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Deploying learning materials to game content for serious education game development: A case study

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ABSTRACT

The ultimate goals of serious educational games (SEG) are to facilitate learning and maximizing enjoyment during playing SEGs. In SEG development, there are normally two spaces to be taken into account: knowledge space regarding learning materials and content space regarding games to be used to convey learning materials. How to deploy the learning materials seamlessly and effectively into game content becomes one of the most challenging problems in SEG development. Unlike previous work where experts in education have to be involved heavily, we proposed a novel approach that works toward minimizing the efforts of education experts in mapping learning materials to content space. For a proof-of-concept, we apply the proposed approach in developing a SEG game, named *Chem Dungeon*, as a case study in order to demonstrate the effectiveness of our proposed approach. This SEG game has been tested with a number of users, and the user survey suggests our method works reasonably well.

1. Introduction

Serious Educational Game (SEG) refers to an alternative learning methodology that applies game technology to primarily promoting players' learning along with gaining positive cognitive and affective experience during such a learning process [1]. Elements of challenge and learning within such a game construct activities for motivation and amusement [2]. SEG is also named in different terminologies such as game-based learning or educational games. In this paper, we treat all those terminologies interchangeably and refers the SEG development to the procedure that builds up a game for a learning purpose.

There are useful approaches to game development for a learning purpose, such as [3,4]. Most of those approaches emphasize that the design of a serious game is mainly from learning materials of a domain knowledge. Hence, those development frameworks have to rely on a close relationship between learning materials and game design (proprietary educational game). Moreover, the proposed development frameworks require rigorous procedures that may involve interviews with target users (including teachers and students) and various experts (e.g., game development, education, psychology and so on), lengthy development stages and testing units. Such development frameworks inevitably incur the high cost because the development process is laborious and time-consuming and hence limit the growth of educational games.

In general, SEG development has to involve two key components: *knowledge* and *game content* spaces [5,6]. The knowledge space is formed to encode learning materials concerning the subject knowledge to be learned by players, while the game content space is formed with playable game elements that convey the knowledge chunks implicitly. This is generally required by any serious games as argued in [7,8] where serious game is defined as a computer program that combines *serious* (for knowledge learning) and *game* (for entertainment) purposes. Thus, how to map the knowledge space to content space becomes one of the most important problems in SEG development. To our knowledge, however, the mapping is a bottle-neck in SEG development as this has to be handcrafted by game developers closely working with education experts in most of existing SEGs.

Unlike most of the existing approaches, we propose an alternative SEG development framework in this paper to address the mapping issue by embedding annotated knowledge chunks into categorized game content/elements seamlessly during SEG development. In one hand, there are abundant education resources (e.g., syllabus or knowledge handbook) that contain the structure of the underlying knowledge chunks as well as sufficient instruction [4] for learning them. Our framework would exploit such information so that knowledge chunks and their connections can be easily annotated by game developers or automatically acquired by using information retrieval techniques. On the other hand, the "purpose-shifting" is a terminology for SEG

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development [9,10] which diverts the purpose of an existing commercial game for knowledge learning. This approach exploits the properties of existing commercial games which fit a learning process, e.g., a player has to *learn* game rules, objectives and strategy to succeed a game. Such a typical *learning* process is also applicable in traditional education systems. As an alternative game development methodology, Procedural Content Generation (PCG) technique can generate game content automatically via algorithms using a random or pseudo-random process that produces an unpredictable range of possible gameplays, for instance, [11]. This will significantly lower the cost of game development. Moreover, the latest PCG work [11] suggests that a proper use of the categorized game content may facilitate eliciting positive gameplay experience. Motivated by the previous works, our framework would suggest making use of PCG and existing entertainment games in SEG development (see Section 3.2 for details). In particular, we believe that embedding annotated knowledge chunks into categorised game content/elements makes the mapping easier to accomplish.

We summarise the main contributions of the work presented in this paper as follows: (a) we propose an alternative framework for effective and efficient SEG development; (b) under our proposed framework, we develop a proof-of-concept SEG, Chem Dungeon, to demonstrate the usefulness of our proposed framework; and (c) we test this SEG with human players via user survey and statistical analysis.

The rest of the paper is organized as follows. Section 2 reviews the related works. Section 3 presents our SEG framework and Section 4 describes our proof-of-concept SEG, Chem Dungeon. Section 5 and 6 reports user test analysis results and discussion, respectively. Finally, the last section concludes the research.

2. Related work

In this section, we outline connections and main differences to relevant SEG development approaches.

