TOWARDS A CONCEPTUAL MODEL FOR ADAPTIVITY IN SERIOUS GAMES

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ABSTRACT

In serious games, learning happens intrinsically while playing and the learning process is based on exploration and experience. Serious games are based on goals, rules, challenge, and interaction with a game world based on a virtual environment. A major goal in modern serious games is to provide adaptivity to the learner. This paper presents a review of literature about adaptivity approaches in both e-Learning and serious games. We argue that the problem in adaptivity approaches for serious games is that they are based on e-learning approaches, where the adaptivity for the game environment is not related to learning content. We conclude that in adaptivity of serious games there is no approach that adapts the game environment based on learning content and that there is no connection between both. We provide a conceptual model that extends e-learning approaches with the concept of the game environment and additionally connects the game environment and game elements with learning content.

KEYWORDS

Serious Game, Adaptivity, E-Learning

1. INTRODUCTION

One of the promises of intelligent tutoring systems ITS is teaching and assisting learning in an intelligent manner. This is overall the hope with all e-Learning systems. In comparison, serious games want to tap into the motivational power of games in order to raise interest in the subject matter taught leading to a higher retention of the content. Although both approaches are different, they both have similar goals. Therefore we strongly believe that combining the motivational power of games with the approaches to intelligently adapt to the learner in e-Learning systems can yield positive results. Serious games in contrast to ITS can be used in different situations. For example, children cannot work with most of the current ITS as they may not yet be able to read, and pilots cannot learn to fly a plane by reading the instructions or watching a video. In this paper we discuss how adaptivity might need to differ in serious games in comparison to e-Learning systems.

The contribution of this paper is threefold: we first we provide an overview of adaptivity approaches and frameworks for e-learning and serious games. In the next step we identify a missing link between the game environment and learning content where learning content is any representation of declarative and procedural knowledge. Finally we propose a model for adaptivity of serious games that includes the missing link.

2. ADAPTIVITY IN E-LEARNING

E-Learning can be traced back to 1960 where one of the first e-Learning systems was developed "PLATO"[1]. In 2003 e-Learning was seen as *"a paradigm shift in the way education is viewed and delivered"* (Hambrecht 2003). Nowadays e-Learning is associated with any form of learning that is supported electronically by any kind of technology. According to (Sirohi 2007) almost all possible technologies are used for e-Learning (Hambrecht 2003). It is a type of Technology Supported Learning (TSL). Some authors additionally emphasize that it is empowered by pedagogy (Nichols 2008).

Adaptivity was created in serious games in order to improve the learning outcome by adapting to the learner in several dimensions. The main approaches in realizing adaptivity in e-Learning can be categorized

as: the macro-adaptive approach, the micro-adaptive approach, the aptitude-treatment interaction approach, and the constructivistic-collaborative approach. (Mödritscher et al. 2004; Modritscher 2006) The *Macro-Adaptive Approach* targets the selection of different alternatives of main components like learning objectives (Mödritscher et al. 2004) as a kind of systematic guidance through learning content with adaptation to individual's learning objectives, performance, and aptitude (Corno & Snow 1986).

In contrast to Macro-Adaptivity, which concentrates on the contents to be taught the *Micro-Adaptive Approach* addresses on adapting instructions. According to this approach there are two main processes: the diagnostic process and the prescriptive process. In the diagnostic process the learner's characteristics are assessed (Rothen & Tennyson 1978). Typical characteristics are learner type, interests, and motivation (Blanchard & Frasson 2004; Vicente 2003). The prescriptive process is "optimizing the interaction between the learner and the task by systematically adapting the composition and sequencing of learning content to the students' aptitudes and recent performance" (Mödritscher et al. 2004). The *Aptitude-Treatment Interaction Approach (ATI)* states that there is no treatment that suits all students. Efficiency of treatments depends on the aptitude of students where students with higher prior knowledge should have more control over the learning process (Snow 1980). In the *Constructivistic-Collaborative Approach* the learner is the central component of the learning theory and is used where computer-based learning systems cannot reach the effectiveness of good human tutors. (Bloom 1984; Mödritscher et al. 2004)

