MIXED REALITY ESCAPE ROOM VIDEO GAME TO PROMOTE LEARNING IN INDOOR ENVIRONMENTS

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Abstract

This work presents a mixed reality escape room video game for mobile platforms, which' development was guided by the framework of constructivist learning theory. The game is categorized as a serious game, and was developed to complement traditional learning activities and support educational events. The narrative is set inside a real building from which the player must escape. In the game, the real world is connected and expanded with the virtual world, and a challenge-award system is used to promote intrinsic motivation, real world exploration, and the use of logic and problem-solving strategies. The game was developed using the Unity Game Engine and uses Bluetooth beacons to locate the player in the real world.

Keywords: Educational, Serious Game, Mixed Reality, Educational Events, Escape Room, Indoor Location.

1 INTRODUCTION

The use of Serious Games has expanded to different areas such as training, medicine, psychology and education [1][2][3]. Specifically in the latter, multiple positive results were achieved, such as an improvement in the adherence of the students to teaching methodologies, their implication or even academic results, thanks to the fun and exploratory nature of serious games complemented with solid underlying pedagogical strategies.

One subclass of serious games are mixed reality games, which can be characterised according to Milgram's continuum from augmented reality to augmented virtuality [4], depending on the predominant presence of the virtual environment or the real world in the game. In our previous work, the explorative strategy of an escape room was used in a game to facilitate the teaching of character writing, with promising results [5]. Many different types of Escape Room games exist in various facilities around the world [6]. In real escape rooms, players must leave a place by finding clues and solving puzzles. In a virtual escape room the objective is the same, and although the realistic component of it is lost, more complex strategies and components can be incorporated in the game in a controlled way. The usual is to apply them for improve soft skills such as communication, teamwork and leadership [7][8]. Some of them have puzzles in which the player must apply his knowledge about a concrete subject [9][10], but the action are performed in the real world. Other projects use the virtual reality to simulate a escape room, yet without any relation with the real world [11]. In this article, we explore the combination of real and virtual escape rooms in a mixed reality game, in order to create a learning experience characterized by a high level of immersion and exploration.

The educational mixed reality escape room envisioned in this work serves as an enjoyable complement to regular university courses, or to support university events. As example, the mixed reality escape room game was implemented to support the GIS day[1], an event to promote geospatial technologies and their applications. The game simulates the (hypothetical) situation of being trapped in a building of the university campus from which the player needs to escape. He therefore is guided to different physical locations by the narrative presented on his smartphone, where various riddles and activities, both virtual (e.g., solve a math equation), physical (e.g., perform a science experiment) or mixed (e.g., use real-world objects/clues in game scenes in the mobile app), are key to escape. For example, through physical wayfinding via landmark-based directions in the mobile app, the player is guided to the basement, where the game presents him with an interactive floor map. Exploring the floor, and through spatial reasoning challenges, he must associate virtual with real world objects to find the next clue.

The game concept, its mechanics, narrative and activities are designed according to constructivist learning theory [12]. Solving puzzles, in conjunction with the process of exploration to escape, requires an active student-centered learning process that fits the learning theory. This allows learners to construct

[1] https://www.gisday.com/en-us/overview

mental models to understand the world around them and achieve more effective learning through the connection with the real world.

From a technical point of view, the game relies on Bluetooth beacons to pinpoint physical locations detectable by the mobile game, and a server-side application, accessible through a web API, that allows the creation and correct retrieval of the georeferenced contents. The game is developed using Unity engine targeting mobile platforms using a plugin to interface with the Google's Nearby Messages API library.

The paper is structured as follows: section 2 outlines the methodology followed, section 3 describes the video game developed according to the methodology described in the section 2. Details about the implementation are also explained. Finally, section 4 summarizes the paper with the conclusion and future work.

