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APPLICATION OF SUBJECT DOMAIN ONTOLOGIES IN E-LEARNING

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Abstract: *This paper presents an overview of two tools for e-learning developed in the Virtual Physical Space (ViPS). The first one refers to the generation of test questions. It is used in the course of education of students majoring in Software Engineering at the Faculty of Mathematics and Informatics (FMI) at the University of Plovdiv. The generation of the test questions is based on an ontology for UML, the processing of which is made by intelligent assistants. The second tool is called a Tourist Guide. It is intended to generate lessons in the area of cultural and historical heritage of Bulgaria in conformity with ontologies, which are created according to the CCO (Cataloguing Cultural Objects) standard.*

Keywords: e-learning, ontology, ViPS, test generation, tourist guide.

INTRODUCTION

Ontologies are formal structures that provide a common understanding of a particular domain. They represent domain semantics and allow intelligent access to information. Since the early nineties, ontologies have been a popular research topic in the field of artificial intelligence for natural language processing, knowledge presentation, and so on. With the introduction of the semantic web, ontologies are becoming more and more popular. Nowadays, the concept of ontology is also widespread in e-learning. The Semantic Web and ontologies are used in e-learning in a number of ways, such as for presenting knowledge in a given area, providing metadata for key concepts and subjects in a given field of study, facilitating the sharing of learning content, personalizing and recommending learning content, curriculum development, and training assessment (Kizilkaya, 2007). Most of the developed ontologies in the field of e-learning are learning task ontologies and subject domain ontologies.

The main purpose of this research is to demonstrate the use of subject domain ontologies in e-learning. The presented ontologies make it possible to create learning content that is structured by basic elements and semantic links between them. Such content can be reused and processed by intelligent applications, which can provide information to users and draw conclusions based on semantically structured information. In addition to knowledge in a particular field, ontologies can be used to gather information about users, such as what part of the knowledge in the ontology they have used, how many times they have used it, and others, which provides an opportunity to personalize the learning process. Two subject domain ontologies will be presented, one of which is used to generate tests in the given domain, and the other one is applied to present knowledge.

The structure of the article is as follows: It starts with the presentation of some research related to e-learning, followed by a brief description of the architecture of the Virtual Physical Space (ViPS) (Stoyanov, 2018), which adapts to e-learning. Next, two e-learning tools that use ontologies in ViPS are introduced. The first one of these tools is designed for the automatic generation of electronic tests (a Test Generation Environment), while the second tool is designed to generate electronic lessons in the form of routes for cultural and historical sites (a Tourist Guide). These routes can be used in e-learning as lessons in history, art history, geography, folk art, and many others.

1. RELATED WORKS

Ontologies in e-learning are used for different purposes. The authors of (Al-Yahya, 2015) provide a classification of ontologies used in e-learning:

– Curriculum Modelling and management. Curriculum elements are modelled to facilitate access and retrieval of curriculum information. This enables the curriculum developers to view the overall curriculum and ensure compliance with the vision and mission of the institution. It also provides a structure where learning units can be linked to outcomes and learning objectives.

- Describing learning domains from different perspectives, allowing for a richer description and retrieval of learning content:
  - Subject domain ontology (history, geography, programming, etc.).
  - Learning task ontology (lesson, activity, assessment item, simulation, exercise, LO, feedback).
- Describing learner data; this is useful for assessment and personalization. Personalization, according to the learner profile, may include sequencing the learning material, and tracking the learner performance:
  - Performance data (assessment data).

    - History data (units completed, etc.).
- Describing E-Learning services:
    - Providing a shared vocabulary for interoperability among various educational systems and the sharing and exchange of data among heterogeneous E-Learning systems.

The study shows that the highest percentage of ontologies in e-learning are used to present knowledge in a particular domain. An example subject-domain ontology is the "mobile computing ontology" (Sameh, 2009), which models conceptual elements in the mobile computing domain and the relationships between these elements. Another ontology is the "construction education ontology" (Raju, 2012), which provides a model of elements and relations in the field of construction education. Other examples include a Java programming ontology (Lee, 2005), which encompasses all concepts and features of the language construct and the relationship between objects. A manufacturing ontology (Bhattacharya, 2012) is used for knowledge representation of the various concepts and details of the products produced by manufacturers.

