Interoperable Adaptivity and Learning Analytics for Serious Games in Image Interpretation

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Abstract. Personalization and adaptivity in computer simulations and serious games are being used to achieve positive long term effects on the users' engagement, motivation and ultimately on the learning outcome. Interoperability regarding the collection of usage data allows for an effective analysis of the interaction and learning progress data. This paper presents an interoperable adaptivity framework combined with a web-based tutoring interface which gives learning analytics insights. The developed framework "E-Learning A.I." (ELAI) acts as an intelligent tutoring agent for simulations and serious games and uses the Experience API (xAPI) protocol. The application of the ELAI has been demonstrated in an adaptive map-based learning game for aerial image interpretation. The scientific research questions affect the possible usages of the collected interaction data, how to manifest adaptivity in games, how to realize interoperable adaptivity mechanisms for simulations and serious games, and how to make use of collected usage data.

Keywords: e-learning, adaptivity, interoperability, serious games, image interpretation

1 Introduction

This paper describes an adaptivity framework for serious games and simulations. Adaptivity in this paper means the continuous adaptation of serious games and computer simulations to the needs of the learners, i.e., interaction mechanisms, content or recommendations are episodically personalized by an automatic intelligent tutoring component. Adaptive serious games and computer simulations for training should keep the users motivated to ultimately increase the learning or training outcome. The users should be kept in an immersive state. For simulations and games user engagement can be achieved by adapting the simulations and games to the needs of the users and by keeping them immersed, e.g., by balancing the adaptivity inside the *Flow Channel* [2,1].

The contribution of this paper is the description of the further developed ELAI concept [9] with focus on the adaptivity technologies, its application and the tutor interface for learning analytics. The problem statement is that in current computer simulations and digital game based learning systems little or no concepts for didactic adaptivity exist [10]. Which interaction usage data can be

used for adaptivity and how to manifest that adaptivity in real games? How to realize interoperable adaptivity mechanisms for simulations and serious games? The proposed ELAI framework is designed to enable interoperable adaptivity to the attached game engines and games or computer simulations, and to enable tutors to monitor the users' progress. The application domain of this research is e-learning for aerial image interpretation for reconnaissance, i.e., the identification and analysis of structures and objects by experts (image interpreters) according to a given task on basis of imagery data [8].

Similar to our approach is the ISAT architecture [4], which provides trainees with a story-wise individualized training environment. Another similar examples for decentralized adaptive architectures are the ALIGN architecture [7], the test and training architecture TENA [5] or the CIGA middleware [6]. A similar architecture also using the xAPI but mainly for learning or gaming analytics (and not directly for adaptivity) can be found in the RAGE EU project [11]. Though multiple overlaps exist between the aforementioned architectures and our ELAI framework, our approach focuses on a holistic interoperability architecture for both learning analytics and adaptivity.

2 Interoperable Adaptivity - E-Learning A.I. (ELAI)

Our interoperable adaptive framework "E-Learning A.I." (ELAI) provides adaptivity to attached simulations or serious games [9]. Its characteristic features are its interoperability aspects and the externalization of the tutoring agent (Figure 1). The software architecture decouples a game engine from the adaptivity component which typically is built into (adaptive) simulations or serious games in a monolithic fashion. It consists of a game engine adapter to capture usage data and to present the adapted content. At its core it has an intelligent tutoring controller which interprets the collected data to adjust the simulations or games [10]. A web-based interface provides tutors with learning analysis insights, e.g., diagrams on the task and learning progress, learning profiles classifications, or features to control the level of adaption for specific users.

