INTERNET OF THINGS ECOSYSTEM SUPPORTING E-LEARNING

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Abstract: *The paper presents the Virtual Education Space (VES) implemented as an Internet of Things (IoT) ecosystem. The basic components of the space are described in more details. Furthermore, the usage of the space is demonstrated for implementing a disabled student scenario. The VES architecture presented in the article allows for integration with different IoT systems to be used for formal and informal learning. In the paper also is present the implementation of intelligent tourist guide that intend to support lifelong learning in Virtual Education Space.*

Keywords: IoT, Cyber-Physical Space, VES, Calculus of Context-aware Ambients (CCA)

INTRODUCTION

The Virtual Education Space (VES) is being developed in the "Distributed eLearning Center (DeLC)" Lab of Plovdiv University "Paisii Hilendarski". The space is a successor of the DeLC e-learning environment providing electronic teaching material and electronic services (Stoyanov, 2012), (Stoyanov, 2010). DeLC supports the internationally accepted standards SCORM 2004 for self-space learning and Question and Test Interoperability - QTI 2.1 for electronic testing. The environment is used to support the educational process at the Faculty of Mathematics and Informatics of Plovdiv University "Paisii Hilendarski".

Although DeLC is a successful project providing effective use of information and communication technologies in education, its significant disadvantage is the lack of suitable integration of its virtual environment with the physical world where the real learning process takes place. Enhancing the environment and transforming it as a cyber-physical space would extend the possibilities of adapting and personalizing of the content and services, especially for disabled people. The new infrastructure known as Virtual Education Space is being built as an Internet of Things (IoT) ecosystem (Stoyanov, 2016), (Stoyanov & al, 2016). VES continues to develop and improve as an e-learning environment and also as an experimental ecosystem for IoT applications.

The VES architecture presented in the article allows for integration with different IOT systems to be used for formal and informal learning. The cultural and historical heritage of Bulgaria is part of the common European cultural tradition and history. For the digital presentation of cultural and historical heritage, the BECC (Bulgarian Electronic Cataloguing Cultural) environment was developed more than ten years ago (Trendafilova, 2007). Cultural and historical objects were presented according the Cataloging Cultural Objects (CCO) standard. The system was updated in connection with the development of an e-learning environment VES. The space provides e-learning services and learning content for blended, self-paced, and lifelong learning. The Lifelong Learning Program provides electronic content on the subject of Cultural and Historical Heritage. According to VES, we develop an intelligent tourist guide that takes into account various factors - the tourist's preferences, location, time available, and the presence and location of cultural and historical objects in the area to propose virtual or real cultural and historical routes. Currently, the guide is being implemented as an IoT application.

This paper presents the architecture of VES as an IoT ecosystem. The rest of the paper is organized as follows. A short review of cyber-physical spaces is considered in Section 1. This is followed by an overall description of the VES architecture in Section 2. Section 3 demonstrates the usage of the space for implementing a disabled student scenario. In Section 4 is present the implementation of intelligent tourist guide as a part of lifelong learning in VES.

1. CYBER-PHYSICAL SPACES

The comprehensive use of the Internet and its gradual transformation into IoT, as well as the globalization of cyberspace, are a prerequisite for the rapid development of Cyber-Physical Spaces (CPS). CPS are engineering systems built and operating by the synergy of computational and physical components. In this sense, physical means elements of the system occupying physical space while cyber refers to the computational and communication components of a system (Bradley & Atkins, 2015). CPS enable the physical world to merge with the virtual world by integrating computational and physical processes and in this way facilitating close integration of computation, communication and control in their operation and interaction with the environment which they are located in (Guo, Yu & Zhou, 2015). CPS are an area of growing scientific and practical interest. Research in this area highlights the need for new models, abstractions, methods and techniques to integrate various components of a system in an intelligent way.

Due to an unprecedented impact of CPS on the way people interact, human and social aspects have to be taken into account. We have reached the point where social and human dynamics become an integral part of the CPS; so inclusion of social dimension is fully justified, i.e. the concept of Cyber-Physical-Social Spaces (CPSS) (Wang, 2010). Moreover, already the concept of Cyber-Physical-Social-Thinking hyper-space (CPST) is already emerging as an expression of the close merging of cyberspace, physical space, social space, and thinking space as the basis for building intelligent worlds (Ning et al., 2015).

Often all these spaces are described as Intelligent Spaces (IS). Building an intelligent space requires considerable effort for system integration. There are also specific issues that are subject to intensive research such as intelligent devices, sensors, and gathering significant data from the physical world; dynamic communication infrastructures connecting spatially distributed devices; system architecture and middleware; understanding of information and interfaces; decision-making and action planning. Intelligent spaces have a wide range of applications - current and potential. For example, they can include robotics, personal assistant with a variety of applications (especially for disabled people), intelligent healthcare, intelligent homes and cities, optimal use and energy saving, intelligent monitoring and environmental control, critical infrastructure protection.

