# TOWARDS AN INTEROPERABLE ADAPTIVE TUTORING AGENT FOR SIMULATIONS AND SERIOUS GAMES

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**ABSTRACT**

Computer simulations and digital game based learning systems have to adapt to the experience and knowledge level of the users to exploit their intrinsic motivation for interaction and learning. To facilitate the deployment of intelligent tutoring tools they must follow interoperability standards. The solution approach described in this paper is a distributed intelligent tutoring agent framework. It communicates with the game engines via the High Level Architecture (HLA) with payloads based on the eXperience API (xAPI) and the IEEE Learning Object Model (LOM). This framework adapts the connected simulations to the experience level of the users to keep them in the flow channel. Its application is image interpretation for reconnaissance. This paper describes the overall system architecture and the general adaptation design principles.

**KEYWORDS**

Adaptivity; Interoperability; E-learning A.I.; Serious Games; Modeling and Simulation

## 1. INTRODUCTION

In view of the fact that most e-learning users nowadays are affine to games and simulations the development of digital game based learning systems is the next logical step (Prensky 2005; Cruz-Cunha 2012). These computer affine users acquire knowledge not only the formal way in schools or universities but continuously while they interact with their smartphones, tablet computers or desktop PCs. The intrinsic motivation to play and interact is exploited to support learning (Schiefele & Schreyer 1994). Simulations and serious games can keep the users motivated and engaged. Engagement – instead of enragement (Prensky 2005) – can be achieved by adapting the interactive programs to the needs of the users and by keeping them immersed in the game or simulation, i.e. by keeping them in the flow channel (Csikszentmihalyi et al. 2014; Chen 2008).

Adaptivity in this paper means the adaptation of serious games and computer simulations to the needs of the learners, i.e. the interaction mechanisms, content or suggestions are personalized by an automatic intelligent tutoring component. Machine learning and data mining techniques are used to find the adjusting screws and parameters for best personalization leverage.

The application domain of this research is image interpretation for reconnaissance, i.e. the identification and analysis of structures and objects by experts (image interpreters) according to a given task. The image data could be optical, radar, infrared, hyper-spectral etc. For example, radar image interpretation is used in search and rescue operations to find missing earthquake victims etc. However, quirky effects of the radar imaging technology make understanding hard for non-experts, so expert knowledge is needed and people have to be trained (Roller et al. 2013).

The problem statement is that in current computer simulations and digital game based learning little or no concepts for didactic adaptivity to the learners needs exist. Intelligent game based learning systems are typically not designed in an interoperable way. For adaptive serious games and adaptive simulations the intelligent tutoring components should be designed as external software systems which follow commonly used interoperability standards for data acquisition and information exchange.

The solution approach described in this paper is a distributed intelligent tutoring agent framework. It communicates with the engines via the High Level Architecture (HLA) with payloads based on the eXperience API (xAPI) and the IEEE Learning Object Model (LOM). It adapts the connected simulations to

the experience and knowledge level of the users to keep them in the flow channel. The contribution of our work is the concept of such an interoperable framework for adaptive simulations and serious games.

## 2. RELATED WORK

The focus of our work is on interoperable adaptivity for computer simulations and serious games for training and digital game based learning. Adaptive serious game is an active research topic (Van Eck 2007; Lopes & Bidarra 2011). It has been shown that effective learning outcomes can be achieved when using adaptive learning games (Johnson et al. 2007; Conati & Manske 2009). For a detailed overview of adaptive educational games see Peirce et al. (Peirce et al. 2008) who also present the ALIGN architecture for non-invasively adapting a serious game to enable a personalized learning experience. The architectural principle and internal setup of ALIGN are very similar to the concept of ours. Also similar is the agent framework TARGET for modular serious games by Jepp et al. (Jepp et al. 2010) TARGET provides serious game environments with believable agents to help players learn skills and to evaluate their performance. The technical aspects and a solution how to connect multi-agent systems to game engines have been presented by Van Oijen et al. in the CIGA middleware (van Oijen et al. 2012). They present an architecture to connect multi-agent systems to game engines using ontologies as a design contract. A further architecture for testing, training and simulation is TENA (Noseworthy 2008). This extensive architecture focuses on interoperability for military test and training systems. Game based learning in image interpretation for reconnaissance is a rather new field and it seems no research has been done in this area yet.

