Sugar Coated Learning: Incorporating Intelligence into Principled Learning Games

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Abstract

Digital Game Based Learning research has come a long way since the introduction of entertainment games in the late seventies. The potential of using games as educational tools has been extensively investigated such that digital games are now acknowledged as valuable learning instruments. However, many of these games have marked weaknesses such as scarcity of sound pedagogy, the lack of proper player profiling, insufficient balance between challenges and skill levels, and unappealing gaming worlds. Many of the concerns regarding effective educational game design may be addressed by examining the best practices from game development and educational research. This paper tackles these issues by bringing together the "tried and tested" techniques from artificial intelligence in education research and digital game research in a cohesive game architecture which encourages principled but enjoyable learning. By applying these techniques, the educational games developed using this architecture gain an adaptive intelligence which fosters measurable learning.

Keywords

Serious games, learning objects, ontologies, intelligent agents, game design

1 Introduction

Proponents of digital game based learning (DGBL) have already established the potential of games as effective learning and teaching tools. Over the past few decades there has been a steady increase in the number of DGBL research projects and publications being produced which affirm the usefulness and appeal of educational games [Van Eck 2006]. At the same time, while the interest in games as educational tools has been increasing, the cumulative access to the Internet via laptop computers and mobile phones has nurtured the evolution of a new type of learner, a digital native [Prensky 2005]. These evolved learners are no longer allured by the traditional teaching methods employed in classrooms because they are constantly being trained, by way of technology, to assimilate and learn in a distributed, collaborative manner. Consequently, educators have integrated technology into their instructional practices in a variety of ways much of which has spawned the e-learning age. However, these attempts have not achieved the desired widespread learning because in many cases the medium was mistaken for the message. The same has been true for educational games where the balance between fun and learning has not been established in a reproducible methodology that can be easily followed by educators and game designers alike. As Van Eck comments, many educational games are not enjoyable to play, and it is questionable what is learnt in the more entertaining educational games [Van Eck 2006].

2 Issues to Consider in Digital Game Based Learning

Several issues have to be addressed when designing and developing a digital educational game. Firstly, the balance between the game challenges and the skill level of the learner/player must be carefully managed since it is a limiting factor in the success of many games. The difficulty in this adaptation is brought about by the wide variations in the "frustration or patience" level of students; some are frustrated easily and others need more challenges. This balance is also influenced by the type of game which is chosen for the design. There are several game genres such as adventure games, role playing games, and strategy games which shape the game's overall effectiveness and are suited for certain learning situations. For examples, adventure game themes are commonly used to encourage reflective and active thinking. Another issue that is important is what sort of skills are meant to be exercised or developed by students for a particular game and also which type of learner is a game best suited for. This is related to a common complaint expressed by teachers who attempt to use games in their teaching; games are typically non-customisable to a curriculum and often contain irrelevant or unnecessary tasks which waste valuable lesson time [Kirriemuir, McFarlane, 2004]. In addition, teachers have difficulty in identifying at which points in the learning process are games appropriate and effective hence the need to define clearly the objectives and goals of an educational game. Above all, the design of an educational game must maintain the gameplay experience of "flow" which essentially makes a game entertaining and fun to play.

3 Addressing the Concerns of Educational Game Design and Development

Many of the concerns regarding effective educational game design may be addressed by examining the best practices from game development and educational research. Effective games irrespective of whether their goals are educational or for entertainment purposes have three major qualities: challenge, fantasy, curiosity. Games built with these principles in mind challenge players with tasks or game levels that match their skill level appropriately. Fantasy is created through virtual worlds, characters, and storylines where players become immersed in the illusion of the game. The quality of curiosity or surprise is a highly attractive feature since it encourages extended gameplay for example by providing different endings to a game or by hiding secret codes which produce different rewards. Within educational research, strong similarities may be drawn between the needs of an educational game and intelligent tutoring systems since they both rely significantly on adaptation and user modelling. Furthermore, the major qualities of challenge, fantasy, and curiosity are manifested within the techniques used by learning systems. For example, learners using intelligent tutoring systems are profiled so that educational materials or learning objects are customized according to their learning needs, knowledge level, and abilities [Mohan, Greer, 2003]. The element of fantasy has been used extensively in educational systems via intelligent pedagogical agents for student interaction, motivation, supervision and engagement to the point where students form a bond with their digital tutors. Adaptive hypermedia systems also encourage curiosity since learners are often taken down different learning paths where the educational material is not always the same after subsequent uses because of adaptation to the student's learning style or profile history. These similarities have essentially prompted the notion that educational games may be used to foster pleasurable and even collaborative learning in a highly motivating and engaging learning environment.

