A HYBRID MODEL FOR STUDENT ASSESSMENT IN A VIRTUAL EDUCATIONAL ENVIRONMENT

Vanya Ivanova, Todorka Glushkova, Konstantin Rusev

Abstract. *One of the challenges in teaching students in a virtual environment is ensuring fair assessment. Any such educational environment provides opportunities for test examination. However, the test score generated often does not correspond to the students' actual knowledge and differs significantly from the teacher's current observations. The hybrid model for assessing students in a virtual educational environment combines different assessment methods and tools used in online education. This model can be effective by combining the advantages of different methods and providing a detailed view of student progress and achievement. The article examines a hybrid model of student assessment in a cyber-physical multi-agent educational environment, where a proposal for more thorough and fair assessment is formed by means of a dialogue between agents serving the test system, the database with the information accumulated in it regarding the knowledge and learning outcomes of each student, and the personal assistant of the teacher. The considered model will be tested using the formal semantics of the Calculus of Context-aware Ambients (CCA).*

Key words: Virtual educational environment, Calculus of Context-aware Ambients (CCA).

Introduction

The development of the digital society places a number of new demands on secondary education. New models, didactic technologies, and pedagogical approaches are being investigated and introduced in an attempt to improve the level of students' knowledge and skills. Assessment is a key activity that is particularly sensitive to changes in the learning environment. Along with the traditional forms, the use of new assessment models is also required, which should provide continuity, flexibility, and personalization as well as opportunities to take into account the individual characteristics of each learner. The problem is becoming more relevant given the change in the educational environment – more and more attention is being paid to hybrid forms of assessment along with the use of virtual educational platforms [1].

Cyber-physical educational environments provide interaction and integration of virtual and physical components. These environments have many advantages, especially when teaching students with special educational needs and children with disabilities, for whom the connection with the physical world is particularly important [2]. Assessment is a basic feature of any such platform and the difficulties are mostly related to the hybrid nature of school education – face-to-face, remote, project-based, etc.

The article examines a hybrid model of student assessment in a cyber-physical multi-agent educational environment, where a proposal for a more thorough and fair assessment is formed through a dialogue among agents serving the test system, the database with the information accumulated regarding the knowledge and learning outcomes of each student, and the teacher's personal assistant. The model under consideration will be tested using the formal semantics of Calculus of Context-aware Ambients (CCA).

Motivation and Related Works

Cyber-Physical Systems (CPS) [3] provide integration between computing, networking, and physical processes. These systems must provide dynamic interaction with objects from the physical and the virtual worlds, which requires the use of autonomous intelligent components. Thus, cyber-physical systems move into cyber-physical spaces, in which users are placed at the center of social interactions. These spaces have the potential to be adapted in all spheres of the modern world such as a "smart city", agriculture, animal husbandry, transport, medicine, tourism, and, of course, education [4].

The creation of educational cyber-physical platforms creates a basis for conducting a dynamic and continuous learning process, tailored to the personal characteristics of each student. An important component of these environments is the development of an appropriate test platform that provides opportunities for assessment and self-assessment of learners [5].

The Virtual-Physical Space (ViPS) is being developed by a team of the DeLC laboratory at the University of Plovdiv as a reference IoT-based architecture that can be adapted to various CPSS applications in diverse areas of implementation. In the field of higher education, the platform of the Virtual Educational Space (VES) is being developed [6], and BLISS in secondary education [7]. An alternative platform used for electronic tests in the Faculty of Mathematics and Informatics is DisPeL (Distributed Platform for e-Learning), whose key elements are administration of the learning process and adaptability of learning content [8].

Checking students' knowledge and skills is a complex process that includes continuous assessment in various forms of examinations, individual assignments and homework, project tasks, etc. Twice a year, entry and exit level tests are conducted in each subject, and in some classes national external assessment is also administered. When working in the cyber-physical school educational platform, these processes can be realized in the interaction of the *smart modules of the electronic diary*, in which the ongoing, term, and annual grades are stored, the *test system* through which test examinations are conducted, and the *personal assistants of teachers and students* through which communication with the system is ensured. Since part of the examinations is implemented in a traditional on-site form in the classroom education system and another part in the virtual education platform, the modeling of scenarios and processes related to their hybrid essence is of particular importance.

CCA Modelling of the Testing System

Ambient-oriented modeling (AOM) is a type of process computing in which the context and interactions between objects from the physical and the virtual worlds play a major role. The Calculus of Context-aware Ambients (CCA) formalism models the system's ability to respond to changes in the surrounding space [9]. A CCA ambient is an identity that is used to describe an object or a component – a process, device, location, etc. Each ambient has a name and boundaries, it can contain other ambients within itself and can be included in another ambient. There are three possible relationships between two ambients – parent, child, and relative. Each ambient can communicate with the ambients around it. Ambients can exchange messages with each other. The message exchange process is carried out in both directions with the notations: "<>" for sending and "( )" for receiving. With CCA, there are two movement options: in and out, which allow ambients to move from one location to another, enter, and exit certain ambients in the ambient hierarchy.

