The APOGEE Software Platform for Construction of Rich Maze Video Games for Education

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Abstract: Nowadays, the integration of serious video games into educational and training processes tends to be more and more popular. The present paper outlines the software architecture of an innovative online platform for an automatized construction of educational video games, which is going to allow non-IT professionals such as teachers, pedagogues, and educationalists to design, automatically generate and personalize educational video games based on a formal descriptive game model. The games represent rich educational video mazes providing didactic multimedia content personalized upon various characteristics of the player. The construction process includes three stages: game design, game validation, and game generation. The integration of analytics tools into the platform will monitor all of the platform's data and processes hence will facilitate the platform users to make more adaptive, effective, and efficient video maze games for education.

1 INTRODUCTION

With the rise of the modern computer era, digital games became a highly popular media thanks to their visual interactivity and ability to represent stories, knowledge, virtual worlds, and interactive objects in an appealing and spectacular way (Salen and Zimmerman, 2004). Most digital games are designed as 2D or 3D video games and can introduce both tangible and intangible cultural artefacts by providing high immersion and engagement (Bontchev, 2016) through "*an integrated form of fun and play*" (Gee, 2003).

Besides video games for fun, there exist also other games designed with purposes different than entertainment. The term *serious game* was introduced by Abt (1970), who defined such a game as having "an explicit and carefully thought-out educational purpose and are not intended to be played primarily for amusement". The majority of serious, or so called applied, games are designed for educational or training purposes, however, there are many such games applied for defense, advertising, marketing, political votes, industry control, and scientific research (Sawyer and Smith, 2008).

Serious games serve as an engaging and motivating means for game-based learning (GBL) and training, however, their design and development require a higher production cost (GALA, 2011). On the other hand, there are few platforms for free of charge, online creation of serious games (Bontchev and Panayotova, 2017). Hence, educational and training institutions cannot afford a variety of educational video games dedicated to different learning domains, that restricts the scale of modern GBL to isolated cases in some schools and Universities.

The present paper outlines the software architecture of an online platform for an automatised creation of educational video games being under construction in the scope of the APOGEE (smArt adaPtive videO GamEs for Education) research project[1]. This innovative open platform is going to allow non-IT professionals such as teachers, pedagogues, and educationalists to construct, automatically generate and personalize educational

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video games based on a formal descriptive game model including semantic structuring of both game and didactic content. The games represent rich educational video mazes defined as a 3D maze video game providing rich didactic multimedia content personalized upon various characteristics of the player (i.e., the learner) and presented within the maze halls not only on learning boards but as well as within puzzle mini-games of various types embedded into each hall. As well, a rich educational maze is supposed to provide rich gaming and learning experience thanks to including intelligent virtual players and applying a dynamic, player-centric adaptation of both difficulty of learning tasks and the audio-visual properties of the game environment.

The paper is structured as follows: after the introduction, we present our motivation to the construct and maintain such an open software platform for construction of rich maze video games for education. We outline some of the major problems with production of the serious games and, as well, the existing tools and platforms for construction of educational video games. Next, we present the process of construction of rich video maze games for education and the software architecture of the platform. In the fourth section of the paper, we discuss some of the services provided by the platform and the micro-services design pattern for their implementation. Finally, we conclude with some remarks about the importance and the practical application of the platform being under construction and, as well, provide some directions about our future works.

2 BACKGROUND

The section presents our motivation to create and maintain the APOGEE software platform for the construction of rich maze video games for education, together with a short review of similar works in the area of automatized construction of educational mazes and puzzles.

2.1 Problems with Production of Serious Video Games for Education

Modern GBL needs various cheap, attractive, and engaging educational video games having a quality similar to the entertainment games and able to embed content from different learning domains. Nowadays, these requirements to the serious games applied for education appear not to be satisfied, at least of several reasons:

- Serious games have a higher ratio between development costs and the number of potential players – educational games have a specific purpose and are targeted to a very limited auditory compared with the commercial games (GALA, 2011);
- Due to the very limited budget of the educational and training institutions, serious games for learning are rather less attractive than games for fun;
- Construction of an educational game requires the inclusion of teachers and pedagogues as core game designers into the overall production process, which is not the usual practice in game studios (Paunova, 2019);
- There is a worldwide lack of free and customizable platforms for the automatic creation of educational games (Bontchev and Panayotova, 2017).

