МАТЕМАТИКА И МАТЕМАТИЧЕСКО ОБРАЗОВАНИЕ, 2016
MATHEMATICS AND EDUCATION IN MATHEMATICS, 2016
Proceedings of the Forty Fifth Spring Conference
of the Union of Bulgarian Mathematicians
Pleven, April 6–10, 2016

A VIRTUAL SPACE SUPPORTING ELEARNING[*]

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This paper provides an overview and presents the architecture of a virtual space supporting eLearning. The various types of components inhabiting the virtual space are examined as well. Furthermore, development of the space as an IoT ecosystem is considered.

Introduction. In recent years the interest towards electronic education has been growing stronger. As a result of that many universities have developed and implemented their own systems for electronic and long-distance education. In line with this trend a Distributed eLearning Centre (DeLC) project was implemented in the Faculty of Mathematics and Informatics at the University of Plovdiv aiming at the development of an infrastructure for delivery of electronic education services and teaching content [1,2]. DeLC is a reference architecture modeled as a network which consists of separate nodes, called eLearning Nodes. Nodes model real units (laboratories, departments, faculties, colleges, and universities), which offer a complete or partial educational cycle. Each eLearning Node is an autonomous host of a set of electronic services. The configuration of the network edges is such as to enable the access, incorporation, use and integration of electronic services located on the different eLearning Nodes. The eLearning Nodes can be isolated or integrated in more complex virtual structures, called clusters. Remote eService activation and integration is possible only within a cluster. In the network model we can easily create new clusters, reorganize or remove existing clusters (the reorganization is done on a virtual level, it does not affect the real organization). For example, the reorganization of an existing cluster can be made not by removing a node but by denying the access to the offered by it services. The reorganization does not disturb the function of other nodes (as nodes are autonomous self-sufficient educational units providing one or more integral educational services).

DeLC suffers from the shortcomings of the widely used eLearning systems that ignore the physical world which they operate in. The observing of the physical environment reveals opportunities for development of context-aware systems. An effective support of the learning process is many-sided dependent on actions and events taking place in different places and at different times; eg, attending lectures and seminars, self-studies, examinations, consultations. However, analysis of the results of the learning process has

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[*] **Key words:** eLearning, IoT, Virtual Educational Space, Intelligent Agents, BDI Architecture.

The author wish to acknowledge the partly support of the NPD – Plovdiv University under Grant No. NI-FMI-004 “Innovative basic and applied research in computer science, mathematics and pedagogy training” 2015-2016.

to take into account all various aspects and can make connection between them. In this sense, we aim to transform DeLC into a new infrastructure, known as Virtual Educational Space (VES), where users, time, location, autonomy and context-awareness are first-class citizens and which enables a uniform treatment and interpretation of information coming from both the virtual environment, as well as from the physical world [3].

The broad usage of the Internet and its steady transformation into a network of objects [4], as well as the globalization of cyberspace, are a foundation for the rapid development of cyber-physical social systems which will lead to essential technological, economical and sociological consequences in the following years. A cyber-physical system implements a tight integration between calculation, communication and control as well an interaction with the environment in which they are situated [5]. We have reached the point where the social and human dynamics become a significant aspect of the cyber-physical systems. One logical consequence is the rise of infrastructures, known as Intelligent Spaces, where humans and objects interact intelligently among themselves in a way known as anywhere-anytime-anyhow. The spaces become intelligent when they are capable of monitoring what is happening inside them, have the ability to model their own behavior and to operate on the basis of their own decisions as well as interact with the inhabiting communities.

The IoT paradigm has been supported by governments around the world and various funding schemes have been proposed [6]. The European Union has set up the European Research Cluster on the Internet of Things funding more than 30 projects [7]. According [8] providing the base for investment into research on Cyber-Physical-Systems managed by the The National Science Foundation (NSF), the primary focus lies on medical systems and projects in the area of software engineering. IoT is one of the major technology topics and part of the 12th 5-year-plan of China.

Some examples of possible IoT applications in the field of education are briefly summarized in the Fig.1.

