Review of Learner Modeling Using Educational Games

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Abstract: The learner model is a key component of any adaptive E-Learning system, including educational games, as it stores the information about the learner, which can then be used to provide personalized experience. Recently, there has been growing interest in creating learner models using educational games. This is due to the limitations of traditional E-Learning systems, since the learner interaction with the computer is rather restricted in such systems. Educational games, on the other hand, not only stimulate learners by increasing their motivation and engagement, but also facilitate a lot of learner interaction that could be observed to create learner models. This paper presents a survey of the field of learner modelling using educational games. In particular, it describes the main methods of learner modelling. This paper also lists several educational games that are suitable for experimentation. Compiling this information can be important to the researchers and developers working in this field, especially to new researchers.

1 INTRODUCTION

Recently, there has been growing interest in learner modelling using all types of games designed for educational purposes. Learner modelling (the process of creating learner model) requires several observations (inputs) collected from learner interaction with the computer. The learner interaction with computer is rather restricted in traditional E-Learning systems (limited to clicks, time that the learner invested in visiting the page, etc.) (Pablo et al., 2009; Stathacopoulou et al., 2007). This information does not really inform us how the learner interacted with that content. Did they read the content? Did they examine it? Did they simply go outside? (Pablo et al., 2009). This lack of information affects the accuracy of learner modelling process. On the other hand, educational games provide ample opportunities of learner interaction with the computer, which can be used to create reliable learner models. Therefore, using educational games (that represent a highly interactive content) to model the learner is a promising trend.

This paper presents a survey of the field and describes the main methods of learner modelling using educational games. This paper also lists several educational game platforms that are suitable for experimentation. This is an attempt to facilitate experimental research in this field. Compiling this information can be important to the researchers and developers working in the field of educational games and learner modelling, especially to new researchers.

The main content of the paper (sections 2 and 3) is a review of existing methods that have already been used to model the learner using educational games. To make the scope of the review more clear we define the concepts of modelling methods as set of ideas and approaches that can be presented at the conceptual level and used to achieve a specific objective. This objective is the creation of learner model.

In this review, we observed those methods that model learners in explicit way and the ones which model them in implicit way. The difference between explicit and implicit methods of learner modelling is related to the ways of extracting information about learners. An implicit method aims to extract information about learners in hidden and unobtrusive way, without endanger the high level of engagement provided by educational games. On the other hand, an explicit method aims to use a direct and obvious way of extracting information and made it overt to learners. The next section of the paper

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presents identified methods that have already been used to model the learner explicitly. Section 3 presents methods that are used to generate learner models implicitly. Section 4 describes and discusses several educational games used to model learners. Lastly, conclusions are drawn and directions for future work are presented.

2 EXPLICIT METHODS

In this section, we will present identified methods that were already used to model the learner explicitly along with examples.

2.1 Evaluation of Questionnaire

Learner modelling can be performed through evaluating the learner's answers to questionnaire at the beginning, during or at the end of the educational game. It can also be done by redirecting learners to an online survey and asking learner to answer questions (Fu et al., 2009; Pourabdollahian, 2012).

The uses of questionnaire can provide direct and precise answers, but this would endanger the high level motivation provided by educational games in case of stopping learner from playing and requesting her/him to answer questions.

As examples of works that used this method, a scale named EGameFlow was used in (Fu et al., 2009) to measure learners' enjoyment of educational games. The scale contained 42 items, presented in Likert-type scales, with 1 and 7 respectively representing the lowest and highest degree to which respondents agree with the items. Similarly, in (Pourabdollahian, 2012), learners were requested to answer a questionnaire in order to evaluate their level of engagement. The questionnaire contained 21 questions based on five-point Likert scale and categorized according to five classifications (challenge, immersion, interest, purpose and control). The data collected from the survey was analyzed by both descriptive and inferential statistics for evaluating the engagement of learners.

