RICH EDUCATIONAL VIDEO MAZES AS A VISUAL ENVIRONMENT FOR GAME-BASED LEARNING

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Abstract: Thanks to their impressive interactive abilities, video games are applied for decades as an engaging means for effective and efficient game-based learning. This paper presents the vision of applying rich educational video mazes as a visual environment for game-based learning. It defines a rich educational maze as a 3D maze video game providing rich didactic multimedia content presented within the maze nodes not only on learning boards but as well within puzzle games of various types. The game designer can embed the puzzle games into each one of the maze rooms and provide learning content personalized upon various characteristics of the player (the learner). In addition, such an educational maze is supposed to provide a rich gaming and learning experience thanks to including intelligent virtual players and applying a dynamic, player-centric adaptation of the difficulty of learning tasks and of the audio-visual properties of the game environment. This paper outlines the essence of a rich educational video maze games including its concept, genre, target audience, look and feel, game interface and artificial intelligence, with a special focus on the mission, challenges, and objectives of the game. As well, it provides some results from an online survey about the usability of such educational video mazes from the student point of view.

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Introduction

In last decades, virtual environments are successfully applied for learning thanks to their ability to attract and engage learners, to motivate and strengthen the individual learning process, to provide various new types of exercises, and to give immediate feedback (Ruipérez, 1997). Educational video games contemplate all these properties within an intriguing gameplay supported by specific game mechanics (Fabricatore, 2007). Thanks to their ability to include tasks for developing motor skills and memory of the player together with planning, decision-making, and problem-solving skills, educational labyrinths and mazes appear to be one of the most popular video games for learning (Kennedy, 1999; Norris et al., 2017). While a unicursal labyrinth provides a single (usually not a direct) path from an initial position to its center or another final position, the multicursal labyrinth is a maze with multiple paths where some of which could have dead ends (Hackworth, 2012). Video maze games were applied for learning various disciplines – from foreign languages (Todd & Tepsuriwong, 2008) to professional skills (Gilbert & Priddle, 2010) and entrepreneurship (Bontchev, 2015). On the other side, puzzles represent a unique genre of digital games that require puzzle solving. Depending of the specific type of the puzzle and its interaction modalities (Carvalho et al., 2012), its solving requires specific problem-solving skills such as image memorization or matching, logic operations, word finding or completion, pattern recognition, etc. The solving process may have some limitations as time limit, maximal number of attempts, achieving criteria, threshold for passing to the next level, or dynamic difficulty adjustment (Silva et al., 2017) of the puzzle game. Solving a puzzle provides fun and satisfaction of the learned issue making such digital games a powerful learning tool (Paul, 2003).

The paper presents the concept of a rich educational video maze and how such a game can be applied as a visual environment for game-based learning. We define rich educational video maze as a 3D maze video game providing rich didactic multimedia content personalized upon various characteristics of the player (the learner) and presented within the maze rooms not only on learning boards but as well within puzzle mini-games of various types able to be embedded into each room by the game designer. This paper presents the concept of rich educational mazes supposed to provide rich gaming and learning experience thanks to including intelligent virtual players and applying a dynamic, player-centric adaptation of difficulty of learning tasks and of the audio-visual properties of the game environment. As well, it provides some initial results from a case study about the usability of video games focused on mazes and puzzles.

Literature Review

The concept of a rich educational 3D video maze is based mainly on two game genres – video mazes and puzzle games.

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Educational Mazes

Among all existing types of video games, playing with labyrinths and mazes appear as a very promising approach for game-based learning thanks to their focus on interaction, assessment, and decision-making. Kennedy (1999) proposed action mazes be applied for training students in processes involving decision-making in order to obtain problem-solving skills and competencies. McFarlane, Sparrowhawk, and Heald (2002) found that movement in 2D/3D spaces, having critical timing for overcoming some obstacles and for meeting challenges, is highly related to the development of motor skills memory and planning. Norris, Davis, and Timple-Laughlin (2017) stated that in maze games learners are confronted with complex problems with multiple possible solutions, which enables the "assessment of learners' higher order abilities (e.g., reasoning, evaluation, decision making)".

