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Artificial Intelligence and Personalization Opportunities for Serious Games

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Abstract

Effectiveness of Serious Games (SG) depends very much on their capacity to provide the right balance between gaming and educational experience. This requirement raises challenges regarding realization of their intelligence and personalization. We aim to overcome the problems of research fragmentation and identify some of the main issues by presenting a summary of relevant contributions from Artificial Intelligence and Personalization, together with a discussion on their future directions. In this paper, we summarize approaches to user and learning goals modeling, user engagement, various levels of game adaptation, how new sensors and mobile technology can better identify the context of the user, content adaptation and reusability.

Artificial Intelligence (AI) and Personalization are both essential aspects of all games, be they serious or entertainment based. In this research the role of AI and Personalization is however focused upon the context of Serious Games (SG) in particular. A concerted research direction is necessary in this area so as to establish future benchmarks and metrics for the effective use of AI and Personalization in serious games design and will benefit relevant research communities in providing clear goals and focus . While the transition of AI and Personalization approaches from research labs to SG products is clearly needed, this is an impact area where research in labs may have a real benefit and impact upon products and SGs on the market, as markets mature over the next few years.

The work presented in this paper is a summary of the current results of an ongoing cooperation between 9 different institutions within a network of 28 research labs and 6 game developers are gathering their efforts to identify the hot topics for AI and Personalization within SG research. We first present our perspective on the main research questions faced by the community and then break them down and relate them with the main challenges within the fields of user modeling and content adaptation. Our goal is to provide for each research challenge, a brief description, a list of related SG examples, the steaming research questions that derive from it and previous contributions from research that address it.

Research Questions and Challenges Identification

We started by identifying two high level research questions for SG that include most of its multidisciplinary spectrum:

- To what extent is the effectiveness and efficacy of learning supported and promoted via SGs?
- How do we relate content (the factual knowledge contained, game mechanics) and context (experiences and activities) to pedagogical goals towards supporting pedagogically-driven design and development of SGs?

From these two high-level questions we derived a more pragmatic approach to AI and Personalization based on: In what ways can personalization improve learning and adapt best to learner requirements?

This questions allowed us to focus upon exploring how personalization undertaken on the fly and dynamically within games environments can specifically benefit the learner. This process involves two distinct challenges: *User Identification* and *Content Adaptation*.

We consider *User Identification* as the process of identifying and inferring the characteristics of who is playing the game. Within this very broad research topic we focus especially on two sub topics that are extremely relevant for identifying a user and keep him actively involved in the interactive learning process: *User Models for Interactive Learning* and *Detection of User Engagement*.

Content Adaptation can be used to provide an effective system response to who is playing the game, by presenting a personalized view of the game content and learning materials. We pay special attention to: *Content Personalization to Learner*, adaptation to *User Experience and Learning Goals* and *Non-Player Characters in a Learning Environment*.

User Identification

User Identification is key in current Technology Enhanced Learning systems since it allows enabling user adaptation, which is a necessary feature in order to increase effectiveness and efficiency of the instructional support.

The basis for user identification is the definition of a model that abstracts the distinctive features of a user, so that it can be continuously updated by the system's sensors while giving input to a personalization engine, that adapts the contents and their provision modalities to the elicited requirements. In this paper we also focus on detection of user engagement, since engagement is a major feature of games and serious games. In order to be effective (i.e., able to support knowledge and skill acquisition), SGs must be appealing and capable of motivating the player towards the activities that have an educational value, exploiting entertainment as a means to deliver instruction.

User Models for Interactive Learning

The rationale behind user models for interactive learning consists in the need to properly adapt to different user learning styles and overall preferences. In this view, we first need to be able to conceptualize the user in terms of learning capabilities. The model consists of those parameters that more accurately characterize the specific users and/or categories. An established way of cataloguing learning styles was proposed by (Fleming and Mills 1992), that developed a theory VARK - that categorizes learners as: Visual learners (with a preference for tools such as pictures, concept maps), Aural learners (listening and discussion), Reading/Writing-preference learners(textual stimulus), and Kinesthetic or Tactile learners (movement and hands-on practice).

A proper framework should include a module able to translate signals from physical (e.g., cameras, Electroencephalogram, etc.) and virtual sensors (e.g., answering to quizzes inside a game) into values filling a proper model mainly integrating learning styles and user preferences. This is the estimated status of the user.

In order to adapt to different learning styles properly we first need to be able to conceptualize the user in terms of his learning capabilities and learning progress. In particular, it is necessary to investigate what the parameters are that more accurately characterize the user and their mapping to specific player categories.

