

Application of Adaptive Game-Based Learning in Image Interpretation

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Abstract. This paper presents adaptive e-learning to a map-based serious game in aerial image interpretation which trains both geographic knowledge as well as the identification of relevant objects. We attach an interoperable adaptivity framework, called “E-Learning A.I.” (ELAI) which adjusts the game’s difficulty and the provided amount of assistance to match the learners need. The underlying software architecture uses the Experience API (xAPI) to collect, store and analyze the captured usage data. The scientific research questions affect the possible usages of the collected interaction data and how to manifest adaptivity in serious games. A study has been conducted to answer questions regarding the acceptance and effects of adaptivity in map-based seek-and-find games for aerial image interpretation. The three main hypotheses cover the questions on the acceptance of adaptivity mechanisms, on the users’ motivation and on the learning outcome effectivity. Although the adaptivity has been recognized, the dynamically inserted virtual agent was rather seen as a disturbance to the game flow. The study verifies the feasibility of the adaptivity framework and reveals issues on the study design of similar adaptive systems. The ELAI software architecture consists of generic and specific components. The most specific component is the so called ELAI-adapter which basically captures and adapts attached games or computer simulations. Obviously this adapter has to be specific to the actual game, genre, characters etc. In our application example we have implemented the ELAI-adapter for the Unity game engine. The xAPI protocol allows to easily connect other xAPI-compliant serious games or e-learning course software. The ELAI-controller interprets the collected usage data and computes influence strategies for the attached games or simulations, which in turn are then realized in the games itself by the ELAI-adapter.

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

1. Introduction

This paper describes the application of Artificial Intelligence (AI) methods to the field of adaptive learning for aerial image interpretation. Adaptivity in this paper means the continuous adaptation of serious games and computer simulations to the learners’ needs. Interaction mechanisms, content or suggestions are episodically personalized by an automatic intelligent tutoring component (Streicher and Smeddinck, 2016). 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.

The scientific research question is how to create adaptivity for computer simulations and serious games, i.e., how to automatically adapt games for learning to the users (Streicher and Smeddinck, 2016). Our solution approach is based on our *ELAI Framework* (Figure 1) (Streicher and Roller, 2015). The underlying system principles are based on commonly accepted standards, like the *Experience API* (xAPI), and on effective adaptive interoperability designs from *Learning Management Systems* (LMS) (Henning *et al.*, 2014). The 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.

This paper presents an application example of the ELAI framework and an evaluation of the concrete implemented adaptivity.

Similar to our approach is ISAT (Magerko *et al.*, 2006) which offers the trainee a story-wise individualized training environment. Examples for decentralized adaptive architectures are the ALIGN architecture (Peirce *et al.*, 2008), the test and training architecture TENA (Nosworthy, 2008), or the CIGA middleware (van Oijen *et al.*, 2012). A similar architecture also using the xAPI for learning or gaming analytics can be found in the RAGE EU project (van der Vegt *et al.*, 2016)

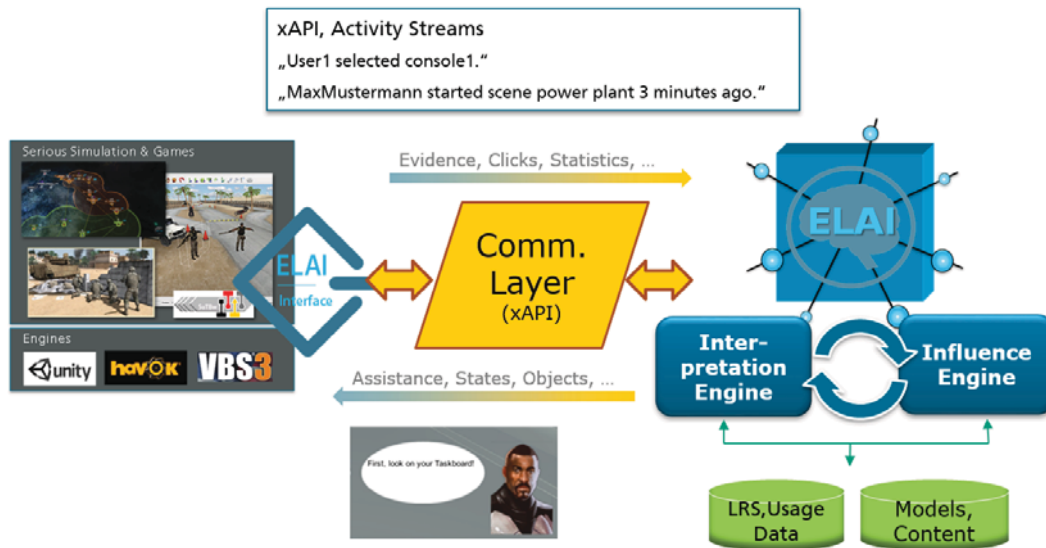


Figure 1: e-Learning A.I. (ELAI) framework architecture

2. Application

This research's application domain is 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. Peculiar effects of various sensor imaging technologies, e.g. radar or hyperspectral imaging, significantly complicates the interpretation, hence expert knowledge is needed and people have to be trained (Roller *et al.*, 2013).

2.1 SaFIR serious game

The serious game *Seek and Find for Image Reconnaissance* (SaFIR) is a prototypical implementation of a seek-and-find game for image interpreters. The game's objective is to find objects (e.g., buildings, vehicles, etc.) in an interactive, geographic map from a top "aerial" view. The players have to locate specific military tank types in a city whilst learning to differentiate the target tank type from various distractor objects. This game objective has the serious background to train image interpreters to correctly differentiate various tank types which could differ by only very subtle variations, e.g., an additional antenna or a displaced hatch. This is in accordance with the task description for image interpreters, i.e., the identification and analysis of structures and objects. Since the game's map is based on real map data from *OpenStreetMap.org* a further learning outcome is to learn the surroundings, e.g., city structure, street names, etc. The players have to move their avatars through a virtual city seeking for the targeted tank. To achieve a broader map learning outcome and increase versatility across game sessions the locations of the tanks are randomized.

