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APPLICATION OF ONTOLOGIES AND DIGITAL LIBRARIES IN SCHOOL EDUCATION

M. T. Grancharova-Hristova^{1,2}, N. S. Moraliyska³, K. N. Rusev¹, V. A. Ivanova¹, V. V. Tabakova-Komsalova¹ ✉

¹ University of Plovdiv "Paisii Hilendarski", Plovdiv, Bulgaria

² Humanities High School "St. St. Cyril and Methodius", Plovdiv, Bulgaria

³ Institute of Information and Communication Technologies — BAS, Sofia, Bulgaria

✉ v.komsalova@uni-plovdiv.bg

Abstract

The article discusses the application of digital libraries, including a network of ontologies and structured databases, in the education of students in secondary schools. The multi-agent platform of VES (the Virtual Educational Space) is presented, based on the reference architecture of ViPS (the Virtual Physical Space), which is being developed in the DeLC (the Distributed e-Learning Center) laboratory of the University of Plovdiv "Paisii Hilendarski". The information and data in VES are supported by a hybrid structure of ontologies and databases, as the designed services are supported by intelligent agents and personal assistants. Through the interaction between these intelligent components, some functionalities are modeled such as conducting virtual excursions in the teaching of various school subjects, automatic generation of tests and surveys, development of project tasks, game-based training, etc.

Keywords: Virtual Physical Space (ViPS), artificial intelligence, ontology, personal assistant.

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ПРИМЕНЕНИЕ ОНТОЛОГИЙ И ЦИФРОВЫХ БИБЛИОТЕК В ШКОЛЬНОМ ОБРАЗОВАНИИ

М. Т. Гранчарова-Христова^{1,2}, Н. С. Моралийска³, К. Н. Русев¹, В. А. Иванова¹, В. В. Табакова-Комсалова¹ ✉

¹ Пловдивский университет «Паисий Хилендарский», г. Пловдив, Болгария

² Гуманитарная средняя школа «Святые Кирилл и Мефодий», г. Пловдив, Болгария

³ Институт информационных и коммуникационных технологий Болгарской академии наук, г. София, Болгария

✉ v.komsalova@uni-plovdiv.bg

Аннотация

В статье обсуждается применение электронных библиотек, включая сеть онтологий и структурированных баз данных, в обучении учащихся средних школ. Представлена мультиагентная платформа VES (Virtual Education Space — виртуальное образовательное пространство), основанная на эталонной архитектуре ViPS (Virtual Physical Space — виртуальное физическое пространство), которая разрабатывается в лаборатории DeLC (Distributed e-Learning Center — Центр распределенного электронного обучения) Пловдивского университета «Паисий Хилендарский». Информация и данные в VES поддерживаются гибридной структурой онтологий и баз данных, поскольку разработанные сервисы поддерживаются интеллектуальными агентами и персональными помощниками. Посредством взаимодействия между этими интеллектуальными компонентами моделируются такие функции, как проведение виртуальных экскурсий по преподаванию различных школьных предметов, автоматическая генерация тестов и обзоров, разработка проектных задач, игровое обучение и др.

Ключевые слова: виртуальное физическое пространство, ViPS, искусственный интеллект, онтология, персональный помощник.

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1. Introduction

In the era of digitalization and the Fourth Industrial Revolution, education is facing new requirements related to the application of artificial intelligence. Various intelligent educational environments and tools are created and introduced in schools. The specialized literature [1] discusses various aspects of the application of AI in the educational process such as automation of assessment, adapting the educational software to the personal characteristics of students, learning through experimentation, inclusive education, project training, etc. Each of these aspects is related to the provision of personalization, interactivity, contextual dependence and adaptability. Attempts in this direction are being made in many countries around the world. We also have experience with the application of such educational environments, which provide services for testing students' knowledge, personal support and inclusive education, analysis and evaluation of various courses, etc. The use of multi-agent platforms (such as the one presented in [2]) ensures adaptability, interactivity, and personalization of the learning process.

