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Dynamically Adaptive Educational Games: A New Perspective

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Abstract. Dynamically adapting educational games seem to be useful for sustaining the engagement of the player to the game. Although there exist several examples of adaptive educational games, they mostly only base the adaptation on the performance of the player, and only adapt the difficulty level or the learning content of the game. In this paper, we propose a model for a richer dynamic adaptation, in which several aspects are taken into account for providing a more personalized gaming experience to sustain the engagement of the players to the game.

Keywords: Educational games, Adaptive games, Real-time adaptation

1 Introduction

One of the challenges in designing educational games is to come up with a game that is appealing, fun to play, and most importantly engaging; but perhaps the greatest challenge is to sustain the engagement of the player. According to several authors, e.g., [1, 2], a successful game is such that its players experience the "flow state", introduced by Csikszentmihalyi [3] and meaning the state of absolute and utter engagement to an activity. It is shown that the flow state has a positive impact on learning [4] and should therefore be considered when designing educational games. Moreover, in his "Experiential Gaming Model" [2], Kiili also uses the flow theory for facilitating a positive user experience of the player, but also stresses *"the importance of designing and balancing challenges in order to generate an optimal learning experience for players"* (page 2). Furthermore, motivation is also considered as a key factor for reaching the flow state [5]; the game must be motivating enough for its players to keep playing it. However, in the literature, no consensus about the source of motivation in games can be found. For some [6, 7], the key source of motivation is the narrative context of the game, whereas for others [5, 8] the system of rewards and goals is the true cause of motivation. In either case, motivation seems to plays an important role. Similarly, in educational games, it is also recommended that an effective design

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should consider the motivation of the learner, in particular both intrinsic and extrinsic motivation [5,8–10]. The two mentioned terms have been differentiated as follow: *"Intrinsic motivation pushes us to act freely, on our own, for the sake of it; extrinsic motivation pulls us to act due to factors that are external to the activity itself, like reward or threat"* (page 1) [5]. Also stimulating intrinsic motivation (in addition to stimulating extrinsic motivation) could be important in sustaining the engagement of the learner (player), especially in the case of people with low motivation for learning, since the use of extrinsic motivation may not always work for these people. However, as it is evident from its definition, the source of intrinsic motivation can be quite different from person to person. Thus, adaptation of the educational game to the individual learner could be a way to increase the intrinsic motivation. On the other hand, while at the start of the game the learner's intrinsic motivation can be good, it may (quickly) decrease during the game for all kind of reasons. Dynamically adapting the game, i.e. while the learner is playing the game rather than only adapting the game when starting the game or at a new level, could be a way to deal with varying motivation. However, achieving *effective* dynamic adaptation in games is quite challenging, and even more challenging in educational games. This is mostly due to the need of having a balance between learning and fun in these games [11, 12], and at the same time providing the correct level of challenge to the player (not under challenging but also not overburdening [2]).

In this paper, we propose a new model for dynamically adaptive educational games. The model allows for adapting an educational game based on different aspects and at different moments, in order to provide a rich personalized experience, to sustain the engagement of the learner, and thus providing a more suitable frame for experiencing the flow state. The rest of the paper is organized as follows: section 2 discusses adaptive games, section 3 introduces the proposed model, and section 4 provides conclusions and future work.

2 Adaptive Games

In the context of educational games, different researches on adaptation have been performed, for example, in the *ELEKTRA* project [13] the notion of micro-adaptivity is introduced to guide and support learners in acquiring knowledge by informing them, providing hints, or intervening when a misconception occurs. There are methods for predicting the actions that the player might take while playing the game and then adapting certain aspects of the game accordingly [14]. There are also methods for generating adaptive game worlds based on the players and their experience model [14].