Task ontologies can be used to model various e-Learning tasks such as assessment, feedback, pedagogy design, search, and retrieval. In educational settings, in general, and in the process of learning, in particular, the assessment of students is an important task.

There are many tools that use ontologies to assess student knowledge. Ontology E-Learning (OeLe) is presented in (Litherland, 2013) and (Castellanos-Nieves, 2011). OeLe is an ontology-based assessment system, which automatically marks the students' free-text answers to questions of a conceptual nature. It does this by mapping the student's answer in the form of a concept map using a domain ontology. OeLe is a web-based system and the type of assessment items it supports include both closed (multiple choice) and open (text response) answers.

In (Al-Yahya, 2014) the authors use two domain ontologies – the SemQ and HistOnto ontologies. The SemQ ontology represents vocabulary (Arabic words from a specific domain), while the HistOnto ontology describes historical facts. A prototype, which accepts ontologies as input and provides Multiple Choice Questions as output is presented in (Papasalouros, 2008). The approach is based on strategies that use ontological axioms and inferred knowledge from OWL ontologies. Other works, in addition to the existing relationships in the ontology, also consider different ontology elements. That is the case of the work proposed by Cubric (Cubric, 2011), which along with relationships, also considers annotations and a semantic interpretation of the mapping between the domain ontology and the target question. The semantic interpretation is based on the notion of question templates that are founded on Bloom's taxonomy of educational objectives (Bloom, 1956).

This paper presents the development of subject domain ontologies that intend to automatically generate test questions and present knowledge in the domain of cultural and historical sites in Bulgaria. Ontologies are developed as part of the Digital Library in ViPS.

2. ARCHITECTURE OF ViPS

The ViPS architecture is being developed as a major project at the Faculty of Mathematics and Informatics of the University of Plovdiv. It has been developed as a Cyber-Physical-Social Systems (CPSS) ecosystem (Sheth, 2013). The CPSS integrates various data originating from physical, cybernetic and social spaces through synthesis techniques to provide human-readable abstractions and conclusions. In this aspect the architecture has the following basic elements (Figure 1):

- Personal Assistants (PAs) – they operate as rational BDI agents and all their mental states are represented by events. They present the users in the space.
- The Ecosystem provides opportunities for the virtualization of real "things" taking into account the time, space and events. In this way, it is essential to propose appropriate formalisms for the presentation and work with the temporal, spatial, and event aspects of the things of interest.
- Operative Assistants (OAs), also implemented as rational BDI agents. OAs interact closely with services or micro-services to deliver the business functionality provided in the space.
- The last aspect concerns the integration between the virtual world and the physical world. We prefer to do this through a transparent intelligent layer of intelligent agents known as guards. The guards perform the data transfer from the physical world to the virtual space as well as information in the opposite direction from the virtual to the physical world. The IoT Nodes are configurations that typically include various types of sensors, controllers, and actuators located in dynamically constructed architectural layers. The communication between a guard and IoT Nodes is usually performed through the Internet and free personal network technology.

Two subspaces are presented in the architecture:

- Analytical Subspace – aiming to provide opportunities for time, space and events to work in a formal way;
- Digital Libraries Subspace – the aim of this subspace is to contain all the resources that are used by different OAs and PAs. According to the structure of the ViPS, the digital library subspace consists of two

elements – the Ontology Network (OntoNet) and the Domain Libraries (DoL). The OntoNet element comprises different ontologies in different domains. It is structured as a hierarchy of ontologies. The Domain Libraries are different resources, for example data bases, learning objects, and others.

