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Combining educational games and virtual learning environments for teaching Physics with the Olympia architecture

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Abstract

Attaining student understanding and motivation for learning is the main challenge of virtual learning environments (VLEs). Educational games easily obtain the student's attention, which is reinforced by an emotional link established between the game and the learner with a high level of interactivity. This research aims to enhance the human computer interaction (HCI) of a VLE through the addition of specific features present in the architectures of serious and commercial video games. The Olympia architecture, which enables the combination of VLEs or serious games with intelligent tutoring systems (ITSs), is introduced. A new generation of learning environments that synthesise the features of both learning environments can be created. Olympia was evaluated in a particular case study focused on teaching introductory Physics to 20 undergraduate students at Tecnológico de Monterrey, Mexico City Campus. A traditional VLE and an enhanced VLE were implemented. The differences between both environments are in their affective feedback, graphics rendering and game mechanics modules. Probabilistic relational models, i.e. Bayesian Networks, were deployed to infer student knowledge. Weighted hypothesis testing was used in evaluating the effectiveness of Olympia. Results show that students learn in a similar way with both learning environments, although they feel more motivated whilst interacting with the enhanced VLE. Olympia is an effective guideline for the creation of intelligent VLEs. Future work will focus on repeating the experiment on a larger population, creating educational games and enhancing the student model.

Keywords: Emotion, intelligent tutoring systems (ITS), Olympia, probabilistic relational models, serious games, virtual learning environments (VLEs).

1 Introduction

An innovative era of learning and delivering instruction has arisen. Ultimate goals are to make the teaching and learning processes more effective, interesting, personalised, interactive and accessible. Virtual learning environments (VLEs) and educational games are effective teaching and learning tools. However, both areas have still challenges to overcome. The key aim has been to find the most effective way of responding to student actions and hence enhancing student understanding. Enhancement with educational games is often sought through the addition of subliminal messages (Williams 2008). Conati (2002) and D'Mello et al. (2008) focus on the enhancement of intelligent tutoring systems through the recognition and generation of emotions in the teaching and learning process.

Noguez & Sucar (2005) introduced a generic architecture that combines VLEs with intelligent tutoring systems (ITSs). This architecture has proven to be effective for teaching robotics at undergraduate level. The architecture of Noguez & Sucar (2005) was improved here through the addition of features and elements in the architectures of commercial and educational games (Bergeron 2005; Adams & Rollings 2007; Sherrod 2007). The student model is a probabilistic relational model that infers the student's cognitive state from student interaction. The architecture was adapted to also enable the combination of serious games with ITSs. The improvements to the architecture were made with the objective of enabling a virtual learning environment to attain a level of interactivity required by an educational game. The result of these improvements is a new architecture, Olympia. Accordingly, it is inferred that an enhancement in the human computer interaction can increase student motivation for learning, which can enhance understanding.

Section 2 reviews the state of the art of VLEs and serious games related to the rationale of this research. In section 3, the aims, objectives, hypothesis, analysis, requirements and design of Olympia are given. In section 4, results on the evaluation of Olympia are discussed.

2 Background and related work

Students' attitudes and aptitudes have evolved to adapt to Information Technology (IT) and applications with high media content, which have changed the expectations of learners. Oblinger (2004) observed that students at undergraduate level had the tendency of being experiential learners and community-oriented. VLEs and educational games have been developed to help teaching, training and learning processes become more engaging, interactive and effective. However, both have still challenges to overcome.

ITSs and VLEs have evolved to offer intelligent learning. Nowadays, the focus is on adapting the response to the learners' needs and preferences. Research has focused on the interface, on the representation of the domain and on the representation of the student (Du Boulay & Luckin 2001). Affective Computing enables computers to recognise and express affect (Picard 1995). Emotion and cognition are deeply intertwined and equally important. While cognition understands and comprehends the world, emotion modulates the functional parameters of cognition and alerts the user in case a possible danger is detected (Norman et al. 2003). ITSs and VLEs more easily attain student understanding through the addition of an emotional dimension (D'Mello et al. 2008). The main question posed has been to what degree do systems have to imitate human teachers (Du Boulay & Luckin 2001).