A work-in-progress at the Open University of Catalonia [9] aims to combine both the virtual and the physical environments in order to provide a better learning experience to the students. In order to support learners with increasing social skill, in this paper, a specific technical framework of ubiquitous learning environment based-on the Internet of Things is designed, which includes three major layers: perception layer, network layer, application layer [10].Using IOT learning can be happened at anyplace, anytime, anypeople, and any content. In [11], the current situation of M-learning under Internet of Things is discussed. The study [12] tries to combine internet of things (IOT) and the techniques of learning analytics to record and conduct the analysis of students' learning process and further enable them and schools to obtain feedbacks that they need and establish an effective lifelong learning environment. The paper [13] presents a tempus project that aimed at collaborating distant ELabs of different Maghrebian and European universities using IoT interoperability. In [14], the concept of Internet of Things and his role in evolution of eLearning applications is presented. The possibility for SCORM to bring inside and outside packages that are able to be used by different SCORM systems and to convert the resources into things is also discussed. In this case, SCORM introduces the Content Aggregation Model which defines a general framework that can be used on learning process based on things according to IoT standard.

Fig. 1. Related Works

The rest of the paper is organized as follows. The second section discusses the basic features of the virtual space. The third section presents the VES architecture. The forth section illustrates the development of the space as an IoT ecosystem. Finally the last section concludes the paper.

Features of the VES. *VES is an intelligent space.* In accordance with [15,16] an intelligent space is a environment that can continuously monitor what are happening in it, can communicate with their inhabitants and neighbourhoods, can make related inference and decisions and act on these decisions. In comparison to DeLC, an intelligent education space will support more effectively the process of blended learning, integrating electronic forms of education with the real learning process. *VES is context-aware.* According to [17] context is all information which can be used to characterize the situation of an identity. By "identity" we can designate a man, a place or an object which are viewed as meaningful for the interaction between user and application, which includes themselves. In accordance to the definition of context, Dei defines that a system is context-dependent if it uses contexts to deliver significant information and/or services, and the importance depends on the user's tasks [18]. In our case context-dependency is the ability of a system to find, identify and interpret the changes (events) in its environment and depending on their nature to undertake compensating actions. The main compensating actions (attributes for context-dependency) are personalization and adaptation. Personalization is the system's ability to adapt to individual features, desires, intentions, goals of the users. Adaptation is the system's ability to adapt to the remaining context features such as area of knowledge, school subject, types of devices used by the end-users. *VES is scenario-oriented.* From user's point of view, the space is a set of separate e-learning services and educational scenarios provided for the use through education portal DeLC 2.0 or personal assistants. Scenarios are implemented by corresponding workflows rendering an account of the environment's state. Thus it is possible to take into account various temporal characteristics (duration, repetition, frequency, start, end) of the educational process or events (planned or accidental) which can impede or alter the running of the current educational scenario. To deal with emergencies (earthquake, flood, fire) there are defined emergency scenarios which are executed with the highest priority. *VES is a controlled infrastructure.* Access to the space's information resources is only possible through the so-called "entry points". The personal assistants operate as typical entry points while the education portal of DeLC is a specialized entry point; a user has to be in possession of a personal assistant or to use the portal to be able to work in the space.

VES Architecture. The VES architecture contains different types of components. Assistants play an important role in the space. Three types of assistants are supported in the space (Fig. 2.):

- *Personal assistants* (*PAs*) – have to perform two main functions providing the needed "entry points" of the space. Firstly, they operate as an interface between their owners and the space and if necessary, carry out activities related to personalization and adaptation. Secondly, they interact with other assistants in the space in order to start and control the execution of educational scenarios. The personal assistants will be usually deployed over users' mobile devices.

- *Operative assistants* (*OpAs*) – usually located on the server nodes of the space, they support the execution of educational scenarios; therefore they implement suitable interfaces to the available electronic services and data repositories. Operatives serve two subspaces, known as D-Subspace and A-Subspace respectively.

- *Guards* – special assistants which are responsible for safety and the efficient execution of the educational scenarios in the space. These are usually intelligent devices that react to various physical quantities in the environment, e.g. smoke, temperature, humidity. The guards represent the real world in the virtual one and act as an interface between the both worlds in the space.