Nowadays, online mazes are proposed for free gaming at plenty of company portals such as education.com[2], thesprucecrafts.com[3], happyclicks.net[4], and many others. Most of these mazes are two-dimensional and intended for preschool kids and for pupils at primary school, however, some of the more complex maze games are suitable for students and adults, as well. There are no examples of customizable or personalizable mazes available online neither platforms for the generation of such mazes, which could be easily customized for various educational curricula. At the moment, there are available only a few and simple tools for automatized creation of mazes. Quandary[5] allows easy 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 node of the transition graph and explores its specific scenario. Action mazes were applied as an effective means for game-based learning in foreign languages (Todd & Tepsuriwong, 2008; Kiliçkaya, 2017) and for improving decision-making professional skills (Waights, 2009; Gilbert & Priddle, 2010). Within the scope of the ADAPTIMES research project, 3D adventure mazes with puzzles for unlocking doors to next maze rooms are used for teaching entrepreneurship (Bontchev, 2015) and Orthodox iconography (Bontchev et al., 2016), whereupon teachers were able to customize maze structure and add their preferred content to the maze rooms.

Puzzle Games

Solving puzzles is one of the oldest challenges and entertainment activities in human civilization (Carvalho et al., 2012). In general, each one-player game can be regarded as a puzzle, where the player "makes a series of moves, trying to accomplish some goal" (Hearn & Demaine, 2009). Regardless of the puzzle type – visual, word-based, logical, mathematical, pattern-based, riddle, or mixed - puzzle solving should entertain the player and should be solvable. Thus, the puzzles and the fun from solving them represent a powerful learning tool (Paul, 2003).

Puzzle games are played in isolation or as a part of other digital games, for example, within an adventure game. Adventure game puzzles can bring pleasure to the player in three ways (Kangas, 2017): by providing pleasure as works of art, by requiring insight thinking, and by advancing the player progression in the game story. The present approach enhances 3D maze games by embedding customizable and personalizable puzzles as learning tasks to the maze rooms (states) in order to attract the player attention, to increase the learnability attributes of a serious game (Blazic et al., 2016), and to provide more engagement and pleasure in the playing process.

Rich Educational Video Maze Games

A rich educational 3D video maze builds up the popular action maze by adding challenges to be met for each of the actions (i.e., possible choices) at a given state of the transition graph. These challenges can be one or several puzzles of various type, which should be solved in order to proceed to the next node of the maze. The ADAPTIMES video games (Bontchev, 2015) may serve as examples of such rich educational 3D video mazes, where the player can opt between several choices but only after solving the puzzles proposed for the current state of the maze.

Game Concept, Genre, Target Audience, and Look and Feel

[2] https://www.education.com/worksheets/mazes/
[3] https://www.thesprucecrafts.com/free-online-mazes-1357461
[4] https://www.happyclicks.net/maze-games/
[5] http://www.halfbakedsoftware.com/quandary.php

The game concept of rich educational video maze games is a 3D maze with direct links (doors) between labyrinth halls (states or nodes), learning boards, 3D objects, and puzzles as mini-video games embedded in each room. The games will be played in single-player first-person mode, whereupon the player will be supported by an intelligent virtual player (i.e. a non-player character, or NPC). NPC's are capable of helping the player to solve the puzzles and to answer specific questions in the learning domain. The concept is intentionally kept as simple as possible in order to facilitate both the design and generation of such games through the APOGEE (An innovative platform for smArt adaPtive videO GamEs for Education) platform based on their formal description as XML documents.

Like the adventure games, the rich maze games have a storyline, an inventory system, dialogue (with NPC), and puzzle solving. On the other hand, they include tasks requiring action such as shooting on moving objects, therefore in that sense can be regarded as an example of action games. Thus, involving various puzzles containing learning tasks, together with dialogues with intelligent NPC, makes the rich educational video maze games well targeted to pupils and students. Depending on the age of the player, the didactic content and the built-in puzzles will be customized at starting the game.