Educational games can easily engage students. However, it is difficult to ensure that the student is focusing on domain knowledge whilst learning to play successfully (Conati 2002). VLEs have been effective at enabling students to understand domain knowledge, although they have had more difficulty motivating them. Research has suggested that the success of educational games is due to an emotional link established between the game and the learner (Bergeron 2005). The emotional link is created through the high level of interactivity offered by educational games, since it results in the delivery of immediate feedback to student actions (Sykes 2006). Learning and entertaining goals are embodied by an educational game. The emotional connection established between the learner and the game and the accuracy of learning and entertaining content influence the effectiveness of the learner experience (Bergeron 2005). Features and elements responsible for the high level of interactivity of commercial (Adams & Rollings 2007; Sherrod 2007) and serious games (Bergeron 2005) were identified through the comparison of their architectures with the architectures of VLEs (Noguez & Sucar 2005; Neji & Ben Ammar 2007; Duarte et al. 2008). The high level of interactivity in the graphic user interface (GUI) is supported through the core mechanics module, which manages the actions-challenges relation (Adams & Rollings 2007). The graphics rendering and audio and playback modules mainly provide immediate feedback to the learner's actions (Sherrod 2007). Hence, the addition of these modules to a VLE's architecture can facilitate enhanced student motivation and understanding.

3 The Olympia architecture

Olympia is a generic architecture that enables the combination of VLEs, educational games and a new generation of VLEs with ITSs. The aim of this research is to enhance the effectiveness of a VLE through the addition of features and elements present in the architectures of commercial and educational games. The objectives are to increase student motivation and hence improving student understanding. The hypothesis of this research states that an enhancement of the Human Computer Interaction (HCI) experience can be a motivating factor and lead to a better understanding of domain knowledge. The methodology of this research started through the design of Olympia. To test the hypothesis and the effectiveness of Olympia, it was evaluated in the specific case study of teaching introductory Physics at undergraduate level. Traditional and enhanced VLEs were implemented. The differences between them are in their game mechanics, graphics rendering and emotional feedback modules, which are related to the sight and hearing senses, which are essential in human communication. Finally, the results were analysed through weighted hypothesis testing (Wasserman 2004).

The Olympia architecture, shown in Figure 1, is a semi-open environment (Noguez & Sucar 2006) where the learner can interact with the simulator to attain specific learning goals. Olympia comprises interaction modules at the GUI level. These modules were incorporated as a result of analysing the architectures of serious and commercial games (Adams & Rollings 2007; Sherrod 2007; Bergeron 2005). A combination of modules can be chosen according to the level of interaction to be implemented. The *Physics and collisions module* comprises the physics and maths driven objects used to enhance the level of realism in the simulation. The *Emotional feedback module* comprises sounds that can set or change the student's mood. The *Interactive AI module* contains the Artificial Intelligence (AI) techniques used to create the believability of a learning environment. The *Input detection module* senses and handles the input. The *Networking module* controls the transmission of data across the network. The *Utilities module* comprises tools that assist completion of the tasks in the most efficient way. The *Scripting module* enables the external control of the application. The *Graphics rendering module* comprises all the graphic resources and manages the graphics and the scenes in real-time. The *Game mechanics module* manages the action-challenge relation. The *teaching and learning AI module* comprises an ITS.

