Generation of Educational 3D Maze Games for Carpet Handicraft in Bulgaria

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Abstract. Serious video games applied for learning purposes play a significant and important role for the modern technology enhanced education. The paper presents an educational 3D maze video game dedicated to the development of carpet fabrication in Bulgaria since 17th century until modern days. The game was automatically generated by means of declarative description of the maze processed by an open software tool named Maze Builder and built on top of Unity game platform and specially designed for automatic generation and easy modification of maze video games. There are explained the maze game design process, the educational tasks embedded into the maze, and a practical experiment conducted with the generated game. The initial results obtained from these experiments are very positive and encouraging with regard of playability of such educational mazes and, as well, concerning their easy and straightforward generation by educators, who are not IT professionals.

Keywords: Video Game, Maze, Generation, Education, Carpet.

1 Introduction

For more than several decades, computer games continue being the most popular media for exciting and fascinating entertainment and fun and, on the other side, an effective tool facilitating traditional activities in areas such as education, professional training, manufacturing, military deal, rehabilitation, advertising, and many other (ESA, 2015). Digital games of this type are called *serious* (Abt, 1987) or *applied* (Schmidt et al, 2015) because they are "*produced, marketed, or used for purposes other than pure entertainment*" (Egenfeldt-Nielsen et al., 2008). The same authors also underline that theoretically any computer game can be viewed as a serious depending on the perception of the players about gaming experiences.

Modern digital games are designed predominantly as 2D and 3D video game and, unlike traditional media as books and movies, provide a highly interactive entertainment. The high of interactivity provided together with an immersive and intriguing 3D virtual environment make game playing an engaging and motivated process, which leads naturally to an adoption of different skills and abilities, such as spatial thinking and cognition, strategic skills and possibilities for memory enhancement (Spence & Feng, 2010). Hence, serious 3D video games continue to be used more and more

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broadly in many spheres of the social life especially when applied for educational purposes. Educational video games are applied as a tool for game-based learning (GBL), which is defined as a specific type of gameplay with well-determined learning outcomes (Shaffer et al., 2005). By means of a plenty of practical experiments of learning with video games, it has been proven GBL provides a great level of learning motivation and engagement at affective, behavioral, cognitive, and sociocultural levels (Plass et al., 2015). Although any digital game possesses some learning aspects and could be potentially used for GBL, serious games embed learning content, elements of instructional design and interactions meaningful in a learning context, which naturally makes them effective tools for modern technology enhanced education. Didactic contents of any curriculum can be easily structured in hierarchical mazes, where a section or a cycle of the labyrinth represents a module of the curriculum in the way it was done in the educational video games for Bulgarian Orthodox iconography (Bontchev et al., 2016).

Although enjoying great popularity during last decades, GBL continues having many serious impediments hampering the ubiquitous use of educational video games. One of the most important obstacles prohibiting a massive penetration of GBL in classrooms is the lack of educational games appropriate for specific curriculum and of platforms for the construction of such video games (Bontchev, 2015). The present research addresses namely this problem by proposing a software platform for automatic generation and easy modification of educational video games of maze type, whereupon the labyrinth is defined in a declarative way including a description of the structure and properties of the maze. The platform is named Maze Builder and is built on top of an existing popular free game engine – Unity 3D. It offers a graphical desktop interface based on the Unity 3D framework, allowing an automatic generation of the game from its textual description of the graph of the maze, characteristics of nodes and links, didactic elements, educational contents and visual presentation. The teacher can define the textual description and content of the future game and specify the maze. This description is structured in XML format and is used by the platform, which generates a specific maze-type video game with educational purposes. The generated games can be either desktop- or web-based and may have a number of didactic elements for each room of the maze - for example, wall panels with slides, doors with questions attached to them, maps, rings, circles, and rolling balls.

In order to validate the approach of automatized creation of 3D educational mazes and to access the benefits of the solution, several 3D maze games for carpet handicraft in Bulgaria were generated. The following sections represent our motivation for completing this work, an overview of the platform, design details about one of the 3D maze games for carpet handicraft, and a discussion about assessment of both platform usability and game playability.