The learning video mazes generated by the current prototype of the APOGEE platform have a rich 3D graphics interface. The feeling of a real maze is preserved during the whole play process, supported by contemporary graphics and visual effects such as high quality textures and graphics, realistic sound and 3D interactive models, effective lighting (e.g., lamps or torches), visualization dynamics (i.e., show and hide the text depending on the distance between the player and the panel), and various graphic effects.

Figure 1: A view of a sample maze generated by the APOGEE platform

Source: Author

Game Progression, Mission, Challenges, and Objectives

The game progression follows the maze navigation performed by the player by solving the learning tasks presented as puzzles embedded into the maze halls and unlocking doors by answering questions. Generally, there is no time limit for both maze crawling and solving mini-games, however, time plays an important role in the overall score of the player. The total user's score has two types of components – one describing the progress of the player and another depicting his/her advancing as a learner. Both these components include effectiveness, efficiency, speed of solving a learning/gaming task, and the amount of acquired knowledge (learning path) or game objects for each individual learner. Together with the identifiers of the player and the game, the score is shown online in a sorted list of all the results currently achieved. Each maze game can be played more than once, whereupon various results will be recorded. As well, a maze game is reentrant, i.e. the player can exit the game and start it again at the same maze hall he/she has been during the last exit.

In the rich educational video mazes generated by the APOGEE platform, the player has one main mission: to learn the game's knowledge both by getting acquainted with the multimedia learning materials and by solving embedded puzzles (presenting learning tasks of a different type) using the skills required to do so. All the actions must be done for the shortest possible time with maximal performance, which is measured by special metrics and used to rank the player among the other players. To accomplish this mission, the player must go through all the maze halls and complete all required game tasks in such a way that he successfully completes the game (reaches the final screen) by achieving the maximum score. The score depends highly on how the player has met the challenges set by the puzzle videogames of different types embedded in the maze halls and providing learning tasks. Each puzzle has a different structure, rule, and didactic content, and sets a number of specific goals that need to be met to complete that mini-game and to complete the learning task. Puzzles might require:

- Mandatory solution - the player is not allowed to proceed to the next hall of the maze (i.e. cannot answer the question unlocking the door for exiting the current hall and enter another) unless the learning task presented by that puzzle is solved;
- Optional solution - the player can unlock the door and proceed to another hall of the maze without solving the puzzle.

A puzzle game may have a single stage (such as an image puzzle) or multiple stages (such as quizzes or rolling balls to predefined positions/objects as shown in Figure 2). A mandatory puzzle requires the solution of all the stages provided within the game, while optional puzzles might be solved partially, just for adding more points to the score. All the puzzle games do not have a time limit for play, but shorter playing time for solving the puzzle (i.e. the learning task) brings points to the player.

Figure 2: A view of sample “rolling-ball-to-ring” puzzle

Source: Author

The maze game generated by the APOGEE platform have one main goal: the player to go through all the halls of the maze and complete all mini-games (puzzles) mandatory for a given hall (i.e. to solve all the required learning tasks) in such a way as to complete the game (to reach the final screen), by collecting the maximal number of points as a learner and as a player and, thus, to achieve maximum result. Each rich video maze game can have mini-video games of different types, built in the maze halls for the presentation of didactic tasks and setting a number of specific objectives for each hall. Therefore, the main goal of the maze game includes the specific objectives of all the mini-games embedded into the maze. The flow of playing APOGEE maze games includes several steps as follows:

- The player registers an individual account at the game portal by describing personal characteristics age, gender, learning/playing style (by means of a quiz), interests and goals relevant to GBL (from a predefined list) and, eventually, some special educational needs;
- The player logs into the game portal with a user username and password;
- The player selects and launches a specific maze game, whereupon its didactic content is customized to the player model including age, gender, style, goals, etc.;
- The player is automatically positioned either in the middle of the maze's starting room or, if this game is resumed, at the center of the hall where he/she was situated during the last exit of the game;
- In each maze hall, the required tasks must be done to allow the player to continue to the next hall, such as solving all mandatory mini-games (didactic puzzles), answer a door unlocking question, and opening the door for advancing forward;
- In each hall of the maze, the player can perform some optional tasks, such as walking/rotating, examining the multimedia content of the learning boards, resolving optional puzzles, asking

virtual player some questions, viewing score points and collected objects, and returning back to the previous hall;
- The player reaches the end of the game, where he/she has to choose either to exit or to start a new game session.

