A GENERAL FRAMEWORK FOR DIGITAL GAME-BASED TRAINING SYSTEMS

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ABSTRACT

A prevailing goal of digital game-based learning is to support education with serious games. Yet serious games have not become an integral part of education so far: the software applications generally focus on the learning aspect of education and disregard support for teaching as well as for communication between teacher and student. In this paper, we present a general framework for digital game-based training systems that adapts serious game design to education. It is based on a schematic representation of education and introduces generic components that support learning, teaching, and teacher-student-communication. It therefore uses two different game player roles and two different parts of the game story: back-story and main-story. The back-story has to be played by the teacher whereas the main story has to be played by the student. By playing the back-story, the teacher can prepare the main-story, which is the actual training session. In addition, teacher-student-communication is supported by reviewing training sessions and generating a visual review log for classroom discussion. The general framework has successfully been used to implement the prototypical digital game-based training system *OpenCrimeScene*.

KEYWORDS

Serious games, digital game-based training system, digital game-based learning, framework design, virtual CSI.

1. INTRODUCTION

Current trends in digital game-based learning research show an increase in the development and use of serious games. Serious games present learning objectives in a game-like environment and tightly connect learning and training to computer game playing. Computer games interactively involve the player in the game world and keep the player's motivation to continue playing at a high level throughout the game. This is significantly desirable for education and makes serious games attractive for learning [14, 28]. Yet serious games have failed to become a successful support to education [32, 33]. Researchers stress that games have to be *integrated into* rather than simply *used during* lessons [11, 17, 31, 35]. However, the question about how to proceed has not been resolved so far and novel approaches to serious game development are called for [12, 20, 33].

We believe the problem is due to a mismatch between technology and application field. Serious games stick to well-known game design patterns that focus on a twofold relationship between game and (student) player. In contrast, education is determined by a threefold relationship between teacher, student, and learning content. Yet teachers are not addressed by the applications. Consequently, serious games turn into an alternative to education rather than into a supplement. General unfamiliarity of many teachers with computer game playing and fixed content of the applications that can hardly be adapted to the lessons further adds to this difficulty. In addition, students often discredit the educational use of serious games when the applications favor fiction over facts to provide a gripping game story. Recent studies on using serious games in education foster our assumption [11, 17, 31].

A general framework for digital game-based training systems (DGBTS) like serious games is introduced here that aims at fully supporting education. The framework adapts game design to education and addresses students and teachers as game players. Moreover, it provides a visual review log of training sessions for classroom discussion. To exemplify the general framework's applicability, we present *OpenCrimeScene*, a DGBTS for crime scene investigation (CSI) training.

2. STATE OF THE ART

The potential of computer games to motivate players to continue playing as well as to reach young learners makes them especially attractive for education [28, 14, 21]. The motivation that is generated by computer games is ascribed to an appropriate balance between stimulation and resolution that challenges players without overtaxing them [15, 7]. Among others, this is achieved by context-based help, gripping game stories, roles players can identify with, compelling interfaces that facilitate playing, etc. [14, 30]. Apart from that, computer game playing allows to train deeper skills like decision making, understanding complex systems, or managing different information sources [28]. The research field of digital game-based learning investigates how to apply serious games to reinforce learning situations in education [27, 29, 20, 32, 10].

Most serious games are used as a training enhancement in practical professional training. Topics range from military to business to government to health issues, etc. [25, 6, 11, 18, 36]. For example, *Levee Patroller* [17], *SGTAI* [1], or *SimPort* [34] address professionals and novices in the domains of levee inspection, traffic accident investigation, and project management, respectively. Like most serious games do, the applications adopt traditional game design: they provide game-like interactive 3D graphics environments to represent the specific learning content and address students as game players. User studies were conducted for each game and provide insightful information on the use of serious games in education. First of all, most students approved of playing *Levee Patroller*, *SGTAI*, and *SimPort* [17, 1, 34]. Authentic representations of real world training were especially well received and generated lively discussions [17]. Yet varying user knowledge of computer game playing was difficult to handle. Several older users had problems interacting with the applications and playing the games [17, 34]. As a result, time-consuming game playing instructions became necessary. These often exceeded schedules and required teachers to change their teaching methods, cf. also [22, 26]. It was concluded that amendments to the curricula would be essential when using serious games in education [17, 1].