SG Examples User model methods have been widely used in the context of Tutoring Systems (del Blanco et al. 2010; Brusilovsky 1998; 2001; 1996; Burgos et al. 2007; Donkers and Spronck 2006; Houlette 2004; Yannakakis and Maragoudakis 2005). Despite their diffusion in such systems and the fact that they should be a fundamental technique also in Serious Games, the scientific references to them are not common. The major example of SG using user modeling for interactive learning has been implemented in the Travel in Europe and SeaGame projects (Bellotti et al. 2009a; 2009b). There, the idea is that an AI runtime module called the Experience Engine dynamically creates missions as sequences of tasks that are dynamically assigned to the user in order to maximize the fulfillment of the requirements expressed by the teacher/game author. The user profile contains parameters such as: skill level, navigation ability (in particular, but not exclusively, for 3D environments), task type preferences, task type need, skill needs and preferences, learning styles needs/preferences (Bellotti et al. 2009c).

Stemming Research Questions Which user models are more useful to the interactive learning process, and at what conditions? What variables should a user model include? What methods should be used to model the user? What measures should be taken in order to estimate in real-time the user? What techniques can be used to infer the users goals?

Previous Contributions The importance of User Models has been discussed across several areas of research (Brusilovsky 2001; Donkers and Spronck 2006; Houlette 2004; Yannakakis and Maragoudakis 2005), including for learning environments (del Blanco et al. 2010; Leutner 1993). Even though the considerations on user models such as in (Brusilovsky 1996) and models such as Demographig Game Design (Bateman and Boom 1995 2012) represent important and well known contributions, the only SG specific model we found is in Travel in Europe and Seagame (Bellotti et al. 2009a, Bellotti et al. 2009b, Bellotti et al. 2009c), that we have outlined above. Given the limited-ness of the studies and evaluations, further research on user models for interactive learning in serious game settings is urgently needed.

Detection of User Engagement

User engagement is both a very particular aspect of game development, and of the success of learning applications. Research in user engagement can provide a very serious contribution to SGs by defining which user inputs are relevant to assess the user engagement in both the game and the learning process. Furthermore, the interaction between the assessment of the learning process and the assessment of the game experience will have an impact on the priorities of the AI strategies used to engage the user in a fun learning process. It is not just about to adapting to learning style but to the way users have fun, and maintain interest in playing a SG.

Since SGs often provide a learner with complex multidimensional environments , adaption must be executed in real-time so as to continuously balance challenge against enjoyment as described in Csikszentmihalyi's concept of "flow"(Csikszentmihalyi 1990). Flow is considered as an intrinsically enjoyable state characterised by deep concentration, enjoyment and often associated with altered sense of time and concern for one's self(Sweester and Wyeth 2005). In this context, players affect and related states such as motivation, empathy and attention are also known to play a key role in influencing learning outcomes(Arroyo et al. 2009).

And the development of serious game adaptive technologies is a non-trivial task. Hocine et al. (Hocine and Gouaich 2011) identified the following challenges:

1. A game should adapt to a players competency levels. Users are likely to express a wide range of cognitive and motor skills affecting both their preferences and performances during game-play. Serious Games must not only take into account their ability to play the game but their existing knowledge of the subject domain (Conati and Zhao 2004). Games that either supersede or fail to meet a players capacity are likely to fail to maintain player engagement [6].
2. Adaptation must meet real-time performance constraints. Consequently, any performance overhead added by the use of adaptive technology must be limited to maintain response time and interaction quality [7].
3. Maintain flow or immersion in the game. While a design constraints, the notion of flow and game-play must be taken into account in the choice of pedagogical approach or exercise-based gaming activity.
4. Correctly Balancing ludic and pedagogical content. Kickmeier-Rust et al. (Kickmeister-Rust and Albert 2012) stated that the ultimate goal of serious game design must be the achievement of the learning objectives and that game-play motivational aspects only serve so as to support this goal. Hence, It is not simply enough to have a player continually engaged with a SG if it does not result in the appropriate pedagogical gains for the player (Rowe et al. 2009). We must take advantage of the other game elements to provide an efficient learning environment.

The game-play/pedagogy relationship described above lies on whether or not ludic and pedagogical content are contributing to an efficient and engaging educational experience. In this context, research in this area should primarily focus on measuring the contribution of these elements towards both learning and enjoyment.

SG Examples EU-funded ALICE game(ALI)

Stemming Research Questions Which user models are more useful to the interactive learning process? What variables should a user model include? What methods can and should be used to model the user? What techniques can be used to infer the users goals?