2. ARCHITECTURE OF THE VES

The VES architecture consists of three logical layers (Figure 1.) briefly presented below.

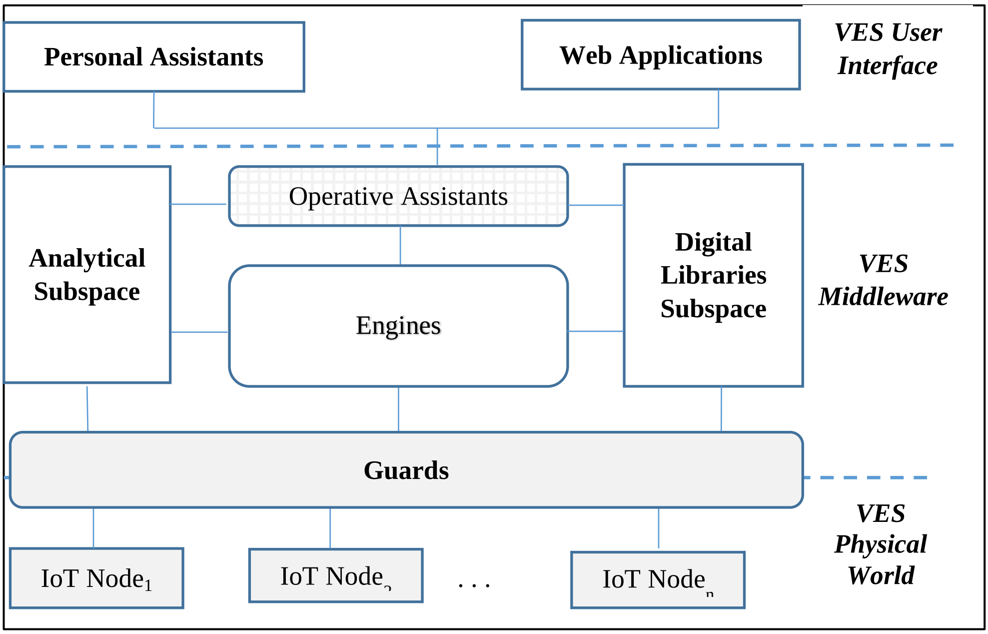

Figure1. Logical Architecture of the Space
Source: Own work

2.1. VES User Interface

Access to information resources and services of the space is basically through *Personal Assistants* (PAs). The main purpose of the PAs is to assist users (in this case students and teachers) in their work with the space; i.e. they act as personalized entry points of VES. The users are provided with their own personal assistant during the first registration in the space. For this purpose, a genetic assistant is maintained that generates a user-specific PA interacting with the education portal and the registration module. A prototype of the PA for students known as LISSA was created in the current version of the VES (Todorov & al., 2017).

Currently, four specialized Web applications operate at this level. DeLC 2.0 is an educational portal providing education services and electronic teaching material to support various kinds of e-learning (blended, self-paced, e-testing, and lifelong). PROJECTS is a site that presents space-related projects. CHH is a specialized project for lifelong learning in the area of cultural and historical heritage using semantic modeling and virtual reality technologies. PUBLICATIONS is a system for scientific publications. The apps interact with the VES middleware by help of operative assistants. PAs and operative assistants are implemented as BDI (Belief–Desire–Intention) rational agents.

2.2. VES Middleware

One of the most interesting (and most complex) components of the ecosystem is the analytical subspace performing two basic functions. The first one is to support modeling of "things" taking into account factors such as events, time, space and location. The Analytical Subspace provides means for the preparation of domain-specific analyses supported by four modeling structures. ONet (Ontologies) is a hierarchy of ontologies to represent the essential features of things. Furthermore, the relationships between the “things” are specified in the ONet. ENet (Events) models various types of events and their arguments (identification, conditions for occurrence and completion) representative of the field of interest. TNet (Temporal) provides an opportunity to present and work with temporal aspects of things, events and locations. In ANet (Ambients), the spatial characteristics of the "things" and events can be modeled as ambients. The work with these structures is supported by specialized interpreters known as Engines, based on the formal specifications Interval Temporal Logics -ITL (Moszkowski, 1998), Calculus of Context-aware Ambients -CCA (Siewe, Zedan & Cau, 2011) and Event Model -EM (Guglev & Doychev, 2017). The second is to provide tools for preparing analyses, statistics, suggestions for improvement of the processes in the specific problem area - in this case the learning process. In the current version, two such tools are developed - a student's book and a teacher’s notebook. The student’s book suggests solutions to improve students' success using appropriate background knowledge and up-to-date information on the learning process; the book saves also the entire history of student’s learning activity. The teacher's notebook collects, summarizes and analyses information about the success of a group of students in a particular discipline. For example, the notebook is able to analyse the learning material personally for each student or for a whole group interacting with the SCORM 2004 Engine (Figure 2). Furthermore, it offers solutions to improve the performance of teaching activities and interacts with the student's books.