As we have already pointed out, the concept of an ambient is an abstraction of the limited space where a calculation is performed. Ambients are mobile and can build ambient hierarchies. Through these hierarchies, each entity in a cyber-physical system can be modeled, regardless of its nature (physical, logical, mobile, or static), as well as the environment itself (or the context) of that entity. In addition, an ambient contains a process representing its capabilities, i.e. the actions that this ambient is allowed to perform, as well as mobility, contextual, and communication capabilities.

Due to its dynamic and hybrid nature, the process of assessing students' knowledge can be modeled using the mathematical notation of CCA. The cyber-physical educational environment is, essentially, a multi-agent system that realizes the processes and services through interaction between different intelligent agents. Each component of the environment is served by one or more specialist assistants and users are represented in the platform by their personal assistants. Each such smart environment component can be represented by a separate CCA ambient. Let us consider the following ambients:

- PA_T – a personal assistant to the teacher;
- PA_S – a personal assistant of the i-th student;
- TS – a specialist assistant serving the Test System in the educational space;
- ED – an ambient providing services related to the use of data from the e-Diary;
- SB – a specialist assistant supporting interaction with the Student Books component;
- AA – an assessment assistant that provides services related to the process of the final student evaluation.

We will model the processes of these ambients by implementing the following scenario: *A student needs to take an exit level test through the testing environment. Based on the student's grades received so far, which are stored in the electronic diary, the teacher assesses the student's knowledge of this subject for the year and places the final grade in the electronic* *diary and the student's book.*

The teacher, through his/her personal assistant, sends a message to the test system assistant with a request to open the test for the student in question. Upon completion of the test, the student's score is stored in the e-Diary database, and the teacher receives information about it. The teacher's personal assistant communicates with the AA ambient with a request to analyze the results of this student according to the considered approach and as a result receives a proposal for a final grade, which it sends to the virtual student's book. The process of this ambient is represented by (1):

$$P_{PA\_T} \equiv \begin{pmatrix} TS ::< Open\ the\ test, Stu\_id > .0| \\ ED :: (Student\ completed\ the\ test, Stu\_id). \\ AA ::< Analyze\ the\ results\ of\ student, Stu\_id > . \\ AA :: (Post - analysis\ evaluation\ proposal, Stu\_id). \\ SB ::< Record\ the\ grade\ of\ the\ student, Stu\_id > .0 \end{pmatrix} \quad (1)$$

After receiving a request to open the test from the teacher's personal assistant PA_T, the TS ambient sends information to the student's personal assistant (2).

$$P_{TS} \equiv \begin{pmatrix} PA\_T :: (Open\ the\ test, Stu\_id). \\ PA\_S ::< Test\ is\ open, you\ can\ start > .0 \end{pmatrix} \quad (2)$$

As soon as the student finishes working on the test, his/her personal assistant sends a message to the ED electronic diary with a request to record the results obtained (3).

$$P_{PA\_S} \equiv \begin{pmatrix} TS :: (Test\ is\ open, you\ can\ start). \\ ED ::< The\ test\ is\ complete, save\ the\ result, Stu\_id > .0 \\ SB :: (Your\ evaluation\ is\ completed).0 \end{pmatrix} \quad (3)$$

The electronic diary records the student's results and sends information to the teacher. When it receives a request from the AA ambient, the ED selects the requested data and sends it for analysis. The process of this ambient is represented in (4).

$$P_{ED} \equiv \begin{pmatrix} PA\_S :: (The\ test\ is\ complete, save\ the\ result, Stu\_id). \\ PA\_T ::< Student\ completed\ the\ test, Stu\_id > .0| \\ AA :: (Need\ data\ for\ analysis, Stu\_id). \\ AA ::< Set\ of\ data, Stu\_id > .0 \end{pmatrix} \quad (4)$$

The AA ambient analyzes the results of the conducted test after a request from the teacher's personal assistant. To access a particular set of data, it submits a request to the ambient of the ED electronic diary. The process is represented in (5).

$$P_{AA} \equiv \begin{pmatrix} PA\_T :: (Analyze\ the\ results\ of\ student, Stu\_id).0| \\ ED ::< Need\ data\ for\ analysis, Stu\_id > .0| \\ ED :: (Set\ of\ data, Stu\_id). \\ PA_T ::< Post - analysis\ evaluation\ proposal, Stu\_id > .0 \end{pmatrix} \quad (5)$$

The closing stage of the implementation of the process is the recording of the student's final grade in the administrative system of the virtual student's book (SB).

The ccaPL programming language is a computer-readable version of the CCA syntax. The interpreter of this language enables testing and verification of the modeled scenario. For the purposes of CCA modeling, we have developed a visual editor, through which base case scenarios can be conveniently and quickly modeled and tested.

The CCA Editor provides diverse functionalities, including the creation of ambients, streamlining the generation and exchange of messages, production of CCA files, enabling the initiation, testing, and validation of CCA scenarios, offering a visual depiction of the accurate CCA files, and furnishing statistics derived from the developed CCA model for the evaluation of the intricacy of individual scenarios.

