Game-based E-Learning Applications by applying the E-Tester: A Tool for Auto-generated Questions and Automatic Answer Assessment

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Abstract: Adaptive E-Learning systems may be a supportive solution for a wide range of learning applications. In order to complement common learning paradigms in computer-based education the digital game-based learning paradigm is an interesting alternative, which can force up motivation, intrigue learners for a new or a priory boring subject, and provide another, more relaxing environment for self-assessment and testing. Despite of these advantages, one main shortcoming is that the creation of game story and curricula-relevant game content is an enormous workload for teachers and learning content providers.
In order to reduce the learning game creation effort, we propose in this paper an enhanced digital game-based learning approach by applying a flexible game shell in combination with auto-generated questions based on the course content and automatic assessment of natural language answers. On the basis of requirements within the AdeLE research project and application scenarios, our development approach as well as the first prototype implementation are highlighted. First experiences and tests based on the prototype implementation are promising.

Introduction

Computer-based learning dates back to the 1960s, and numerous research results and "new" insights have been published as well as a lot of different developments have been made available, as stated in (Mödritscher et al. 2004). As a well known result, just transferring learning content into the digital domain does not meet the needs and objectives of learners and teachers. Despite the long history in computer-based learning research and the development of numerous systems over the last decades, from our point of view a number of open problems and requirements are not considered sufficiently. Thus, we initiated the four-year research project "Adaptive e-Learning with Eye-tracking", in short AdeLE, see (Garcia et al. 2004) and (AdeLE 2005).

An important objective of the AdeLE research in the context of this paper is to support various didactic models and learning paradigms. In order to complement already implemented developments and to enhance the AdeLE system, we have decided to add and experiment with a more interactive and enjoyable approach, the digital game-based learning approach.

A Proposal for an Enhanced Game-based Approach

In general, as a matter of fact many people like to play games for enjoyment and pleasure. It is obvious, games may strengthen different sorts of skills by playing in a save artificial environment by underlying rules. In fact,

enhancing skills and accumulate knowledge follow learning concepts. Babies and young children apply very effectively to the concept “learning by playing”, such as imitation, and “trail and error”. They are in a “secure” environment and can play, and they are allowed to make mistakes. Unfortunately, particularly mistakes are very often not allowed in educational environments and may frustrate learners. Opposite to that and to overcome that problem, games may provide artificial environments, where mistakes and “trail and error” are allowed.

A good starting point for information about digital games are among others (Mitchell et al. 2004), (UniGame 2003), (Clark 2004) and (Kirk et al. 2004), which are also the basis for this paragraph. Since the 1970s, video games have emerged and the broad adoption of personal computers has brought digital games into daily life. According to the DFC Intelligence forecast, the worldwide market of digital games is said to grow between 37 % to 45 % from 2002 to 2007. Virtually all users form 4 to 60 plus are the market’s target groups. According to different studies, some of them spend a lot of leisure time on such games, often more than 8 hours per week. Players’ engagement for doing so are given by characteristics, such as enjoyment and fun, active involvement, emotions, and ego gratification. Of course, this mechanisms can also be used for learning purpose. Digital game-based learning may be suitable for a wide range of “hard” and “soft” learning objectives, such as facts, skills, decisions, behaviour, creativity and communication. In order to follow different learning objectives and learning styles there are various possible game styles, such as game shows, strategy games, adventure games and simulation games. The games could be built as so called hard-wired implementations, which are fully tailored to an particular application. A more flexible solution could be gained by means of game engines, game templates or game shells, which can be fed by particular content for different learning applications. Despite the advantages of the flexible solution, teachers and learning content providers are confronted with another serious problem: they have to create the content for the games, such as questions and answers, problem formulation, and the like. I.e. content has to be created hand-made in order to follow the curriculum or particular learning content and objectives. The following drawbacks are obvious: (1) Game creation causes a lot of workload, in particular the curriculum-relevant game content creation for teachers and learning content providers. (2) The application of game-based scenarios are fixed to pre-defined subjects and content. Any changes of corresponding content in curricula may cause additional workload for updating the game content. And finally, (3) covering the entire curricula also by game-based learning approaches in order to provide selectable alternatives for learners may dramatically exceed human and finance resources. In addition, these efforts will multiply by taking into account personalization efforts , such as different knowledge levels.