Conducting and analysing of the education process are supported by background knowledge saved in the Digital Libraries Subspace (partly satisfying DSpace specification) and by the actual data supplied by the guards. In our case, digital libraries store electronic content, test questions, publications, diploma works, and course projects. A meta-level implemented as interrelated ontologies supports intelligent search and comfortable work with this subspace.

The operative assistants provide access to the resources of both sub-spaces and accomplish interactions with personal assistants and web applications.

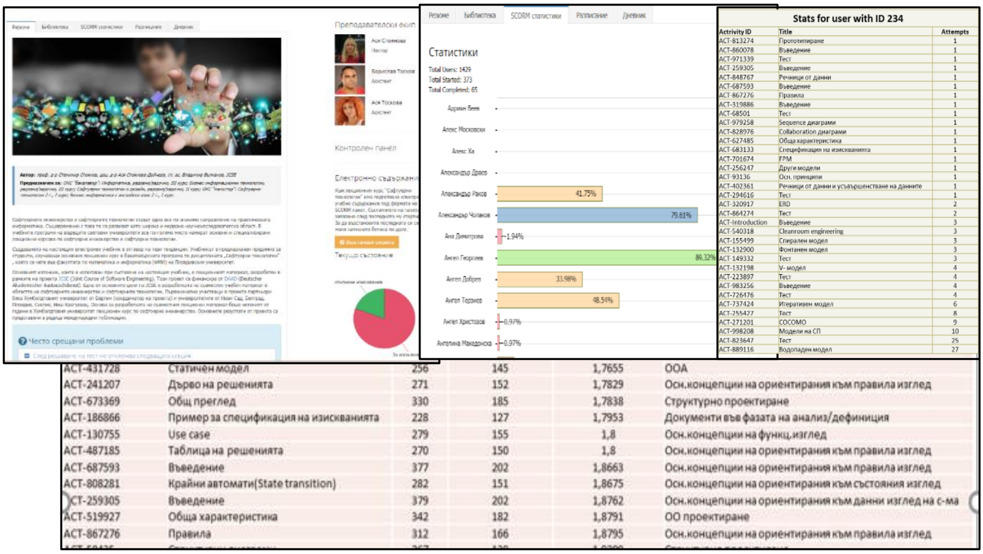

Figure 2. Success rate analyses in one discipline

Source: Own work

2.3. VES Physical World

Guards operate as a smart interface between the virtual and the physical world. They provide data about the state of the physical world transferred to the virtual environment of the space (both sub-spaces). There are multiple IoT Nodes integrated in the architecture of the guards that implement access to sensors and actuators of the "things" located in the physical world. The sensors-actuators' sets are configured in accordance with the application. The communication in the guard system operates as a combination of a personal network (e.g. LoRa) and the Internet.

In addition, the guards identify and localize events that could hinder the normal course of the learning process and react activating sutable emergency scenarios.

3. IMPLEMENTATION OF SAMPLE SCENARIO FOR DISABLED STUDENTS

VES offers a variety of services for all students, such as electronic lectures, e-tests, e-scheduling, etc., but changes in the physical world are especially important for students with disabilities. Therefore, we will look at an example scenario for students with motor problems. The student with mobility disabilities participates in the space with his wheelchair, which provides him/her a specific support environment. Upon entering in the education university zone, the personal assistant PA starts a two-way communication process, providing the student with both standard educational services and some specific ones connected with movement of wheelchair in the campus's physical environment. We will look at a specific service for students with mobility disabilities: ensuring a convenient route for moving the student’s wheelchair to the study hall or lab. The student with movement difficulties is introduced into the system through his smart wheelchair and through his mobile device. We will use CCA formalization to model the service.

3.1. CCA - algebraic semantics of contexts

The Ambient plays a major role in Calculus of Context-aware Ambients modeling. We can treat it as a limited space in which certain actions are carried out. Each Ambient has a name, a boundary, and may contain other ambients in itself, and be included in another ambient. Between two Ambients there are three possible relationships: parent, child and sibling. Each Ambient can communicate with other Ambients around it by sending and receiving messages. The notation "::" is a symbol for sibling Ambients; "↑" and "↓" are symbols for parent and child; "<>" means sending, and "()" - receiving a message. The Ambient can be mobile, i.e., to move within the surrounding space. In the CCA, four syntax categories can be distinguished: processes (P), capabilities (M), locations (α) and context expressions (k).