In recent years, the team from the DeLC laboratory at Plovdiv University has been developing a reference architecture of the Virtual Physical Space (ViPS) [3], which can be adapted to different subject areas — tourism, smart agriculture, “smart” cities, and education [4]. Each new ViPS adaptation expands the functionality and adds information and knowledge to the digital libraries of the space. The adaptation in the field of e-learning is called the Virtual Education Space (VES) [5]. This information is organized in different structures — databases and ontologies. The purpose of the article is to present an approach to the use of this information in the education of students both in the classroom and in different interest clubs.

2. The Virtual Education Space (VES): structuring of knowledge

VES is a Cyber-Physical-Social Space (CPSS). It is developed as a multi-agent system, whose functionalities are realized through the interaction of personal operational specialist assistants and guards. Two subspaces are included in the software architecture of VES (Figure 1):

- The Analytical Subspace (AS), which takes care of the virtualization of the objects from the physical space and the analysis and processing of the dynamically incoming information.
- The Digital Library Subspace (DLS), which stores the necessary information related to the specific application or context.

Let us now look at the second subspace. The information in DLS is organized, integrated, and managed through the use of various metadata standards [6]. One of the main components of this subspace is the ontological hierarchy (OntoNet), in which the knowledge of the described subject area is stored. According to the purpose of the ontology and the subject area under consideration, the created ontologies can be organized in hierarchies, which allows them to be semantically connected (Figure 2).

Ontologies are a kind of semantic representation of knowledge and are very suitable for the development of such systems; however, the development process is time-consuming and too slow, which delays the work on the creation and use of the system. This has motivated us to use the existing databases, which store a huge amount of information about various historical, geographical, and natural landmarks in our country and which are part of the work of our team on the BECC and BULCHINO projects [7]. Another issue for the agents that have to process the information is that the databases have a different structure. To solve this problem, we have created a unified structure of a common database that meets the