Educational games span multiple disciplines since they draw upon theory and best practices from game design, artificial intelligence, computer science, psychology, learning science, cognitive science, and even gender studies. By following the lessons learnt from some of these disciplines as they apply the digital games, the design and development of these games may be carried further. Consider a situation where students converge in an educational game which is able to adapt to their every learning need: their knowledge and skill level, their tastes with respect to devices and delivery modes, their learning style, and their preferred user interface format. Intelligent agents working in the background select, cut, compose, and render new game scenes and activities from numerous learning objects by examining and comparing the ontological descriptions of the users and the game domains. Dynamic transformations within the game scenes, activities, and character interactions would be activated as learning objects undergo their own autonomous metamorphosis based on the students' needs during gameplay. Essentially, students would be inadvertently customizing games for their own learning purposes in a flexible, collaborative, and enjoyable setting. The finished products may even be reused by teachers or by other students who have similar likes and needs. The next section tackles these issues by bringing together the "tried and tested" techniques from artificial intelligence in education (AIED) research and digital game research in a cohesive game architecture which encourages principled but enjoyable learning.

4 Principled Game Architecture

Ontological engineering, intelligent agents, and semantic web techniques when used in conjunction with the fundamental guidelines and principles of game design have the potential to radically transform the way people learn. The game architecture discussed in this section incorporates some of these technologies which are currently being used in AIED research to improve educational tools. There are five essential components in our educational game architecture: a game engine, a player model, intelligent agents, educational content and its associated metadata. Some of these pieces, such as the game engine, are core components in any digital game and therefore would be automatically required in an educational digital game. However, there are other components such as the player model which may not necessarily be a part of traditional games but which are crucial for successful adaptation of the gaming experience. The general architectural design is shown in Figure 1 which illustrates how the components interact with each other during gameplay.

4.1 The Game Engine

The first component is the game engine which controls the rendering of the visual gaming environment, the characters, the animations, and sound effects. A game engine is an important component since it essentially controls the execution of a game by capturing user actions and providing feedback to the users through activities and events. Within different game genres, feedback may be delivered in various ways such as audio feedback (induces tension and builds the gaming atmosphere), visual or informative feedback (dispenses information to the players and draws them into believable gameplay) or indirect feedback (subtle guidance cues embedded within the areas of gameplay). As a learner interacts with an educational game, his/her input is captured by the game engine; after a series of steps the game environment is altered by the game engine (feedback) according the current state of play as shown in Figure 1.

4.2 The Player Model

Within adaptive hypermedia research, adaptation of content is based on student models which record the learning styles, current knowledge, and learning needs of students. The user model in the game architecture (player model) when applied in a similar manner adapts a game's tasks, presentation, difficulty, and rewards to suit a player/learner. A typical player model would therefore record aspects of the game which are important to the user such as information about the player's choice of character design, last level or stage attained, rewards collected and so on. In addition, a player model facilitates loading a previous game or saving the state of a current game as is common in entertainment computer games. However, the value of the player model in an educational game architecture is seen when the learning style(s), current knowledge and skill levels, and learning goals of the player are modelled in a gaming context. This information allows a game to be selected and shaped according in a manner that best suits the learning needs of the player since for example, a player's learning style favours certain types of interaction and therefore certain game genres. In addition, a player model provides a measurable account of the learning which has taken place while playing specific games since, as shown in Figure 1, the game engine periodically updates the player model during gameplay.