2.2 Interpreting Body Posture and Physiological Signals

Various hardware and software equipments have also been used for modelling the learners. Behaviour of the learners can be recognized through identifying gestures, body posture and physiological signals. It is done by identifying and labelling different reactions to game events and then looking for common features of body expressions (Peters et al., 2009; Jimenez et al., 2011).

This method can provide additional information for modelling learner. However, it requires the use of additional hardware and software equipment. Furthermore, observations collected using these equipments can be interpreted in different ways and this can endanger the reliability of learner models.

(Jimenez et al., 2011) used Electro Encephalogram readings using a Brain Computer Interface (BCI) for psychometric input to measure attention. BCI offered the possibility of reading electric signals generated by neural activity in the brain, which could be used to assess the learners' attention levels. In another example (Peters et al., 2009), learner's level of attention was evaluated using two components. The first component detected user gaze behaviour based on input from a web camera. This component used either the eye direction or the head direction to establish the screen-space coordinates of where the user was looking. The second component measured attention levels using a neurophysiological recording device.

3 IMPLICIT AND UNOBTRUSIVE METHODS

Several methods are used to generate learner models implicitly. In this section, we are going to identify and discuss methods that have been used in the literature.

3.1 Translating Learner's Actions

In this method, the set of actions made by the learner during the game can be interpreted and translated into descriptive information useful to model the learner. In addition, experts or automated systems define to each set of actions an appropriate description. These descriptions are then used to model the learner (Mark, 2012; Conlan et al., 2009).

For example, the learner model in (Mark, 2012) aimed at creating a representation of learner's cognitive traits. To do that, the study established connections between the behaviour of the learner and his/her actions in the game. Specifically, the manifestations of traits that the learner may exhibit during game-play were identified. This could provide evidence of the learner's cognitive abilities.

The learner model's goal in (Conlan et al., 2009) was to generate a real-time evaluation of a learner's skills. The skill assessment engine component was responsible for translating each learner's actions

within the game into a list of probabilities that show the likelihood of each relevant skill having been acquired by the learner. The learner model determined which skill states had increased or decreased in probability.

3.2 Interpreting Interaction Traces

In this method, the game engine monitors and records interaction between the learner and the game, generating a trace of actions performed by the learner during the play sessions and tracking a lot of different parameters in the game (start game, end game, quit game, phase changes, significant variables, time, performance, tasks completed, etc.). At the end of the game play, these traces can be delivered to a group of experts or automated systems in order to identify what information can be extracted from these traces and infer a lot of useful information for modelling purposes (Stathacopoulou et al., 2007; Bouvier et al., 2013a; Bouvier et al., 2013b). For example, learner's learning style was modelled in (Stathacopoulou et al., 2007) by monitoring learner's actions over time, where each response such as a keystroke, mouse move or drag was timed and recorded. The learning environment stored all available information about what a learner was doing in a log file, recording each learner action with a time stamp. Furthermore, this work used teachers' expertise in order to select the appropriate measures of learners' observable behaviour to serve as indicators of learners' learning style.

Learners' engagement was identified in (Bouvier et al., 2013a; Bouvier et al., 2013b) by relying on their traces of interactions performed in the learning game. The study proposed an approach that consists of three stages. The first stage aims to determine the high-level engaged-behaviours. The second stage aims to characterize these engaged-behaviours by identifying the underlying chains of actions. The last stage aims to detect these chains of actions among all the actions recorded.

3.3 Interpreting Conversation

In this method, information about the learner is extracted from his/her communication with a Non Player Character (NPC). The NPC poses questions and records learner's choices during these conversations and questions answered during game dialogues (Pablo et al., 2007; Genaro et al., 2008).

For example, learner's learning style and learner's preferences were modelled in (Pablo et al., 2007) by interpreting conversations between the learner and NPC during the game play. In particular, the NPC queried the learner on his/her preferences and other questions. Depending on the learner's choices during these conversations, the game detected his/her learning style and also detected his/her preferences.

A NPC in the (Genaro et al., 2008) monitored perpetually the learner and requested her/him to answer questions. The system collected and processed the learner responses. After that, it calculated learner's level of motivation. Then it selected one rule from a set of rules taken from theory and reacted aiming to sustain or enhance the current level of motivation.