Unlike other game-based learning solutions, we propose a game-based e-learning approach, where the content for the game scenario is automatically generated out from the corresponding e-learning content. This allows to apply game-based application of learning content of the entire course with less effort and updates are transparently available in the game-based environment.

For short, our solution is as follows: Subject-dependent questions or more general problems are automatically generated by means of our E-Tester tool, which is discussed in detail in section “First Prototype Implementation”. These questions or problems are the input for different game templates and game shells. Students or group of students have to cope with these tasks in the game environment, and have to type in or provide natural language answer documents, which are sent back to the E-Tester tool. In the next step, the E-Tester automatically assesses the answers against the corresponding e-learning content and provides the game environment with assessment results, which can be used to determine next steps in the game scenarios.

In the scope of the AdeLE research, there are two important requirements for the digital game-based learning approach: (1) We want to complement existing learning activities by the game-based learning paradigm. This should not only provide a further learning alternative, but it should also be used to force up motivation, intrigue learners for a new or a priory boring subject, and enforce collaboration and strengthen social behaviour. (2) Furthermore, we want to embed self-assessment and testing in another, more relaxing environment. This is motivated by the fact, that in particular in adaptive e-learning, pre-knowledge and knowledge acquisition in learning sessions are important and essential information in order to maintain a fine-grained user model. Just this appropriate user information can be used in order to estimate the proper knowledge level as well as to provide proper, personalized content. Therefore, for grading the pre-knowledge we apply a combination of self-assessment by the users and complement this information with a quiz-based game. In order to estimate the learning progress, also quiz-based or other game approaches with embedded questions have to be completed by the learners.

Application Scenarios

In order to clarify our digital game-based learning approach, based on the discussion and requirements stated in the section above, some applications scenarios are highlighted in this section.

Peter is a Ph.D. student and has enrolled the course “Knowledge Management” on the AdeLE system. Within the enrolling process, he has to fill up a form in order to self-assess himself by estimating his pre-knowledge for some subtopics of the course between tree knowledge levels “novice”, “normal” and “expert”. Based on this information, the first online lesson starts with a quiz-based game by providing questions from the course content. He has to response by typing in natural language answers and he collects scores. Finally, Peter gets a feedback about his pre-knowledge compared to the course content, and the system can build a fine-grained users model about the user knowledge for tailoring the content of the course.

Mona is undergraduate student in history of arts and has to complete the course “Italian Arts in the 16th century”. She has already enrolled the course weeks before, but since visiting for the first time no topic has be finished yet. The interactive digital course assistant has noticed that, and according to a online survey accomplished by the system has identified low motivation and interest in the subject. The system suggests an adventure-based game style, where course content based questions and problems have to be solved by reading parts of the learning content and searching for answers on the internet. The questions are embedded in flow of the game story and have to be solved in order to complete the game. At the end of the game, Mona has played more than 40 hours, and 25 % of the course have already been completed.

Automatic Answer Assessment and Digital Game-based Learning at a Glance

According to our proposal for an enhanced game-based learning approach and application scenarios stated so far, the main idea for the development combines a novel tool for auto-generated questions and automatic answer assessment as well as the application of game templates or game shells. Both issues are discussed in brief in the following subsections.

Computer-based Auto-created Questions and Answer Assessment

From the question creation point of view, some E-Learning systems or E-Learning management systems provide tools for easy creation and management of assignments and assessment, see for example (Cristea et al. 2004), (Pesin 2003), and (CORONET 2004). However, these tools are only supporting teachers and tutors in creation of hand made questions. Of course, automatic content abstraction and concept identification is an ongoing research topic since the early days of modern information retrieval, see for example (Sparck Jones et al. 1997) and (Cardie 1997). But to our best knowledge, no tool has been invented to create automatically questions based on content.