Previous Contributions Fairclough (Fairclough 2007) discussed potential elements for the measurement of real-time relevant brain activities for Brain Computer Interface (BCI). Additionally, a number of EEG-based algorithms have been developed towards detecting and monitoring user engagement(Chaouachi et al. 2010; Russell, Weiss, and Mendelsohn 1989; Liu et al. 2010; Prinzel III et al. 2003) so as to develop autonomous adaptive systems. Through these algorithms, it is possible to identify to an extent levels of vigilance, anxiety, arousal or engagement.

However, for these algorithms to provide reliable data (to an extent), it is necessary to carry out a large amount of data gathering, system training and computationally intensive off-line processing. In the particular context of real-time SG applications, it is wholly unrealistic to project implementing heavy, data hungry algorithms. Thus, trade-offs and concessions must be made between 1) The spectrum of detection (granularity) and the amount of data gathered and 2) Detection accuracy and processing time. Realistically, current state-of-the-art in signal processing would only allow for a real-time algorithm to detect general states such as alertness or arousal with a low degree of reliability. It is clear for now that signals detected through these algorithms need to be correlated with task-based performance indexes such as success rates, speed or reliability.

Content Adaptation

Content Adaptation enables SGs to realize the final step of in-game player personalization. Steered by the underlying data and models stemming from *User Identification*, content adaptation uses this data to generate or customize personalized game content.

Content Personalization to Learner

In order to change how content is presented and effectively adapt to the user, SGs include knowledge on what learning styles have been classified and what content presentation strategies map to each of them. Typically, a supporting user model is responsible for dynamically assigning the player to these different learning styles and strategies. The appropriate strategies can then be applied by a specialized component (*e.g.* centralized AI managers, content generators, agent organization frameworks), which constructs and presents the personalized content to the player.

SG Examples Content personalization techniques are used in two serious game examples which are part of two previous European projects. Several publications regarding techniques used to adapt the interactive application to the learner have been reported in the projects *The 80 days Project* (80D ; Kickmeier-Rust, Göbel, and Albert 2008)and the *Elektra Project* (Elektra ; Kickmeier-Rust et al. 2006)

Additionally, in(Hullett and Mateas 2009), such techniques were also used in scenario generation applied to emergency rescue training games. Furthermore, earlier work from (Magerko, Stensrud, and Holt 2006) and (Niehaus and Riedl 2009) supports the generation of personalized scenarios in military training games.

(Bellotti et al. 2009a) describe the Experience Engine, a runtime content delivery management engine, designed to optimize the serious game experience, joining educational value and entertainment. Personalised conditions for presentation of different content in interactive TV-based serious games are presented in (Bellotti et al. 2001).

Stemming Research Questions How, when and which content should adapt to the player?

Previous Contributions The answer on how to adapt content to the user entails different strategies. Each strategy is derived from the different aspects to which the user has access in the game (both interactively or just visually). As such, a complete answer should cover a wide range of methodologies and techniques. In this paper we will only discuss some that we found more relevant: Interactive Storytelling, Procedural Level Generation and Adaptive Game Balancing.

Interactive Storytelling is a medium where a user can influence the narrative and its evolution, in real-time, and as such, the game surrounding content can be adapted to the user. The approaches taken by researchers to adapt story knowledge to dynamic interactive environments fall between two extremes: *Character Centered Approaches*: all story knowledge is encoded in the character's AI. (Cavazza et al. 2002) and *Mediated Approaches*: conflicts between story development and user interaction are managed by a special entity called the mediator.(Figueiredo et al. 2008; Mateas and Stern 2003; Saretto and Young 2001)

In Procedural Level Generation the adaptation occurs through the generation of content tailored specifically to the users characteristics. This tailored content can refer to both: (i) training/teaching scenarios and missions and (ii) game worlds and its objects. As recently surveyed in (Lopes and Bidarra 2011), many approaches are already being researched, *e.g.* evolutionary algorithms, semantic modeling or answer-set programming.

Adaptive Game Balancing is an effective adaptation method, where game features (typically the challenge level) are adjusted to player performance. The standard approach for this is Dynamic Difficulty Adjustment, a technique where AI behavior is automatically balanced to match the measured player ability (*e.g.* using case-based algorithms).

User Experience and Learning Goals

Alongside with adaptability to the user's learning capabilities is the capacity to support the user, both task and emotion wise. Such adaptation is a delicate balance between satisfying both user and tutors intentions.

SG Examples The application of techniques to balance the fun and learning experiences can be found in two games. One is from the Elektra Project addressing the players immersion versus the game based learning(Elektra ; Kickmeier-Rust et al. 2006)

Another example is the serious game Crystal Island is an environment that supports an inquiry-based approach, where the story is a sort of a container of elements to be taken in considerations in order for the player to solve problems in the domain of biology (Mott and Lester 2006).