Another study on the benefits of using the strategy game *Europa Universalis II* for history lessons yielded similar results [11]. The results conformed with general expectations regarding the motivational potential of computer games but yielded unexpected difficulties: students questioned the educational use of the computer games in general and distrusted the game's representation of historical facts. Moreover, teachers could hardly instruct the students when playing because they were unfamiliar with the software applications. Educational use of the game was not as good as expected; more suitable software applications were called for [11].

Immune Attack is an example of a suitable software application [24]. The game supports teaching of immunology to senior high school and first year university students. It is situated in a virtual body through which the player navigates in a microscopic robot. The player is regularly provided with facts to proceed from level to level and implicitly gets acquainted with the immune system's inner processes. In addition to the learning aspect, *Immune Attack* comes with a recommendation of biology textbooks and a teacher's guide to support classroom use. The game is a first step to *integrate* game experience into education.

Although serious games have a potential to enhance education, their application to education is still problematic. Game content can hardly be adapted to lectures and teachers have difficulties in dealing with such kinds of applications. We suggest to reconsider the software type of serious games itself and to identify mismatches in software design and the application field of education.

3. ADAPTING SERIOUS GAMES TO EDUCATION

The key question addressed by this paper is, What kind of properties does a DGBTS have to possess in order to serve education? Therefore, educational and game playing situations need to be examined. Basically, every educational situation is defined by *teacher*, *student*, and *learning content*, as well as the relationships of

teaching, *learning*, and *communication & interaction*. In pedagogy, this is well known as the so-called *didactic triangle* [23].

On the other hand, common game playing situations are defined by *player* and *game* as well as the relationship of *game playing*, which is generally determined by problem solving. Consequently, serious games address the student as a game player and represent the learning content in a game context (game world and story). This relates to *learning situations*. However, to serve *educational situations*, all elements of education have to be addressed.

We suggest providing game player roles for both teachers and students first of all. This will allow teachers to participate in the fun-part of game playing and will acquaint them with DGBTS more easily. Moreover, we suggest using distinct interaction paradigms that represent learning, teaching, and communication & interaction. Finally, we suggest integrating existing learning material into the DGBTS to closely link the applications to real life education. A general framework for DGBTS will be necessary that extends common serious games design patterns and comprises all of these issues.

4. DESIGN OF A GENERAL FRAMEWORK FOR DGBTS

Most computer games use *story elements* and *role allocation* to reinforce the player's identification with the game [14, 2]. Typically, the game story contains a certain *conflict* that challenges the player [9, 30]. In a DGBTS, game story and conflict have to be determined by the learning content. Moreover, the game story has to offer *two* distinct game player roles that suit teachers and students. The goals and ambitions of these roles have to conform to *teaching* and *learning*. Both situations are determined by an opposite yet closely connected approach to handling learning material: *problem presentation* and *problem solving*. To transfer this to a game context, we suggest splitting the game story into two sub-stories: *back-story* and *main-story*. Each sub-story has to provide a sub-conflict that has to be resolved by the player either by presenting a certain problem (teacher player) or by solving a certain problem (student player).

The back-story is a common feature in computer games. Usually, it comes as introductory text or visuals and introduces the player to the pre-plot of the game [2]. Here, the idea is to make the back-story an actual part of the game and to address the teacher as its player. While playing the back-story, the teacher presents a problem and specifies the main-story. On the contrary, the main-story represents the actual training session that has to be played by the student. In addition to supporting learning situations, the aim of the main-story is to introduce the student to the pre-plot of the story, which has been specified by the teacher.