Besides the serious problems with serious games listed over, the GALA Roadmap (2011) identifies several other obstacles and open issues hampering the massive penetration of GBL as a modern method of technology-enhanced teaching and training:

- Difficult and non-adequate accordance between the game mechanics and the learning paradigms;
- Lack of a reference framework for achieving compliance of the gameplay issues with the learning objectives;
- Due to a shortage of effective tracking of individual learner progress, educational games could hardly be applied for assessment purposes;
- Educational games need smart and realistic virtual players, i.e. NPCs – for this purpose, adequate psychological theories should be applied together with modern AI techniques.

Next to Gala, Shapiro (2014) outlines ten crucial obstacles hampering video games to be applied in education. He pointed out three important technological handicaps preventing a wide usage of educational games, namely purchasing cost, problematic discovery of video games suitable for a specific curriculum, and uncertain ways for applying video games into the teachers' practice.

All these problems stated over made us start the construction of an open and free software platform for the construction of educational video games.

2.2 Similar Works

Undoubtedly, many people and organisations try to answer problems with the production of serious games for education. The need of platforms and tools

for an automatized construction of educational games led to appearance of such software especially for creation of mazes, quizzes, and puzzles as simple single-player video games missing intricate narrative, high interactivity, and complex character development.

Up to present, there are available only a few and simple online tools for automatized creation of mazes and puzzles. Quandary [2] is a very popular tool facilitating the creation of 2D online action mazes. Such mazes represent multi-stage scenarios composed by states dedicated to a concept and having several possible choices/actions to proceed within the maze. After selecting an action, the player moves to the next state of the transition graph and explores its specific scenario. Action mazes were successfully applied for game-based learning in foreign languages (Kiliçkaya, 2017) and for improving decision-making professional skills (Gilbert and Priddle, 2010). Next to Quandary, Qedoc Quiz Maker [3] proved to be another popular freeware for creating and distributing interactive educational and training modules. The versatile playback environment of Qedoc Quiz Maker can serve not only as a player of quizzes with questions of hundred different types but as a system for exam revisions, a learning tool including generators of mathematical problems, or a flexible manager of surveys. Recently, another maze generator was proposed within the scope of the ADAPIMES research project (Bontchev and Vassileva, 2017). The generator created 3D adventure mazes with puzzles for unlocking doors to next maze rooms, whereupon teachers were able to customize maze structure and add their preferred content to the maze rooms. However, there are no examples of customizable and personalizable mazes available online neither of platforms for generation of such mazes, which could be easily customized for various educational curricula.

3 THE APOGEE PLATFORM FOR RICH MAZE VIDEO GAMES FOR EDUCATION

Based on several previous experiences in the area of generation of personalized learning paths (Vassileva, 2012), emotionally-adaptive learning games (Bontchev and Vassileva, 2017), and educational video mazes (Bontchev and Panayotova, 2017), the APOGEE project develops the idea of an automatic generation of rich video maze games for education. This section outlines the paradigms of rich educational video maze games and explains their construction process and the software architecture of an online maze game platform planned to be developed until 2020.

3.1 Rich Educational Maze Games

The APOGEE online platform will allow automatized construction of rich video maze games for educational purposes. Such games apply as a game container a 3D planar video maze, whose halls (rooms) represents rich didactic multimedia content by means of:

- learning boards;
- puzzle mini-games of various types representing learning tasks;
- smart virtual players, or non-player characters (NPCs), providing help and answers to the player questions.

The didactic content can be personalized upon various characteristics of the game player/game-based learner model such as:

- Demographic characteristics like age and gender;
- Learner/player characteristics:
  - Static parameters – goals and preferences, knowledge level, learning-playing style;
  - Dynamic features – effectiveness, efficiency, and speed of solving tasks.

The personalized didactic content of the learning tasks is presented by puzzle games embedded into maze halls and having various types, such as answering a question or quiz for unlocking a door, arranging a pre-generated 2D puzzle, solving a ‘word soup’ puzzle, rolling balls marked with both text and texture to certain positions or objects, detection of hidden objects and classifying them by specific feature, and memory or shooting games. Solving puzzles in a maze hall may be mandatory or optional. The player should solve all the mandatory puzzles in order to proceed to the next hall of the maze. Optional puzzles might be solved just for increasing the learner’s score, or just for fun.