In educational games, the adaptation of games is mostly in the form of difficulty adjustments or content adaptations, ranging from its simplest form of adjusting the difficulty level of exercises or content on each new start based on the previous performance, to dynamic adjustments based on the real-time performance. There are models that use both parameters, performance and content, for creating adaptive educational games. For example, "The Competence-based

Knowledge Space Theory" [15] is a prime example of a model providing different learning paths for the same learning topic to the players based on their competencies. We agree that these type of adaptive games do indeed provide a personalized experience, but we wonder whether they also meet one of the requirements for successful learning, i.e. take into consideration that "*people learn in different ways* and *at different paces*"? [1] The current adaptation techniques can deal with the aspect "people learn at different paces", but not with the aspect "people learn in different ways". We argue that performance and content, although being undoubtedly important factors for adapting games, are merely two factors out of a group of factors that can be used for creating an effective learning experience in educational games.

3 Proposed Model

We propose a new model for dynamically adapting educational games. The overview of our model is given in Figure 1. Our model is roughly built on top of the experiential gaming model proposed by Kiili [2], which in turn is based on the flow theory [3] and the Kolb's learning style theory [16]. Based on Kiili's work, the goal of his model is to provide a link between gameplay and experiential learning. At the heart of his model lie *challenges* that should be based on educational objectives. These challenges should be appropriate for the player to sustain motivation and engagement.

In our model, similar to Kiili's, challenge is of considerable importance. As a structuring framework for defining the challenges, we opt for the *learning style model of Kolb*, which advises to go from concrete experience to reflective observation, abstract conceptualization and then active experimentation. The challenges in the game should be determined based on the educational objective of the game and Kolb's learning style theory. As an example, for a game with the educational objective of learning mathematical concepts, the first few challenges of the game would be defined based on concrete experience, then a reflective observation on the challenges should be provided to the player, then challenges on abstract conceptualization, and finally on active experimentation. Furthermore, the challenges must be tightly coupled with the game.

As the personality of the player may have an impact on how he can be motivated to play, learn, and stay engaged, our model also takes into consideration the personal traits of the learner. To model *the personality of the player*, we currently use the big five personality trait theory [17], one of the most researched and accepted theories in describing human personality. In this theory, five dimensions are used to characterize the personality of a person (Neuroticism, Extraversion, Openness to experience, Agreeableness, and Conscientiousness). The values of the big five personality traits of the learner will be used as the starting point for personalization; for instance if the player is generally an anxious (Neuroticism) person, lesser or even no temporal constraints could be considered in the game.

As we also want to give due consideration to the fact that "people learn in different ways", we also consider the *learning style* of the player. For this, we

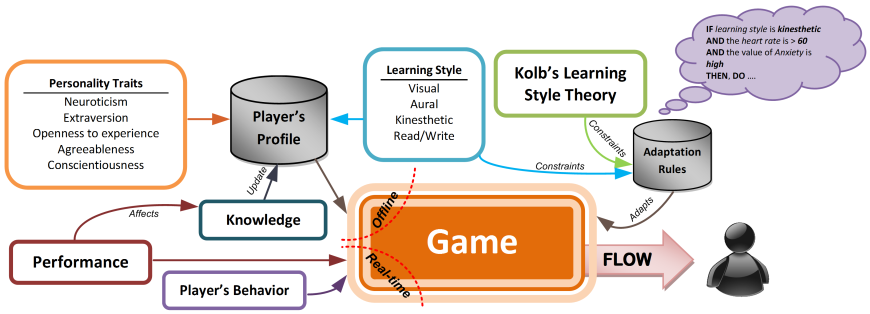

Fig. 1. Dynamic Adaptive Educational Game Model

use the VARK learning style theory [18], where learners are categorized into four groups based on their learning preferences (Visual, Aural, Read/Write, or Kinesthetic). The VARK learning style theory is actually an instructional theory indicating what method of instruction is going to be more appropriate for a person. For example, a person might learn better, if the learning material is presented to him/her in a more visual way (visual learning style) or if the person could kinesthetically interact with the learning objectives perhaps through gestures using for example Microsoft Kinect (kinesthetic learning style).

Furthermore, and well-accepted, the knowledge level of the player also plays an important role in the adaptation, as the learning challenges should not be too easy but also not too difficult. The knowledge level of the player can be assessed from the records of the previous performances of the player.