2 Motivation

This section outlines our motivation to create the Maze Builder platform for automatic generation and easy modification of educational 3D video maze games. We start with an outline of the barriers for contemporary game based learning, which motivates us in

construction of an open platform for creation of educational video games superior than the existing ones.

2.1 Barriers for Modern Game Based Learning

Modern educational games provide an effective means for fostering contemporary technology enhanced education. A meta-study on the empirical evidence on the effectiveness of serious games applied for education based on 40 research works revealed that 29 from all the selected studies show positive results proving educational games are superior to other types of learning material (Backlund & Hendrix, 2013). Learning by playing video games brings to learners high cognitive, behavioral, affective, and sociocultural issues, which are rather different from other forms of learning (Plass et al., 2015). These issues donate learners with strong motivation, engagement, adaptivity, and so called *graceful failure* while playing educational video games.

On the other hands, modern GBL still suffers from many problems of a different nature restricting its penetration at classrooms and out-of-class training. Shapiro (2014) outlined the top ten obstacles to using games in the classroom identified by a survey conducted with 700 teachers and aiming at identification and ranking the major barriers to the application of GBL. Among them, we would like to underline three essential technological impediments hampering the massive application of GBL, namely:

- costs of purchasing games;
- difficulties in finding video games that fit a specific curriculum;
- uncertainty about the ways of integrating games into instruction (Shapiro, 2014).

Such technological barriers can be eliminated by offering free platforms for automatized creation of educational video games on behalf of non-IT specialists such as teachers, instructors, and pedagogues.

2.2 Platforms for Creation of Educational Video Games

Educational video games have relatively high costs because they should fit a specific curriculum and aligned with given didactic goals. Therefore, it is very hard to imagine a universal software platform serving for the construction of educational games of any types. Existing platforms are restricted to a creation of educational games of specific types such as maze games (Bontchev, 2015). Mazes (or labyrinths) are traditionally used in entertainment games such as Dungeon and Dragons[1]. They and can be structured as graphs that can be matched to the structure of a specific curriculum. Hence, maze games appear very appropriate for interactive representation of content where learners have to make decisions how to proceed within the maze by choosing one from multiple options. On the other hand, mazes can be combined with quizzes, puzzles and other mini-games embedded into the labyrinth that makes them a universal tool for GBL in any learning domain (Bontchev et al., 2016). The player navigates through a

[1] http://dnd.wizards.com/

branching tree designed by the educator for given curriculum, solves didactic tasks and, based on his/her current outcomes, chooses how to move the story.

For using maze game for education, teachers should be able to construct hierarchical video mazes for their curriculum and to customize maze nodes with preferred content. As the majority of teachers do not have IT skills, such platforms have to allow easy and automatic game construction process.

There are available some simple tools for maze creation such as Quandary[2], which allows possible creation of web-based 2D action mazes. Another tool designed for developing interactive learning contents is Qedoc Quiz Maker[3]. The Qedoc Quiz Maker can be used for creating and distributing interactive educational and training modules, featuring a powerful WYSIWYG editor. The flexible playback environment can become a quiz player, an exam revision system, a corporate learning tool, or a survey instrument. The Quiz Maker features about 100 different question types, including learning games such as memory games, anagrams and mystery words, question types and special question types such as mathematical problem generators. On the other hand, in the scope of the ADAPTIMES project, there was conceived a constructed software tool for easy creation and customization of 3D video mazes (Bontchev, 2016). The tool is based on the Brainstorm eStudio[4] platform and is intended to help game-based learning, far not only in the entrepreneurship domain. Teachers can construct 3D video mazes by using the graph editor and, next, can customize rooms for any domain through the property editor. However, the tool is not free for use and is limited only in the research project.