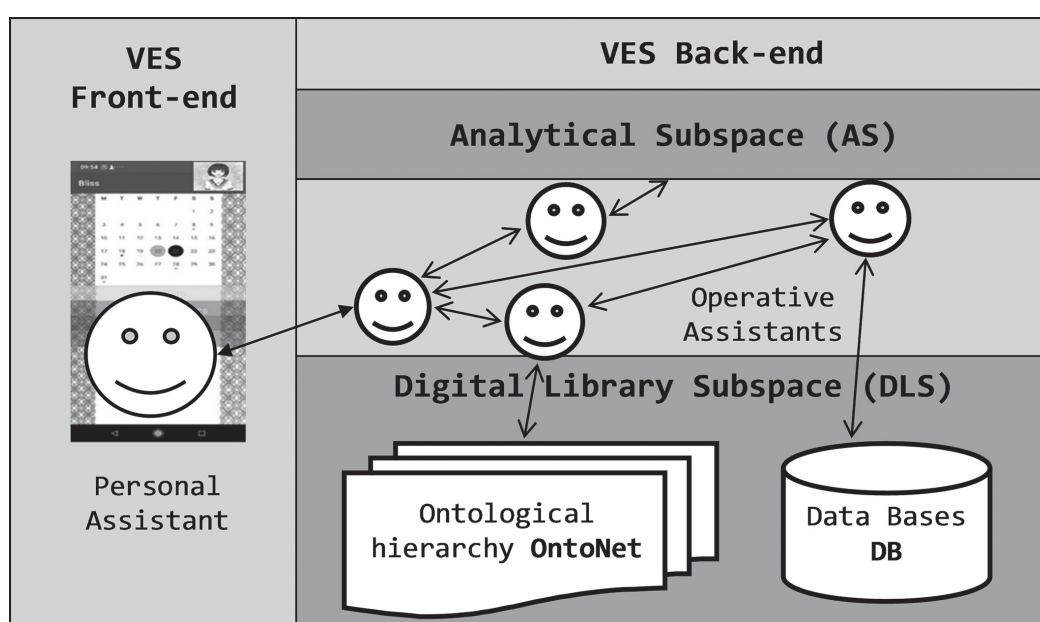


Fig. 1. The general architecture of VES

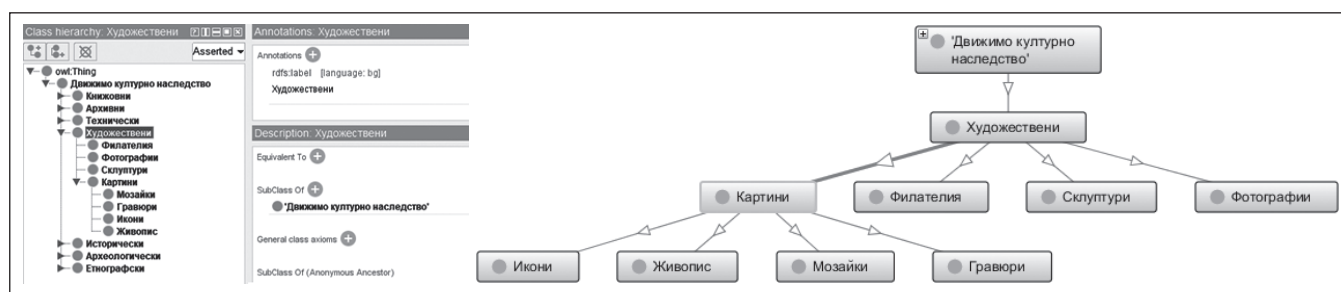


Fig. 2. Structuring an ontologies hierarchy for the cultural, historical, and natural heritage of Bulgaria in OntoNet

requirements of the standard for the presentation of cultural and historical sites CCO*. Using separate scripts for each database, we transferred the existing information to the unified database. The script for transferring data for icons and painters is presented in Figure 3.

Through this approach, knowledge from different fields of application and academic disciplines can be structured in the Subspace of the DLS digital libraries such as history, geography, biology, literature, etc. We will look at some possibilities for applying this knowledge in high school education.

* CCO — Cataloging of Cultural Objects. http://personal.sirma.bg/vladimir/cco/Cataloging_Cultural_Objects.pdf

3. Application of virtual excursions in school education

3.1. Virtual excursions

Virtual excursions take place in the compulsory, elective, and optional classes, especially in the subjects of literature, philosophy, history and civilization, geography, and biology. They are relevant and applicable in the modern Bulgarian school. This method of work increases the motivation of students to search, find, and present information. In this way, their horizons are broadened and research interest is generated.