All the characteristics of the player/learner model serve for personalization of learning content and, as well, for dynamic, player-centric adaptation of difficulty of learning tasks (presented by puzzles), the

[2] http://www.halfbakedsoftware.com/quandary.php

[3] https://www.softpedia.com/get/Others/Home-Education/Qedoc-Quiz-Maker.shtml

audio-visual properties of the game environment, and the NPC behavior.

3.2 APOGEE Construction of Rich Educational Maze Games

The construction of rich educational maze games using the APOGEE platform includes three stages: game design, game generation, and game validation.

3.2.1 Game Design

Rich educational maze games use a planar maze consisting of halls connected each other by means of doors. By default, the doors are locked and need to be unlocked by the player by providing the correct answer to the door question. After unlocking a door, the player can open it by a mouse click on the door and, next, proceed to the next hall. If a hall contains mandatory puzzles, they should be solved in order to answer the unlocking question. The learning content of a hall of spread on learning boards (canvases), puzzles, and an NPC available at the hall for helping the learner. Besides learning content, a hall has also gaming content consisting of various assets like 3D gaming objects, music and sounds to be played in the hall and at specific situations; illumination, decoration, and textual help messages (parameterized at design stage), and textures for the walls, floor, and ceiling.

The game construction process is presented in fig. 1. Currently, game designers need to describe their game formally within an XML document presenting both the learning and gaming contents. As far as only a third of the surveyed teachers are definitely positive about constructing an XML design document for their games (Bontchev and Panayotova, 2017), the project team develops an online drag-and-drop maze editor for facilitating the maze design. The editor is controlled by the maze XML Schema (i.e., an XSD document) in order to reflect future changes in the organization of maze halls. It consists of:

- A connectivity editor serving for defining the connections between the maze halls;
- A property editor facilitating the design of each maze hall including content for the learning boards, definition of embedded mini-games, and all needed gaming assets together with properties of the available NPC.

The didactic content for both the learning boards and the puzzles could be defined in several versions in order to be personalized at the beginning of the play according to the static and dynamic characteristics of the learner model (ADAPTIMES, 2019).

At each moment of the design process, the maze designer can generate and download the XML document defining formally the designed maze game. The generated XML is a valid instance of the XML Schema provided to the editor.

The XML document describing the maze game should be validated by a XML Schema (XSD file) before starting the maze game generation process. Fig. 2 represents a scene of the roll-the-balls puzzle game automatically generated by means of a XML document describing a sample history maze (Terzieva, 2019). There are shown two balls having on their upper canvases blazons, and four rings having appropriate titles. The goal of this puzzle game is to roll each ball to its matching ring.

3.2.2 Game Generation

Among the many types of serious games, we have chosen rich educational maze games because they can be easily generated automatically by applying a formal, XML description of the maze game, together with all needed game assets. The maze generation is possible by means of a custom plugin named Maze Builder and developed for the Unity 3D game platform (Unity, 2018). For an offline, local generation, the plugin should be imported into the Unity game editor as a custom package. Next, it requires entering an XML document valid against the XML Schema and describing a maze game, together with an archive of all the gaming assets. Having the XML maze definition document and the asset archive, the Maze Builder plugin generates the maze in few seconds. The generated maze can be viewed and, if needed, updated in the Unity visual game editor as shown in fig. 2. For example, the designer could change the didactic content presented on a learning board, or the position of a hidden object or of a destination circle on the floor for rolling a ball to it.

Finally, the maze designer is supposed to do a build of the generated maze game for a given platform such as PC desktop, Web browsers, or mobile devices. For the future, the processes of generating the maze and building the video game for a specific platform are going to happen online, without any additional intervention by the game designer.

3.2.3 Game Validation

After the automatic generation of a rich educational maze and building the maze video game for a specific platform, the game designer should validate the constructed video game by playing it.