3 Overview of the Maze Builder Platform

In order to be able to try the feasibility of the idea for a simple but effective construction of educational 3D mazes by means of a free and open tool for automatic generation of the maze using an existing free game engine, we designed and developed the first prototype of Maze Builder software platform.

3.1 System Requirements

Unlike previous design approaches of a platform for construction of maze games based on closed 3D graphics platforms and allowing generation of only desktop games, the present system is based on using a popular and free game engine, which allows easily any further enhancements. Hence, we selected Unity 3D as a target game platform because it appears fully compliant with our functional requirements:

- 3D game engine;
- Free for non-commercial use;
- Distribution to multiple possible platforms – e.g. desktop, web, and mobile;

[2] http://www.halfbakedsoftware.com/quandary.php
[3] http://www.softpedia.com/get/Others/Home-Education/Qedoc-Quiz-Maker.shtml
[4] http://www.brainstorm.es/products/estudio/

- Automation – adding automated processes so that a non-professional could easily use them;
- Easy customization and extension;
- Have supporting documentation and the community around.

On the other hand, the quality requirements include good portability, extendibility, scalability, maintenance, performance, and usability for non-IT people.

3.2 System Design

The Maze Builder platform is designed as an extension to the Unity 3D editor – a so called *unity package*. When the game designer creates a new game project in the Unity 3D editor he/she imports the Maze Builder package, thus making available the Maze Builder menu option providing the Maze Builder popup dialog for import of both the maze description and resources. The game designer should have prepared all required game assets (image and audio files) and the formal description of the maze as an XML file valid towards a predefined XML schema. All they are to be imported into the project, which results in the creation of a 3D maze in the Unity 3D editor as shown in Fig. 1. The game designer is able at this point to perform some customization of the maze (for example, move objects around or manually modify text or textures). The generated maze can now be built for the desired target platform (for example Windows executable file or WebGL for a web-based game).

The Maze Builder platform utilizes the features of the Unity 3D game platform without any need for the game designer to have skills with manipulating 3D objects or with the Unity 3D editor itself. If the designer has more advanced skills, then he/she can still use the full potential of the Unity 3D platform.

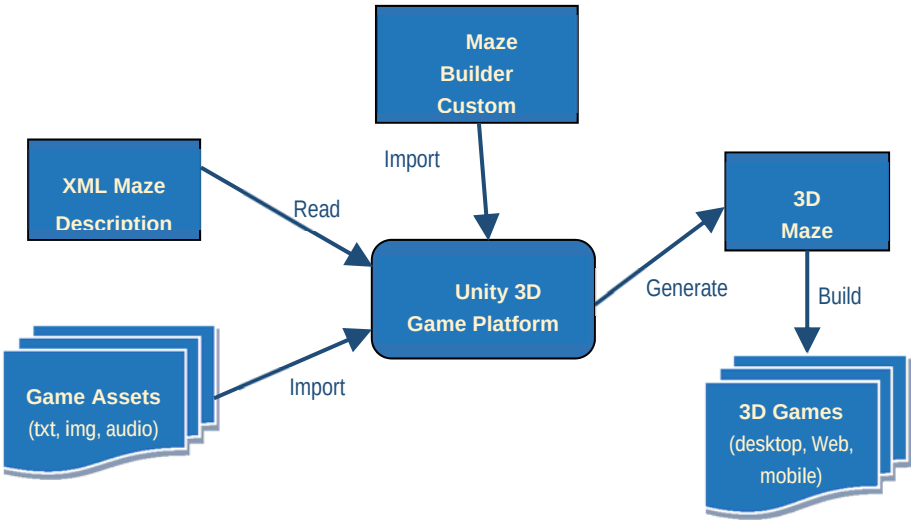

Fig. 1. Conceptual model of the Maze Builder platform.