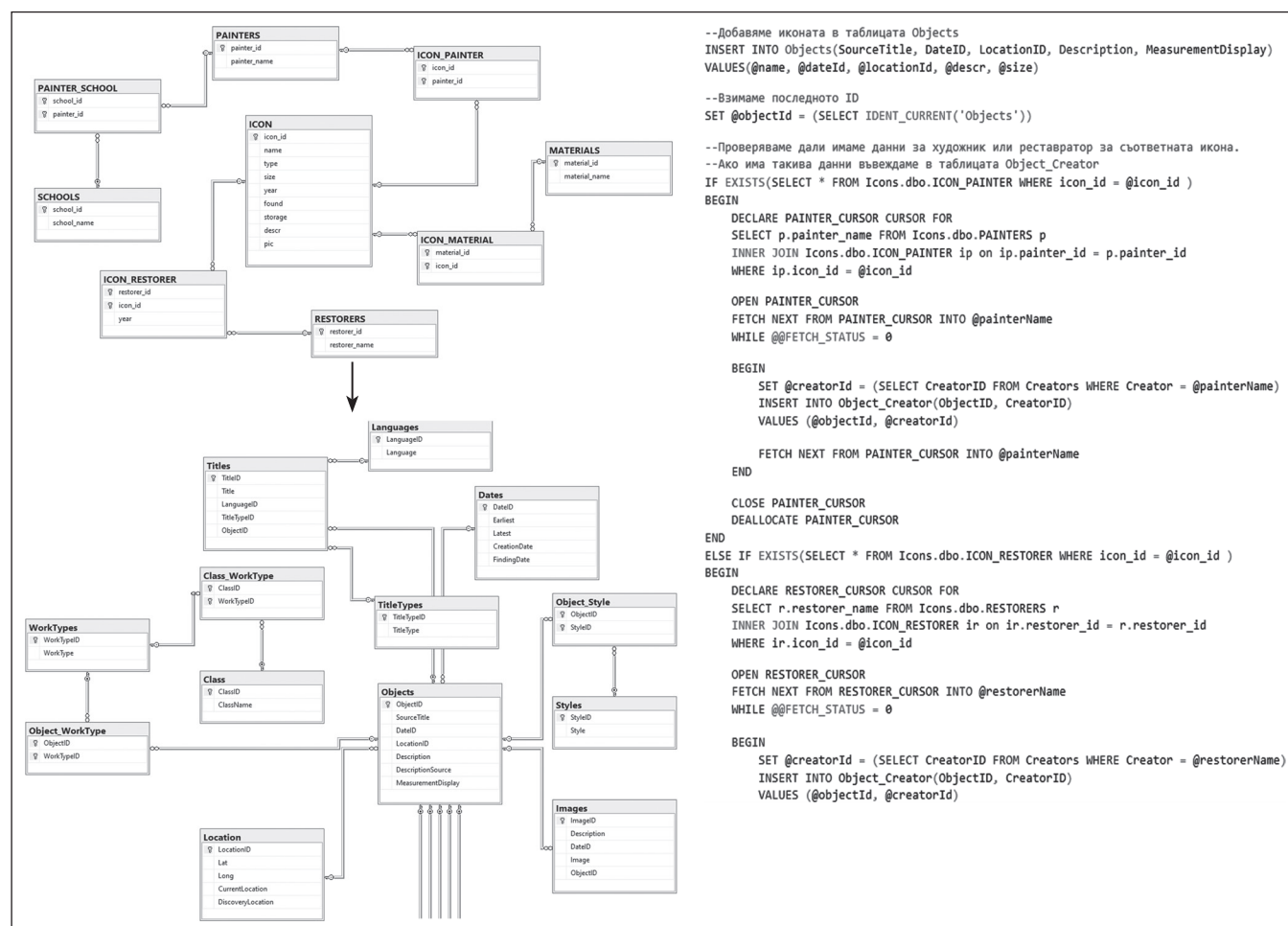


Fig. 3. Transfer of information to the unified database in DLS

The main goal is to generate virtual routes following the particular didactic goals. To provide knowledge about the specific cultural, historical, and natural sites of the ontological network, some specialized agents in the multi-agent environment of VES are used, such as:

- QGA (a Questionnaire Generation Assistant) — an operative assistant that communicates with the user's PA and collects his/her requirements by using the OntoNet meta-ontology.
- KGA (a Knowledge Generation Agent). After receiving the student's requirements, it retrieves the information from the OntoNet ontological network about the objects of interest to the user.
- RGA (a Route Generation Agent) — this assistant is responsible for creating the virtual route; it uses the capabilities of the Analytical Subspace.
- DBA (a Database Agent) — this assistant retrieves and processes information from the unified database. It receives the request from the KGA and transmits the processed information to the RGA for route generation.
- PA (a Personal Assistant) — this is the student's personal assistant that serves to communicate with the student.

At this time, there are various ontologies in the ontological network related to the teaching of history — for example, related to folk costumes, revival houses, writers and famous people, and others. On the other hand, we have rich information in the unified database about various cultural and historical sites such as artists, monasteries, icons, Thracian treasures, lakes, caves, natural landmarks, and many more. The creation of virtual routes is part of the work on the development of a context-sensitive tourist guide, presented in [8].