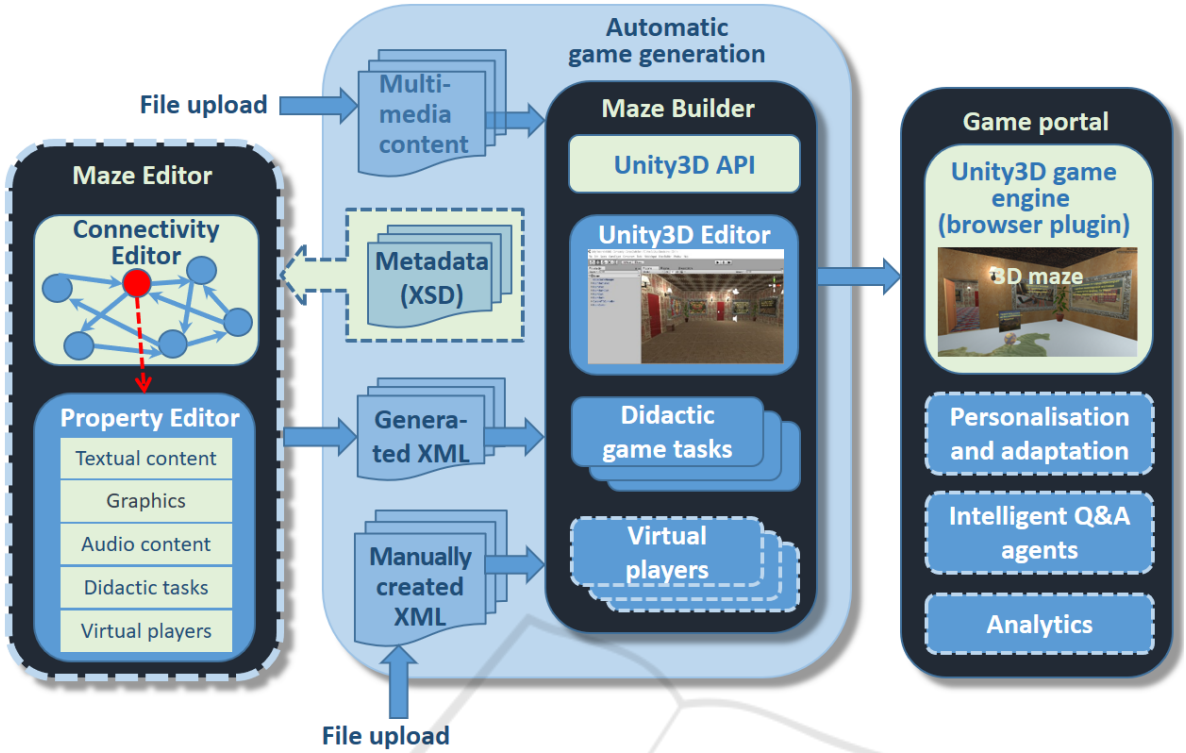

Figure 1: A view of the APOGEE maze games construction process (the modules in dotted line are under development).

For the moment, rich educational maze video games can be played easily only at PC desktop platforms or Web browsers due to the complexity of the 3D maze interactions. In order to validate the game generation process, the game designer (supposed to be a non-ICT people such as teachers or pedagogues) should play at least once the maze game. He/she should check the appearance of the didactic content on both the learning boards and puzzle mini-games, the location of generated hidden objects, the interactivity and all the issues concerning the gameplay.

Figure 2: A view of a generated maze game with a roll-the-balls puzzle mini-game.

When playing the game through the online game platform, the player will enter the game with his/her personal ID, i.e. with his/her player´s model. Thus, the personal characteristics of this player will be applied at the beginning of the play for content personalization and dynamic adaptation of the gameplay. Hence, the designer can inspect all the gameplay issues of the generated rich educational maze and, if needed, to update the game model and the XML game definition document and to launch again the generation and build process.

3.3 Software Architecture of the APOGEE Game Platform

Nowadays, one of the most common approaches used for the implementation of distributed applications is the micro-services architecture. This architecture is based on SOA and it is built from a small one or more services that can be deployed independently of one another (Fowler and Lewis, 2014). Each micro-service can exist as a standalone application and it is responsible for a performing a task, part of the overall workflow. Usually, these services are connected to each other over HTTP and communicate between themselves through an interchange of messages (Dragoni et al., 2018).

