Usage Simulation and Testing with xAPI for Adaptive E-Learning

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Abstract. The systematic development of adaptive e-learning systems benefits from the principles of test-driven development, i.e., pre-defined software test cases help to improve the systems to meet the expected (adaptive) behavior. However, the inherent variability of adaptive systems can make test case development tedious and inflexible to maintain. This paper presents a concept for an interoperable, flexible testing tool for adaptive e-learning system development and systematic testing of xAPI compliant e-learning systems. It provides visual inspection and editing functionalities, xAPI simulation, and checks for adaptivity responses. This enables the systematic testing of adaptive systems and an improved development process. An xAPI recording functionality combined with a visualization of the usage flow helps in the test case development. A prototype implementation in a serious game for image interpretation verifies the concept. The concept is domain independent and valid for any xAPI compliant system.

Keywords: Adaptivity · Testing · Interoperability · Modeling · xAPI

1 Introduction

Adaptive learning systems (ALS) can help the users to better achieve their learning goals [6]. In this context, Intelligent Tutoring Systems (ITS) try to personalize the learning experience and adapt learning environments to the needs of the users. However, the development of verified adaptive learning engines (ALE) can be hard because just a verification of single software units does typically not reflect how the whole ALE responds to varying interactions of real users. Here, the systematic development of adaptive learning systems can benefit from established testing principles in software development, e.g., test-driven development or data-driven testing [3]. To this end a black-box and data-driven testing approach can be applied not only to software units but at a higher-level to the whole system. This is done in our solution approach. In this paper we present the concept for a usage simulator and adaptivity testing tool which is compatible with the Experience API (xAPI) to achieve interoperability with other learning systems. It offers xAPI recording functionalities to live capture activity streams to generate test cases. This can help in the systematic development or parametrization of adaptive systems. ALS pose additional challenges to the testing methodology because of their often high complexity and deliberate variability. As the human factor introduces further non-deterministic aspects it makes the high-level testing of all usage combinations a non trivial task. In contrast to typical unit-testing of smaller software components, the high-level testing addresses test cases for the overall system, i.e., collections of xAPI usage interaction sequences are used as input and the responses of adaptive systems are checked as output. An analogy from software development would be regression tests with invariance classes.

Our field of application is adaptive learning for image interpretation[5]. The research questions concern systematic development of ALS, interoperability, analysis of behavioral usage data, and visualization of adaptivity.

Similar work has been presented by [4,1,7]. We target adaptive computer simulations and serious games. In this context, user and behavioral modeling for serious games is done by [4]. The automatic generation of user models in adaptive serious games has been shown by [1]. Standardization and interoperability for e-learning systems is an active and evolving research topic [2].

2 AdapSimTester - Simulation & Testing Tool Concept

From the necessity to systematize the higher-level systems tests during software development, the desire arose for a tool in which behavior patterns can be edited, visualized and simulated in a deterministic yet realistic way.

Questions Based on interviews with adaptive technology developers various challenges have been identified:

- How to realize black-box testing and generalizability?
- What standards exist for modeling and handling behavioral usage data?
- How to simulate realistic usage data? How to synthesize that data?
- How to achieve variability and realism in the simulated data?
- How to visualize adaptivity? How to visualize the responses of an adaptive system, e.g., for visual inspection and analysis?
- How to simulate realistic bad or wrong behavior? How to simulate unsure or nonconstructive behavior?

Requirements The req. specifications for the targeted assistance tool include:

- Record usages (scenarios) from attached learning environments via xAPI.
- Visualize scenarios and provide graphical editing capabilities.
- Scenarios can be sent as xAPI statements to other systems.
- Dynamic modifications and randomization of scenarios.
- Visualization and verification of adaptivity responses.

Test Cases Information about the context is crucial for adaptivity; a single data point does typically not contain enough information as a set of observed usage actions (context). Therefore our concept makes use of usage sequences to form test cases or scenarios, i.e., the collection of serial user interaction data points which are basically the sequence of xAPI input statements. The context and the sequence of actions define a scenario $S = (A, T)$, where $A = a_i | i \in \mathbb{N}, a_i \in X$ is a set of actions, $T : A \rightarrow \mathbb{N}_0$ is a time function, and $X = \mathcal{A} \times \mathcal{V} \times \mathcal{O}$ is the set of all possible actions X consisting of all actors $\mathcal{A}$, all verbs $\mathcal{V}$, and all objects $\mathcal{O}$.