The process of organizing virtual study tours is realized through the following scenario:

- The student defines his/her goals, tasks, and desires for the virtual tour in a dialogue with his/her personal assistant (PA).
- The PA communicates with VES and conducts a dialogue with the specialist assistant QGA that organizes a survey with questions to clarify the student's desire. This functionality is realized by dynamically retrieving information from OntoNet.
- After clarifying the student's wishes, the request is transferred to the KGA agent that searches for information in the meta-ontology first.
- If it finds an ontology on the topic, it extracts the knowledge from this ontology and transmits the result to the RGA agent.
- If it is found that there is no suitable ontology but there is information about a relevant database in OntoNet, the request is forwarded to the DBA specialist assistant, which retrieves the information from the unified database and transmits the structured information to the RGA.
- After this, the RGA receives the information from the database or the respective ontology, generates the virtual excursion, and transmits it to the student's PA.

To model this scenario, we use CCA (Calculus of Context-aware Ambients) [9], which is based on ambient-oriented modeling [10]. In the formal semantics of CCA, ambients are defined as identities that are used to describe an object or component — a process, device, location, etc. Each ambient has a name and a location. There are three possible relationships between any two ambients (parent, child, and sibling). Ambients can exchange messages with each other. Since the CCA notation contains symbols that cannot be directly interpreted, a special ccaPL language has been developed, which is a computer-recognizable version of the CCA syntax [11]. The program code is written in a plain text editor, which requires a very good knowledge of the CCA notation. This greatly complicates the process of programming test scenarios. Therefore, we decided to develop a specialized visual editor CCA Editor through which to implement the simulation, testing, and verification of the described scenarios for the implementation of various services in the VES educational space.

3.2. Generation of tests and surveys

The information stored in the DLS can be used to dynamically generate test questions and surveys. An intelligent environment has been created in VES, the task of which is to conduct surveys or to check the knowledge of students using the ontologies in OntoNet. This includes automatically generating test questions and evaluating student responses. From a user's point of view, the system is a test system that asks a certain number of questions sequentially, giving each question a specific answer time. The answer to each question is checked immediately after receiving it in the system. Immediately after completing the test, the results are provided to the student and the teacher.

In the developed prototype environment, an opportunity to generate different types of questions is provided. They comply with the IMS Question and Test Interoperability Specification (QTI) standard, differing in the way they are set and their answer options:

- Open questions;
- Missing words;
- True/false;
- Closed questions with one correct answer;
- Closed questions with several correct answers;
- Essay-type text questions.

The IMS QTI specification defines a standard format for presenting the content of questions and assessment results, ensuring interoperability and interoperability between different training-related systems. The results of testing the model are presented in [12], and the prototype of the test system — in [13].

3.3. Project work, game-based training

The information stored in the ontologies and databases allows for its use in the project activity and the game-based training in the classical forms, the interest clubs, the extracurricular work, and in the STEM centers.