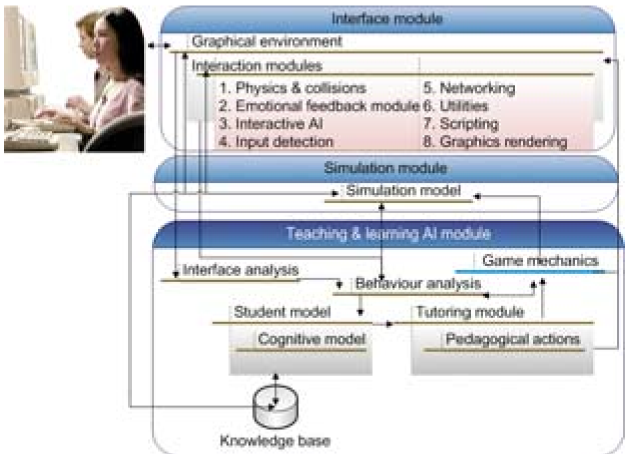

Figure 1. Olympia architecture

3.1. Case study

In 2007, a need to find new ways of motivating and challenging students of Physics at undergraduate level at Tecnológico de Monterrey, Mexico City campus was evident. The creation of an intelligent virtual learning environment embodying ITSs was suggested as a possible way forward. Environments can be accessed online by lecturers to consult students performance. Users must authenticate through a username or password. The students are between 18 and 24 years old and are familiar with the use of IT.

3.2 GUI design and student model

An enhanced VLE and a traditional VLE, shown in Figure 2, were designed. The former includes an enhanced look and feel with high quality graphics and sounds that are synchronized with positive and negative feedback and the learner interacts through keyboard events. In contrast, in the latter, the learner interacts through sliders and buttons and it has neither sounds nor graphics which accompany the final feedback message. The story depicted by the case study is about an astronaut who needs to return to his spaceship using his tools, e.g. pipe wrench, screw driver, adjustable wrench, before the oxygen is depleted. To attain this goal, the student must use Physics principles. Using the VLE, the student can explore the effect that mass and velocity, i.e. speed and its direction, in a particle system have over the conservation of momentum. The *relational student model* (Sucar & Noguez 2008) was generated using an expert-centric approach and is used to understand the student's actions. This understanding is used by the *tutoring module* in choosing the pedagogical response. Feedback messages are synchronized with music and graphics to express happiness and sadness in cases where the student attains or fails to attain the learning objectives.

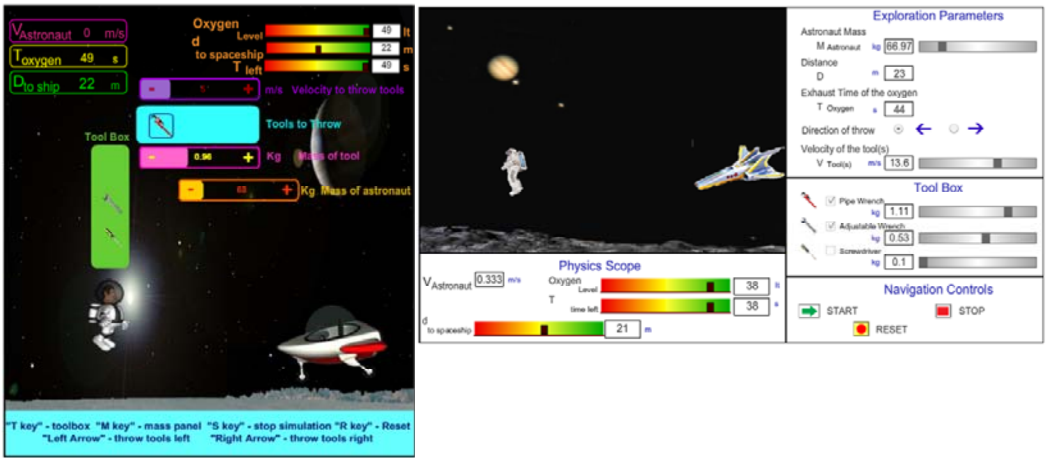

Figure 2. Interfaces of enhanced VLE (left) and traditional VLE (right)

4 Results and evaluation

20 undergraduate Engineering students reading an introductory Physics module (Physics I) at Tecnológico de Monterrey, Mexico City campus were separated equally into control (traditional VLE) and experimental (enhanced VLE) groups. The probabilities, corresponding to the topics: linear momentum, velocity and conservation of momentum, were inferred from student interaction. The average probability of each topic was calculated for the total number of interactions per student. Also, the total number of student interactions and successful cases were calculated. This data was analysed using weighted hypothesis testing (Wasserman 2004). The statistical function, Z_0, shown in Equation (1), was used to validate hypotheses with a small quantity of data.

$$Z_0 = (\bar{X} - \mu)/(\sigma/\sqrt{n}) \qquad \text{Eqn. (1)}$$

Where, μ is the median of the control group, $\bar{x}$ is the median of the experimental group, n, the total population and σ is the standard deviation of the control group.