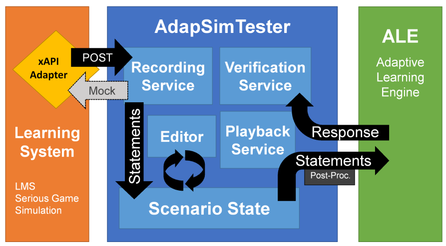

Fig. 1. Software architecture

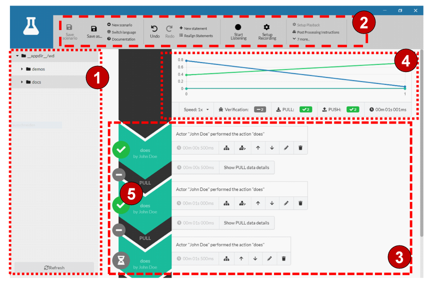

Fig. 2. Web user interface

Functionalities The tool "*AdapSimTester*" basically consists of four main parts (Fig. 2): (1) scenario repository; (2) management, recording and playback functionalities; (3) editing, visualization and control of usage sequence elements; and (4) visualization and verification (5) of adaptivity responses. The scenario repository (1) lists stored usage sequences which can be loaded for editing and simulation. The loaded or edited scenario can then be simulated (2) by sending the underlying xAPI statements to attached xAPI compliant systems. The central UI element (3) displays the usage sequence. Each xAPI statement is represented as one element. Variability of the statements is addresses by different coloring, i.e., statements with identical classes are identically colored. Each statement box can be edited, i.e., in an edit dialog the xAPI values for actor, verb, object, etc. can be edited, and randomization can be applied to increase variability. Elements can be manually added or removed. To ease the development of complex usage sequences, AdapSimTester offers a recording mode where it listens to the xAPI statements of an attached system. The author uses the attached system in a prototypical way according to a (adaptive) user story. In simulation or playback mode AdapSimTester "plays" the xAPI statements to the adaptive engine. The engine's responses are displayed (4) for visual inspection and verification (5).

Visualization The objective of adaptivity is to dynamically adjust (adapt) the learning environment to the needs of the users [6], typically based on an interpretation of the perceived interaction data input. The result of the interpretation process is used to control the adaptivity, e.g., dynamic difficulty adjustment, content modification, or learning path changes. One implementation possibility is to value each action with a normalized performance score $S \in [0; 1]$ [5]. This can also be found in the xAPI specification in the optional attribute *result*. Although this score encodes no further information on the quality of an action itself, it can however be used in an application invariant, generic way. Further scores can enrich the quality of the adaptation [5], e.g., outputs like a $skillLevel \in [0;1]$ or a $helpingLevel \in [0;1]$. These scores can be checked and visualized, and they can be used to evaluate the users' actions, i.e., constructive/progressing, neutral/stagnating, or nonconstructive/declining.

3 Realization & Application

We implemented our usage simulator concept as a Web application using NodeJs and ReactJs (Fig. 1 & 2). It has been applied to an adaptive learning engine [5] for educational serious games in image interpretation. A preliminary study on helpfulness and applicability by a small software team have shown positive results. Two serious game have been attached to AdapSimTester via xAPI and the recorded activity streams have been used as test scenarios. The tool has been used to successfully verify an already implemented adaptivity logic [5].

4 Conclusion & Outlook

We present the concept for a simulation and testing tool "AdapSimTester" which can help in the development of adaptive learning systems. Our concept makes use of the xAPI to achieve interoperability and easy applicability to other systems and domains. The black-box approach as well as the recording and playback functionalities support generalizability and ease of use.

The usage simulator is going to mature in the ongoing development of our next adaptive systems for educational serious games. An evaluation is going to test hypothesis on usefulness, applicability and usability.

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