3.2. CCA modelling of intelligent wheelchair

The wheelchair has a variety of physical sensors that collect information about changing environmental parameters and interact with the modeled virtual educational space. We will consider the wheelchair (and the active area that it creates) as a separate Ambient, with internal Ambients: the student’s mobile device and the personal assistant PA that communicates with VES. When the wheelchair physically enters the university campus, an automatic identification process is started. After verification, VES sends a response to the student's PA, containing a list of appropriate services for him/her. When a wheelchair enters in the active campus zone, a guard assistant (GA) is activated to provide information on the activity and performance of the important zones for the wheelchair. Upon leaving the university campus, the active area of the wheelchair stops interacting with the learning space and follows the student's automatic logout, which terminates the use of the provided services.

The student with mobility disabilities gets all learning services from the educational space. After recognizing the wheelchair (and the student in it), the system activates Personal Assistant (PA) of the student, which takes care of the delivery of all the educational services and learning resources to the mobile device, like all other students. The specific services that the environment will provide to this student are mainly related to his / her mobility in the physical space of the university campus. Once the student receives the list of all services (sList) from his PA, he / she understands at which floor and in which room the relevant training session or exam will be held. This information must be delivered at a certain time before the event begins so that the student with the wheelchair can move to the appropriate room in the university building. The wheelchair has to pass through a series of important points (zones) such as ramps, lifts, opening doors and more. Each of these important points is provided with a collection of sensors that dynamically provide actual information to Guard Assistants (GA).

Once the PA receives information about the upcoming event, it sends a message to AmbiNet Ambient (ANet) in the Analytical Subspace asking for an appropriate route to be generated. ANet starts a bidirectional communication process with the corresponding GA for providing of up-to-date information from the physical world. After receiving the list of currently active zones from the GA, ANet Ambient generates a list of appropriate routes and sends it to the student's PA. From the received information, the student chooses a route and sends it to the Cart ambient. When the wheelchair moves in the physical campus, GA tracks its location and, when it is close to some of the important zones, activates the sensors associated with opening the doors, providing a lift, etc. If in real time any of the important zones changes its status and becomes inactive, GA promptly informs PA, which expects the student to choose a new route.

For the presentation of the CCA model of this service, we will use the following ambients: PA-personal assistant; AS-Analytical Subspace; ANet; GA; IoTN- IoT Nodes in real world. Let's imagine that the personal assistant received information about the lecture on Artificial Intelligence, which will take place in a 422 study hall at 10 o'clock. CCA processes of these ambients can be modeled as follows:

$$P_{PA}=\begin{pmatrix} !::(lecture\_AI, room\_422, time\_10).AS::<location, room\_422, PAi>.0\,| \\ !AS::(listRoutes).0 \end{pmatrix}$$

$$P_{AS}=\begin{pmatrix} !PA::(location, room\_422, PAi).ANet\downarrow<location, room\_422, PAi>.0\,| \\ !ANet\downarrow(listRoutes, PAi).PA::<listRoutes>.0\,| \\ ANet\downarrow(room\_422, PAi).GA::<room\_422, PAi>.0\,| \\ GA::(listIZ, PAi).ANet\downarrow<listIZ, PAi>.0 \end{pmatrix}$$

$$P_{ANet}=\begin{pmatrix} !AS\uparrow(location, room\_422, PAi).AS\uparrow<room\_422, PAi>.0\,| \\ !AS\uparrow(listIZ, PAi).AS\uparrow<listRoutes, PAi>.0 \end{pmatrix}$$

$$P_{GA}=\begin{pmatrix} !AS::(room\_422, PAi).IoTN::<PAi>.0\,| \\ IoTN::(listIZ, PAi).AS::<listIZ, PAi>.0 \end{pmatrix}$$

$$P_{IoTN}=\left(!GA::(PAi).GA::<listIZ, PAi>.0\right)$$

3.3. Verification scenario by ccaPL – simulator

For describing of CCA processes, the programming language ccaPL was created. The interpreter of ccaPL has been developed as a Java application. Based on the main version (Al-Sammarraie, 2011), we developed a special simulator for verifcation the scenario described above. The notation "A === (X) ===> B" means that Ambient "A" sends an "X" message to Ambient "B". "Child to parent", "Parent to child," and "Sibling to sibling" provide information about the relationship between sender A and recipient B according to the hierarchy of ambients. The scenario that we presented has the following ccaPL program realization:

PA

[AS::send(location,room_422,PAi).0|AS::recv(ListRoutes).0]|

AS

[PA::recv(location,room_422,PAi).ANet#send(location,room_422,PAi).0|

ANet#recv(room_422,PAi).GA::send(room_422,PAi).0|

GA::recv(ListIZ,PAi).ANet#send(ListIZ,PAi).0|
ANet#recv(ListRoutes,PAi).PA::send(ListRoutes).0|

