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Learning Analytics Framework for Educational Virtual Worlds

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Abstract

This paper presents a learning analytics framework for 3D educational virtual worlds that focus on discovering learning flows and checking its conformance through process mining techniques. The core of this framework is an Opensim-based virtual world platform, known as OPENET4VE, that is compliant with the IMS Learning Design specification and that has the ability of monitoring and registering the events generated by students and teachers. Based on these event logs, process mining algorithms automatically extract the real learning flow of the course, allowing teachers to introduce changes in the learning flow initially proposed.

Keywords: Learning analytics; Process mining; 3D Educational Virtual Worlds; IMS Learning Design; Petri nets.

1. Introduction

3D Educational Virtual Worlds (3D EVWs) have been widely recognized as environments that favor the continuous and dynamic interaction among the students and teachers that participate in a unit of learning [1,2]. The immersive nature of this kind of environments encourages students (as avatars) to perform learning activities that were not initially planned by the teachers, such as interacting with others students through chats, looking for new multimedia contents or using new 3D physical artifacts to learn about a given topic. In order to improve the learning design of a course and be able to assess its efficiency, teachers should know the *real* flow of learning activities that students have followed during the course. With this objective in mind, the use of

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learning analytics techniques might seem a good solution, since they analyze the data generated by the avatars to discover the student behavior in the execution of the learning design.

Learning analytics is a discipline whose aim is the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environment in which occurs [3]. Some learning analytics-based works focused on 3D EVWs have appeared with the aim of showing the engagement of the students to adapt the virtual world experience to its needs [4], enabling teachers making effectively use of educational scenarios in virtual worlds [5], and visualizing the behavior data from students with autism spectrum disorders [6]. However, to our knowledge there is not any work that discovers the *real* workflow of the learning activities, called learning flow, undertaken by avatars in 3D EVWs.

The approach proposed in this paper is based on process mining techniques [7], which analyze the events generated in the 3D EVW by means of the interaction of the avatars with the components of the 3D teaching scenario and with other avatars. Some authors have considered this same approach to discover learning flows in computer-support collaborative learning [8], in collaborative writing [9] or in multiple-choice questions tests [10]. However, there is not any approach for mining learning processes in 3D EVWs, where there exist a high number of events generated by the avatars and therefore to discover and check the conformance of the learning flows is more complex.

In this paper we present a process mining-based learning analytics framework for 3D educational virtual worlds. This framework has two main components: the first one is a 3D EVW platform that posses the ability of *(i)* coordinating the execution of learning flows based on the IMS LD specification [11] through a IMS LD-compliant engine based on the Petri nets formalism; and *(ii)* monitoring and registering the events generated by the avatars through a set of scripts that capture the interactions with the 3D teaching scenario. The second component is a process mining system that implements a set of algorithms to automatically discover learning flows from the event logs collected by the 3D EVW platform.

2. Process mining framework

Our solution for process mining, depicted in Fig. 1, adapts the generic framework proposed in [1] to the learning activities supported by a 3D EVW:

- *Educational world*. As with any e-learning system, in 3D EVWs the participants of the learning activities are the teachers and students, which become the avatars of the 3D teaching scenarios. On the one hand, teachers design and implement learning strategies following some instructional methodology and also support the learning activities to be carry out by the students. On the other hand, students are the core of the educational activities and thus 3D teaching scenarios should focus on facilitating their participation and interaction with other students and/or teachers (avatars). Fig. 2 depicts an example of 3D teaching scenario.
- *Process models*. Our framework is based on the execution of IMS LD units of learning [11], a well-known educational modeling language that has been specifically developed to design adaptive learning strategies. In IMS LD the learning flow is described through a theater metaphor where there are a number of plays, which can be interpreted as the runscripts for the execution of the unit of learning. These plays are *concurrently* performed and they consists of a number of acts, which are understood as modules or chapters in a unit of learning. These acts are executed in *sequence*, and in each of them the students and teachers undertake *in parallel* an activity or a structure of activities, which are carried out in *sequence* or by *selection* of a specific number of activities. Note that the activity selections are really executed in parallel when all the control branches need to be performed (selection n of n). This situation could happen, for example, when students must perform a practical exercise and have a talk with the teacher, but they can decide the order in which both activities are undertaken.