2 METHODOLOGY

The goal of this work is to explore the use of the constructivist learning framework to design an educational mixed reality escape room video game, hereby identifying the key steps to follow in order to successfully create this type of video game. On one hand, the developed video game has to support the learning process. On the other hand, it has to be engaging for students to achieve a learning experience that has to be both enjoyable and instructive. This video game doesn't replace classical learning forms, instead, it can be used to complement regular courses or support educational events. Following, we explain the process used to design our educational mixed reality escape room video games and its realization.

The video game has been designed to achieve player-centered learning. For this purpose, we have chosen a mixed reality video game in which the real world is joined and augmented by the virtual world. This union allows to remove limits that can be interposed in the learning process since it creates a safe environment that offers near-real-life experiences in which the player can revise and apply the knowledge acquired without consequences in the real world. The location component is the link between the real and the virtual world and it is essential to provide a learning based on the current context of the player.

The developed video game has been conceived as a "game in education" [12], since it has been designed and developed according to the constructivist learning theory framework. This type of games requires strategy, hypothesis evaluation and problem solving, usually in a progressive order [13]. Different characteristics have been taken into account in the game design. One of them is the intrinsic and extrinsic motivational component that allows to activate efficient cognitive strategies to solve problems [14]. The challenge, curiosity, the sense of control and freedom, fantasy, competition, cooperation and recognition are factors which promote intrinsic motivation. [15]. In the design of our game, most of these factors have been considered. The curiosity by the player is one of the main characteristics of escape room games, in which the player must explore his environment to find clues. The narrative guides the player through clues in a non-linear way, thus producing a feeling of freedom and control to the player. During the course of the game, the player must continuously face challenges. Each challenge is related with the next, and solving it yields a reward that allows to face the next challenge, until finally the ultimate goal is reached: to escape. Linking the virtual world with the real one allows adding options, objects and dimensions that cannot be found in the real world, so it adds fantasy to the game. The learning process is integrated within the game narrative. It is important to keep the motivation of the player through the course of the game to allow him to put in practice his knowledge [16], making the game enjoyable and avoiding boredom that could compromise the learning process. This integration is based on constructivist paradigms such as emerging narrative, which suggests learning through the player's roles and the interpretation of the graphic elements which guides the player in the game.

The design based on the previously mentioned characteristics is generalized and summarized in the following three steps:

1 **Define the final reward that the player will get.** In this case, the final reward is a tangible prize, yet it could also consist of other tangible or intangible rewards, such as an increase in a student's grade or the access to a supplementary exercise on subject matter less dominated by the student. The reward is achieved when the player has completed the game, and he therefore has put into practice all the knowledge the game intends to evaluate or teach.

2 **Design the tests and puzzles.** What do we want the player to learn? The player has to use his knowledge to solve the challenge. In our example game, one of the proposed puzzles requires the interpretation of a real map and tests the player's spatial skills, as well as the use of logic and the interpretation of the emerging narrative. To solve each puzzle, regardless of its nature, the player must have overcome all the dependencies between them. If the player arrives to a puzzle without having overcome the dependencies, e.g. through exploration, he will not be able to solve it. For example, to open the door a code is necessary; the player may arrive to the door, but the player must have found the clue or object which provides him with the correct code before he's able to open the door. The virtual world allows us to make sure that this process is completed and the player does not use brute force to solve the riddles.

3 **Design the connections between challenges and awards.** How do actions flow and how is the player led within the game? This connection is made through the explicit and emerging narrative. Also, the challenges are presented gradually and the reward of one is part of the resolution of another. First of all, the player is put into context and shown what the final challenge is and what he should achieve. Then, smaller and easier challenges are proposed that prepare the player to face the final challenge.

To carry out the implementation of this type of escape room, the following two tools are indispensable:

- a tool in which it is possible to develop a video game that could be run in mobile devices. There are many tools available for this, such as game engines (like Unity or Unreal) or even tools that allow to develop mobile applications without programming knowledge (p.e Thunkable).
- a mechanism to determine the player's indoor location. For example through wifi signals, GPS data (not very reliable in indoor environments), bluetooth beacons or any other way to retrieve the player location.