3.3 Generation of Educational 3D Mazes

The functional testing of the Maze Builder platform included automatic generation of many simple mazes having one or several rooms. It supposed creation of valid XML maze definitions (by an external text editor) of mazes with grid connectivity containing descriptions of rooms, their interconnection through doors, and game tasks located inside each room. More precisely, a room description can include the following:

- room name, textures of the walls, ceiling and floor, and audio for playing in that room;
- up to four doors to other rooms - each one with a question with possible answers, whereupon the right one serves for unlocking the door;
- learning boards (up to 8 per room) – each having both text and image explaining an learning object;
- hidden objects spread inside the room – to be found by the player for getting points;
- didactic tasks for the room – puzzles requiring rolling balls either to given position of the map or inside a specific ring. The educator can define N balls and M rings and set their mapping within the same XML document.

3.4 Playing Activities

There are a number of activities, which can be performed in every room of the generated 3D maze games:

- To view slides on the walls - containing both textual and visual information;
- To find hidden objects – there is a visual indication of the number of hidden objects within the current room and upon finding the hidden object the player also sees a visual indication that the object has been found and points are earned;
- To play a puzzle game – the mini game contains balls and corresponding circles or rings; the user needs to match each ball to the right circle or ring; there is a textual and visual information associated with each ball, circle or ring as a hint to the player for the correct match;
- To answer a question – each door can be linked to a question and the door remains locked until the question is correctly answered; once the question is correctly answered, the door gets unlocked and the player can freely open and close the door as many times as he/she wants without the need to answer the question again;
- To open a door – leads the player to the next room in the maze where he can perform any of the above activities again.

The listed activities are defined by the game designer for each room and are not mandatory – it is up to the game designer to decide which ones to add, it is possible to define the maze so that the player will only view the slides and roam freely without any restrictions (like answering questions to proceed further).

4 Practical Experiments with an Educational 3D Maze Game for Carpet Handicraft in Bulgaria

In order to validate practically the Maze Builder platform for automatic generation and easy modification of educational 3D video mazes, we designed and generated an educational 3D maze for the development of carpet handicraft in Bulgaria. Next, we conducted practical experiments with the game aiming at validating both the usability of the Maze Builder platform and playability of the generated video game.

4.1 A 3D Maze for the Development of Carpet Handicraft in Bulgaria

In order to test and validate the platform, there was created an experimental 3D video game supporting education in Bulgarian ethnography. The game is dedicated to the fabrication of carpets in Bulgaria since the 17th century to the present times. The maze of the games consists of six rooms interconnected by locked doors, which can be unlocked by answering a question (Fig. 2). After a door is unlocked, the player can open or close it from any side of the wall, therefore he/she can crawl the maze in both the directions for that one door. Each room of the maze contains four pairs of slides dedicated to the mastering of carpets in Bulgaria. The central room starts with an introduction in the field providing some information about the game, as well. Both the west and northwest rooms deal with the fabrication of carpets in Tsiprovci, while the east and northeast rooms explain the development and specifics of carpet production in Kotel. The final, north room provides information about the machine production of carpets in Sliven.

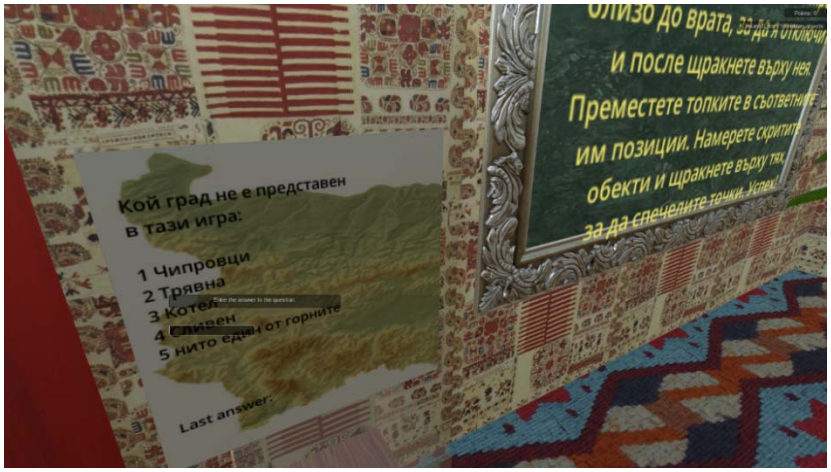

Fig. 2. Answering the question for unlocking the door to the west room.