The assistants implemented as rational BDI-agents are active context-aware components that operate autonomic (have control over own actions and internal states without direct intervention of humans or other agents), reactive (perceive their environment maintaining continuous contact with this environment and respond to changes occurred), proactive (are able to be proactive exhibiting a goal-driven behavior), and social (are able to interact and cooperate with other assistants via ACL [19]). BDI (Belief-Desire-Intention) architecture [20, 21] presents a model known as "practical considerations" where the decision-making process of a rational agent can be completed in two steps:

- *Deliberation* – at this stage, the agent decides what to do (what purpose it wants to achieve) using its mental states such as beliefs (represent perceptions of the agents about their environment), desires (represent agents' wishes or tasks that have not been converted into intentions), and intentions (represent the current agent's goals that are committed desires);
- *Planning* (*means-ends reasoning*) – at this stage, the agent decides how to meet the goal.

Operative assistants are active components exhibiting a more complex architecture. An agent in itself is not a suitable software component for delivering business-functionality. A service is good decision for functionality but is static and cannot operate as a separate component in the space. For that reason corresponding service interfaces are implemented for the operative assistants. Since all functionalities that the VES components can use and expose while inhabiting the eLearning ecosystem are provided as services, the space is open for new components able to provide their capabilities as services too regardless of the technologies used for their implementation. The basic functionality delivered by the space is deployed in the both subspaces (D- and A-) that interact intensively during execution of educational scenarios. D-Subspace is designed for a direct support of the educational process providing the following three engines:

- *SCORM Engine* (*SEng*) – delivers educational content for self-study of students, usually in the form of SCORM 2004 electronic packages. The SCORM Engine consisting of SCORM Player, SCORM Manager and SCORM Statistics modules is implemented according to the ADL's SCORM 2004 R4 specification [22]. SCORM was developed to support the creation and portable delivery of reusable teaching content for self-spaced computer-based training. The teaching material is stored in a digital library that can be accessed by the students during their self-study. The SCORM Engine traces the progress of the students actually working with the content. The collected information is delivered to the T-Notebook for analysis and evaluation of the students' performance.

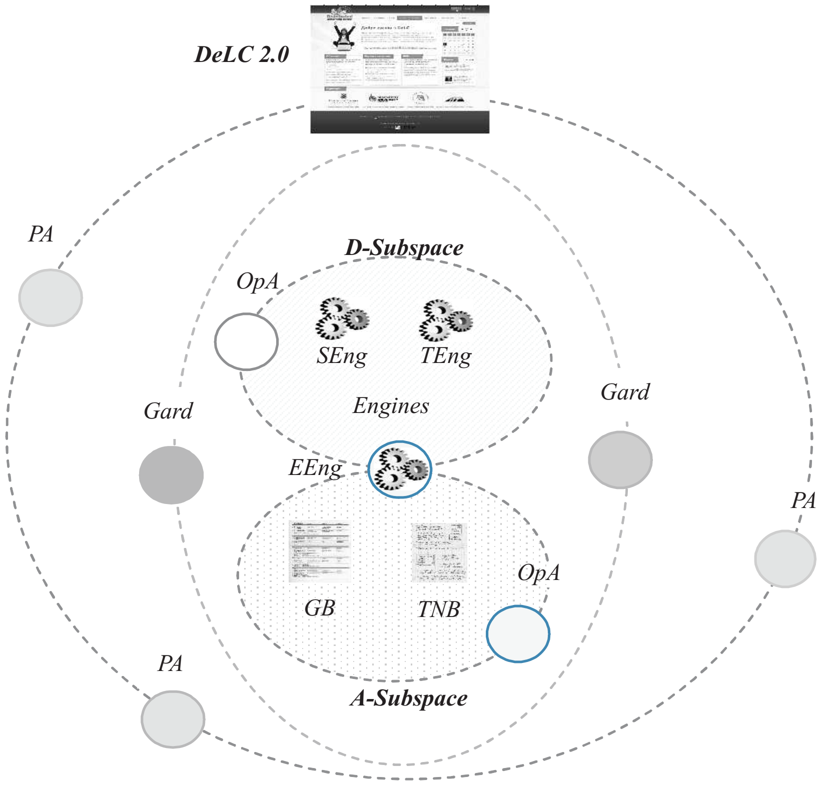


Fig. 2. VES Architecture

- *Test Engine* (*TEng*) – provides all its functionalities according the QTI 2.1 standard [23] as a result of the communication between two base modules – a User Interaction Provisioning (UIP) and an Assessment Provisioning (AP) module. The UIP provides the sensing means of the system to the users environment. While the AP is responsible for analysis of the data received from all the eTesting system's sensors – not only the sensors targeting the users environment (UIP) but also from the ones referring the inner VES space changes concerning the personalized learning state of the user (extracted from the SCORM engine).

