#hasPlanningScheme"/>
      <Class abbreviatedIRI="objects:ClosedScheme"/>
  </ObjectSomeValuesFrom>
  <ObjectSomeValuesFrom>
       <ObjectProperty IRI="#hasPlanningScheme"/>
       <Class abbreviatedIRI="objects:OpenedScheme"/>
  </ObjectSomeValuesFrom>
</ObjectUnionOf>
```

Figure 8. Axioms for the SubClasses of the "BulgarianRevivalHouse" and the "HouseOfTheRevivalPeriodProper"

The generated guestion from this axiom is presented in Figure 9 – in this case, the TGE takes only one ObjectValue of the ObjectUnionOf Axiom to generate a question. Currently, *RevivalHousesOntology* includes 613 classes and 7724 logical axioms.

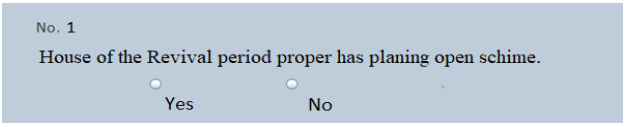

Figure 9. A generated question for the hasPlaning Schima object property

3. Conclusions

Creating ontologies in order to be used by the Test Generation Environment supports the exam process of students and helps them to study in different fields. When testing the environment with knowledge of the new ontologies, no problems arising from their use were noticed. The environment performs its functionalities as expected and there are no differences in performance and results due to the change in the knowledge base. But it should be noted that adding meta-knowledge to ontologies in order to be able to generate and check questions automatically takes a lot of time.

Statistics on the work of TGE have been collected. Major problems regarding its use have been defined and eliminated. The most common criticism from students is that the generated tests are in English and not in Bulgarian. For this purpose, ontologies developed in Bulgarian and adding meta-knowledge to them are needed. The algorithm for generating questions also needs to be changed due to the grammatical differences between the two languages. For this

future purpose, the proposed ontologies in the article are developed in two languages – English and Bulgarian.

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