3 RESULTS

A mixed reality video game for mobile platforms called "Escape The Place" is the concrete result of this work. The video game was developed to support the GIS day, an event to promote geospatial technologies and their applications. Unity was used to implement the game, bluetooth beacons were used for the indoor location, and a plugin was developed for the communication with the Unity game engine. A third-party web dashboard was employed for their setup and administration.

In the following subsections, the video game is described and the implementation of the indoor location is detailed.

3.1 Escape The Place

Escape The Place simulates the (hypothetical) situation of being trapped in a building of the university campus. The player is in his office when suddenly the light goes out. The player is physically present in the office and the virtual world allows to propose to the player this hypothetical situation.

The virtual world offers the player several options: explore his physical environment to trigger an event in the story, review and use objects that are stored in his inventory, and get help. This options are shown in the menu scene (Figure 1). The player must physically move from one place to another inside the building depending on what happens in the story.

Figure 1 Menu scene.

In this game the player has to go in person to the entrance of the building, the kitchen and the basement. Once the player is physically in one of these places, the game shows the scenes and the part of the story that corresponds with that context (Figure 2). When the player is in a non-relevant area, the game displays the menu scene. The scenes only appear when the player is in a real-world place of interest and he presses the explore option in the menu scene. In this way, the game does not reveal anything automatically and requires the player to face the challenge of finding the next step to follow and explore the area, just as it would be done in a real escape room. The action scenes are interactive and have point and click mechanics. The player can find virtual objects, that can be used at the scenes.

Figure 2 Story scene.

The player has in his inventory some previously recorded notes in which he can find relevant information. Under the sink there is a toolbox. The kitchen is a real place in the building but, in this case, the toolbox is a virtual object. The player, through logic, must deduce that in the toolbox he can find some object that can be useful in the situation in which he is. When the player is in the real-world kitchen, he can explore the surroundings using a explore option and, by doing so, the scene of the kitchen appears on the screen. The door under the sink is interactive and will open if the player touches it (Figure 3). There he will find a flashlight (Figure 4).

Figure 3 Kitchen scene when player touches the door under the sink.

Figure 4 Inventory.

In the notes it is also written that the list of codes is in the basement. The player must find the basement of the building. The story tells that the player opens a door in the basement and he finds a file cabinet but it is closed. To open it he must resolve the puzzle in the device that blocks the file cabinet. Also, he needs to use the flashlight to see the puzzle (Figure 5). All of this happens in the virtual world. The puzzle is a real map which corresponds with the basement. He must understand the map and touch a correct combination of doors (Figure 6). A sticker is stuck on the file cabinet and it shows the clue of this combination of doors (Figure 7). The player can only understand what the clue indicates if he applies his geospatial skills to relate the map with the real context where he is.

When he solves the puzzle, the file cabinet opens and he gets a code list. From this moment, he can go to the entrance and introduce the code in the panel to open the exit door (Figure 8).

Note that the game does not have to be linear and the player could follow a different sequence in the story. All the modules of the story, although connected, are independently accessible; the player could visit relevant places in any order. For example, the player could first go to the basement, then go to the kitchen and finally, arrive to the entrance. However, note that prerequisites may exist between puzzles:

even though a certain puzzle is accessible to the player, to solve it, it may be necessary to solve another puzzle first. The design and implementation of the game allow this player freedom.

Figure 5 Flashlight in details.

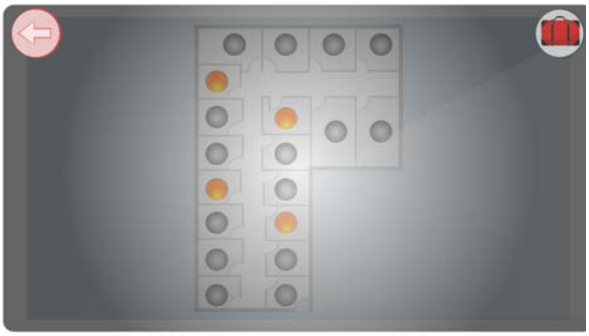

Figure 6 Interactive puzzle.