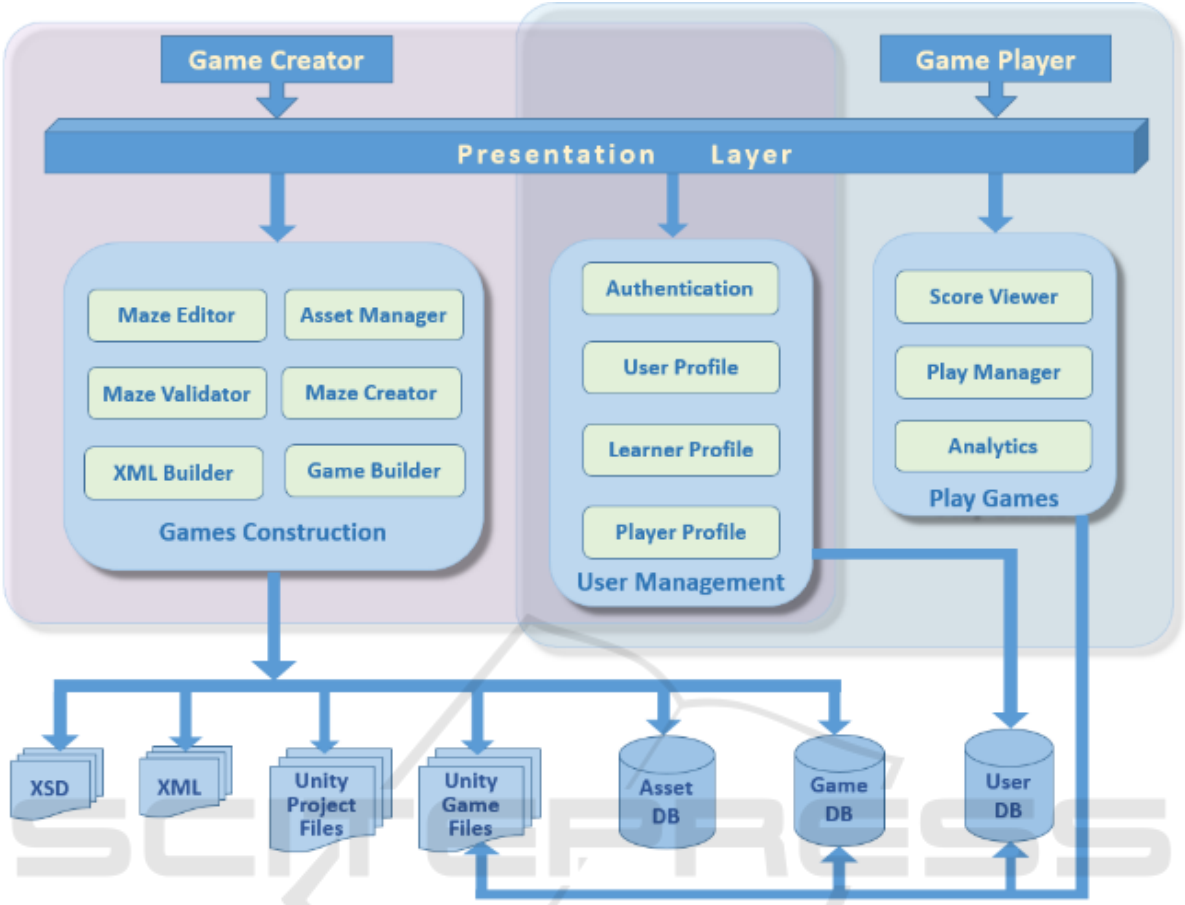

Figure 3: The APOGEE software platform architecture.

The micro-services approach assures scalability, maintainability, easy integration, and decentralization.

Precisely, because of the above-mentioned advantages of the micro-services, the software architecture of the APOGEE game platform follows this architectural design pattern. As it is shown in fig. 3, the APOGEE architecture consists of a presentation layer, several web services and a persistent layer responsible for data storing. Each one of the web services is implemented as a standalone application and can be developed and changed independently by others. The web services are separated into three groups such as follows:

- Games construction services – it consists of six web services (maze editor, maze validator, maze creator, XML builder, game builder, and asset manager) responsible for a game construction. The maze editor allows a game labyrinth to be created / edited and store its structure in an XSD file and in the Game DB. The maze validator validate the XSD file produced by the maze editor;
- User management services – it includes four web services (authentication, user profile, learner profile, and player profile) related to management of profiles of different users;
- Play game services – it contains three web services (score viewer, player manager, and learning and gaming analytics). The analytics will provide the data for processing, analysing and extracting valuable knowledge and information from it.