Macro-adaptive and Computer-managed Instructional Systems were developed from 1963 to 1967 where different systems were developed like 'Keller Plan', 'Prescribed Instructional System (IPI[1])', 'Adaptive Learning Environments Model (ALEM[2])', 'Individually Guided Education (IGE[3])', and 'Program for Learning in Accordance with Needs (PLAN[4])' (Mödritscher et al. 2004). *Computer-managed instructional systems (CMI)* are a class of systems that were developed according to the macro-adaptive approach but extended it with diagnostic features.. CMI systems are much more effective than pure macro-adaptive instructional systems, in terms of adaptive e-learning." (Mödritscher et al. 2004)

Pedagogical Agents is a class of e-Learning systems that focus on the interactions with learners. Example systems like COSMO and MORE try to detect and increase the motivation of learners while using a system. They focus on giving the user someone who accompanies the learning process and intervenes with direct interaction, and by changing the learning-system properties in a non-invasive way.

Constructivistic-Collaborative e-Learning Systems are following the constructivistic-collaborative approach. Computer-based collaborative tasks (CBTC) and Computer- supported collaborative learning (CSCL) focus on group learning while cooperative tools (CT) or intelligent cooperative systems (ICS) try to give an impression of a co-learner. Intelligent Constructivistic Environment for Software Engineering learning (INCENSE) is an example system that is based on the constructivistic approach, and that tries to integrate into the working environment of software engineers. Another way to construct knowledge is implemented by HERMANA, which is a dynamic background library that can be used to enable experts directly to construct knowledge. *Intelligent Tutoring Systems (ITS)* are adaptive instructional systems that can adapt their teaching rules to the individual's performance by applying AI techniques by comparing the learner with expert solutions (Bloom 1984; Anderson et al. 1995; Niemiec & Walberg 1987).

One additional approach to intelligent tutoring are Adaptive Hypermedia Systems (AHS). Based on ITSs they try to combine adaptive instructional systems and hypermedia-based systems. (Mödritscher et al. 2004).

3. ADAPTIVE SERIOUS GAMES FRAMEWORKS

Serious games do not only consist of the content that needs to be tailored towards the learner, but also of game-design oriented components (Tan et al. 2007). Learner components are 'psychological needs', 'cognitive development', and 'learning behavior'. Psychological needs need to be considered according to the theory of Developmental Stages. Cognitive needs focus on the 'Piaget's Stages of Cognitive

[1] IPI was developed at the University of Pittsburgh in 1964.

[2] ALEM was developed based on IPI

[3] IGE was developed at the University of Wisconsin in 1965.

[4] PLAN was developed by the American Institutes for Research in the Behavioral Sciences in 1967

Development'. Learning behavior focuses on behaviorism and other learning theories.

Game design oriented components are 'multimodality', 'task' and 'feedback'. According to the most frameworks, multimodality focuses on the interaction between learner and the game, and proposes the use of sound, text, movies, animations and visual effects. The 'task' component proposes the design of tasks in the game with different difficulties where the difficulty should be for on each player. The 'feedback' component should be considered according to 'The Engaging Multimedia Design Model'. In this section we will show some adaptivity approaches taken in serious games and how they relate to approaches used in e-Learning.

(Bellotti et al. 2009) propose an 'Experience Engine' that allows to insert, quantitative specifications for effective skill acquisition. The focus is on educators after the design of a game. In this context, task and game authors are adding content separately, while the task author does not have influence on what task will be integrated in the game. Game authors decide what task should be selected and if they fit in the game idea. Adaptivity in this engine is based on the selection of tasks, where the tasks are organized in missions, and missions in objectives. The intelligence of this engine is based on observation of the player and the in the decision of the selection of tasks called "Model of the Delivery Strategy".