3.4 Interpreting Learner's Errors

The goal of this method is to retain the information of what the learner has learnt, and what the learner has learnt incorrectly. In addition, this method records learners' misconceptions, errors, number and type of mistake made by the learners, learner failure and success and the time taken to complete the game (Champagnat et al., 2010; Khenissi et al., 2013).

For example, learner failure and success in (Champagnat et al., 2010) are pursued. In the case of failure, the game has to be permissive with the learner. This done by punishing the learner (worse results, handicaps at the time of the following tests, less points) but not stop him from playing or reiterate the stage.

Learner model in (Khenissi et al., 2013) detected learner's deficiency in programming subject. To do that, the learner model keeps track of the learner's wrong answers when he/she arranges a set of unordered instructions in order to form a program. In particular, when the learner moves an instruction in inappropriate place, the learner model records the incorrect answer and provides him appropriate helps.

3.5 Path Follow

The goal of this method is to follow the path of learner during the game play, record learner trajectory towards a goal and then interpret and infer information about the learner. In fact, each path has a specific meaning and leads to specific information about the learner (Moreno-Ger et al., 2008; Genaro et al., 2009).

For example, (Moreno-Ger et al., 2008) described the game as state transition systems in order to assess learner activity inside the game. During the game play, actions of the learner triggered state transitions and the sequences of

actions leaded to one or many end states. The game engine kept track of transitions, checked the states that the game went through and generated reports describing them.

A virtual observer within the educational game in (Genaro et al., 2009) monitored the learner and identified his/ her learning trajectory. Learning trajectory identified was compared to different predefined learning trajectories. This comparison informed the learner model to take a decision on how to proceed.

4 EDUCATIONAL GAMES USED TO MODEL LEARNER

This section describes educational games used to model the learner. Most of these educational games include mechanism to extract specific information about learners. This is an attempt to facilitate experimental research in this field and help a new researcher in the field to start his/her own work.

4.1 Prime Climb

Prime Climb is an educational game designed to help 6th and 7th grade students practice number factorization. Prime Climb consists of series of mountains. Each mountain is divided into hexes labelled with numbers. Two players must collaborate to climb these mountains. Each player can only move to a number that does not share any common factor with the partner's number. If a wrong number is chosen, the climber falls and swings from the rope until the player select a correct number. During the game, each student has a pedagogical agent which provides support. This educational game was cited in many works for different purpose (Conati and Maclaren, 2009).

4.2 Learning Version of Pacman Game

Learning version of Pacman game (LPG) aims to motivate learners to correctly answer the questions of the programming languages. In the traditional version of Pacman game, players control Pacman through a maze, eating pac-dots. When all dots are eaten, Pacman is taken to the next stage. In addition, there are four enemies who roam the maze, trying to catch Pacman. If an enemy touches Pacman, a life is lost. Near the corners of the maze are four dots known as power pellets that provide Pacman with the temporary ability to eat the enemies. When all lives have been lost, the game ends. In the Learning version of Pacman Game, when Pacman eats a power star, the learner has to respond to a question (about the programming language) in order to continue the game having a 'reverse' role (Pacman can move freely and eat the enemy for a short period) (Khenissi et al., 2013c).

4.3 Talking Island

Talking Island is an educational Massively Multiple Online Role-Playing Game (MMORPG) designed to teach English vocabulary and conversational skills to elementary school students. It includes elements that are generally found in an MMORPG (e.g. team-work, battles, pets, and role-playing situations). The learner can practice the pronunciation thanks to voice-recognition module included in this game. In fact, this module diagnoses the correctness of the pronunciation and determines whether the learner reaches a new level or passes a quest. In addition, this game allows players to team up, communicate via voice or texts, and solve quests jointly (Hou, 2012). This educational game is accessible online at http://www.talking-island.com/