Game Mechanics

Game physics follow the actual movement of a person in a 3D maze, as the movement is on the floor of the maze, from a hall into a hall through doors, which are generally closed and locked. In order to move from one hall to another, the player must unlock the door by submitting a correct answer to the question of this door and then opening it. If the hall contains some mandatory video mini-games in the form of puzzles, the player must first solve them in order to be allowed to answer the question for unlocking the door. Non-mandatory puzzles in the hall can be played as an option.

The game's economy is limited to managing the player's metrics. The player's results are a record with the following structure:

- Acquired effective learner knowledge/player skills – indicates what the player knows/can. Increases when answering correctly a quiz questions, solving an image puzzle, moving a ball to the correct position or 3D object, etc.;
- The efficiency of demonstrating knowledge/skill – indicates how the player has shown in his/her game knowledge/skill and depends on the number of attempts to solve puzzles before providing the right solution;
- Playing speed – indicates how fast the player plays effectively and is represented by the sum of the reciprocal values of the playing time of each mini-game and for the entire maze;
- Total score – a weighted sum of the parameters listed above.

Game Interface

The visual system of the maze game follows a 3D first-person player, i.e. the player does not see himself. The player controls the game by solving the puzzles, answering the questions unlocking doors, and advancing to the next maze hall. There are specific control commands for each puzzle game. For the maze and all the puzzle games, embedded sound effects are applied in moving/rotating the player, selecting a puzzle mini-game or an element of it, answering a question, etc. The creator of the game can assign an audio recording for playback in each of the maze halls. This audio recording starts playing when entering the room and ends when exiting it. When re-entering the same room, the audio is played back from the beginning.

Artificial Intelligence

The maze game has no opponent and enemy NPCs. At each hall, there might exist one generated virtual player playing the role of an assistant of the real player. When displayed, the NPC walks around the room without leaving it so that he does not face the real player and the objects in the hall. The NPC makes use of algorithms of pathfinding, collision detection, and decision-making on how to proceed walking. For answering a question, the NPC contacts an intelligent agent generating the most appropriate answer.

Case Study Results

This section presents some of the initial results from a case study about the usability of video games focused on mazes and puzzles. The study was conducted online in 2018 within the scope of the APOGEE research project (Paunova-Hubenova, 2019; Terzieva, 2018). In order to outline the requirements for future rich educational maze games, the project team researched the student needs of educational mazes and puzzles by mean of a survey published online through Google Forms. The questionnaire (see the Appendix) consisted of 22 questions (in Bulgarian) concerning the amount and types of played computer games similar to those in (Ventura et al, 2012), educational games’ applicability, and preferred genres and types of educational games.

Up to the moment, we received 658 valid responses from 665 students in total. All the participations were voluntary and anonymous. The respondent age appeared to be between 8 and 24 years, while the gender balance was 50.2% boys versus 49.8% girls. The majority of our respondents reported playing video games less than an hour weekly, while 23.1% replied playing 7 hours or more. 47.6% reported playing their favorite game less than 10 hours in total, while 38.9% answers they have played it for more than 50 hours.