There are two main advantages of considering the IMS LD specification as the educational modeling language for representing the units of learning delivered in the 3D teaching scenario. The first one is that IMS LD has been widely used to describe collaborative leaning strategies, which are commonly supported by educational virtual worlds through the interactions among avatars. The second one is that there exist Petri net-based formal representations of the IMS LD learning flow [12]. Therefore, the validation of the results of the process mining activities is easier: it is possible to define formal parameters to determine the precision and completeness of the mined solution.

- *3D Educational Virtual Worlds Platform (3D EVW Platform)*. This platform provides the infrastructure to support the avatars' activities and interactions in the 3D teaching scenarios, assist the avatars during the development of the learning activities, and record the events that occur during the learning flow. To provide these functionalities we have selected OPENET4VE [13], a 3D EVW platform that enables the execution of IMS LD units of learning from virtual worlds, and more specifically from Opensim-based virtual worlds [14].

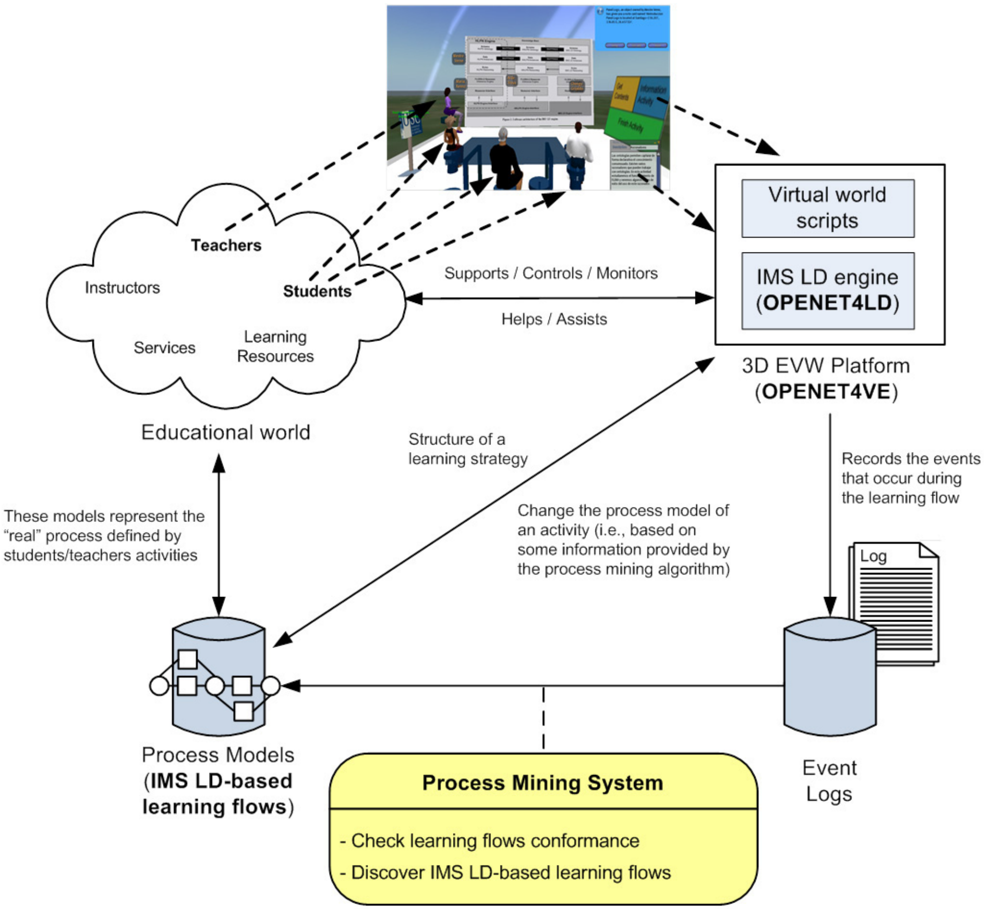

Fig. 1. Framework for learning analytics in 3D educational virtual worlds.

This execution is in charge of an IMS LD-compliant engine, known as OPENET4LD [12], that controls the coordination of the learning flow and monitors and registers the interactions among the avatars, the interactions of the avatars with the physical elements of the 3D teaching scenario (through scripts of the virtual world platform), and the access to the services and learning resources that support the execution of the learning activities.