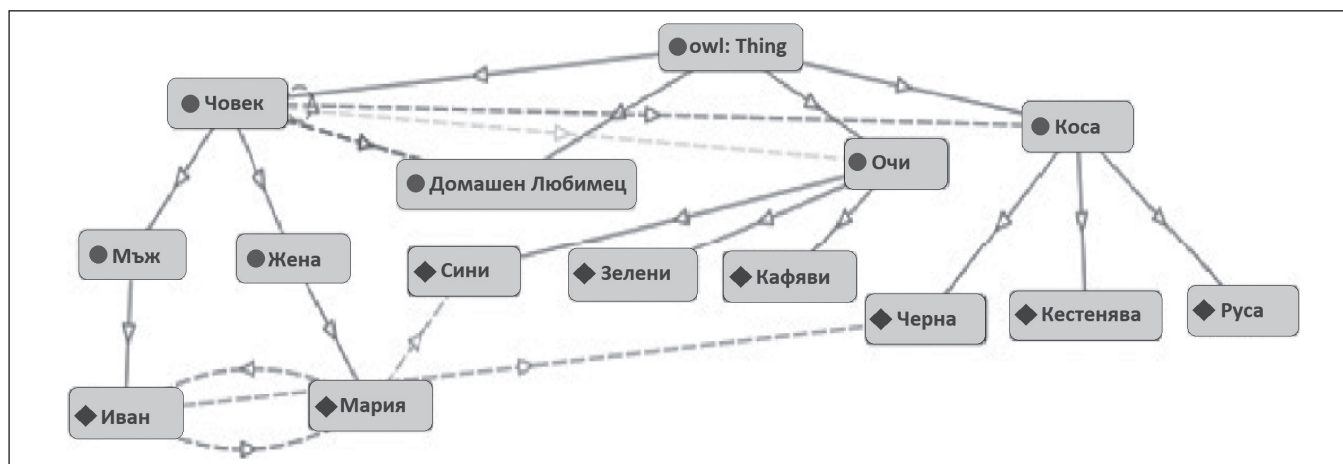


Fig. 4. The simple ontograph

In these classes, well-chosen tasks can significantly reduce the abstractness of the learning content and increase the interest in it. Various project assignments can be considered in the interest clubs in the STEM centers. We will present an example project assignment for creating an ontology related to biology. The information in the ontology can be presented in a very simple way. It comes down to compiling affirmations, which consist of a subject, a predicate, and an object. The construction of these three elements is called a triplet. The set of triplets represents the logic in the ontology. To acquaint students with the essence of ontology, the following project task can be used, which can be considered in a club of interests. “Maria is 16 years old. She has blue eyes. Maria has a classmate Ivan. He is black-haired. There is a pet dog. The dog is a Pinscher”.

In the specific example, the triplets are composed — “Maria is blue-eyed”, “Maria is 16 years old”, “Maria is Ivan’s classmate”. In them, “Maria” is a subject, while “the blue-eyed”, “16”, and “Ivan” are objects. In the triplets — “Ivan has black hair color”, “Ivan has a pet dog”, “Ivan is a classmate of Maria”, “Ivan” is the subject; “a dog”, “black”, and “Maria” are objects. The object properties are — “has hair color”, “has a pet”, “is a breed”, and “is a classmate”. The property “is a classmate” is symmetrical because just as Ivan is a classmate of Maria, Maria is a classmate of Ivan, i. e. Ivan and Maria are associated with the same property. The instances in the ontologies are specific objects of a given class; here, Maria and Ivan are introduced as such. In the example under consideration, “Pet” is a class, and “Dog” is a subclass of “Pet”. The breeds Pinscher and Doberman were introduced as individuals in the “Dog” class. Maria’s age is represented using a primitive data type — the integer 16.

This analysis can be described in the form of an ontology in the Protg program. It creates classes and properties and introduces individuals. Class is an abstract concept and can be both a subject and an object. Predicates are the properties that connect the object to the subject. They can be an object and data. Object

properties have a domain and a rank. Individuals must meet certain conditions to be part of a class. Based on the information entered in the ontology, an ontograph can be made, which shows the connections between the classes and the individuals (Figure 4).

The use of game-based training has proven its effectiveness as a didactic technology that increases the activity and motivation of all students and, in particular, students with specific educational needs. The Multi-Agent Testing Environment (MATE) was created as a separate module in VES to support game-based training. A key feature of MATE is the combination of a passive virtual environment with active components implemented as intelligent agents [14].

The information available in digital libraries allows for the creation of various games such as the “Question Game”. This type of game is based on the technology described above to generate questions using the knowledge in the ontologies and capabilities of the multi-agent system. The personal assistant PA can be used for personalization, which, after communication with the student, passes the selected subject area (such as history, literature, geography, biology) to the specialist assistant QGA (Question Generation Agent). It searches for the appropriate information and, through the use of various templates, generates a question, which it transmits to the personal assistant together with the correct answer and several other distractors. After receiving the student’s answer, the system generates a result and continues with the next question.