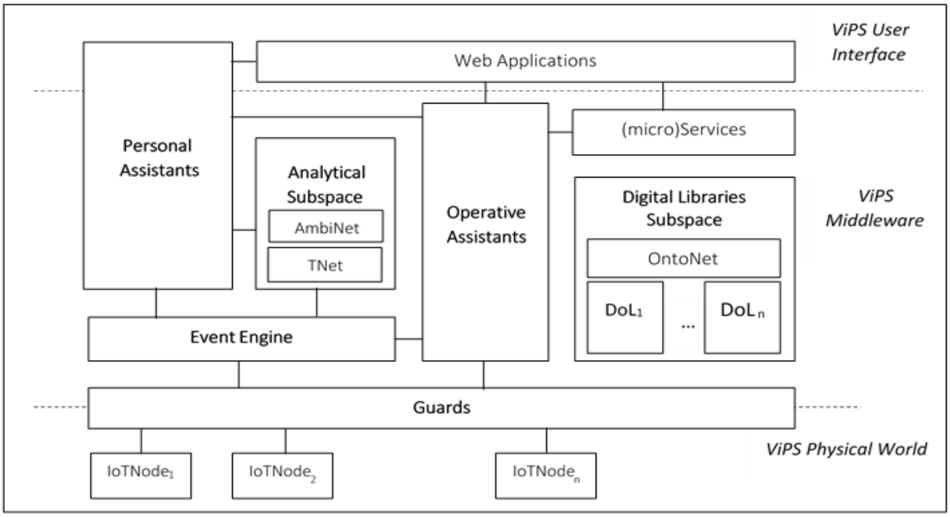

Figure 1. ViPS architecture
Source: Own work

The proposed ViPS architecture is also successfully applied in e-learning. A personal assistant for students named LISSA (Todorov, 2016) was developed, as well as specialized personal assistants for specific services in ViPS. The digital library has specialized resources such as test questions, SCORM-based learning content, and ontologies used by personal assistants or operational assistants to provide a variety of training services.

3. TEST GENERATION ENVIRONMENT

The automated test generation environment is intended for use in software engineering education. Its main task is to generate a test, to enable users to answer the questions and evaluate them by using a UML ontology (Unified Modelling Language).

The tests that are provided by the environment are made up of short answer questions, all of which are different. The functionality of the test environment is shown step by step in Figure 2, using an activity diagram. When the work of the environment starts, a test begins. Then the first question is generated and displayed for the user. The student has a limited time to answer each question, that is why when a question is displayed, a timer starts. It counts down the remaining time until the next question. The user has to type in his/her answer before the time is up. The question check is performed when the test-taker switches to the next question or when the time is up. When the answering of a question is completed, the system checks if that is the last one. If it is not the final question, a new one is generated and the whole procedure is repeated. When the answer of the last question is checked, the results are presented to the user to review the number of his/her correct and wrong answers. In addition, the questions with the wrong answers are displayed, so that students can analyse their knowledge and catch up on missed information. Figure 3 presents the graphical user interface of the environment with two types of questions – short answer questions and multiple choice ones.

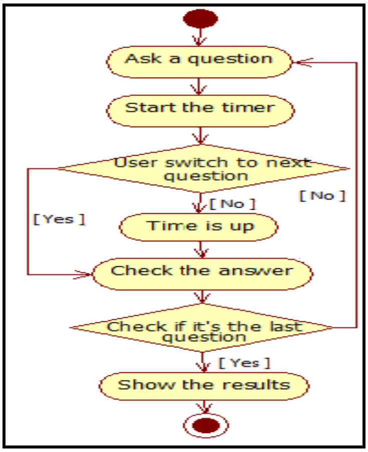

Figure 2. Activity diagram of the test environment functionality
Source: Own work