All of the rooms except the first one contain a collection of hidden objects (two per room) to be found by the player and embedded mini-games with ball rolling objectives. Players have to look for hidden objects on the floor, ceiling, pots, etc., being initially

semi-transparent and turning fully textured after clicking onto them. As well, players have to solve various tasks requiring rolling balls to appropriate locations on a map or into a specific ring, in order to allow the question for unlocking the door to the next room. Fig. 3 shows rolling a ball to the location of the town of Tsiprovtci, whereupon readers can see the central room (through the open door to it) and a hidden object in the center of the pot in the corner from the right side (after clicking on it, it will receive full color and texture). On the other hand, Fig. 4 presents a game task at the northwest room of the maze requiring rolling three balls (right) to their correspondent rings (left), with a semi-transparent hidden object hanging from the top.

Fig. 3. Rolling a ball to the location of the town of Tsiprovtci.

Fig. 4. A game task for rolling three balls (right) to their correspondent rings (left), with a semi-transparent hidden object hanging from the top.

4.2 Experimental Setup and Procedure

In order to evaluate the qualities of the maze created through the developed software platform, a practical experiment was conducted using the educational video game described in 4.1. The experiment involved 17 volunteers of two types:

- educators who passed through a demonstration of generation of a maze game and arrangements of didactic objects embedded into it and watched a video about the maze creational process available at https://www.youtube.com/watch?v=3IBqYooKwQg (2:39 min.);
- students – learners through the generated serious game available online at http://adaptimes.eu/carpetgame/ and who played the game either online by a Firefox browser with Unity Web Player Plugin installed from https://unity3d.com/webplayer, or offline by downloading the desktop version of the game from this Web page. A video containing a demonstration of a game session with the generated game is available at https://www.youtube.com/watch?v=ZLH4F6gq9Gs (3:20 min.).

All the volunteers have participated entirely anonymously. Experimental tests passed through a procedure, which included:

- learning about the game and how to play;
- independent game session without time constraints - the learners have played one or more games to the end either in a Web browser, and/or using the desktop version of the game loaded locally on their computer;
- filling in a 12 item questionnaire about the usability of the Maze Builder platform – only by the educators;
- filling in a 17 item questionnaire about the playability and learnability of the game – by both the educators and learners.

4.3 Initial Results

This section outlines our motivation to create the Maze Builder platform for automatic generation and easy modification of educational 3D video maze games.

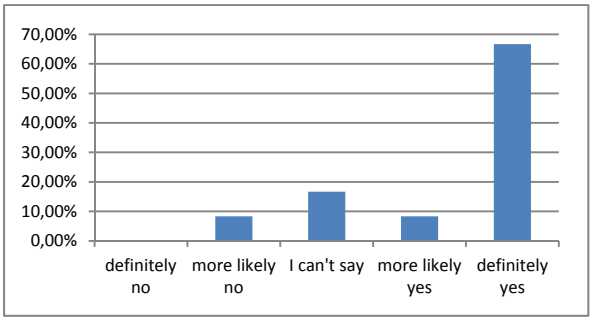

Fig. 5. Results for the “Do you think that educational video maze games are an effective tool facilitating education?” question.

2/3 of the participants have answered with “Definitely yes” to the question “Do you think that educational video maze games are an effective tool facilitating education?” (Fig. 5).

50% of the participants have found that using text in XML format to for describing video maze games is definitely a good idea whereas none have answered with definitely not or more likely not. Full results can be seen in Fig. 6.