ANet

[AS@recv(location,room_422,PAi).AS@send(room_422,PAi). 0|

AS@recv(ListIZ,PAi).AS@send(ListRoutes,PAi).0]]|

GA

[AS::recv(room_422,PAi).IoTN::send(PAi).0|

IoTN::recv(ListIZ,PAi).AS::send(ListIZ,PAi).0]|

IoTN[GA::recv(PAi).GA::send(ListIZ,PAi).0]

Implementation of the CCA-model in the ccaPL environment allows to track the processes of the participating ambients as well and the sequence of the sent and received messages between them. The animator allows visualization of the participating ambients, their location and processes.The processes of all participating ambients can be traced to each step of the scenario implementation, which makes it possible to immediately identify inconsistencies, errors and inaccuracies (Figure 3).

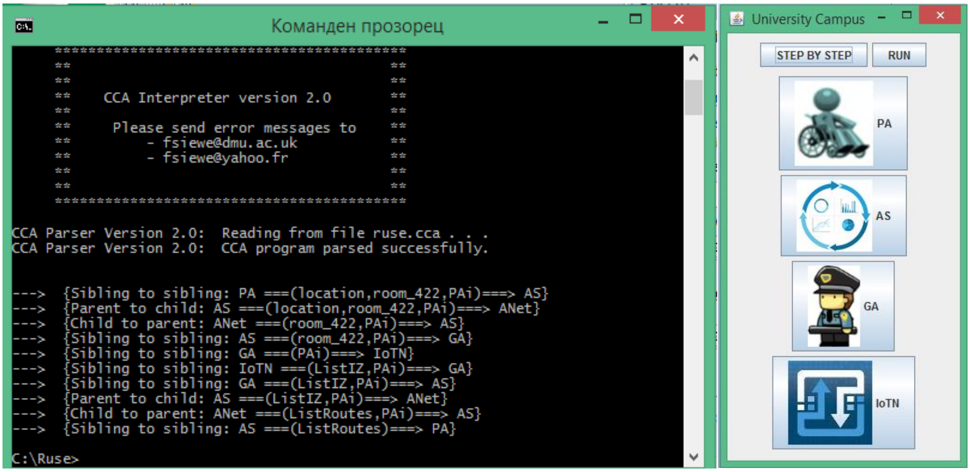

Figure 3. Implementation of the scenario in the simulator

Source: Own work

4. IMPLEMENTATION OF THE TOURIST GUIDE IN LIFELONG LEARNING IN VES

The main objective of LLL (Life Long Learning) is continuous personal development. This determines the vast variety of pedagogical technology and educational systems. LLL integrates equally all categories of educational activity (formal, non-formal and informal) and provides an opportunity for education and training of individuals from an early childhood age throughout their entire conscious life.

The basic architecture of VES is built up of different intelligent assistants, which can assist these directions for lifelong learning. Informal education is inherently self-training or self-education. As part of the realization of the module for informal education in VES a tourist guide is being developed for the cultural and historical heritage of Bulgaria. The Tourist Guide (TG) is a specialized assistant intended to support lifelong learning in VES (Ivanova, Toskova, Stoyanova-Doycheva & Stoyanov, 2017). Its main task is to generate a tourist route for users according to their wishes and location. The route includes cultural historical objects and information about them. In this way, the user enriches his / her knowledge of the region for which the route is generated. The TG can be used in defferent educational organizations for informal learning in Biology, Geography and other natural and social subjects.

The life cycle of the TG includes the following basic steps:

- A tourist inquiry – in order to "get acquainted" with the tourist, the TG conducts a brief survey, which gathers information about the tourist's personal preferences and interests, as well as the time available to him or her.
- Selection of appropriate cultural and historical objects – using the information from the survey, the guide chooses objects to visit in the area that would be of interest to the tourist.
- Generation of a tourist route – from the selected set of cultural and historical objects, the system prepares a route taking into account the physical characteristics of the area to visit, such as its location, distance, working hours, and time available to the tourist. Because of any planned or occasional events (e.g. incidental failure to view the object), individual objects can be excluded. The route also offers a sequence for viewing the selected objects.
- Route realization – the tourist can choose one of the two options to realize the route: virtual tour – the TG provides information about selected cultural objects in the form of text, photos and videos, depending on the information stored on the system server; real walk – the TG assists the tourist during their visit and viewing of the objects.

Each object has two types of presentation on the guide's server:

- A cultural and historical object (CHH objects) – depending on the nature of the presentation, it includes different features in accordance with the CCO standard.
- Ambient – for characterization of the location and condition as a physical feature in a real location (area) of a separate CHH object or a group of CHH objects, designated as an exposition.