4.4 e-Adventure Educational Game Engine

E-Adventure is a game engine designed to facilitate the creation of educational games. Games delivered by e-Adventure engine are point and click adventure games. During the game, learner can learn by the interaction with objects, consultation of in-game books and conversations with other characters. The <e-Adventure> engine includes mechanisms that can monitor the learner's activities and then provides adaptation and assessment (Pablo et al., 2007). The E-Adventure platform is accessible online at http://e-adventure.e-ucm.es/

4.5 ELEKTRA Game

The ELEKTRA game is a narrative-driven adventure game. In this game, the learner has to solve several physics-oriented puzzles. A virtual character (representing the ghost of Galileo) guides, advises and encourages the learner during the game (Conlan et al., 2009). The ELEKTRA project is accessible online at http://www.elektra-project.org/

4.6 80Days Game

80Days is an adventure game used to teach

geography for a target audience of 12 to 14 year olds and follows European curricula in geography. The game story is about an alien scout called Feon which kidnaps a Boy (play character) and travels with him around the world in a spaceship to collect relevant geographical information. The player assists the alien to explore the planet and to create a report about the Earth and its geographical features. In the course of the game, the player discloses the aliens' real intention which is preparing the conquest of the earth. The player has to save the planet and the only way to do it is to draw the right conclusion from the traitorous Earth report (Kopeinik et al., 2012). The 80Days project is accessible online at http://www.eightydays.eu/

4.7 Instruction Right Place Game

Instruction Right Place Game allows learners to benefit from the drag and drop technology to construct a program (from any programming language) in an amusing way. This educational game breaks down complex programming tasks and guides learners through a series of small steps to form a program interactively (Khenissi et al., 2013a; Khenissi et al., 2013b; Khenissi et al., 2014).

4.8 Educational Games and Methods of Learner Modelling

The process of creating learner model requires several observations (Inputs) collected from the learner's interaction with the educational game.

Methods described in this paper will use these inputs in order to extract specific information about learner (Outputs). This information will be stored in the Learner Model. Most of educational games previously cited include mechanism to extract specific information about learners and then give them adaptation. Table 1 summarizes input, methods and output used by these educational games, and cited in the literature, in order to model learners.

Table 1 shows that different educational games have used different methods for creating learner model. For example, the educational game Prime Climb has used body expression of the learner, as input, and *interpret body posture and physiological signals* method in order to model learner's emotions. Indeed, manifestations of emotion are expressed immediately through the body. Hence, the best way to extract these manifestations is to interpret body posture and physiological signals of the learner using hardware and software equipment. As another example, the table shows that learner's deficiency can be modelled using *interpreting learner's errors* methods. In particular, this method tracks errors of the learner in order to interpret them.

5 CONCLUSIONS

In this paper, we focused on learner modelling using educational games. In particular, we gathered information from various works in the field and identified the most important methods used. Furthermore, several educational games used to model the learner and available for researchers are presented and discussed

The use of educational games can improve learner motivation, increase learner's desire to learn and develop positive attitudes toward many subjects. Furthermore, learner modelling through the use of educational games can create a reliable learner model that has an extremely important role in adaptive learning system.

For future work, we will look how to adapt the game experience to the individual learner using learner model. In fact, adaptation service in educational game can improve the learning process.

Table 1: Educational Games and Methods of Learner Modelling.

	Educational games	Inputs	Methods	Outputs
1	Prime Climb	Body Expression	Interpreting body posture and physiological signals	Learner's emotions
2	LPG	Questionnaire	Evaluation of questionnaire	Learner's level of knowledge
3	Talking Island	Learner behaviour	Interpreting Interaction traces	Learner activity
4	E-Adventure	Conversation of the learner	Interpreting conversation	Learner's learning style
5	ELEKTRA game	Actions of the learner	Translating learner's actions	Learner's skills
6	80Days game	Learner behaviour	Path follow	Learner's competences
7	Instruction Right Place Game	Errors of the learner	Interpreting learner's errors	Learner's deficiency in programming subject

Therefore, we will discuss methods and techniques used in this field.

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