## 3. ADAPTIVE INTEROPERABLE TUTORING AGENT

The proposed framework for the adaptive interoperable tutoring agent consists of a game engine adapter, a communication layer based on HLA with xAPI payloads aligned to IEEE LOM and an external intelligent tutoring agent which interprets the collected data to adjust the game or simulation mechanics.

Serious games should keep the learner motivated to ultimately increase the learning outcome. One of the most prominent exploited psychological models to describe the users' motivational state is the flow principle (Csikszentmihalyi et al. 2014; Chen 2008). A highly motivational state with high immersion corresponds to the so called flow channel (Csikszentmihalyi et al. 2014), i.e. challenge and skill level are balanced. The general adaption design principle of the proposed framework is to keep the learner in this flow channel. A typical adjustment screw is to dynamically adapt the difficulty level or to modify the game mechanics (Van Eck 2007). One has to keep in mind that for a game the gaming aspects must come first and the learning content second, because “an educational game is first a game and an educational tool second” (Van Eck 2007; Peirce et al. 2008). In Intelligent Tutoring Systems (ITS) reorganization of learning content along adaptive learning paths is a feasible method to achieve personalization (Szentes et al. 2011; Swertz et al. 2013). However, in a game setting the narrative elements are prominent and they are often designed as static and linear with certain sequencing constraints (Salen & Zimmerman 2004). The ALIGN system by Peirce et al. respects those constraints by introducing consistency and game constraints which ensure that recommendations match the narrative consistency (Peirce et al. 2008).

We propose to a) exploit the principles of storyboards (Fujima et al. 2013) in combination with constraint models for structuring courses (game/simulation mechanics), and b) to use the principles of the Web-Didactic (Swertz et al. 2013) and the IEEE LOM metadata schema to structure and semantically annotate the content. The Web-Didactic introduces knowledge types and metadata ontologies for learning objects (LO). Games structured by storyboards are basically sequences of episodes (macro level), whereas each episode has (atomic) scenes as children (micro level) (Fujima et al. 2013). The amalgamation of storyboards with the Web-Didactic in combination with the IEEE LOM metadata schema (IEEE Learning Technology Standards Comittee 2002) yields a meta model for semantically annotating and structuring game content, similar to the SG-LOM presented by El Borji et al. (El Borji & Khaldi 2014). Storyboards for serious games are then the equivalent to learning pathways in ITS. An implementation of storyboards as a Resource Description Framework (RDF) graph allows to have semantic interoperability as well as to use semantic tools like logic reasoners. Semantic interoperability is the key to dynamically exchange nodes or subgraphs. On basis of the

Unique Resource Identifiers (URI) similar concepts can be found in the open linked data, i.e. using ontologies. For example, in a dialogue modeled with RDF storyboards and with a multiple choice question the difficulty adaptation is to dynamically insert, remove or modify distractors. The taxonomic topology of ontologies can be used to find distractors of higher or lower difficulty levels. Concepts in the taxonomic neighborhood are strongly semantically related and therefore have a low inter-class distance, i.e. they are much harder to differentiate, whereas unrelated concepts have a higher inter-class distance.