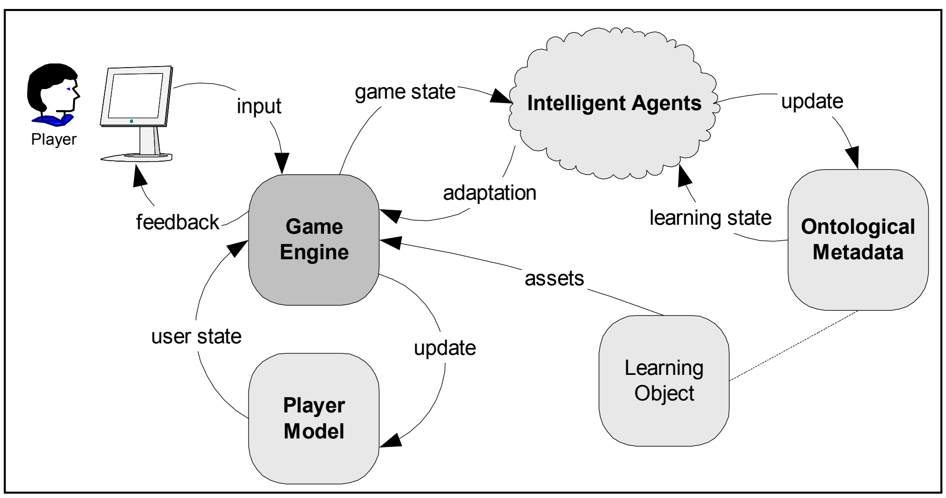

Figure 1: Flow of data in game architecture

4.3 Intelligent Agents

Agents are the third component in the game architecture and they introduce intelligence into the game using two types of rules: gameplay rules and pedagogical rules. Gameplay rules are a mainstay of digital games and they essentially shape and mould the game world by defining the boundaries of the game and how the game works internally. These rules define how characters in the game behave and look, how the game is presented, how the external scenes transition and flow into one another, how the assets react in response to player input, how and when different types of feedback is given and so on. The pedagogical rules on the other hand control the underlying instructional mechanisms which direct the learning activities that players should be doing. These rules determine what type of informative feedback/guidance should be given, they adjust the difficulty levels of the activities, they select appropriate activities/assets based on the players learning needs, skill level, and gaming context, they determine the type of rewards and hidden secrets to be given, they continuously evaluate the player model looking for strengths and weaknesses in the player's learning progress and so on. By combining these two categories of rules, the intelligent agents facilitate extended gameplay since the challenge-skill balance of the game would be maintained, as shown in Figure 1, with steady feedback through continuous evaluation of the player model and game state.

4.4 Educational Content

Every game has an environment which is used to stage the gameplay. These environments create the fantasy and illusion of virtual worlds where players face challenges, building up to one or more events which reward the player and increase the skills and knowledge of the player [Oxland 2004]. As such, within the context of serious games an immersive storyline is supplied by the educational content which takes the form of learning objects. Game assets such as the sound effects, music scores, avatars and non-player characters, dialogue, scenes and backgrounds, challenges, rewards, and game levels are primarily provided by learning objects. In particular, principled instructional design, tailored for specific skill development and assessment, guides the game activities represented in the learning objects. These pedagogical activities are categorised by the learning objects according to their value to the player both in a gaming sense and from a learning perspective. The intended learning objective, difficulty and requisite skill levels, type of challenge, trigger events and reward factors are associated with each gaming activity in the learning objects so that the game's rhythm and pace can be set in the gaming environment. Figure 1 shows how these learning objects fit into the gaming architecture by supplying assets to the game engine as appropriate for the game's state and progression. For example, if a difficult activity is to be presented to the player but the intelligent agents decide that the player does not have the basic skills required to handle the activity, the game engine is instructed to swap in an activity that is of similar value but less difficult so that a fair challenge is presented to the player.