All three previously mentioned dimensions: knowledge, personal traits, and learning style, will be determined before the player commences playing the game, e.g., through questionnaires, or they may be predefined if the educational game targets a specific group of people (e.g., kinesthetic learners). This information will be saved in *the profile of the player* and used in each play session. Personal traits and learning style are considered to be rather stable during a given period of time (although they may change during the lifetime of a person), and therefore we consider them to be fixed during the playtime. Knowledge, on the other hand, may increase during playtime and thus, updates the profile of the player after each session. Since the mentioned three factors are used for adaptation before the player actually starts playing the game, we called this *offline adaptation.*

On the other hand, *performance* and *player's behavior* can be used in real time to dynamically adapt the game, therefore we call this *real time adaptation.* There are several elements that can be measured for determining the performance of the learner (e.g., success rate, number of errors, task completion time); similarly, there are also different elements that can be taken into account to determine the player's behavior or state (e.g., facial expression, eye gazing, speech analysis, heat rate, and attention level). Nowadays, a variety of (non-intrusive) devices exists to determine the variations in the value of these elements in real-time (e.g., high definition cameras for detecting heart rate, cameras with thermal lens for detecting anxiety, cameras with facial expression recognition). Also some devices promise to assess more than one element at the same time, e.g., Microsoft Kinect 2.0 would measure heart rate, eye gazing, and facial expressions. Based on these values, the game can be adapted in real-time to sustain the engagement of the player by trying to keep the flow state. To perform the adaptation, the adaptation engine (abstracted as part of the game component in the figure) uses a set of *adaptation rules*. Based on the inputs (offline and real-time) relevant adaptation rules will be triggered. The adaptation rules are in the form of CONDITION-ACTION rules. An example adaptation rule could be:

```
IF(learning_style==‘kinesthetic’ && heart_rate >60 && anxiety==‘High’)
THEN{ difficulty_level-=1;
      ENVIRONMENT_TEXTURE(Relaxing);
      GAME_MUSIC(Relaxing);
      IF(EXISTS(Temporal_Constraint))
     THEN{ remove(Temporal_Constraint);  } }
```

There are many aspects of a game that can be adapted, (e.g., textures of game objects, the environment, the sounds, NPC interactions). What should be adapted at a specific moment is specified by the adaptation rules. In order to determine the conditions (IF-part) and the consequences (THEN-part) of these adaptation rules, experiments and research in close collaboration with experts in psychology and pedagogy is required. Note that the adaptation of the educational material of the game should be done with respect to the Kolb's theory; Kolb's Learning style theory in fact constraints the possible adaptation rules.

4 Conclusion and Future Work

We started by giving the motivation for having adaptive educational games. We noticed that for most educational games the adaptation is limited to the level of difficulty. However, this does not guarantee that the player stays engaged. Personality aspects, such as the personal traits and the learning style of the player, should also be taken into consideration. Therefore, a new model for more effective adaptation of educational games is proposed. The model is based on different existing and well-accepted theories from different domains: the flow theory of Csikszentmihalyi, the learning style model of Kolb, the big five personality trait theory, and the VARK learning style theory. In addition, we propose a distinction between two types of adaptation, offline adaptation and real-time adaptation. For offline adaptation, we not only consider the current knowledge level of the player but also his personality and learning style. For the real-time adaptation, we propose to monitor not only the performance of the learner, but also the behavior (or state) of the learner. This latter becomes more and more feasible thanks to new non-intrusive technologies. Using this information, the game can be dynamically adapted so that the players not only experience the flow state, but this experience sustain for longer periods. In future work, we will examine how we can do the adaptation in order to achieve this goal and keep the perfect balance between playing and learning. This is not straight forward; there is always the chance that by performing a certain change, the experience of the user is distorted. Furthermore, it is also necessary to evaluate the suitability and effectiveness of the different theories used (flow model, VARK, Big Five, and Kolb's theory).

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