4. Conclusion

The application of information and knowledge from ontologies and digital libraries in school provides an opportunity to increase the interactivity, activity, motivation, and efficiency of the learning process. The adaptation of VES to the learning conditions in the classroom as well as extracurricular forms and interest clubs provides an opportunity to expand the possibilities of the learning environment, personalize

the learning and take into account the individual characteristics of each student. Project and game-based learning is an approach that allows for more in-depth mastery of basic ideas, concepts, and presentation of knowledge through rules and it also helps to increase student activity.

References

1. Guan C., Mou J., Jiang Z. AI innovation in education: A twenty-year data-driven historical analysis, *International Journal of Innovation Studies*. 2020;4(4):134–147. DOI: 10.1016/j.ijis.2020.09.001
2. Krasteva I. K., Glushkova T. A., Stoyanov S. N. Modeling and development of a multi-agent space for the secondary school. *Informatics and Education*. 2020;35(4):53–62. DOI: 10.32517/0234-0453-2020-35-4-53-62
3. Stoyanov S., Glushkova T., Doychev E., Stoyanova-Doycheva A., Ivanova V. Cyber-physical-social systems and applications. Part I: Reference architecture. LAP LAMBERT Academic Publishing; 2019. 100 p.
4. Stoyanov S., Glushkova T., Stoyanova-Doycheva A., Doychev E. Virtual Physical Space — an architecture supporting internet of things applications. *2018 20th Int. Symp. on Electrical Apparatus and Technologies (SIELA)*. Bourgas, IEEE; 2018. DOI: 10.1109/SIELA.2018.8447156
5. Stoyanov S., Glushkova T. E-learning in a virtual education space. *Proc. 4th Int. Conf. "Informatization of Education and E-learning Methodology: Digital Technologies in Education" (IEELM-DTE 2020)*. Krasnoyarsk, 2020:55–64. Available at: <http://ceur-ws.org/Vol-2770/paper8.pdf>
6. Di Iorio A., Schaerf M. The Organization information integration in the management of a Digital Library System. *IEEE/ACM Joint Conference on Digital Libraries*. London; 2014:461–462/ DOI: 10.1109/JCDL.2014.6970225
7. Govedarova N., Stojanov S., Popchev I. An ontology based CBR architecture for knowledge management in BULCHINO catalogue. *CompSysTech '08: Proc. 9th Int. Conf. on Computer Systems and Technologies and Workshop for PhD Students in Computing*. 2008;67:V.5–1. DOI: 10.1145/1500879.1500953
8. Stoyanova-Doycheva A., Glushkova T., Ivanova V., Doukovska L., Stoyanov S. A multi-agent environment acting as a personal tourist guide. *Book chapter in Studies in Computational Intelligence*. 2020;862:593–611. DOI: 10.1007/978-3-030-35445-9
9. Siewe F., Zedan H., Cau A. The Calculus of Context-Aware Ambients. *Journal of Computer and System Sciences*. 2010;77(4):597–620.
10. Glushkova T., Stoyanov S., Popchev I., Cheresheva S. Ambient-oriented modeling in a virtual education space. *Comptes rendus de l'Academie bulgare des Sciences*. 2018;71(3):398–406. DOI: 10.7546/CRABS.2018.03.13
11. Al-Sammarraie M. H. Policy-based approach for context-aware systems. Software Technology Research Laboratory, De Montfort University, Leicester, UK; 2011. 227 p. Available at: <https://dora.dmu.ac.uk/bitstream/handle/2086/5386/Thesis.pdf?sequence=1&isAllowed=y>
12. Stancheva N., Stoyanova-Doycheva A., Popchev I., Stoyanov S. Automatic generation of test questions by software agents using ontologies. *2016 IEEE 8th International Conference on Intelligent Systems (IS)*. IEEE; 2016:741–746. DOI: 10.1109/IS.2016.7737395
13. Stancheva N., Stoyanova-Doycheva A., Stoyanov S., Popchev I., Ivanova V. An environment for automatic test

generation. *Cybernetics and Information Technologies*. 2017;17(2):183–196. DOI: 10.1515/cait-2017-0025