We shall model the previously described sample CCA scenario to illustrate the procedures involved in modeling, simulating, verifying, and testing a scenario within a virtual educational environment utilizing the functionalities of the CCA Editor.

Initially, the modeler is required to select an application domain in which the CCA scenario will be implemented and executed. The next step entails the selection of ambients (Figure 1). In instances where no pre-existing ambients align with the specified criteria, they will be generated and subsequently stored in the CCA Editor database as required.

During the subsequent phase of scenario implementation, it is imperative to establish communication among previously established ambients. This communication is achieved through the creation of messages in the CCA Editor (Figure 1).

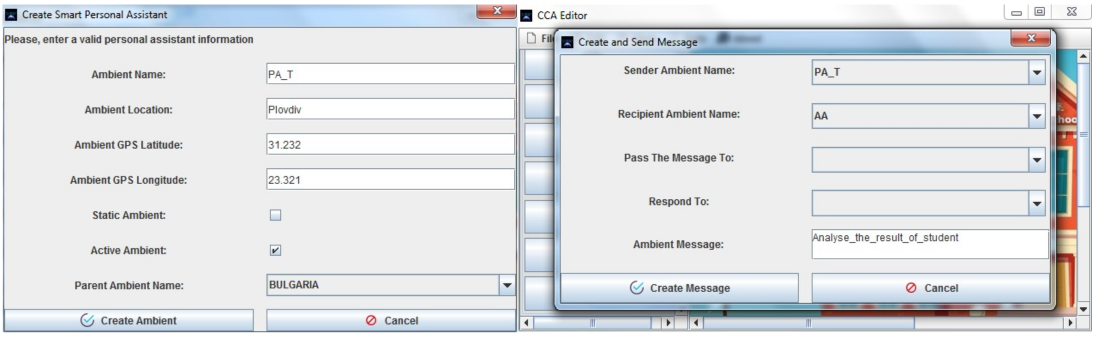

Figure 1. Creating Ambients and Messages

After the preceding steps, the modeling process progresses to the stage of model generation. In this phase, all ambients and messages undergo access, processing, and transformation utilizing a specialized programming language referred to as ccaPL. The final result is archived within a file and subsequently stored in a designated directory specifically allocated for the generated CCA models.

Upon the generation of the CCA file, it is executable using the conventional "ccaPL" programming language interpreter. Prior to execution, the produced file can be examined and modified within the CCA Editor. Following the generation of the CCA file and potential review or editing by the modeler, the conclusive phase of scenario implementation entails executing, testing, and verifying the CCA model using the "ccaPL" programming language interpreter (Figure 2).

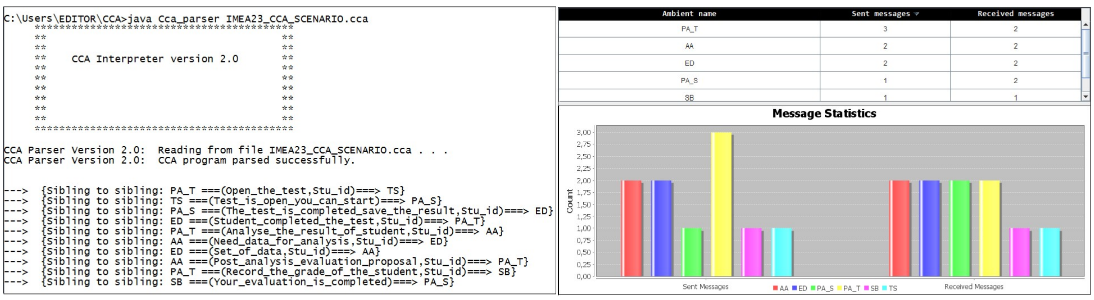

Figure 2. CCA Scenario Results and Statistics

The ultimate phase entails scrutinizing the achieved results, facilitated by the Analysis Module. This module is formulated to provide a spectrum of statistics pertaining to ambients and messages. It aims to optimize the developed scenario by implementing measures directed at reducing complexity and interactions among the ambients (Figure 2).

Although the distribution of messages among ambients in the developed CCA scenario is relatively uniform, it is noted that certain ambients, such as the Personal Assistant of the Teacher (PA_T), Assessment Assistant (AA), and E-Diary (ED), bear a slightly higher message load than others. Consequently, it can be inferred that redistributing some of the messages to less burdened ambients is a plausible optimization strategy.

The CCA models generated are archived within the Data Module and can be employed in subsequent modeling and optimization procedures.

The efficacy of the CCA Editor is evident in its capacity to accelerate the development process and streamline the editing and modification of CCA scenarios. The team is dedicated to improving the application by integrating diverse features that simplify scenario modeling for end users, thus eliminating the requirement for extensive knowledge of the CCA and ccaPL programming language.

Conclusion

The development of base case scenarios related to the assessment of students in a hybrid environment is part of the preliminary modeling of the educational school environment. An interesting problem to be addressed is the creation and use of a suitable algorithm for analyzing the learning outcomes of individual students and modeling the behavior of the corresponding intelligent assistant.

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