Figure 7 Sticker with a clue.

Figure 8 Numeric panel of the exit door.

Next, the steps of the design explained in section 2 are exemplified for the Escape the Place game.

1 **Define the final reward that the player will get**. Since our game was designed to support the GIS day, the reward is a badge with a cool GIS-related message, such as “Be a Legend” or “Bon Mappétit”.

2 **Design the tests and puzzles.** The following tests and puzzles have been used in this game.

- Interpret the emerging narrative. The player has a notebook with some notes. He reads in this notes that the toolbox is under the sink. He can imagine that there could be a useful object there.
- Find a virtual object. The player is in the kitchen and remembers the clue in his notes. In the virtual environment, he touches the door under the sink and finds the flashlight inside the toolbox.
- Use a virtual object. The player discovers a virtual file cabinet locked by a device with an associated puzzle whose content is difficult to see. He can use the flashlight that was previously found and is stored inside the inventory.
- Interpret a map and use spatial skills. The player understands that the puzzle corresponds to a (physical) map of the basement and he must touch, in the virtual counterpart a combination of correct basement doors.

3 **Design the connections between challenges and awards.** Different ways have been used to present information to the player to give clues and connect the different test. In addition to the emerging narrative, the story is shown with dialogs. Through them, the player can discover the next step to follow in the game, for example he can head towards the front door. The following virtual objects support the emerging narrative.

- Notebook with some notes. The player finds the notebook in his inventory, an option in the virtual world. The virtual world allows him to explore all objects that he finds in detail.
- Sticker with a hidden combination of doors. The player finds a sticker with a code. He does not know its meaning, however, he explores the real world and finds the relation between the code and the basement door codes.

- List of codes. The player has a code list which has been obtained after solving a puzzle. He finds the exit code in the list, so he introduces it in the numeric panel.

Figure 9 shows a dependency graph of the key elements of the game. Colored nodes represent an entry point in a new scene (area), with the red node the starting point of the game; non-colored nodes represent actions available in the virtual world; grayed out nodes represent actions in the physical world. Edges represent information/actions to transition between nodes. Colored regions represent the physicals areas where action takes place. Moving from one region to another is done physically, after which the corresponding game scene is loaded in the game.