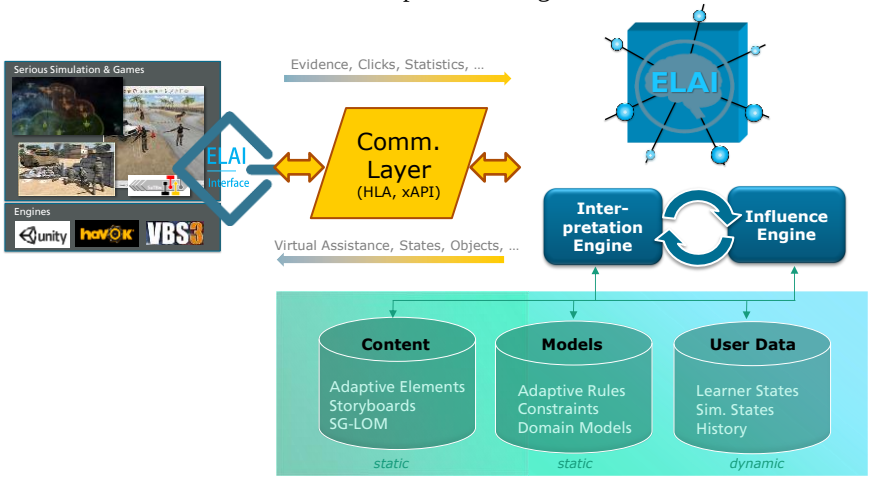


Figure 1: Architectural view of the interoperable tutoring agent framework

The proposed architecture decouples game engine and the adaptive entity, here named as "E-Learning A.I." (ELAI) (Figure 1). Every engine which implements a HLA compliant interface can be connected; in our case we focus on the game engines Unity 3D, Havok and VBS3. The HLA object model is designed to transport mainly the social web format Activity Streams to collect data about the user interaction over time. The active influence (adaptivity) is done by standard HLA class identifiers to create, modify or destroy entities in the HLA connected game engines. The adapter has to be implemented for each engine and the models (storyboards, adaptive rules etc.) have to be defined for each game or simulation.

## 4. APPLICATION SCENARIO

As a proof-of-concept a prototype for the Unity game engine has been implemented. The application format is the genre of Seek & Find (S&F) which has similarities to the search aspects of image interpretation. The task of this typical game is to identify objects on a map. The visible goal of the game is to collect as many points as possible; incorrect answers have a negative impact on the score. The hidden goal is to learn where points-of-interest (POI) in a certain city are located. The logic component is realized as a behavior tree which dynamically sets the difficulty based on the ratio of correct and incorrect answers. The objects (questions) are selected based on the taxonomic topology neighborhood selection algorithm (section 3) and by introducing a dynamic variable amount of distractors (other POIs and "clouds") to the game. Whereas the basic S&F principle of the game (GUI) are hard coded in Unity, the dynamic parts like the map image, the questions, the positions of the POIs and the distractors are "injected" by the external tutoring agent framework.

## 5. CONCLUSION AND FUTURE WORK

This paper describes the concept of an interoperable adaptive tutoring framework for serious games and simulations, specifically its overall system architecture, the general adaptivity principles and the implementation aspects. The main objective is to keep the learners motivated, i.e. to keep them immersed in the game or simulation by guiding them through the flow channel. Computer simulations and digital game based learning systems have to adapt to the experience and knowledge level of the users to exploit their

intrinsic motivation for interaction and learning. The concept and architecture is basically a distributed intelligent tutoring agent framework. Its main application field is image interpretation and the adaptivity concepts in this paper are focused on this domain.

The framework is part of an ongoing research project for image interpretation. The goal is that it can easily be used by other engines, serious games or simulations as well.

## REFERENCES


El Borji, Y. & Khaldi, M., 2014. An IEEE LOM Application Profile to Describe Serious Games «SG-LOM». *International Journal of Computer Applications*, 86(13), pp.1–8.

Chen, J., 2008. *Flow in Games*.

Conati, C. & Manske, M., 2009. Evaluating adaptive feedback in an educational computer game. In *Lecture Notes in Computer Science*. pp. 146–158.

Cruz-Cunha, M.M., 2012. Handbook of Research on Serious Games as Educational, Business and Research Tools.