Besides game playing experience that appeals to both teacher and student, the idea of back-story and main-story implies two different interaction paradigms: *authoring* of training sessions and *training*, i.e., *experiencing* training sessions. The former corresponds to teaching situations, whereas the latter corresponds to learning situations. Moreover, the dependency of back-story and main-story expresses communication & interaction between teacher and student. It will additionally contribute to *reviewing* training sessions and, as a result, to generating a visual review log. Such a visual review log is intended to directly support communication & interaction by serving as a basis for classroom discussion.

Based on these considerations the general framework for DGBTS is illustrated in Figure 1. It introduces three components: *authoring component*, *training component*, and *reviewing component*, which represent the concepts of back-story (authoring), main-story (training), and dependency (reviewing). Furthermore, the general framework proposes using a specific *data presentation* based on external as well as internal data. The elements of the general framework will be discussed more closely below.

The authoring component addresses the teacher. It has to provide interaction means for authoring training sessions by playing the back-story. This will be introduced here as *in-game authoring*. During the playing experience, teachers specify the main-story implicitly or explicitly. Implicit specification denotes to change the scenario by playing the game; explicit specification denotes to change the scenario by integrating external material or creating tasks. In-game authoring requires an appropriate game-based user interface that supports

- playing the back-story
- accessing and integrating external data
- creating tasks.

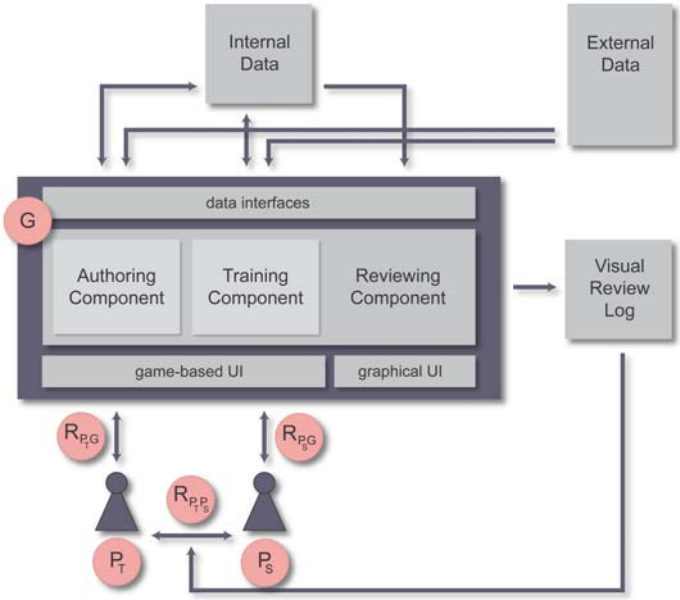

Figure 1: The general framework represents all elements of the extended game universe.

The training component addresses the student. The component conforms to traditional serious games and implements *in-game training*. In-game training has to allow expert game players, as most students can assumed to be, to experience the learning material in the game context by playing the main-story. The training component has to support explicit links between game story and real world education so that students consider the DGBTS as educational tool. In-game training requires an appropriate game-based user interface design that supports

- playing the main-story
- accessing and integrating external data
- accomplishing tasks.

The reviewing component is intended to support communication & interaction and, thus, addresses teacher and student. Since communication & interaction is a human relationship, the technical representation is not straightforward. We suggest reviewing training sessions and generating a visual review log therefore. Such a visual review log could directly be used to serve classroom discussion and would directly support an integration of DGBTS into education. Therefore, the reviewing component has to implement

- logging of specified data and data changes such as those caused by user interaction
- evaluation of the logged data in terms of training session assessment
- visualization of the assessment in a comprehensible visual review log.

The implementation of the reviewing component is not trivial. Data specification, logging, assessment, and visualization are complex research fields each. Thus, few approaches exist that concern the assessment of user interactions in virtual environments [16, 8, 19, 13].