From the answer assessment point of view, the support of assessment in E-Learning systems is difficult due to the variety of testing options. Multiple choice tests are often applied for system-supported, automatic assessment of knowledge acquisition (Kuechler et al. 2003). Advantages are perceived objectivity and the marking efficiency, once the answer template has been constructed. As a disadvantages, (Wood 1998) argues that free response of questions, or unseen text in our terminology, may be superior in measuring achievement of educational objectives. However the assessment of such natural language answers, exercises and essays is more complex. A simple but very helpful way is to provide a tool for managing student works as well as annotating and marking them, for example as implemented in the CORONET system (Dreher et al. 2004). But an automatic assessment of natural language content is a big challenge. Some research work can be identified for automatic answer provision, for example (Lytinen et al. 2000), and for determining candidates of definitions by a given concept, see for example (Cimiano et al. 2004). In recent years there has been a growing interest in this problem of grading unseen textual input such as student essays. First into the field seems to have been (Page 1966) with Project Essay Grade (PEG). (Landauer et al. 1998) developed the Intelligent Essay Assessor, using Latent Semantic Aanalysis techniques. The E-rater (Burstein et al. 1998) scoring engine is now extensively used in the USA by the Educational Testing Service in its processing of the GMAT (Graduate Management Aptitude Test) exams. Another approach was taken by (Larkey 1998) who used a text categorisation technique, text complexity features, and linear regression methods. Such developments and the interesting backgrounds to the research approaches can be referred to in (Shermis et al. 2003).

There is a productive research group at Curtin University in Perth, Western Australia, who are developing some new and innovative approaches to Automated Essay Grading (AEG) in addition to conducting trials of existing systems. Results of such trials have been reported in (Palmer et al. 2002) and (Williams at al. 2004). The E-TESTER was inspired by this work and enables auto-generated questions and the assessment of the answers in game-based applications as discussed in the following sections.

Development Support for Digital Games Creation

In general digital games represent an increasing market worldwide, but there is an enormous effort to build entertaining games, which encompasses issues, such as appealing visualization and graphics, strong and compelling story, and high interactivity. In order to reduce production costs, some sort of game development tools – game templates, game shells and game engines – are available. (Mitchell et al. 2004), (UniGame 2003) There can be identified a variety of such tools. On one hand, there are a lot of commercial or open source offline tools, see for example (Madmonkey 2005) and (FPR 2005). On the other hand, game producers can get support by online wizards in order to create and host Web-based games, either as a commercial service or free of charge. (Kirk et al. 2004) report about supportive tools for teachers and trainers.

Despite the advantage of reducing production resources, game content – e.g. questions and answers for a quiz-based game approach- has to be created manually and is "hard-wired" embedded into the game. To overcome the second problem, (Stelovsky 2001) introduces a XML-based definition language by applying external configuration set ups for easy to change game content. However, to our best knowledge, a solution for the first problem by automatically game content creation is not reported by researchers and developers in that context.

Development Approach and First Prototype Implementation

Implementation Solution

In order to follow the requirements in the scope of the AdeLE research stated in the section "A Proposal for an Enhanced Game-based Approach" as well as to meet the requirements highlighted in the section "Application Scenarios", a flexible game-based system is designed to be an encapsulated system, which can interact with E-Learning systems or can be used as a stand alone system. For controlling, managing and interacting with the system, a communication interface is provided. The game system itself is composed of two modules, the game shell and the E-Tester component, which are discussed in in the following pharagraphs.

The first component itself, the game shell, is flexible and can incorporate different game styles and game stories. To be useable in Web-based learning environments, the system is provided with a Web-capable graphical user interface by using java applets and flash. The communication interface allows external systems to control the game environment, for example game style and story. The game content – questions and answers or problems– is created automatically by the E-Tester from specified learning content. These questions or problems are part of the game story and have to be solved in order to succeed tasks and to step forward in the game. Unlike other systems, our approach can deal with natural language answers.