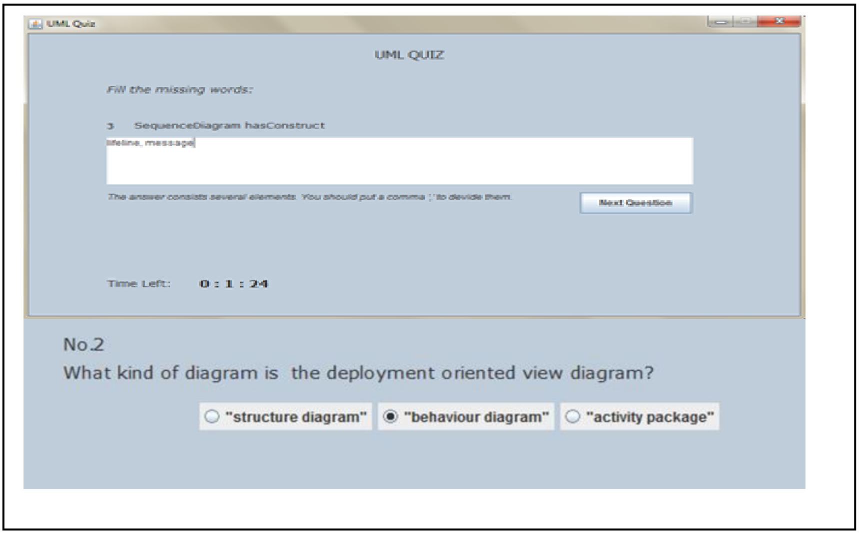

Figure 3. GUI of the Test Generation Environment
Source: Own work

3.1 Test Environment Architecture

The architecture of the environment consists of two components:

- Front-end component – a Graphical User Interface (GUI), which users use for communicating with the environment to do the UML test;
- Back-end component – Intelligent Agents (IA), which generate the tests, check the user's answers and analyse the results.

The intelligent agents, developed in the architecture of the test environment, are Operative Assistants in the architecture of ViPS. Figure 4 presents the architecture of the Test Environment. It is developed as a multi-agent system. The main components in its architecture are two OAs – a knowledge base and a database.

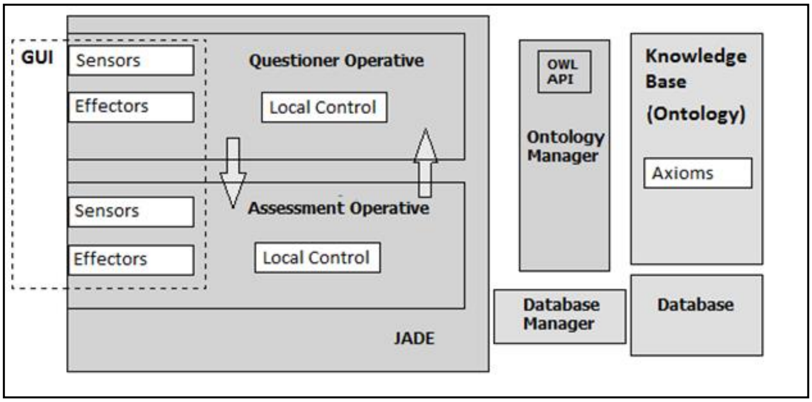

Figure 4. Architecture of the Test Environment
Source: Own work

The two operative assistants are the Question Operative (QO) and the Assessment Operative (AsO). Each of them has its own specific tasks, but their architecture is identical. They are realized as JADE agents (JADE), which process structured educational content (ontologies). Both agents are used by operatives to interact with their environment. They share a database, a knowledge base, and a graphical interface, and have their sensors and effectors, through which they access the Graphical User Interface (GUI). The sensors capture the environmental changes necessary for the agents' work. In case of changes, these are all external ones occurring in the graphical interface, caused by the actions of the user. The effectors aim to influence the environment and make changes in it. Each operative has its own local control, which is responsible for the coordination of the sensors and the effectors, as well as for its basic functions. It determines which effector/ behaviour is to be performed based on the available information received from the sensors or extracted from the knowledge base or the database.

The QO is the operative that generates the entire test. It forms the questions on a particular topic using an ontology. Through its sensors, it determines the start and end of the test and moves to the next question. The QO effectors are responsible for the presentation of the generated test questions and other information to the user. The most important behaviour of this agent is the Question Generator. It is a specific algorithm for the generation of test questions such as using axioms from an ontology. The role of the AsO is to check the users’ responses to the questions and keep the information about them during the test. The operative has several behaviours that process, analyse, and evaluate the users' responses by using an ontology again. The agent's basic behaviours for these functionalities are the Answer Processor and the Assessment Service. The main theoretical model for generating questions and assessing them is presented in (Stancheva, 2017).

In addition to their specific functionalities, in order to perform and coordinate their tasks, the operatives have to communicate with each other during the test. This communication is realized in accordance with the FIPA standard. The QO and the AsO use asynchronous messages to communicate, when needed. The QO sends an informative message to the AsO, when the generation of the current test question is completed. In this way the AsO receives the needed information in order to check the answers of this question in the ontology. When the test is completed, the QO sends a request message to the AsO to obtain the results of the test when they are available. In response, the AsO sends the results and the necessary information to the QO.