Many of the questions were directed to the educational game types and their importance for the game-based learning process. Question 15 asked the students what kind of learning games would they prefer to play. We applied a 5-level Likert scale (1 – definitely no, 2 – rather no, 3 – cannot judge, 4 – rather no, 5 – definitely). The obtained statistics are presented in Table 1 below. We did a one-sample t-test for testing the null hypothesis that the population mean is equal to a specified value μ_0=3 (cannot judge), meaning the respondents cannot judge the preferred type of learning games. The critical value of t (for two-sided distribution and alpha equal to 95%) is 1.960 that is lower for all the values of t, therefore, the null hypothesis should be rejected making the obtained results statistically significant.

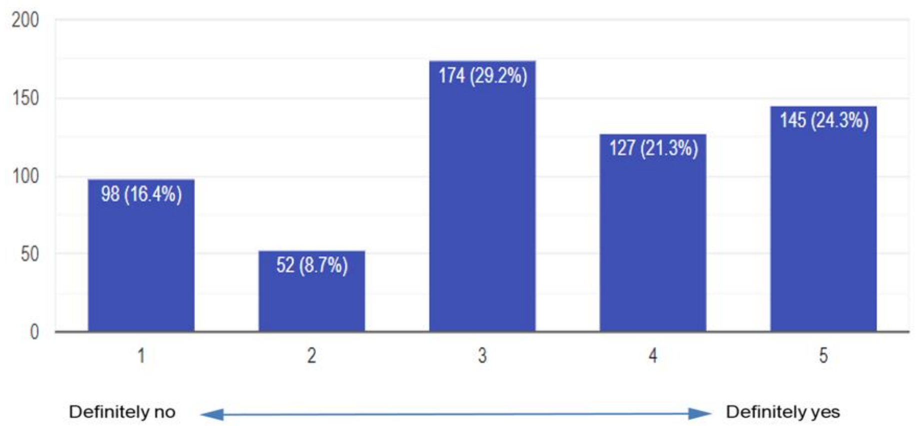
Table 1: Student preference of learning games

	Simu-lators	Action-adventure	Social	Exer-games	Shooters	Virtual env's	Puzzles	Mazes
M	3.32273	3.58758	3.32962	3.12660	3.25990	3.03492	3.23186	3.11569
SD	1.39236	1.31011	1.28714	1.33059	1.49570	1.38424	1.41137	1.39190
SE	0.05424	0.05103	0.05014	0.05183	0.05826	0.05392	0.05498	0.05422
t	5.94575	11.50457	6.56898	2.44069	4.45743	0.64712	4.21405	2.13205

Source: Author

Question 21 asked the students "Do you consider the generated educational maze games should include computer players (NPC) to help the learner and answer his questions in the subject area?". Figure 3 reveals that 45.6% of the respondents are positive about NPCs, while only 25.1% replied negatively (M=0.32836, SD=1.36159). A one-sample t-test confirmed the results are statistically significant.

Figure 3: Bar chart of the results for question 21



Source: Author

Next, we asked the students what other learning mini-games would they suggest to include in the maze game. They confirmed the usability of the puzzles already planned to be included into the generation process such as rolling balls to given places/objects, answering quizzes, word searching games, discovering hidden objects and classifying them by specific feature but asked for adding shooters and 2D puzzles, as well.

Conclusion

Automatized construction and generation of rich educational video mazes provide a powerful means for massive game-based learning. This paper presented how a rich educational video maze game can provide didactic multimedia content presented within the maze rooms on learning boards and puzzle mini-games of various types, personalized upon the characteristics of the player (the learner). Thanks to the personalization and, as well, to the inclusion of intelligent virtual players and to the dynamic, player-centric adaptation of difficulty of learning tasks and of the audio-visual properties of the game environment, such maze games promise rich gaming and learning experience.

The presented initial results from the case study about the usability of video games focused on mazes and puzzles are very positive and encourage us to continue work on the generation of such games. Next versions of the generation platform (Terzieva, 2018) are going to include effective avatars of virtual players with adaptive behavior according to the player's model (including the knowledge and skills displayed, as well as his/her psycho-emotional state), and adaptation and internationalization of the user interface. In this way, the platform-generated video game will offer an exciting user experience with realistic visual style in a rich three-dimensional virtual world.

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