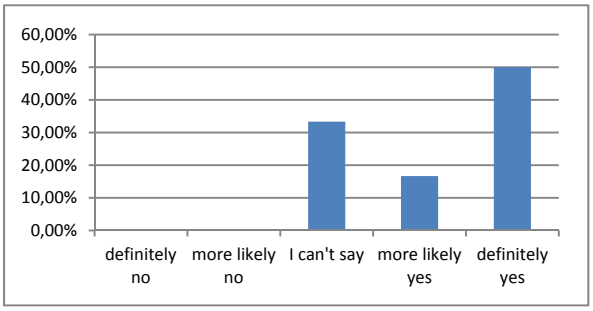

Fig. 6. Results for the “The idea to use text in XML format for describing video maze games is very good and has future” question.

58.33% of the participants have answered that the utilized learning tasks such as moving objects to certain positions or next to other objects, answering test questions for unlocking doors to other rooms and finding hidden objects, are definitely very appropriate for educational games as shown in Fig. 7. On the other hand, the majority of the participants found that the time spent on game and amusement obtained is high (36.36% - definitely yes, 36.36% - more likely yes), shown in Fig. 8.

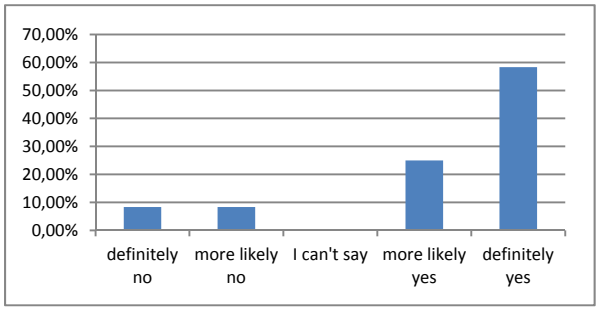

Fig. 7. Results for the “The utilized learning tasks such as moving objects to certain positions or next to other objects, answering test questions for unlocking doors to other rooms and finding hidden objects, are very appropriate for educational games and significantly facilitate education” question.

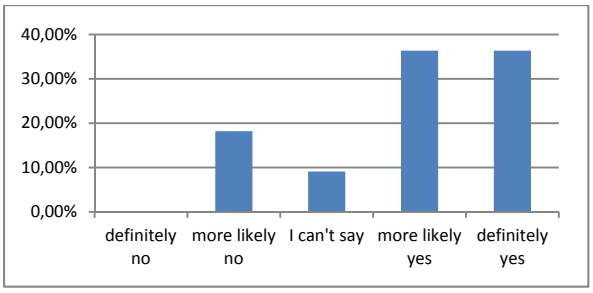

Fig. 8. Results for the "The time spent on game and amusement obtained is high" question.

5 Conclusions

Massive penetration of video games for educational purposes at schools, universities and training centers is still in its infancy. It should be supported by institutional frameworks, well-defined processes and, most important, by free tools for game construction by non-ITC specialists. The paper presented a free software platform for creating educational maze games, called Maze Builder. The platform is implemented as an open-source extension of the Unity 3D editor following a conceptual model developed in the analysis phase. An experimental maze game about the development of carpet handicraft in Bulgaria was created to validate the platform. A practical experiment was conducted using the maze game where the participants had independent game sessions and filled a questionnaire. The initial results shown video maze games prove to be an effective tool for education and using XML for maze description is definitely appropriate according to the participants in the questionnaire. The experimental game has been found very entertaining, the story pleasing and the game controls were attractive to the players.

Based on the reported initial results from a practical experiment with using Maze Builder for generating 3D maze video games, we can conclude that school and university teachers can use the platform for presenting the studied material in a more engaging way. Video games generated by the platform provide the possibility for embedding short quizzes and puzzles for consolidating the knowledge. Also, the platform can be used for professional training including not only textual and visual information but also practical questions and tasks. Further enhancements will include customization of learning boards and maze rooms, an inclusion of custom 3D objects and avatars for multi-player mode, and aggregation of question databases for presenting more than one question for unlocking a door. As well, we plan further experiments with more participants using the new versions of the platform in order to evaluate and enhance both the platform usability and playability of constructed maze games.

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