In reality, the TG is a multi-agent system that includes intelligent and executive (reflex) agents. The life cycle architecture includes two basic components:

- back-end component: it consists of different modules, distributed in two layers – a knowledge base and operational assistants performing the tasks of gathering information for the client's needs and generating it in an appropriate cultural and historical route;
- Front-end component: it consists of an intelligent assistant that takes care of presenting the route and object information to the client's mobile device using the information generated by the operational assistants in the back-end layer.

The active modules of the back-end component are the following assistants (Figure 4):

- QGA (Questioner Generation Assistant) – the responsibility of this operational assistant is to generate and conduct a survey with the tourist to identify his or her preferences, wishes, and time available. The survey results are used to generate a tourist profile.

- KGA (Knowledge Generation Assistant) – using the tourist profile, the assistant selects the elements of the primary route. The primary route elements are expositions or separate CHH objects.
- CCAA (Calculus of Context-aware Ambients Assistant) – it generates a final route by completing the primary route with additional information such as the location and status of the expositions (or individual objects), the working time, etc. The assistant uses the ambient presentation of the CHH objects included in the primary route. In fact, the final route is a set of possible sequences for viewing the objects.

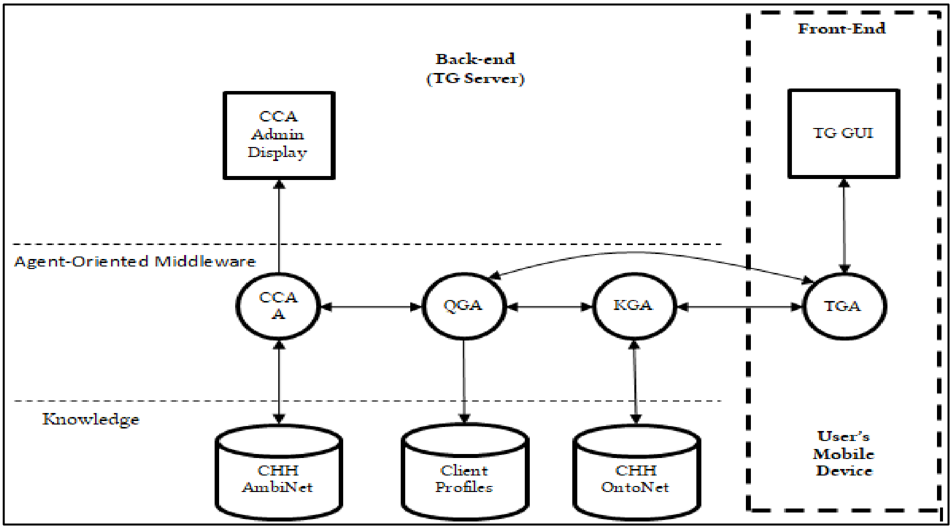

Figure 4. General architecture of the TG

Source: Own work

The TGA (Tourist Guide Assistant) operates in the Front-end component and performs the following basic functions:

- It serves as a tourist's GUI – the tourist can only communicate with the guide through this assistant. This agent is responsible for the proper visualization of the information received from the operating agents on the client's mobile device. It visualizes the questions that the QGA generates and returns the received answers back to it. It is responsible for visualizing the information about the various cultural and historical objects and for visualizing the route generated by the CCA.
- Establishing the tourist location – by using the GPS capabilities of the client's mobile device to determine his or her position.
- Life Cycle Management – it prepares a "schedule" for visiting the cultural objects and follows its observance.

4.1. The ontology knowledge base - CHH-OntoNet

CHH-OntoNet tourist guide is a server component, which takes place into Knowlage base is a repository implemented as a network of ontologies. It has two main functionalities:

- Defining expositions of interest to the tourist;
- Preparing information about the objects included in the offered tourist route.

Ontologies are developed in accordance with the Cataloging Cultural Objects (CCO) standard, which contributes to the easy and convenient dissemination and sharing of data between different systems, communities, and institutions. Currently, there are ten ontologies that have been developed. Almost all of them represent different aspects of the CHH objects and one, titled Meta-ontology, that contains information about the other ones. The purpose of Meta-ontology is to support working with the ontology network, especially when the survey is created.

The ontologies that describe CHH objects are Costumes, Expositions, Museums, Objects, Materials, Locations, Folklore Regions, Agents, and Subjects. The division of the knowledge into multiple separated ontologies is important for two reasons. First, it makes it easier and more convenient to follow the requirements of the CCO standard. And second, it is an effective way of distributed maintenance and editing the knowledge in the ontologies. Also adding new knowledge to one or more ontologies is relatively easy. Currently, the CCH objects stored in the ontologies are traditional Bulgarian costumes, along with information about the expositions and museums in Bulgaria where they are kept.