An Ontology Manager Entity (OME) has been implemented to establish the connection between the operational assistants and the ontology in the knowledge base. Its function is to act as an interface between the agents and an ontology. It provides services that agents use when they need knowledge from an ontology. This includes loading one or more ontologies, extracting knowledge by predefined criteria, or confirming the authenticity of knowledge. The OME is implemented as a Java class that uses the OWL API as a library for accessing the OWL ontologies.

The database in the Test Generation Environment architecture is realized as a relational one. It stores data on test subjects and their results. A database manager (Database Manager) is implemented to access the database, used by the OAs to access, retrieve, and record data.

3.2 Knowledge Base of the Test Environment

The knowledge base of the test generating environment is an ontology developed for the syntax of the Unified Modelling Language. The main purpose of creating an ontology is to be used by the Operational Assistants QA and AsO to generate questions and evaluate them.

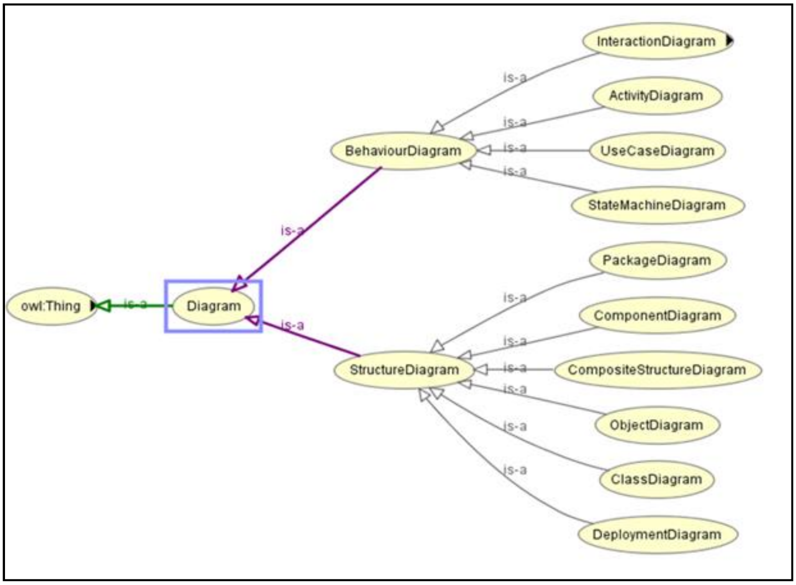

Figure 5. UML Ontology
Source: Own work

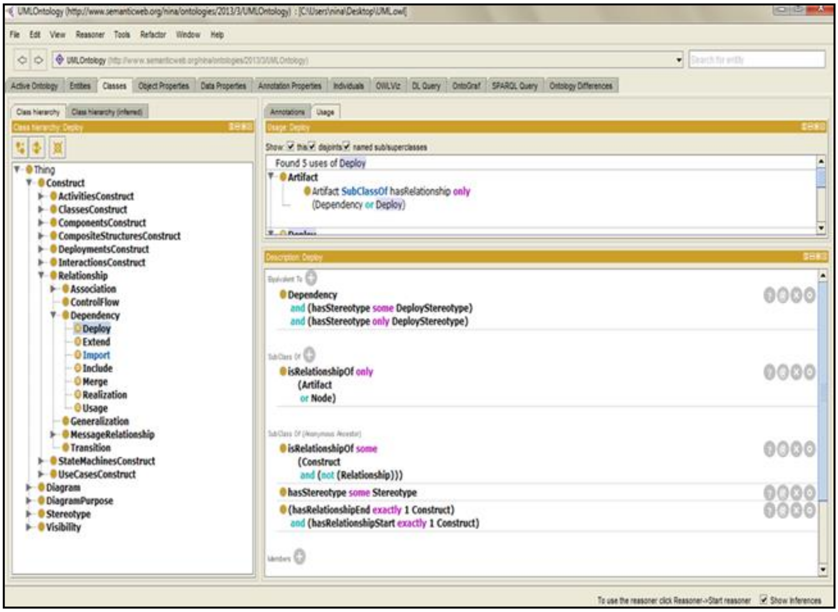

Figure 6. Dependencies for the Deploy class in a UML Ontology
Source: Own work

In the ontology, knowledge is presented about all the diagrams and elements that build UML. The concepts are described through a hierarchy of classes that are related to each other by property ("object property" or "data property").