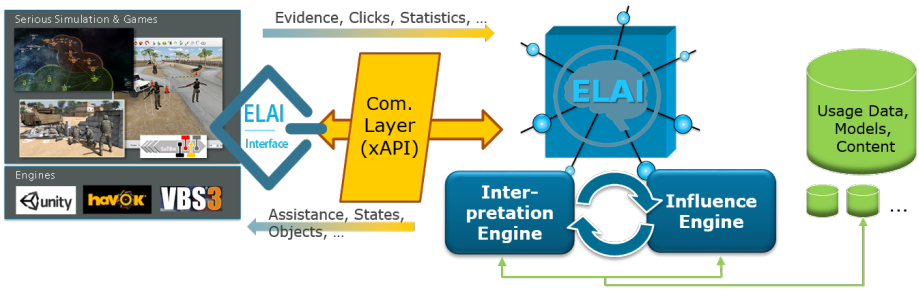

Fig. 1. ELAI Framework

The game engine adapter is specific to each engine, genre and game. Its main purpose is to bidirectionally communicate with the ELAI controller, i.e., it collects data on the users' interaction, on the game, on the scene and on the game objects. On the way back it modifies the game, e.g., it "injects" a virtual agent which gives recommendations, or it makes in-game modification to game objects or of the game flow, i.e., modification of the underlying state machines. The communication layer mediates the data between the game (game engine) and the ELAI controller, and it uses the e-learning interoperability protocol *Experience API* (xAPI). The tutoring component, the ELAI controller, is the central "intelligent" element of the ELAI framework. It has an interpretation engine (for usage data analysis) and an influence engine (to select adequate reactions). Both can make use of artificial intelligence technologies. In our prototype we implemented rule-based heuristics and k-means clustering. The rule-based heuristics are used to determine the learners' state to get a performance score which is used by the adaptation (influence) component. Clustering is used to dynamically find difficulty levels (i.e., the borders) and classify new learners according to that levels. In contrast to other e-learning systems we propose to use a flat user model which basically is a collection of all user interaction data in the xAPI/Activity Stream format. Additional extracted "higher information" from the *Didactic Factors* [3] is stored in that collection as special xAPI statements as well.

We implemented a software prototype in a serious game for image interpretation. The game's objective has the serious background to train image interpreters to correctly differentiate various vehicle types which could differ by very subtle differences, e.g., by just an additional antenna. The implemented didactic factors to analyze the player's state are the overall task duration, the task difficulty and the task helping count. The weighted linear combination of these factors yields an index value which is used as helping level and adaptivity trigger. Techniques for dynamic difficulty adaptation for image interpretation have been realized, e.g., blurring, noise, partial occlusion, deterioration by compression artifacts, etc. The helping level controls how often and in which quality the virtual agent offers context-relevant textual hints, i.e., at the lowest level the agent is passive, whereas at the highest level the agent pro-actively offers navigational hints.

As the ELAI architecture makes use of the xAPI protocol, tools for learning analytics can be attached. For instance, this allows to report on the number of successfully completed game sessions or on the frequency of some interactions. Such type of reports are already included in some xAPI *Learning Record Stores* (LRS) or in some xAPI tools (e.g., xAPI Dashboard). For the ELAI we added the functionality to manually control the adaptivity parameters via a web-based interface, e.g., control on the difficulty, helping or skill level.

Evidence of a first evaluation of the prototype show that the adaptivity mechanisms are positively recognized by the participants. Further work has to address issues with the current realization of the virtual agent - it should be triggered on-demand only. However, the adaptively adjusted helping level and the quality of the hints showed to be appropriate. The web-based tutor interface was well accepted and rated as helpful to interpret the learners' progress.

3 Summary

This paper presents the interoperable adaptivity framework for simulations and serious games, called "E-Learning A.I." (ELAI). The solution approach is a decentralized software architecture which decouples game engines from internal adaptivity components which typically are monolithically built into (adaptive) simulations or serious games. The architecture consists of a game engine adapter and a communication layer to capture data and to present adapted content. At its core is an intelligent tutoring controller (the ELAI controller) which interprets the collected data to adjust the simulations or games. The architecture has been verified in a seek-and-find game for image interpretation. Future work will address other games and simulations as well as further analysis of usage data.

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