The APOGEE platform is accessible for two type of users – game creator and game player. As it is shown in fig. 3, the first one (game creator) uses the web services of game construction and user management, and the second one (game player) uses the web services of play games and user management. Both types of users communicate with the web services through a presentation layer presented by the user interface of the APOGEE system. First, the user is authenticated by username and password. Then,

depending on his / her role (game creator or game player) continues to create / edit games or to play a game.

4 DISCUSSION

The central objective of the APOGEE project is to create a software platform for construction and generation of smart adaptive 3D video maze games consisting of a metadata-driven maze editor and a Unity3D-based maze builder using an adaptation control engine, an intelligent question and answering (Q&A) agent, and declarative game description and semantically structured virtual representation of artefacts. It is very important non-IT professionals such as teachers, pedagogues, and educationalists to be able to use an open platform to construct, automatically generate and personalize engaging educational video games. Hence, the target user group for the APOGEE platform will include not only IT users but also people having no or limited knowledge in programming and data science (Dankov and Birov, 2018) such as teachers or pedagogues. The platform will provide the possibilities of creation of educational games for three main groups of users:

- Users with experience in XML design - they will create the game's design document from scratch with any plain text editor and then upload it to the server;
- Users with an initial experience in mark-up languages – they will create the game design document using the XML templates provided by the portal and then upload it to the server;
- Users with no experience in mark-up languages - they will create the game in the online editor and then generate the XML game design document to be used for generating the maze.

The APOGEE platform addressed all the existing problems and challenges listed in Section 2.1. First, game development costs will be practically zero because users will only design the educational games and, next, generate and build it automatically. The generated maze games promise to be more attractive than today's serious games thanks to the inclusion of various puzzles, game assets, and intelligent virtual players. Teachers and pedagogues will act as core game designers into the overall production process, using a free and customizable platform for the automatic creation of educational games without any need of outsourcing to game studios. As well, smart services will help designers to tailor the gameplay issues with the learning objectives and specific curriculums. Personalization of learning content and dynamic adaptation of difficulty will incur greater motivation, engagement and flow among the learners, following a complicated learner model and the design of the adaptation mechanisms (ADAPTIMES, 2019).

Finally, the analytics tools integrated into the platform will provide effective tracking and monitoring of individual learner progress. The analytics services are planned in three directions:

- Learning analytics – such as efficiency, effectiveness and time to learn through games by the learner;
- Gaming analytics – like efficiency, effectiveness and time of play by the player;
- Additional analytics – an opportunity of integration of new analytics tools for the purpose of the platform, such as Business Visual Analytics (Dankov and Birov, 2018) for monitoring overall data and statistics of the platform, game creators, and players.

For realizing all the platform services, the architecture of micro-services has been preferred over the monolithic or layered approach for developing distributed applications. Micro-services expose their functions to other services or applications through an API and can be deployed and scalable independently. The architecture of the APOGEE platform follows micro-services design pattern. Its code is split up into three composite web services (Game construction, User management, and Play games) built around three business contexts and each of the services is composed of several small services having a single responsibility. Thereby, it is achieved flexibility, scalability, independence, and maintainability.

5 CONCLUSIONS

The paper presented an innovative open platform for an automatized creation of educational video maze games being under construction in the scope of the APOGEE research project. This platform includes a drag-and-drop editor for creating a game and provides methods for automatic generation of adaptive video maze games. Hereby, it allows non-IT people easily to design and creates educational maze games. Moreover, it provides possibility of different pedagogical strategies to be embedded in the educational maze games that greatly facilitates the game process development and reduce its production cost.

Modern video games tend to include automated conversational entities such as virtual players (i.e., NPCs) playing the role of personal assistants doing tasks for the player, competitors or opponents

(Adams and Rollings, 2006). They are well accepted by real players in the way people interact with chat bots as a regular part of a chat room. Question-answering was proposed first in role-playing games but appears to be very important for any game having NPCs. The APOGEE approach plans to apply question answering, where possible answers to a question in a given domain are ranked and incorporated in large-scale goodness polarity lexicons by means of a semi-supervised way. Smart NPCs should provide adequate answers to the player´s questions, especially to those belonging to the game learning domain.