One of the important things about developed ontologies is that all of them are interrelated. For example, Costumes is one of the main ontologies and contains descriptions of the Bulgarian costumes. It references knowledge from other ontologies – for example, clothes as a type of object (along with their basic characteristics) are described in the Objects ontology. The Objects ontology, in turn, uses concepts about materials (needed for the object creation). These terms are defined and described in the Materials ontology. The descriptions of the folklore regions of Bulgaria, represented in the Folklore Region ontology, use knowledge from the Locations ontology (cities within the regions, mountains, rivers, plains, and other geographical locations). The museums with their architecture and history are described in the Museums ontology. They are regarded as objects of cultural and historical heritage but also as the place where the expositions or costumes are preserved and can be seen. Accordingly, some of the knowledge needed to describe the museums is also defined in other ontologies, for example the materials for the construction of a museum are contained in the Materials ontology. Expositions with their characteristics and objects included in are described in the Expositions ontology. The museums and exhibitions as an object were created by someone, i.e. knowledge from the Agents ontology is used and, by analogy to costumes, they are also defined in the Objects ontology. The

Subjects ontology contains knowledge about the historical period of the described objects, which is used in the Costumes, Museums and Expositions ontologies.

The CCO standard uses two components required for describing data: work records and authorities. Work records all items or records that are described. Currently, three types of work records are presented in the ontologies. The first one is Bulgarian traditional costumes used in different folklore regions of Bulgaria. The second type of work record is the expositions that contain the costumes. And the last one is museums where expositions, respectively costumes, are located. The last two objects are considered as stand-alone work records because of the characteristics they have. But also they can be regarded as Personal and Corporate Name Authority. All left ontologies that described some of aspects of Bulgarian cultural-historical heritage represent some authority. For example, Locationas and FolkloreRegions ontolgoies correspond to the Geograhy Place Authority.

4.2. CHH AmbiNet

To model the scenarios in the CHH AmbiNet we will use the Calculus of Context-aware Ambients (CCA), which enables mobile ambients to respond to environmental changes. Contextual expressions are used to ensure the fulfillment of a given option only under certain environmental conditions, i.e. in a particular context.

In the CHB AmbiNet (Figure 5) we realized CCA modeling of the following service: Generating a route with a visit to requested objects determined by a tourist survey. The following figure presents the main ambients in the CHH AmbiNet and the interaction between them.

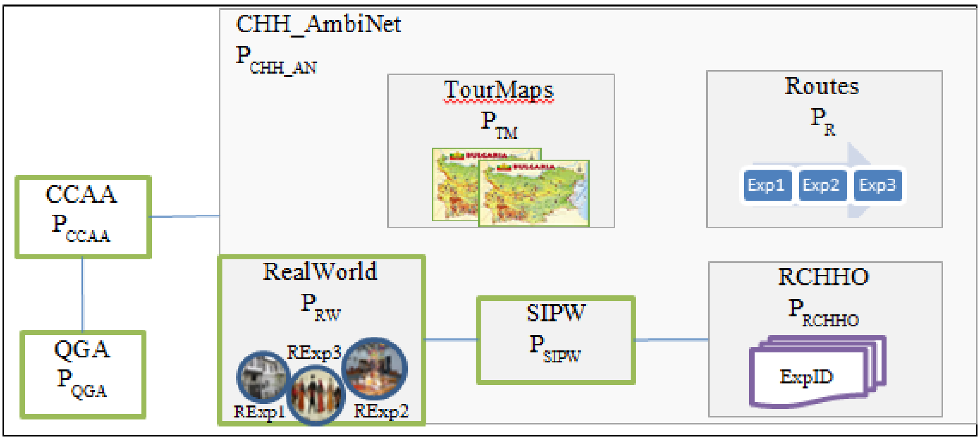

Figure 5. CHH AmbiNet

Source: Own work

The search for suitable tourist routes can be realized through different algorithms. Since the tourist map with the location of all objects is known, one way to improve the search efficiency is to set a limited number of open-to-visit expositions with tourist objects (islands) through which the search is done with fewer steps. For example, if we are looking for a path between a tourist's current location and the furthest tourist destination, it is appropriate to limit the search to a few steps: first to the nearest object, then to some of the other ones and so on, to the furthest object. Intuitively, these particular positions are the Search Graph islands, which are required to be a mandatory part of the route to move from a location to a destination. Once the islands are identified, we can break the common problem of searching into several simpler problems. This reduces the search space because, instead of dealing with one solving problem, a few simpler ones are considered.