The main advantage of the OPENET4VE platform is that translates the IMS LD specification into a *formal* representation of the learning flow based on Petri nets, that is, the execution of an IMS LD unit of learning means the execution of the equivalent Petri nets that models its learning flow. This formal modeling facilitates the development of process mining techniques to discover and check the conformance of IMS LD learning flows.

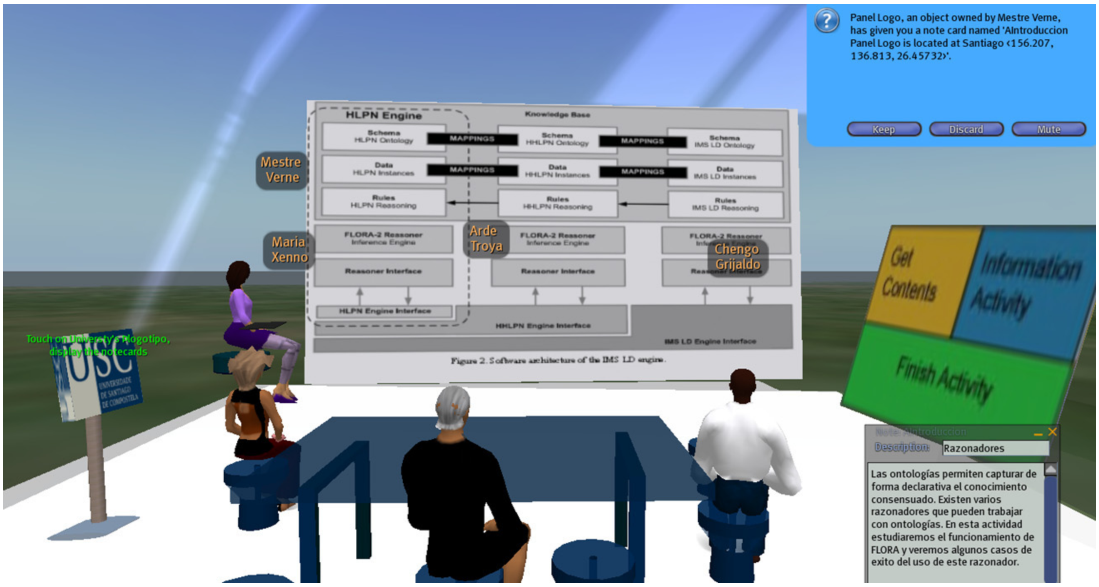

Fig. 2. Example of 3D teaching scenario.

- *Event logs*. Event logs are the inputs of process mining activities. These logs must record the identifier of the unit of learning, the learning activities that have been undertaken, the avatars that have participated in these learning activities, the time at which the activities has been started and how long they last, and the changes the avatars have produced in the 3D EVW as consequence of performing these activities. In order to generate these event logs it is necessary to develop a set of scripts to capture the events launched as result of the interactions of the avatars on the physical components of the 3D teaching scenario. Once the events are generated, these scripts invoke a set of web services that store the information about the event in a database, which is external to the virtual world platform (e.g., Opensim) and it is managed by OPENET4LD.
- *Process mining system (PMS)*. It provides the set of process mining algorithms that consume the log files generated by the avatars when they undertake the learning activities of the IMS LD learning flow. Thus there are algorithms to *(i)* automatically obtain the Petri net which explains the behavior observed in those event logs (*process discovery*); *(ii)* determine the discrepancies between the IMS LD learning flow designed by the teacher and the Petri net that has been really followed by the avatars and that probably include new learning

activities (*checking conformance*), or *(iii)* to evaluate whether the learning activities contribute to achieve the pedagogical objectives.

3. Conclusions

Learning analytics techniques enable teachers to know what is happening in the students' learning process. This is particularly relevant in 3D EVW, where the interactions among students are continuous and therefore there is a lot of noise, that is, a high number of activities that are not significant from a pedagogical point of view. The process mining-based framework presented in this paper describes the main components needed to develop applications that automatically extract the learning flow undertaken by students in virtual worlds. However, to obtain these results, the process discovery algorithms must be more robust to noise than the current algorithms of the state of the art.

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