The second component, the E-Tester, can be seen as a specialized service, which is fed with content, generates questions and evaluates the answers against the content. Unlike MarkIT (Williams & Dreher 2004) E-Tester is not designed to do automatically marking and rating, rather the system is focused on natural language text questions and answers, at this time in the English language. In the future, we would propose to accommodate other languages, assuming our approach is successful. The idea of the E-Tester is based on exploiting the E-Learning content as a model answer. That content, subdivided by predefined logical units (e.g. sections or lessons), is the source for the proprietary representation of the knowledge for further processing. The system uses an adapted Context Free Phrase Structure Grammar (CFPSG) parser to perform "chunking" of document sentences into Noun Phrase (NP) and Verb Clause (VC) structures. Proprietary structures, based on the rules of transformational grammar, are used to represent the semantics of the content. A thesaurus permits the construction of meta-level information. Many different expressions of the same document content can thus be represented by one semantic representation, or in our terminology semantic concept. It is the internal representation of these concepts, which are further used by the E-Tester system in two ways. First, the concepts represent candidates for questions. Based on these concepts the systems creates simple questions like "What is <concept1>?" or "Explain <concept2>." As a further work it is indented to extend the internal representation by semantic reasoning for creating more complex questions and for rating the importance of the concepts. Secondly, the concepts represent the model answer in an abstract way. By applying the same procedure as described above, the students' answers are processed to derive a semantic model. The assessment is done by comparing the concepts of the model answer and the concepts of the student answer. Questions and answers, scores and progression of the story are supplied for further use by external systems.

First Prototype Implementation

The first running prototype implementation as described as follows is not yet fully integrated into the AdeLE system. The prototype development consist of first implementations of a simple game shell, the E-Tester component and its combination. At the very moment the game shell provides just one game style, a simple quiz-based approach. The graphic user interface is built on HTML, as depicted in Figure 1. The development of these game scenario allows to estimate pre-knowledge as well as knowledge acquisition compared to the course content or simply to play the quiz in the scope of particular subject domain of the course.

The second component, the E-Tester is implemented in C++ and Java and permits identification of the main concepts from unseen content, the course content. This technique is used to create simple questions like “What is <concept>?”. It also assesses the student answers against the course content.

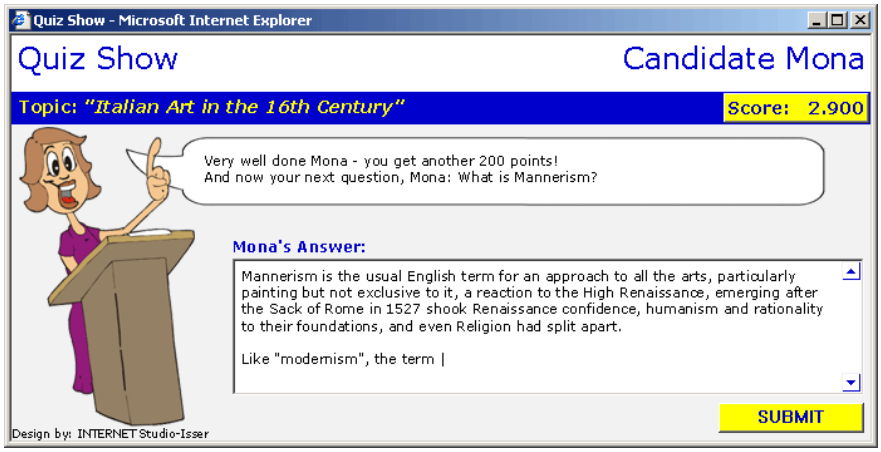

Figure 1:Quiz style game approach

Conclusions and Further Work

We have discussed an enhanced digital game-based learning approach by applying auto-generated questions based on the course content and automatic assessment of natural language answers against the course content. This allows to build a flexible system applicable in a wide range of application scenarios, and it reduces the workload. Within the AdeLE research, the game-based paradigm is interesting (1) for complementing other learning paradigms and to force up motivation, and (2) to apply self-assessment and testing in another, more relaxing environment.

First experiences and tests are promising, and we intent to integrate the game-based system completely into the AdeLE system and add several game styles and stories. At this very moment, we are starting to work on a E-Tester version for German Language.

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