The hypothesis given in section 3.1 was divided into two alternative hypotheses (H_A) and two null hypotheses (H_0): H_0 -"The students acquire the same quantity of knowledge interacting with the two learning environments" and H_A -"The students interacting with the enhanced VLE acquire more knowledge than the students interacting with the traditional VLE"; H_0 -"The students have the same motivation whilst interacting in both learning environments" and H_A -"The students interacting with the enhanced VLE have more motivation than the students interacting with the traditional VLE".

The data plotted has a right tale behaviour profile. The risk of wrongly rejecting the null hypothesis, α, is fixed at 0.05 for standard convention. As a result, $Z_{0.95} = 1.645$. To reject the hypothesis the null hypotheses, Z_0, must be larger than 1.645. Tables 1 and 2 show the data obtained from evaluating

Equation (1) using the data acquired during student interaction. The two null hypotheses could not be rejected with the data obtained. These results may be due to the small population size, since Z_0 is a measure of the existent evidence against the null hypothesis. Also, the probabilistic relational model requires some improvement. The node saved in the student model, which represents the final result of the interaction, should not be part of the model. The GUI interface of the enhanced VLE is less intuitive than the GUI of the traditional VLE. As a result, many students made the observation that found difficulty interacting with it. The differences between the interfaces of both learning environments were kept relatively minimal for this preliminary research. The students were asked to complete a questionnaire, addressing the qualitative aspects of this research, after interacting with the system. In this questionnaire the students evaluated the traditional and enhanced VLEs using a scale between 2 and 10, where 2 is completely disagree and 10 completely agree. The results of the questionnaire showed that students feel more motivated while interacting with the enhanced VLE.

	Average knowledge detected (%)					
	Velocity and rectilinear uniform movement		Linear momentum		Conservation of momentum	
Statistical function	Enhanced VLE	Traditional VLE	Enhanced VLE	Traditional VLE	Enhanced VLE	Traditional VLE
Average	65.88	61.83	61.09	59.69	58.81	57.67
Standard deviation	19.79	16.62	24.38	22.33	19.48	17.84
Z_0		1.09		0.28		0.29

Table 1. Data on student knowledge

	InteractionResults (number of cases)			
	Successful cases		Total cases	
Statistical function	Enhanced VLE	Traditional VLE	Enhanced VLE	Traditional VLE
Average	2.20	2.70	7.50	6.60
Standard deviation	2.04	2.15	4.06	2.69
Z_0		-1.04		1.50

Table 2. Data on student motivation

7 Conclusion and future work

This research focuses on enhancing the effectiveness of a VLE through the addition of features present in the architectures of commercial and educational games. This research is focused on testing the hypothesis, which states that a high level of interactivity increases motivation whilst learning and enhances student understanding. The Olympia architecture was introduced in this research. Olympia incorporates features of VLEs, commercial and educational games. In testing the research hypothesis, Olympia was evaluated in the specific case study of teaching introductory Physics at undergraduate level. A traditional VLE and an enhanced VLE were implemented. The latter comprised high quality graphics, sounds synchronised with positive and negative feedback and with the student interacting with the environment through keyboard events. Experimental results show that students learn in a similar way in both environments, but that they feel more motivated when interacting with the enhanced VLE. Olympia is an effective guideline for future work, which will focus on experimenting on a larger population, enhancing the student learning model and further employing educational games technology and techniques.

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