4.5 Ontological Metadata

One problem highlighted earlier was the difficulty teachers experience in trying to find suitable games for their students. This problem is also encountered when trying to locate suitable educational material. As such, domain modelling using ontologies has become an effective means of producing metadata which explicitly describes the objectives and goals of learning objects. Learners would be interacting with such a game in a manner that utilizes several categories of ontological metadata which are associated with these learning objects [Mohammed, Mohan, 2007]. These include contextual ontologies about the learners (prerequisite skill and knowledge), pedagogy (learning styles, learning designs, learning activities), historical/statistical usage (popularity, ratings, test scores), domain descriptions (topics covered), and organisational structuring (file types, sizes, sequencing, device requirements). Consequently, these learning objects which power educational games would provide similar metadata but additional gaming related information. The domain ontologies would therefore describe the game's genre, theme, characters, backgrounds, scenes and so on. The pedagogical ontology additionally describes the game's goals, challenges, game play strategies, rewards, missions, and required skills. The learner ontology would function as a player ontology as well, and consequently stores information on the player's character state and customisation, accomplishments, defeats, performance, scores, learning progress, and game progress. Since most of the assets in a game correspond to parts of or entire files, these would be described in the structural ontology which records the sequencing of the scenes, swappable points in the game play (for rewards, challenges, secrets), gameplay and spatial segmentation, cropping, and save points. Lastly, the historical/statistical ontology in the context of an educational game records game popularity, high scores, well-liked aspects of the gameplay, successes in achieving learning objectives, prevalence of discovery of secrets, frequency of successful challenges, and user evaluations. When these ontologies are analysed collectively by the intelligent agents, the inherent semantics of the game from a gaming perspective and from a learning perspective are made available. Without this level of description, joint adaptation of the gaming and learning experiences is not possible or effective.

5 Similar Work

Although DGBL is a new and upcoming research area, there are several examples of serious game research projects which support the arguments behind our principled game architecture. These include the use of detailed conceptual descriptions of learning objects (assets) which describe the pedagogical strategies associated with activities, the resulting and expected learning outcomes, the knowledge state and progression of the player during the game and so on. For instance, the <e-Game> project [Martinez-Ortiz et al. 2006] aims to integrate educational video games into different parts of pre-existing courses based on the use of descriptive mark-up of the game storyboard. This project depends on the mark-up which outlines the conceptual meaning of the scenes, characters, learning activities, and events in the game in an XML format. Within our game architecture, this mark-up corresponds to the conceptual learning object descriptions in the metadata of the learning objects. An important difference however is the specific use of ontologies in our architecture as opposed to regular XML metadata. The reason for this choice is that ontologies operate at both a semantic and syntactic level by providing a vocabulary of terms together with their constraints and relationships whereas XML simply operates at the syntactic level and tends to be limited by inconsistent expressions. Furthermore, many adaptive hypermedia and intelligent tutoring systems are adopting ontologies as a means of knowledge representation. Nonetheless, the <e-Game> project supports the need for well-defined parameters from a pedagogical and domain perspective within educational games.

Another research project which bolsters the need for these descriptions is the Elektra project [Kickmeier-Rust et al. 2006]. The Elektra project takes a multidisciplinary approach to serious games development by incorporating techniques from computer science, game design, cognitive science, and learning science. One important similarity between the Elektra framework and the game architecture set out in this paper is the need for an adaptive engine which implements the pedagogical gaming strategy for the entire game. This adaptive engine drives the personalisation of the gaming experience by executing rules which operate on the player's learning state and learning paths throughout the game. The intelligent agents in our architecture fundamentally perform these tasks although they are not explicitly referred to as an adaptive engine. In addition to this, the Elektra project advocates the need for incorporating sound pedagogy and engaging game design when developing educational games as maintained throughout the paper thus far.

6 Conclusions and Future Research

DGBL research has come a long way since the introduction of entertainment games in the late seventies. The potential of using games as educational tools has been extensively investigated, and it is now established in the DGBL literature that educational games are valuable learning instruments [Kickmeier-Rust et al. 2006; Kirriemuir, McFarlane, 2004; Prensky 2005; Van Eck 2006]. However, the marked weaknesses of these games such as the scarcity of sound pedagogy, the lack of proper player profiling, the insufficient balance between challenges and skill levels, the technologically poor and unappealing game designs, and the non-customizable nature of these games have been acknowledged and now must be addressed. These issues have been tackled in this paper by bringing together the "tried and tested" techniques from AIED research and digital game research in a cohesive game architecture which encourages principled but enjoyable learning. By applying these techniques, the educational games developed gain an adaptive intelligence which fosters measurable learning. Furthermore, the importance of the work in this paper is significant since the shortcomings experienced in developing games and educational content may be altogether avoided when building a principled educational game since the architecture is generic and not governed by any specific implementation.

Future research that is to be undertaken includes firstly the extension and repurposing of learning objects currently designed for learning management systems into a gaming context. These learning objects have already been marked up with ontological metadata surrounding various aspects of usage, and they will be reworked to include the parameters necessary for use in educational games. In addition, an agent-based gaming framework which is built using the game architecture and general principles set out in this paper is also the focus of future research.

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