Data presentation is essential when presenting learning content in a game-based user interface. We propose using game levels to encapsulate internal data and to organize the training sessions. Data access can be granted via data interfaces of the respective components. Game story data like scenery and environment serve as the basis for back-story and main-story; they have to be accessible by the authoring as well as by the training component and, thus, have to be encapsulated in the game levels. Specific back-story and main-story data like player characters and user interfaces have to be encapsulated in the authoring and training components themselves. Furthermore, we proposes integrating existing learning material like text, images, or video to further link real world education into digital game-based training. Teachers could use external learning material to enhance the back-story and pose problems. Students could use external learning material to accomplish tasks and solve problems. External data are intended to support teachers using existing learning material. They are furthermore intended to reassure students that DGBTS are relevant and useful for education.

5. APPLICATION SCENARIO & USABILITY TESTING

The presented framework has been used to implement a prototypical DGBTS for crime scene investigation (CSI) training called *OpenCrimeScene* [4]. The prototype targets practical CSI training situations at a Police College. CSI comprises numerous procedures to protect and assess the crime scene like taking pictures of the crime scene or collecting fingerprints. Therefore, police students have to learn how to use and apply certain (forensic) tools. Taking pictures requires knowing how to handle an SLR camera; collecting fingerprints requires knowing how to apply powders and brushes, etc. Teachers therefore reproduce crimes at practice crime scenes that have to be investigated by students. *OpenCrimeScene* is intended to reproduce this kind of teaching and learning on a digital level.

OpenCrimeScene provides a "cops & robbers" game story to represent CSI training in a game context. The main theme of the story is "housebreaking." In such a story setting, authentic CSI tools can be added for cops and robbers each, and the player roles of cops and robbers can be assigned to students and teachers, respectively. Moreover, the game story can be split into a robbers-part, the back-story, as well as into the cops-part, the main-story. To start with, the back-story has to provide means to steal scene objects, and to leave human traces at the virtual crime scene like fingerprints. In contrast, the main-story has to provide means to solve the crime by taking pictures of the crime scene and by collecting fingerprints.

As proposed by the general framework, *OpenCrimeScene* consists of an authoring component, a training component, and a reviewing component. General game data like the scene environment are encapsulated in different case files, the game levels, and can be accessed by all components. Specific data of the back-story and main-story are provided by the authoring and training components each.

The authoring component implements the back-story of housebreaking. It provides a the robber character that can be used to break into houses and remove or alter inventory. Furthermore, the robber can leave fingerprints and footprints when interacting with scene objects. In order to implement implicit authoring, the system has to add fingerprint or footprint data to the virtual crime scene whenever object selection or navigation is triggered by user input control. However, implicit authoring has not fully been implemented so far. Explicit authoring was implemented using a graphical user interface and picking functionality. Figure 2 illustrates screenshots from *OpenCrimeScene's* authoring component.