2.2 SaFIRa – SaFIR adaptive

SaFIRa is SaFIR plus adaptivity. The adaptive elements are (1) injection of a virtual agent which offers adaptive hints, based on the user model; (2) dynamic difficulty adjustment (DDA) of the target object size; (3) DDA of the occurrence frequency of covering clouds and distractor objects. SaFIRa introduces a virtual agent avatar that follows the user's avatar and offers context-relevant help (Figure 2). The implemented didactic factors to analyze the player's state are the overall task duration, the task difficulty and the task helping count. The task duration is the time for the ongoing game session (mission). The task difficulty is manifested as the size of the searched object plus an artificial covering with procedurally generated clouds. An easy difficulty level means that the target object is rendered rather prominently, i.e., big and easy to spot with almost no disturbing clouds. A high difficulty level corresponds to a more hidden and smaller target object with parts of the screen (and the object) covered by artificial clouds. For further dynamic difficulty adjustments we also implemented various image processing techniques, e.g., blurring, noise, partial occlusion, deterioration by compression artifacts, etc. The level of assistance controls the frequency and quality of context-relevant textual hints given by a virtual agent. It has three stages: (1) the lowest level only hints at the general direction of the target object; (2) the second level also discloses the exact distance (Figure 2); (3) the third level additionally reveals the path to the goal by drawing a line (like a navigation system).

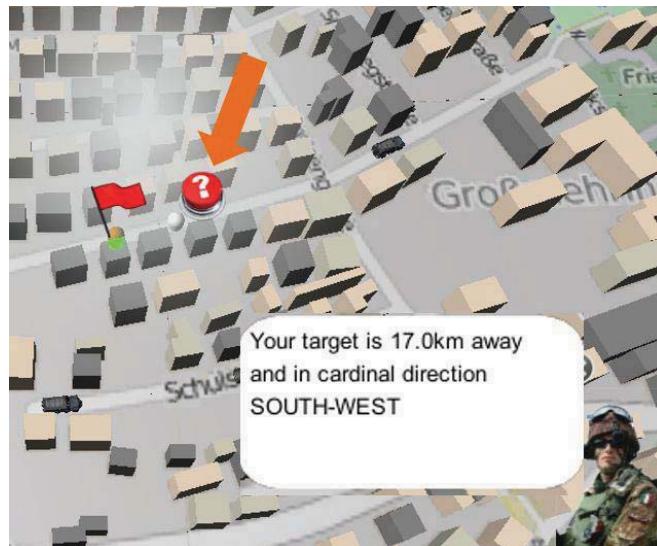


Figure 2: Seek-and-Find adaptive ELAI game "SaFIRa" (arrow indicates the clickable virtual agent avatar)

3. Evaluation

The study evaluated the following hypotheses (H_i): H_1 : the users recognize the adaptive mechanisms, i.e., recognize adaptation effects regarding their current context; H_2 : the users feel an increased motivation by the adaptations; H_3 : a learning effect can be measured.

3.1 Experimental setup and test execution

The study has been conducted with pre- and post-test questionnaires in a supervised fashion (Biegemeier, 2016). To familiarize the participants with the game they had to complete a task-independent pre-test beforehand. $n=12$ participants have been randomly split into two groups with 5 and 7 participants. This imbalance in favor of the test group increased a bit the empirical data for H_1 (adaptivity check). The control group played the game without adaptation (adaptivity features turned off).

3.2 Results

Regarding hypothesis H_1 , both groups correctly identified games without adaptation (score 80 %), and games with adaptive hints (score 85 %). Most participants evaluated the adaptivity as generally helpful (score 83 %). The adaptively triggered hints from the virtual agent were evaluated as not overly helpful (score 66 %); the control group evaluated the manually triggered hints as more helpful (score 76 %). This means that the adaptivity has been recognized, but in this game the automatically triggered hints were rather seen as a disturbance of the game flow.

The empirical evidence backs up hypothesis H_2 , i.e., the test group subjects stated that they would feel an increased motivation to continue playing. The test group evaluated the automatically determined (adaptive) difficulty level as fitting (score 96 %); the control group, which played with a static difficulty level, evaluated it as not fitting (score 36 %). The game's variety was evaluated better in the test group (score 71 % vs. 60 %).

Regarding the learning outcome (hypothesis H_3) there was no difference between test and control group; both correctly identified the correct tank types (score 100 %). Most probably the task to find the correct tank type has been too easy. As a consequence the experiment design must include a greater variety of tasks (in quantity and quality) to effectively measure the dedicated influences of multiple adaptivity mechanisms. Altogether we conclude that the adaptivity effects have been positively evaluated but the helpfulness was not as high as expected.

4. Conclusion

This paper presents the application of the interoperable adaptivity framework for simulations and serious games, called "E-Learning A.I." (ELAI), to a seek-and-find game for image interpretation. The whole system has been evaluated in a small user study with $n=12$ participants. Although the adaptivity has been positively

recognized, the adaptive hints were rather seen as a disturbance of the game flow. Our experiment consisted of too easy tasks which did not explicitly demand adaptive assistance. This has to be addressed in future work with a redesign of the study and more difficult game tasks, e.g., more varying distractor objects. The architecture itself is feasible and future work can include other attached games or simulations as well.

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