As argued by Damir et al. [5] based on their interviews with education experts, game developers and players who involve themselves in SEG, it is crucial to have a seamless connection between knowledge and game content spaces in SEG development. Moreover, they further emphasize that two spaces must be controllable [5] to allow for gaining the controllability in tailoring game elements that are likely affecting different kinds of the player's experience such as learning, enjoyment, motivation, engagement and so on. In addition, it is suggested by Hussaan et al. [6] that there are three components in SEG. Apart from learning and game resources, domain concept should be introduced to specify the relationships between learning materials. Specifically, it facilitates using learning resources to formulate strategies in carrying out learning based on game resources. Nevertheless, this approach [6] emphasizes that all of those components have to be taken care by education experts via interactions with students or game players.

Gamification [12] is a typical SEG development approach that explicitly takes knowledge and game content spaces into account in development. The basic idea underlying gamification is directly embedding game elements (e.g., avatar, badges, levels and scores) into the learning process. Doing so make students more actively engaged in the learning process when they are situated in a game-like presentation of the learning materials. In [12], education experts and game developers handcraft the combination of the two spaces, which is laborious and time-consuming. Similarly, Belloti et al. proposed an approach for adaptive SG via building up the proper connection between knowledge and game content spaces [13]. Their approach breaks down a serious game into subsequent tasks by considering diversified connections between learning materials and game elements. Then, adaptation is carried out by offering a proper task sequence to an individual player to maximize their positive learning and positive affective experience [13]. However, the game design (in particular, the mapping between two spaces) relies heavily on education experts. Hence, the development cost is often very high. Technically, such an approach is also subject to limitation. The mapping task becomes difficult if one of the content space is large and complex. Hence, we do not think this approach is extensible in SEG development.

Unlike the above approaches, our proposed SEG framework would exploit the instructional resources and makes use of appropriate PCG techniques towards minimizing the cost. Thus, our proposed framework is expected to connect knowledge and game content spaces seamlessly in SEG development.

3. Methodology

In this section, we propose an alternative framework for SEG development especially for addressing the mapping issue pertaining to two spaces. To accommodate that, the framework exploits learning resources and making use of the latest PCG techniques.

The advantage of structuring serious game content in two spaces of learning materials and game content provides a higher degree of control for the game generation. In the existing SEG approaches, however, education experts have to be the prominent force in the process of deploying learning materials into a SEG. Thus, an expert is expected to deeply understand characteristics of learning materials and game content according to their expertise in order to link the two spaces. However, it becomes infeasible and unscalable in the presence of complex learning or game content space. Hence, game developers are demanded to utilize the natural and inherent game elements to deal with the knowledge deployment issue. This is feasible since sophisticated education resources are accessible easily and the PCG techniques allow for flexibly controlling game elements to embed knowledge chunks. Thus, we believe that making use of learning resources and making use of the latest PCG techniques could slash the expense of SEG development. Furthermore, given the semantic descriptions of those content spaces, the developer can formulate different aspects between them, which sparks a proper deployment.

To address the issues mentioned above, we propose an alternative framework for SEG development as illustrated in Fig. 1. First, learning materials and game elements are in separate spaces. In one hand, annotation takes place to describe education materials naturally from the meta-data retrievable from reliable resources. Then, we need to establish the strategy for presenting them to players, based on their retrieved properties or using the corresponding learning resources. On the other hand, categorisation of game content space consists of a couple of steps. It starts with a difficulty categorisation which groups game content according to the level of challenge. Subsequently, within each of the pre-defined content categories, e.g., difficulty levels, and given a

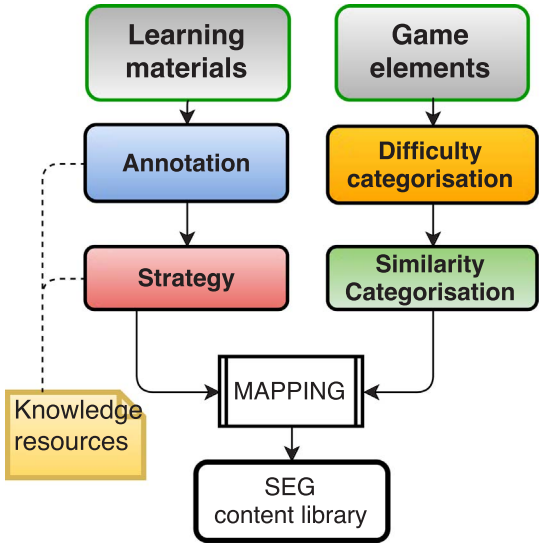

Fig. 1. An alternative SEG development framework.