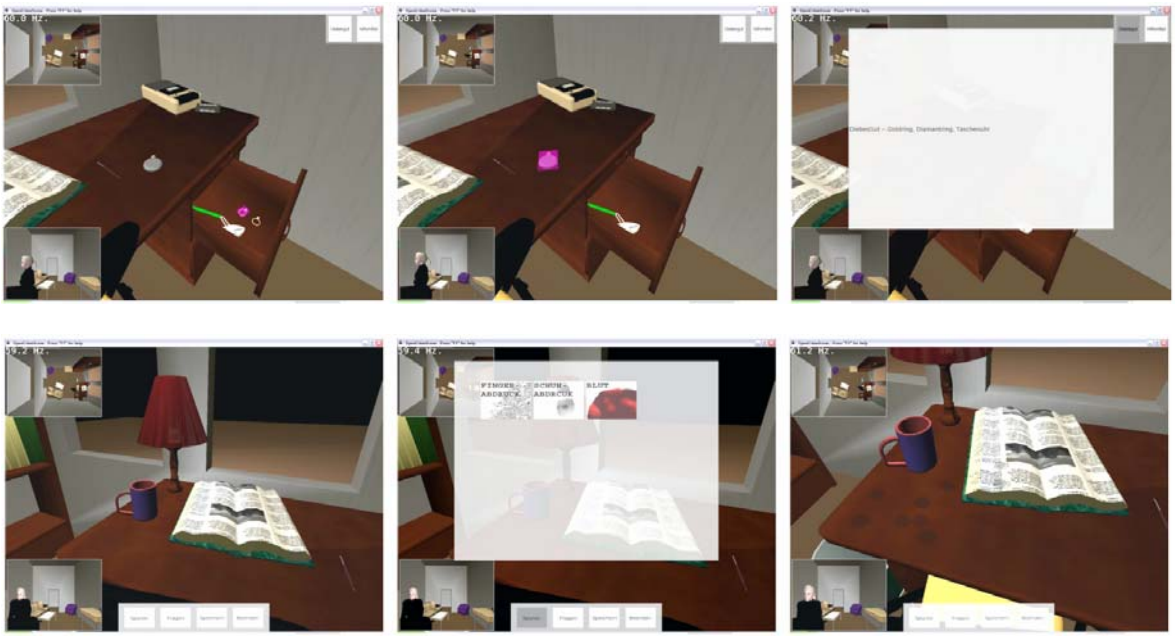

Figure 2: The images illustrate authoring means of *OpenCrimeScene*. When selecting an object in the scene, the object is highlighted and can be "stolen." By selecting the robber's bag, the robber can see what kind of objects have already been stolen (upper images). To explicitly leave traces at the scene, the teacher has to activate a bottom menu, which gives access to fingerprints, footprints, and blood traces. After selecting a trace it can be added to the scene via picking (lower images).

In contrast, the training component implements the main-story of housebreaking investigation. It provides a cop character as well as interaction means for criminalistic procedures such as taking pictures of the scene and finding evidence. Collection of fingerprints has not been implemented so far due to time restrictions. Instead, a virtual SLR camera that realistically represents the parameters of a common SLR camera was developed [3]. Students can specify the camera parameters, take pictures of the scene, and view them immediately to better understand the correlations between parameter settings and final image. Figure 3 illustrates screenshots from *OpenCrimeScene's* training component.