Very promising work was done in the project ELEKTRA (Peirce et al. 2008; Kickmeier-Rust et al. 2006) (Enhanced Learning Experience and Knowledge Transfer). ELEKTRA proposes an approach for non-invasively adapting a game to enable a personalized learning experience. The goal of ELEKTRA is to establish a methodology with the advantages of computer games for educational purposes. The adaptive game engine in ELEKTRA helps the learner to experience personalized learning situations. However ELEKTRA is not only being adaptive regarding knowledge but also regarding motivational states, learning styles, or didactical strategies (Kickmeier-Rust & Dietrich Albert 2008).

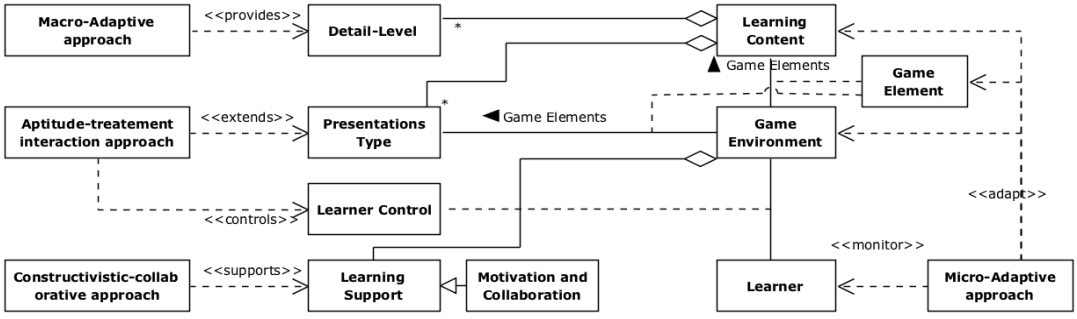
(Köhler et al. 2011) proposes a model for representing stories, which allow selecting the best learning path based on inferences made about the learner with the Knowledge Space Theory (KST). The authors argue that additionally to a KST model an additional structure is required, which defines dependencies and mutual exclusions between the quests that make up the story.

In (Ismailović et al. 2011) the authors propose to use serious games for literacy acquisition in early reading. The authors propose a model for adaptivity of the game to the learner and collaboration between learners. The authors present an example serious game weMakeWords. weMakeWords is an adaptive serious game for literacy acquisition that enforces collaborative actions between players where children aged between 4 and 8 are constructing words in teams. In this work a skill based model was proposed that follows that learning path of the learner and maintains a learner's profile based on the acquired skills. In this work, the authors found that with the game, German children aged between 4 and 8 years were able to learn up to 4 words in Chinese, even though they never heard and saw Chinese. Another finding was, that children were able to learn game rules faster when supervised by a tutor.

4. A CONCEPTUAL ADAPTIVITY MODEL FOR SERIOUS GAMES

The following Figure models the four main approaches: the macro-adaptive approach, the micro-adaptive approach, the aptitude-treatment interaction approach and the constructivistic-collaborative as they are related to serious games. We additionally extended the used approaches by including the "Game Environment" and the relation of "Game Elements" to learning content.

Figure 1. A Conceptual model for adaptivity in serious games (UML class diagram)



5. SUMMARY AND CONCLUSION

It can be taken for granted that intensive research is conducted in the direction of serious games. There are magnitudes of papers about the advantages of serious games. However only a minority of them deals with adaptivity. Combining adaptivity approaches as used in e-Learning with the motivational power of serious games could improve learning. Unfortunately we found that adaptivity in serious games is mostly based on approaches that were designed for e-Learning. Most of the frameworks and models described in this paper are based on this approach, which leads to the fact that the adaptivity of the game environment is missing. We found that most promising applications of e-learning approaches in serious games are virtual tutors ('tutor adaptivity') where adaptivity is applied in form of the tutor's talk or by changing the its gestures. We model the game environment as the learning situation of serious games which needs to be adapted based on the named approaches illustrated in Figure 1. In order to combine the promising approaches in e-Learning with serious games, the link between learning content and game elements needs to be established.

This paper presents a conceptual model that provides the link between the game environment in serious games and the learning content.

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