In this way axioms are formed, which represent assertions about the UML language. Thus, information is stored not only symbolically, but also semantically, so it can be used not only as text for processing and visualization. We have concepts related to the meaning, which allow us to make conclusions about the truth of statements in the field. In Figure 5 there are shown some of the main classes in a UML ontology.

Each class of a UML ontology has its restrictions. They represent its relation to other classes or individuals through its properties. Thus, each class is semantically defined. Each subclass inherits all the restrictions of its super classes. Restrictions form anonymous (unnamed) classes in an ontology, which makes an ontology even richer and enables it to draw logical conclusions about individual concepts. Figure 6 shows the restrictions for the Deploy class.

The restrictions, created for the UML classes, belong to one of the following types: existential, universal, or cardinal. Existential restrictions ("some" or “some values from”) represent a relation through a property with at least one class. Universal restrictions ("only", "all values from") limit the relationship by a given property to be of a specified class only. Cardinal restrictions represent the number of connections.

Our ontology contains over 850 axioms so that it provides a variety of questions, which can be presented by the Test Environment.

4. TOURIST GUIDE

The Tourist Guide (TG) is intended to generate routes related to cultural and historical sites in accordance with the location and wishes of the users. The generated routes can be used for learning in different areas – history, geography, etc., in which case they can be called lessons.

The TG is realized as a specialized personal assistant in ViPS (Glushkova, 2018). To accomplish its main task, it uses the Cultural and Historical Heritage Ontology Network (CHH-OntoNet), which is a part of OntoNet in ViPS. The CHH-OntoNet contains a hierarchy of ontologies presenting different cultural, historical, and natural sites. The structure of ontologies is done according to the CCO standard (CCO). All new objects that are added to CHH-OntoNet comply with the standard. A major priority in the selection of cultural and historical sites for inclusion in CHH-OntoNet is that they are unique to Bulgaria. That is why we have chosen Bulgarian folklore for the first area and in particular Bulgarian Folklore Customs. We are currently working on more unique sites for Bulgaria such as Old Houses, Dialects in Bulgaria, and others.

The life cycle of the TG consists of the following steps:

- *User Questionnaire* – the TG interviews the user about his/ her interests. To conduct the questionnaire, all the questions asked are derived from the ontologies according to each user's responses;
- *Select Route Objects* – After the questionnaire, the TG determines which are the objects of interest to the user;
- *Route Generation* – the TG generates a virtual and a real route, and the user can choose from the two options.

The Tourist Guide is realized as a multi-agent system consisting of three operational assistants and one personal assistant. The operative assistants perform the tasks of user interviewing, generating routes, and retrieving information about cultural and historical sites from the ontologies. The personal assistant is responsible for presenting the information to the user.

4.1 CHH-OntoNet

The CHH-OntoNet consists of ten ontologies, nine of which describe a certain part of the cultural and historical heritage of Bulgaria: Subjects, FolkloreRegions, Costumes, Agents, Objects, Locations, Materials, Museums, and Expositions. These ontologies, as well as their knowledge, are structured in a way that meets the requirements of the CCO standard. There are ontologies corresponding to the dictionaries, defined in the standard, and others in line with the specific objects that are described.