- *Event Engine* (*EEng*) – shared for the both subspaces it implements the event model specified for the whole space. The events are used to create more complex structures, such as plans, schedules, personal calendars. The interface also provides an event editor.

Furthermore, a digital library is managed in the D-Subspace where the teaching content prepared mainly in accordance with the SCORM and QTI standards (other formats are also possible, eg. .pdf, .ppt, .doc, . . .). In addition, the digital library provides a flexible security mechanism allowing definition of cascading access rules per users, roles and/or role groups. There are three different access rights: view, download and manage, each of which with several access levels.

A-Subspace secures all activities related to the organization, control and documentation of the education process. In the administrated database is stored all the necessary useful information for planning, organizing, protocoling and documenting the educational process. Two basic components operate in this subspace:

- *Grade book* (*GB*) – the student's grade-book stores and analyzes information on the success rate of students in all the studied courses. It is currently being developed in accordance with the Grade Book specification of the Common Cartridge standard [24].
- *Teacher's notebook* (*TNB*) – it is designed for the analysis of the success rate of students in a particular course of studies. In addition, it helps the teacher to organize his/her duties during the current education period.

DeLC 2.0 operates as a special entry point in the space allowing access to the space's resources out of the personal assistants. DeLC 2.0 is built as a dynamic web application distributed in two main areas – an education portal operating as a specialized user interface and server side (Fig. 3). Both areas communicate by using pure HTTP requests, RESTful services and Web Sockets. An application in the browser consists of a pure HTML 5 and CSS 3 implementation combined with dynamics provided by JQuery and responsiveness delivered by Bootstrap.

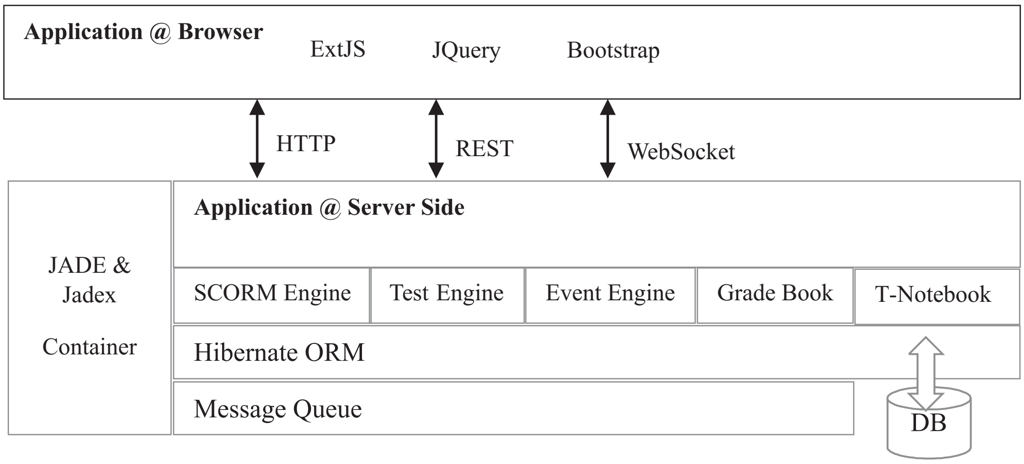
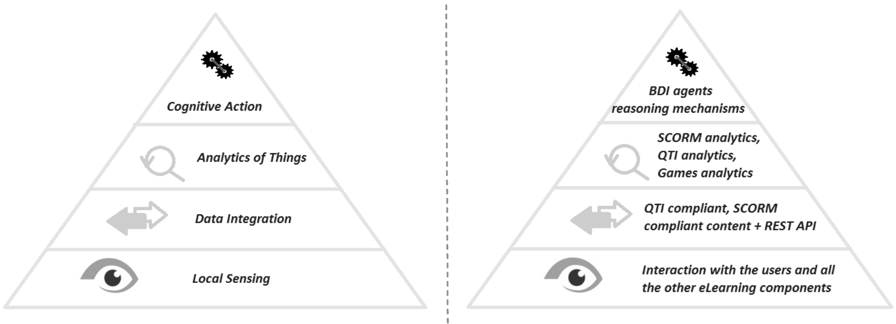