This helps to reduce the search volume and is an example of how we can dynamically use the incoming information from the real world to improve the search efficiency. The search for a path between the current location and the destination by using this approach is realized using the following formally described algorithm:

- Identify a set of objects (islands) $i_0,\ldots,i_k$
- Find paths from a location to i_0, from i_{j-1} to i_j for each j, and from i_k to a destination.

Each of these problems is expected to be simpler than the common one and therefore easier and quicker to solve. The preliminary identification of the islands is of particular importance, as the use of inappropriate islands can make the problem even more difficult than the original one. It is also possible to determine an alternative decomposition of the problem by selecting a different set of islands. For each selection of islands, the complexity of the algorithm is different. This algorithm does not guarantee the detection of an optimal route but it ensures the discovery of one or several possible routes. If we want to provide the tourist with the optimal route, we need to additionally implement an optimization algorithm. In the presented model, the time for providing a route is limited, and so are the computing resources, which determine the choice of the considered search method.

4.3. CCA Admin Display Module

The CCA Admin Display module is designed to track the processes in the scenario implementation. For this purpose, simulators of the presented tourist services have been developed. We will look at a simulator described in the presented CCA model which tracks the processes of searching and discovering a tourist route.

Based on the basic version of ccaPL environment, a special simulation is developed to track the processes of the personalized contextual-sensitive tourist guide. The output data from the environment is difficult to read without prior knowledge of the CCA formalization. For ease of use, an animator for the ccaPL environment has been developed.

The System administrator can track the implementation of a model scenario in simulation mode both via a console and the animator in the ccaPL environment.

For example, after a dialogue with the tourist, let the QGA identify three objects for a visit in the primaryRoute – traditional costumes from the Rhodope region, traditional crafts and Renaissance houses, and let the tourist's mobile device identify his or her location in the town of Smolyan. The QGA transmits the location and the primaryRoute to the CCAA, which transfers this information to the CCA_AmbiNet. There, after a dialogue between the ambients described, it is established that the three desired objects are physically located in three separate expositions that are currently open for visits. The search method described defines the location of the nearest exposition, then the next one, and so on, until generating several possible visit routes – the ListFinalRoutes. This list is transferred to the tourist and after he or she chooses a route, the PTG launches the next services related to visiting the objects (Figure 6).

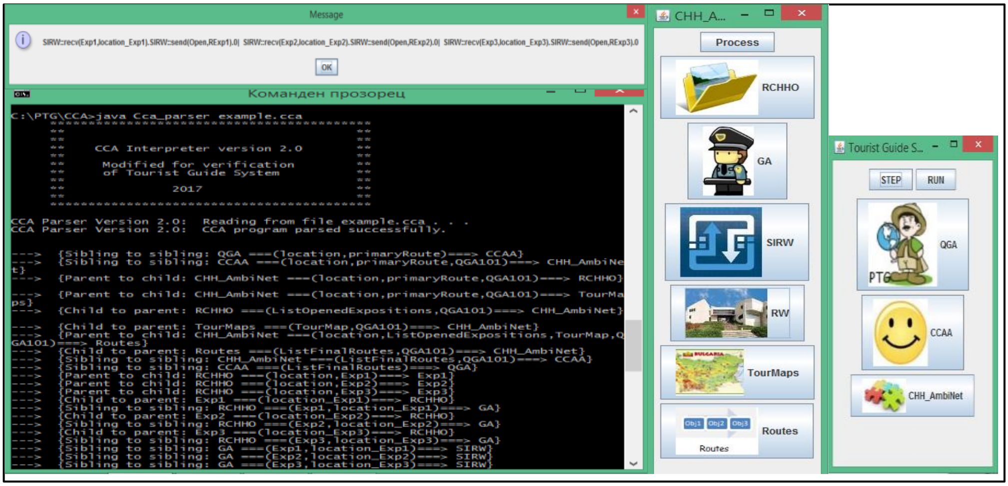

Figure 6. An animated ccaPL simulator of LLL Tourist Guide

Source: Own work

CONCLUSION AND FUTURE WORK

For years, VES has been used to support the educational process at the Faculty of Mathematics and Informatics of Plovdiv University. The space is supported by various types of components. The active components are personal and operative assistants specified as rational BDI agents (Wooldridge, 2009). The agents are implemented by help of the JADE (Bellifemine, 2007) and JADEX (Pokahr, 2003] development environments. Because agents are not suited to provide functionality, they are combined with services including micro-services. Furthermore, two different applications of the VES are presented in more detail.

There are several directions for the development of the VES. One of these is a transformation in a reference architecture applicable to new domains such as smart city, smart environment, and smart medicine. With respect of the Touristic Guide, we are going to extend the repository with new objects belonging to the Bulgarian cultural and historical heritage.

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