14. Glushkova T., Petrov A., Stoyanov S. Game-based training and testing through by creation of virtual world. *Education and Technologies*. 2018;9(1):113–118. Available at: http://www.edutechjournal.org/wp-content/uploads/2018/08/1_2018_113-118.pdf

Information about the authors

Maryaia Todorova Grancharova-Hristova, Ph.D. student at the Faculty of Mathematics and Informatics, University of Plovdiv "Paisii Hilendarski"; IT teacher at the Humanities High School "St. St. Cyril and Methodius", Plovdiv, Bulgaria; *ORCID*: <http://orcid.org/0000-0003-4083-4600>; *e-mail*: m.grancharova@ghp-plovdiv.org

Nevena Sevdalinova Moraliyska, Ph.D. student, Institute of Information and Communication Technologies — BAS, Sofia, Bulgaria; *ORCID*: <http://orcid.org/0000-0003-3561-5438>; *e-mail*: nevena.uzunova@gmail.com

Konstantin Nikolaev Rusev, Ph.D. student at the Faculty of Mathematics and Informatics, University of Plovdiv "Paisii Hilendarski", Plovdiv, Bulgaria; *ORCID*: <http://orcid.org/0000-0003-1372-9434>; *e-mail*: k.russeff@uni-plovdiv.bg

Vanya Angelova Ivanova, Ph.D., Chief Assistant Professor at the Department of Education in Mathematics, Informatics and Information Technology, Faculty of Mathematics and Informatics, University of Plovdiv "Paisii Hilendarski", Plovdiv, Bulgaria; *ORCID*: <http://orcid.org/0000-0002-0043-8606>; *e-mail*: vantod@uni-plovdiv.bg

Veneta Veselinova Tabakova-Komsalova, Ph.D., Chief Assistant Professor at the Department of Computer Systems, Faculty of Mathematics and Informatics, University of Plovdiv "Paisii Hilendarski", Plovdiv, Bulgaria; *ORCID*: <http://orcid.org/0000-0002-0617-9844>; *e-mail*: v.komsalova@uni-plovdiv.bg

Информация об авторах

Гранчарова-Христова Мария Тодорова, аспирант факультета математики и информатики, Пловдивский университет «Паисий Хилендарский»; преподаватель информационных технологий, Гуманитарная средняя школа «Святые Кирилл и Мефодий», г. Пловдив, Болгария; *ORCID*: <http://orcid.org/0000-0003-4083-4600>; *e-mail*: m.grancharova@ghp-plovdiv.org

Моралийска Невена Севдалинова, аспирант, Институт информационных и коммуникационных технологий Болгарской академии наук, г. София, Болгария; *ORCID*: <http://orcid.org/0000-0003-3561-5438>; *e-mail*: nevena.uzunova@gmail.com

Русев Константин Николаев, аспирант факультета математики и информатики, Пловдивский университет «Паисий Хилендарский», г. Пловдив, Болгария; *ORCID*: <http://orcid.org/0000-0003-1372-9434>; *e-mail*: k.russeff@uni-plovdiv.bg

Иванова Вана Ангелова, Ph.D., главный ассистент кафедры «Обучение математике, информатике и информационным технологиям», факультет математики и информатики, Пловдивский университет «Паисий Хилендарский», г. Пловдив, Болгария; *ORCID*: <http://orcid.org/0000-0002-0043-8606>; *e-mail*: vantod@abv.bg

Табакова-Комсалова Венета Веселинова, Ph.D., главный ассистент кафедры «Компьютерные системы», факультет математики и информатики, Пловдивский университет «Паисий Хилендарский», г. Пловдив, Болгария; *ORCID*: <http://orcid.org/0000-0002-0617-9844>; *e-mail*: v.komsalova@uni-plovdiv.bg

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