Fig. 3. DeLC 2.0 Architecture

At the server side, the core services provided by DeLC 2.0 include the minimal functionality needed for the majority of the current web applications: security (implements the security mechanism with per roles, per groups and per users' rules), Web Content (it allows a definition of static web content), and Control Panel (the management of the above services, the plugins, and so on). There are also two additional services that are provided by the platform at a lower level: Message Queue (is used by all the plugins and core services as a message bus for asynchronous communication between the different components) and ORM Layer (an object-relational transformation layer that is used by all components for communication with the database). Furthermore, DeLC 2.0 supports interfaces to D- and A-Subspaces by means of plug-in technology. Each plugin provides unique functionality which is integrated in the portal seamlessly. Currently, SCORM engine, Test Engine, Event Engine, Grade Book, and T-Notebook plugins in a different state of completion are supported by the platform. The JADE [25] & Jadex [26] Container makes possible the creation of agents that can operate in the portal and in this way to ensure interaction with the operative assistants of the space.

VES as an IoT Ecosystem. The Internet of Things (IoT) is an extension of the Internet into the physical world, in which physical entities (objects/ devices/ things) are interconnected [27]. The IoT paradigm will make it possible for virtually any *thing* around us to exchange information and work in synergy with each other leading to dramatic improvement of the communication as an act of knowledge exchange and accumulation. The main components of the IoT that all IoT definitions outline are: the devices or objects (*things*), the wired/wireless networks and the Internet, and the information/knowledge storage facility. The *things* are the core units of an IoT ecosystem – they establish the connection between the physical world of entities and the digital world of the Internet. For a *thing* to be able to operate as a part of such an ecosystem, it has monitoring, sensing, actuation, computation and processing capabilities. All these capabilities define it as an autonomous, proactive unit that can exchange knowledge and information with others in order to make decisions, to make plans, to reach its personal or a shared goal. All these features are classified and structured in the IoT stack (Fig. 4a) – the Local Sensing layer that is used to gain knowledge from the environment, the Data Integration layer that is used to share that knowledge across the ecosystem, the Analytics of Things layer that processes the gained knowledge and the Cognitive Actions layer that based on all the gathered knowledge can reason about further actions, plans, goals.



a. *The IoT Stack* ***b.*** *VES IoT Stack*

Fig. 4. IoT Stacks

The VES is defined as an abstraction of the whole learning process decoupling it into its different aspects without interrupting the connectivity between them. Thus, the VES is composed of components that handle the user interaction with the system and vice-versa. It is responsible for maintaining a shared knowledge throughout its components

Using: representation of commonsense knowledge and scenarios; the knowledge can be used to reason about the scenarios.
Basic notions: Event (represents an event or action that may occur in the world), Fluent (represents a time-varying property of the world, such as the location of a physical object), Timepoint (represents an instant of time).
An event may occur at a timepoint. A fluent has a truth value at a timepoint or over a timepoint interval. After an event occurs, the truth values of the fluents may change. An application can manage commonsense knowledge about the effects of events on fluents; specifically, knowledge about events that initiate/terminate fluents and events.

These notions can be presented in **first-order logic** as follows.

- $HoldsAt(f,t)$ – fluent f is true at timepoint t.
- $Happens(e,t)$ – event e occurs at timepoint t.
- $Initiates(e,f,t)$ – if event e occurs at timepoint t, then fluent f will be true after t.
- $Terminates(e,f,t)$ – if event e occurs at timepoint t, then fluent f will be false after t.