Stemming Research Questions How can we maintain an engaging user experience inside the intended learning experience boundaries? How can techniques from diverse areas of AI engage the player? How can the techniques still support the learning experience while supporting engagement?

Previous Contributions Part of the answer to this topic is found on the previous one, especially in Interactive Storytelling, since it is by design a mechanism which guides the user throughout its experience. By combining the learning goals and the fun goals in this process the two sides of the user experience are balanced. However, three more areas are fundamental to address it: Natural Language Processing, Strategy Formulation and Learning Adaptation and Intelligent Tutoring Systems.

The Natural Language Processing, plays an important part since it provides to non player characters the ability to converse with users using natural language, a much more natural way of communicating for humans. Several techniques can be used to improve natural language processing in a system.

Regarding Strategy formulation, even though mainly used in commercial games the techniques under this topic enable AI to adapt strategies to the user, this upkeep the original goals of the AI (in a learning context those might be learning goals!). In doing so, provides means for games to avoid becoming predictable and boring.

The Learning Adaptation and Intelligent Tutoring Systems techniques have been widely used outside the gaming field. However, in combination with Interactive Storytelling they provide important methodologies to manage user experience.

Non-player Characters in Learning Environments

The personalization of game content includes the adaptation of all the interaction modalities found in games(Peirce, Conlan, and Wade 2008). Since NPCs are currently one of the most relevant elements of game interaction we should carefully address their impact on the learning goals while designing and creating NPCs for educational purposes. The central goal for NPCs is believability through natural behaviors and intelligent interaction(Zielke et al. 2009).

SG Examples Currently there are several SG which make use of NPC AI in order to create personalized and more realistic learning environments. In the area of negotiation skills for specific cultural contexts there is Elect Bilat(Hill Jr et al. 2006) making use of tutoring technology, dialogue manager and social simulation to create more realistic NPCs and provide intelligent interactions for the user. Another example is the utilization of crowd simulation is the riot control scenario of the ADMS SG from ETC Simulation.

Stemming Research Questions Which non-player character behavior models are best suited for interacting with a learner/user?

Previous Contributions Throughout our survey of techniques there are three areas which offer fundamental contributions to the topic of NPCs: Artificial Tutors, NPC Competitors and Crowds.

The Artificial Tutors are mainly applied through NPCs for collaboration with the user or pedagogical agents. These play an important role for several serious games purposes:

educational and motivational support, emotional regulation, improvement of fun/immersion and instantiation for collaboration. Models for tutoring agents(Nunes et al. 2010; Kickmeier-Rust and Albert 2010) address important challenges which emerge from the needed interdisciplinary work from HCI, pedagogy and psychology.

The NPC competitors, complement the universe of roles of the Artificial Tutors by empowering NPCs the capabilities to undertake antagonistic tasks regarding the learner. The competitive nature is frequently useful in learning environments for the creation of required challenges (examples chess adversary, terrorist npc, mob npc), where the agents must be able to plan strategies for challenge creation.

Crowds NPCs (Anderson et al. 2009; Thalmann et al. 2004) bring the behavioral issue to the context of a high number of characters, alongside with its own set of challenges such as simulation performance and variability of the generated behaviors. However, when properly applied (human like behaviors, as it has seen in numerous techniques) create a very impressive added value to the believability of a learning environment. Imagine a SG where you learn the taks of a mob control policeman where the mob to be controlled is composed of just 5 or 6 NPCs. The believability and impact of this simulation will be drastically reduced when compared with another situation where you have hundreds of NPCs.

The different types of NPCs for SG presented are complimentary, in the sense that they can provide a SG different aspects to NPCs believability (individual and social) and immersion(Zielke et al. 2009).

Conclusions

AI and personalization are crucial aspects of SG, but their effective and efficient design and implementation still represent major challenges. To achieve various pedagogical goals in different educational contexts, it is important to simplify the process of authoring and adjustment of SG by people without programming skills. In this paper we have identified several research topics that we consider relevant in this field, like identification of learning goals, user modelling and engagement, as well as different levels of game adaptation. They should be further investigated and realized, in order to support effective and efficient design, development, and deployment of SG.

If we want to take into account various factors that influence these complex processes, multidisciplinary research is required. Our aim is to use the opportunity that the GALA Network of Excellence on Serious Games is providing us from this perspective, and proceed with more in depth investigation and analysis of the key issues, some of which we have outlined in this paper. We hope this endeavour will help to reduce the gap between SG research and SG industry.

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