As future works, we plan to conduct practical experiments with the APOGEE platform. The experiments will include validation of the usability of the platform by non-IT specialists (meeting their game design requirements) as well as an assessment of the adaptability and usefulness of virtual agents. Hereby, that will make easier for teachers to apply game based learning at schools and Universities. The APOGEE platform provides an open solution that allows zero development cost, easy maintaining of educational and gaming content, and applying of specific pedagogical strategy in a video maze game. Moreover, with the APOGEE the game creators will be able to apply a dynamic, player-centric adaptation of both difficulty of learning tasks and the multimedia game assets that is a key factor for an effective learning process. This will facilitate the designers to develop the platform and the creators to make more adaptive, effective, and efficient educational games, for various learning domains. The players will have their own statistical metrics of success and failures, as well as an opportunity for competitions between players for achieving best results.

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REFERENCES

Abt, C.C. 1987. *Serious Games*. University Press of America.

Adams, E., Rollings, A. 2006. *Fundamentals of game design*. Prentice-Hall.

ADAPTIMES. 2019. *Declarative model of educational maze games with semantic structuring of game and didactic content*. Project Deliverable D2.1, http://www.apogee.online/results-en.html, last viewed on May 20, 2019.

Bontchev, B. 2016. Serious Games for and as Cultural Heritage, *Digital Presentation and Preservation of Cultural and Scientific Heritage*, Issue No. 5, 43-58.

Bontchev, B., Panayotova, R. 2017. Towards Automatic Generation of Serious Maze Games for Education, *Serdica J. of Computing*, Vol. 11, No 3, 249–278.

Bontchev, B. P., Vassileva, D. 2017. Affect-based adaptation of an applied video game for educational purposes. *Interactive Technology and Smart Education*, Emerald, ISSN: 1741-5659, 14 (1), 31-49. DOI: 10.1108/ITSE-07-2016-0023.

Dankov, Y., Birov, D. 2018. General Architectural Framework for Business Visual Analytics, Business Modeling and Software Design, *Lecture Notes in Business Information Processing*, Proceedings of 8th International Symposium BMSD 2018, Vienna, Austria, July 2–4, 2018, Editors: Shishkov, B., Springer Int. Publ. AG, ISSN 18651348, 280-288.

Dragoni, N., Giallorenzo, S., Lafuente, A. L., Mazzara, M., Montesi, F., Mustafin, R., Safina, L. 2017 Microservices: yesterday, today, and tomorrow. *Present and Ulterior Software Engineering*, Springer, Cham, 195-216.

Fowler, M., Lewis, J. 2014 Microservices,. http://martinfowler.com/articles/microservices.html.

GALA. 2011. *GALA Roadmap*. Deliverable D1.6, Ver. 2, November.

Gee, J. P. 2003. What video games have to teach us about learning and literacy, *J. of Comp. Entertainment*, 1, 20-28.

Gilbert, A., Priddle, J. 2010. Using an action maze to develop problem-solving skills in family law. *Networks*, 13, 24-29.

Kiliçkaya, F. 2017. Infusing Action Mazes into Language Assessment Class Using Quandary. Chapter in *Balkan Educational Studies – 2017*, ed. H. Asutay, Trakya University, 223-231.

Paunova, E. 2019. Didactic mini video games – students' and teachers' point of view, Proc. of *ISEIC'2019*, March 20-22, Czech Republic.

Salen, K., Zimmerman, E. 2004. *Rules of play: Game design fundamentals*, MIT Press.

Sawyer B., Smith, P. 2008. Serious games taxonomy. *Presentation given at Serious Games Summit*.

Shapiro, J. 2014. Games in the Classroom: Overcoming the Obstacles, https://ww2.kqed.org/ mindshift/2014/ 09/12/games-in-the-classroom-overcoming-the-obstacles/, last viewed on May 20, 2019.

Terzieva, V. 2019. Game-based teaching in history – case study in Bulgarian schools, submitted to *EDULEARN'2019*, 1-3 July, Palma de Mallorca, Spain.

Vassileva, D. 2012. Adaptive e-learning content design and delivery based on learning styles and knowledge level. *Serdica Journal of Computing*, 6(2), 207-252.

Unity. 2018. *Unity User Manual*. Version 2018.3, https://docs.unity3d.com/Manual/index.html, last viewed on May 20, 2019.