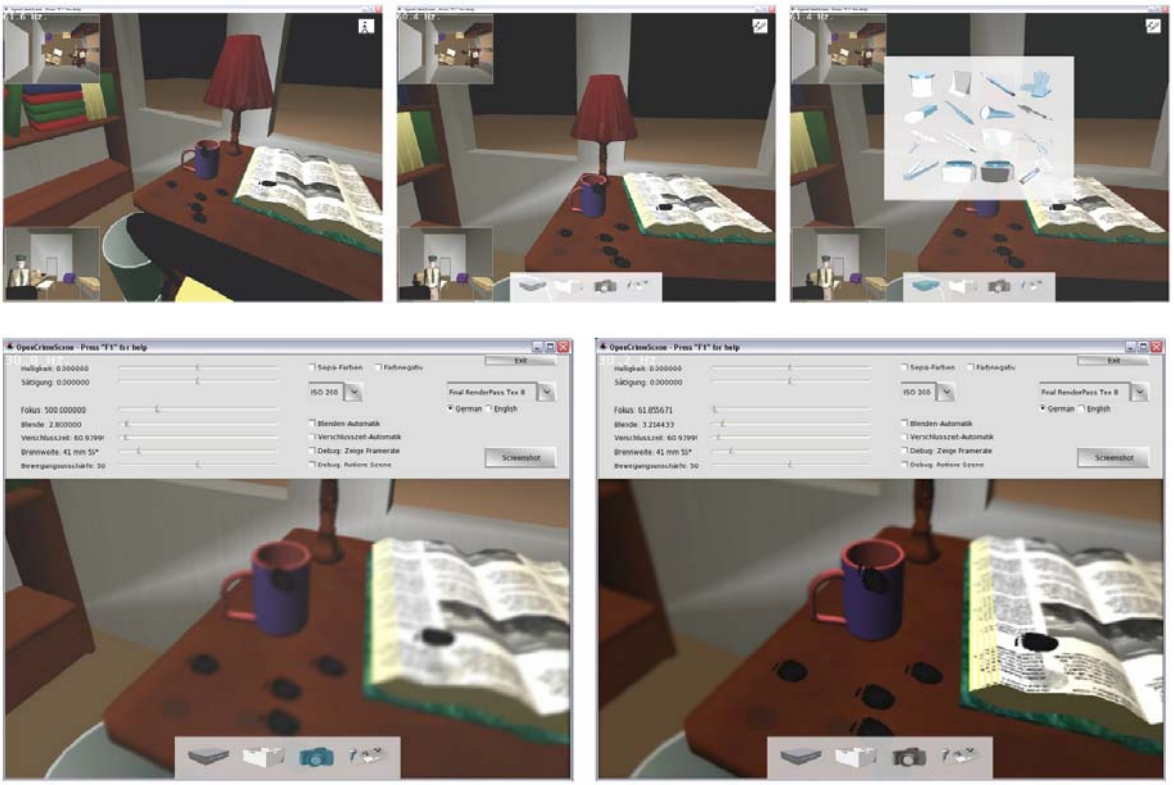

Figure 3: The images illustrate training means of *OpenCrimeScene*. The cop can navigate through the environment and find evidence. Forensic tools can be accessed via a bottom menu (upper images). When selecting the SLR camera tool, the student can train how to take pictures of the scene. The SLR camera provides an interface that presents all parameters of a real SLR camera. These can be specified as in reality and pictures can be taken in real-time (lower images).

Finally, the reviewing component for *OpenCrimeScene* is designed to log important user interactions like placing evidence or taking pictures of evidence. Yet automatic reviewing and review log generation has not been implemented so far due to time constraints. In order to make an assumption on the usefulness of a visual review log for classroom discussion, different user positions were logged manually and visualized in an overview image [5]. The result looked promising and was used for a first usability testing.

To evaluate the general framework, a usability testing was conducted at the Police College. The testing included 5 teachers and 6 students who were given a questionnaire about the prototype. Main goal of the usability testing was to find out about the participant's familiarity with computer games and about how the participants judged the novel concepts provided by the general framework. All participants showed great interest in using DGBTS for training. In terms of familiarity with computer game playing the results were as expected: 4 students and only 1 teacher considered themselves as advanced or expert players. In terms of the new concepts, all participants highly approved of teacher player and visual review log for classroom discussion. Negative feedback concerned the graphics of the prototype that are outdone by recent computer games. Regarding the financial and manpower resources available for commercial computer games, this is

acceptable though. The usability testing is currently conducted with expert computer scientists to elucidate the technical aspects of the framework and is considered as future publication by the authors of this paper.

6. CONCLUSION

Use of serious games in education still is problematic. One reason is that the applications only focus on learning situations. Teaching situations and classroom discussion is generally not supported by the applications. To overcome these difficulties, we introduced a general framework for developing and implementing DGBTS. The framework addresses all aspects of education: teaching, learning, and communication & interaction, by providing generic components for authoring, training, and reviewing training sessions. What is especially novel in our approach is that teachers and students are both addressed as game players. We believe this to be essential for actually integrating DGBTS like serious games into education. The framework not only gives teachers the possibility to adapt the training sessions to their lectures, but also lets them participate in the fun-part of game playing. We expect that both points will motivate teachers to use DGBTS in class. At the same time, students will be reassured of the educational use of playing and using DGBTS when teachers prepare training sessions. Also, we assume that the idea of teacher player vs. student player might provide some extra motivation for students to engage with such applications. The generation of comprehensible visual review logs of training sessions will further support teachers in better assessing student's learning progress when using DGBTS. The concepts provided in this paper will have to be evaluated further with real DGBTS that are based on our framework. The *OpenCrimeScene* prototype is a first step into that direction. Although a first usability testing yielded positive feedback on the new concepts, an extensive user study will have to verify the results. Furthermore, it would be of high interest to apply the general framework to different application scenarios like math or physics. We assume such theoretical subjects to be very interesting in terms of story design because the connection between subject matter and context will not be as obvious as, for example, practical CSI training.

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