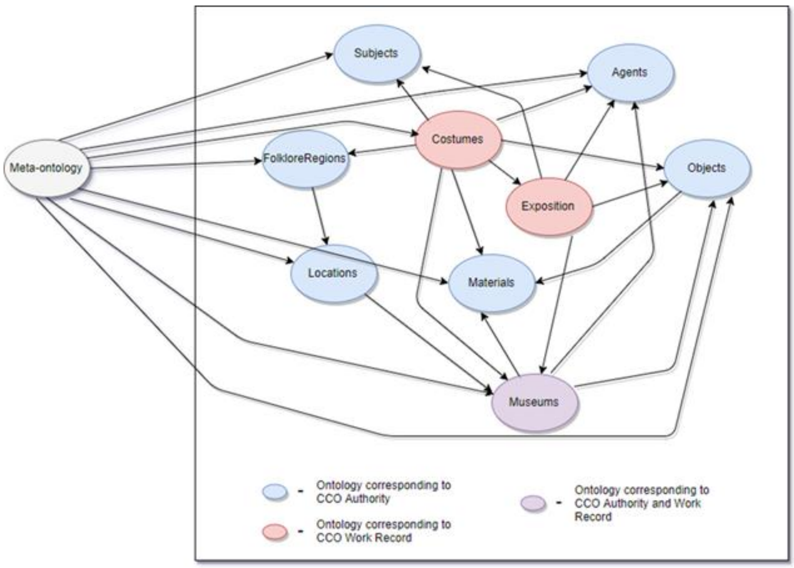

Figure 7. Ontologies in CHH-Onto-Net
Source: Own work

The distribution of knowledge in particular ontologies is very important. On the one hand, it is easy and convenient to compare the knowledge to the requirements of a standard. On the other hand, the separation of the domain of the cultural and historical heritage of Bulgaria into separate sub-domains allows effective, distributed maintenance and editing of the ontologies and knowledge in them. Separate ontologies can be upgraded and changed without influencing the others. Also, the addition of knowledge and new ontologies related to new objects is simple and it does not require to make changes to the structure of the others.

The objects of the cultural and historical heritage, such as traditional Bulgarian costumes, are usually placed in different expositions. At the same time, these expositions are located in specialized museums. This is a precondition for the development of additional ontologies containing knowledge about the expositions and museums.

In Figure 7 can be seen all the ontologies that have been created so far, as well as the relations between the knowledge in them. Each of the presented ontologies uses knowledge from other ontologies to describe some of the concepts. In this way, a network of interconnected concepts is created in separate ontologies. For example, Costumes in the Costume Ontology uses Objects (includes concepts such as types of clothing and their basic features), Materials (materials used in the manufacture of traditional costumes), and others.

The Meta-ontology is the only ontology that does not contain knowledge about the cultural and historical heritage of Bulgaria. It describes additional knowledge related to the other ontologies. This knowledge is used as a distributor by the operational agents to determine where and what to look for when they are creating a survey.

CONCLUSION

The development of ontologies in e-learning takes on an increasing role in the education process. The created ontologies provide great opportunities for facilitating the teachers' work, customizing learning resources, making it easier to search and organize the learning content, and automating student testing in a given area.

The article presents applications for presenting learning content in an interesting way, in the form of cultural and historical routes using the CHH-OntoNet, and for assessing students' knowledge by automatically generated and checked questions from a UML ontology. Both tools consist of a knowledge base in the form of ontologies developed with Protégé OWL (Protégé) and intelligent assistants developed as JADE agents.

Another operative assistant that is developed in the ViPS environment is intended to generate the structure of the learning content in the subject of software engineering according to specific criteria of the lecturer. For its purposes, it uses the Software Engineering Ontology that is located in the Digital Library of ViPS. The main idea is to link this ontology to the existing learning objects (SCO elements, pdf materials, lectures, etc.) in the Digital Library and the created structure of content to be filled with specific content.

As of today, the prototype of the Test Generation Environment has been used in a Master’s degree program in Software Engineering at Plovdiv University with a small group of students. During their course of study, they used the Test Generation Environment for self-training in UML. At the course completion, the learners provided valuable feedback, expressing an opinion that the test environment was convenient to use, it helped them to prepare for the exam, but they would prefer to have a user interface in Bulgarian. That would be possible if we translated the UML ontology into Bulgarian; however, for the time being, we have developed it only in English. Last but not least, the students declared that the generated questions were not repeated. This is because the ontology is rich – it contains over 800 axioms, and test environment has a profile for each student that has used it. As far as the Tourist Guide prototype is concerned, it has not yet been experimented with in class, because we are still working on the CHH-OntoNet. The development of the cultural and historical heritage ontologies is a time-consuming process, which requires collaborative work of more people competent in this field.

New ontologies will be developed in the future to be used in eLearning in ViPS. In addition to ontologies for presenting a specific domain and for presenting tasks, we are considering the development of ontologies that will help to customize the electronic content.

Acknowledgements

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