Fig. 5. Event Calculus

as well as providing means for enabling the seamless communication between them via the Internet. In order the VES to be able to act as an IoT ecosystem, it has to comply with the layers from the IoT stack [28] (Fig. 4b).

The *things* in the IoT system monitor the ecosystem itself so the sensing layer is enriched with sensing capabilities concerning the changes in the state of the ecosystem. In the space, this is achieved by constantly keeping a service-and-agent-based communication between these components seamlessly via the Internet. Sensors can be of different types: physical, virtual, and logical [29]. The *sensing layer* is mainly composed of the SCORM Engine and Test Engine – they are sources of virtual sensor data; they deliver information about the student's progress of self-study and examination. In addition, various user interactive components as personal assistants, the web application directly accessible to the users (DeLC 2.0) could provide virtual sensor data. Physical sensor data are supplied by the gards. The *data integration IoT stack layer* is implemented based on using specifications compliant content representation. In the space, two standards (SCORM 2004 and QTI 2.1) sharing a common metadata specification (LOM) are basically supported. The content is exchangeable both ways – towards the ecosystem by imports and out of the system by exports. Again all data exchange with the outer world is service based adopting the REST concept for maximal platform independency. The *analytics of things IoT stack layer* is composed of Grade Book and Teacher's Notebook that receive sensor data directly provided by the SCORM and QTI engines. It could be also enriched with information as a result of the reasoning intelligent actions performed on a higher level over the straightforward statistics data. Thus, the analytics are personalized in a generalized way concerning the whole educational process not scoped to a certain educational aspect. The *cognitive actions layer* is implemented as a multi-agent system of rational agents having mind states – beliefs, desires, intentions. They gain and share a common knowledge that has an impact on all the VES components behaviors on different levels of granularity in order to complete the educational scenario currently selected.

The interoperability of the VES IoT stack is enhanced by an event model implemented in the space. The model is formal presented by help of various constructions proposed by a

Scenario description: “On Monday (10:30, December 14, 2015), a student failed an examination test because she/he didn’t study the relevant teaching material and didn’t work out the control tests during the self-study. After a week she/he due to appear supplementary examination. On Friday (10:30, December 18, 2015), the student didn’t yet study the material and didn’t work out the sefl-study tests. The student’s PA is informed of this and warns the student.”

Analytical layer: The Grade Book analyses the above scenario by the help of the following model presented as an EC axiom: “$(Happens(e,t_1) \wedge Initiates(e,q,t_1) \wedge Initiates(e,s,t_1) \wedge t_1 \wedge t_2 \wedge \neg\exists e,t(Happens(e,t) \wedge t_1 < t \wedge t < t_2 \wedge Terminates(e,s,t))) \Longrightarrow \neg HoldsAt(q,t_2)$”.

Sensing layer: the engines provide the following sensor data:

- e = “self-study” ← Event Engine
- q = “failed” ← Test Engine
- s = “no study” ← SCORM 2004 Engine
- t_1 = “Monday” ← Calendar
- t_2 = “Friday” ← Calendar
- t = (Tuesday, Wednesday, Thursday)

PA: On Friday (after 10:30, December 18, 2015), PA informed for the situation (by interacting with the Grade Book) generates and sends warning.

Fig. 6. A simplified educational scenario

formalism known as Event Calculus (EC) [30] briefly introduced in Fig. 5. The application of events is demonstrated with a simplified scenario implemented in the space (Fig. 6).

Conclusion. The presented concept for an IoT eLearning space defined as a virtual space composed of proactive things modelling each aspect of the educational process, manages to put the online education into the IoT concepts for a functioning interconnected ecosystem. The space is being implemented as successor of DeLC.

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ВИРТУАЛНО ПРОСТРАНСТВО ЗА ЕЛЕКТРОННО ОБУЧЕНИЕ

Станимир Стоянов

В статията е направена обща характеристика и е представена архитектурата на информационна инфраструктура, наречена виртуално пространство, предназначена за доставка на електронни образователни услуги и учебно съдържание. Разглеждат се различните видове компоненти, изграждащи структурата на виртуалното пространство. Дискутира се реализацията на пространството като екосистема, изградена на принципите на Интернет на нещата.