Csikszentmihalyi, M., Abuhamdeh, S. & Nakamura, J., 2014. *Flow and the Foundations of Positive Psychology*, Springer.

Van Eck, R., 2007. Building Artificially Intelligent Learning Games. In *Games and Simulations in Online Learning: Research and Development Frameworks*. Hershey, PA, USA: IGI Global, pp. 271–307.

Fujima, J., Jantke, K.P. & Arnold, S., 2013. Digital game playing as storyboard interpretation. *2013 IEEE International Games Innovation Conference (IGIC)*, pp.64–71.

IEEE Learning Technology Standards Comittee, 2002. IEEE Standard for learning object metadata. *IEEE Standard*, 1484(1), pp.2004–2007.

Jepp, P., Fradinho, M. & Pereira, J.M., 2010. An agent framework for a modular serious game. In *2nd International Conference on Games and Virtual Worlds for Serious Applications, VS-GAMES 2010*. pp. 19–26.

Johnson, W.L., Wang, N. & Wu, S., 2007. Experience with serious games for learning foreign languages and cultures. In *Proceedings of the SimTecT Conference*.

Lee, J., Baines, V. & Padget, J., 2013. Decoupling Cognitive Agents and Virtual Environments. In *CAVE'12*. Berlin, Heidelberg: Springer-Verlag, pp. 17–36.

Lees, M., Logan, B. & Theodoropoulos, G.K., 2006. Agents, games and HLA. *Simulation Modelling Practice and Theory*, 14, pp.752–767.

Lopes, R. & Bidarra, R., 2011. Adaptivity Challenges in Games and Simulations: A survey. *IEEE Transactions on Computational Intelligence and AI in Games*, 3(2), pp.85–99.

Noseworthy, J.R., 2008. The Test and Training Enabling Architecture (TENA) Supporting the Decentralized Development of Distributed Applications and LVC Simulations. In *Distributed Simulation and Real-Time Applications, 2008. DS-RT 2008. 12th IEEE/ACM International Symposium on*. pp. 259–268.

Van Oijen, J., Vanhée, L. & Dignum, F., 2012. CIGA: A Middleware for Intelligent Agents in Virtual Environments. In *Proceedings of the 2011 International Conference on Agents for Educational Games and Simulations*. AEGS'11. Berlin, Heidelberg: Springer-Verlag, pp. 22–37.

Peirce, N., Conlan, O. & Wade, V., 2008. Adaptive Educational Games: Providing Non-invasive Personalised Learning Experiences. In *2008 Second IEEE International Conference on Digital Game and Intelligent Toy Enhanced Learning*. IEEE, pp. 28–35.

Plch, T., Jedlička, T. & Brom, C., 2013. HLA Proxy: Towards Connecting Agents to Virtual Environments by Means of High Level Architecture (HLA). In *Proceedings of the First International Conference on Cognitive Agents for Virtual Environments*. CAVE'12. Berlin, Heidelberg: Springer-Verlag, pp. 1–16.

Prensky, M., 2005. "Engage Me or Enrage Me": What Today's Learners Demand. *Educause review*, 40(October).

Roller, W., Berger, A. & Szentes, D., 2013. Technology based training for radar image interpreters. In *2013 6th International Conference on Recent Advances in Space Technologies (RAST)*. IEEE, pp. 1173–1177.

Salen, K. & Zimmerman, E., 2004. *Rules of Play: Game Design Fundamentals*.

Schiefele, U. & Schreyer, I., 1994. Intrinsische Lernmotivation und Lernen. Ein Überblick zu Ergebnissen der Forschung. *Zeitschrift für pädagogische Psychologie*, 8(1), pp.1–13.

Swertz, C. et al., 2013. Lernpfadmodellierung mit der Webdidaktik für die adaptive Erweiterung von Lernmanagementsystemen.

Szentes, D. et al., 2011. Enhanced test evaluation for web based adaptive learning paths. *2011 7th International Conference on Next Generation Web Services Practices*, pp.352–356.