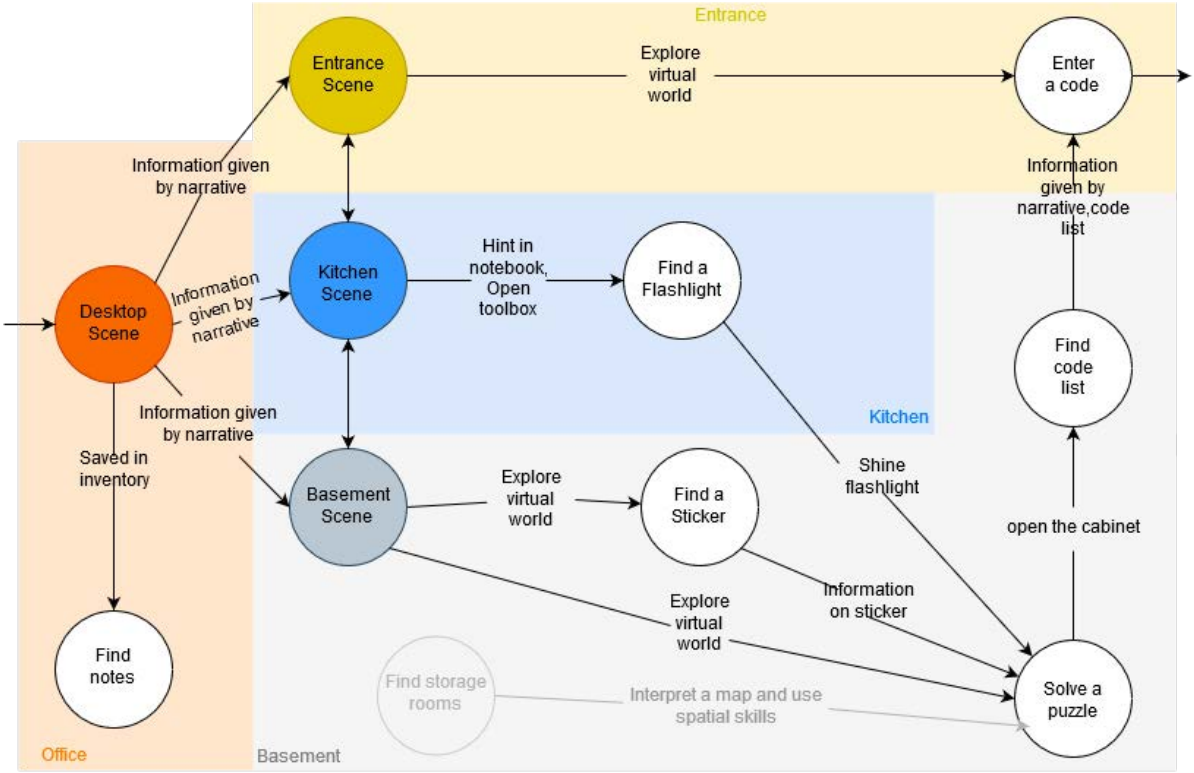

Figure 9 Dependency graph with the key elements of the game.

3.2 Indoor Location

One of the most important features required by a mixed reality indoor escape room video game is to know where the player is located within a building. Since the action of an escape room video game always happens in places that have been defined beforehand, there is no need to continuously track the player's position inside a building; it suffices to know when a player enters or leaves a relevant area. Technically, this is also more straightforward and more reliable than implementing a complex indoor positioning system.

Being able to check if a player is near a relevant area or not and to identify, from a predefined set of areas, near to which area the player is, allows to cover a wide variety of game scenarios. One economic and reliable way to implement this kind of indoor location systems is via Bluetooth Low Energy (BLE) beacons.

A beacon is placed in a relevant area and broadcasts the game area identifier, which nearby devices can detect. Since all recent smartphones (from the last 3 years) have BLE support, the entry barrier for playing is low. The smartphone running the game scans the area looking for game-related beacons, and as such the game is aware if a relevant area is nearby or not, and which area it is.

There are libraries available that simplify the aforementioned process of linking beacons to a smartphone app and making them discoverable from it. For example, Google's Nearby Messages API[2] (GNM-API), allows to discover nearby phones running the same app (a feature that can be used to implement local multiplayer games) and beacons bound to the app unique identifier. GNM-API is

[2] https://developers.google.com/nearby/messages/overview

available for both platforms: Android and iOS. This API makes cross platform and beacon-to-smartphone communication possible. One relevant feature of it is that the deployment of the beacons can be configured through a web dashboard and an independent smartphone application is also available to facilitate the beacon setup process. This greatly simplifies the process of configuring an indoor location system for our games.

The figure Figure 10 presents a screenshot of the web dashboard displaying the beacons deployment done for the game presented in this work. On the one hand, green circular areas represent beacons' signal umbrellas and the real world areas where the smartphone game displays context-aware content. On the other hand, the remaining blue area represents the region where the game can't identify where the player is and thus making it not relevant for the course of the game.

Aside from the escape room videogame, a Unity bridge plugin has been developed to be able to access to the GNM-API native libraries available in the two platforms (Android and iOS). This plugin can be reused to easily implement other mixed reality escape room videogames that follow the design methodology presented in this work.

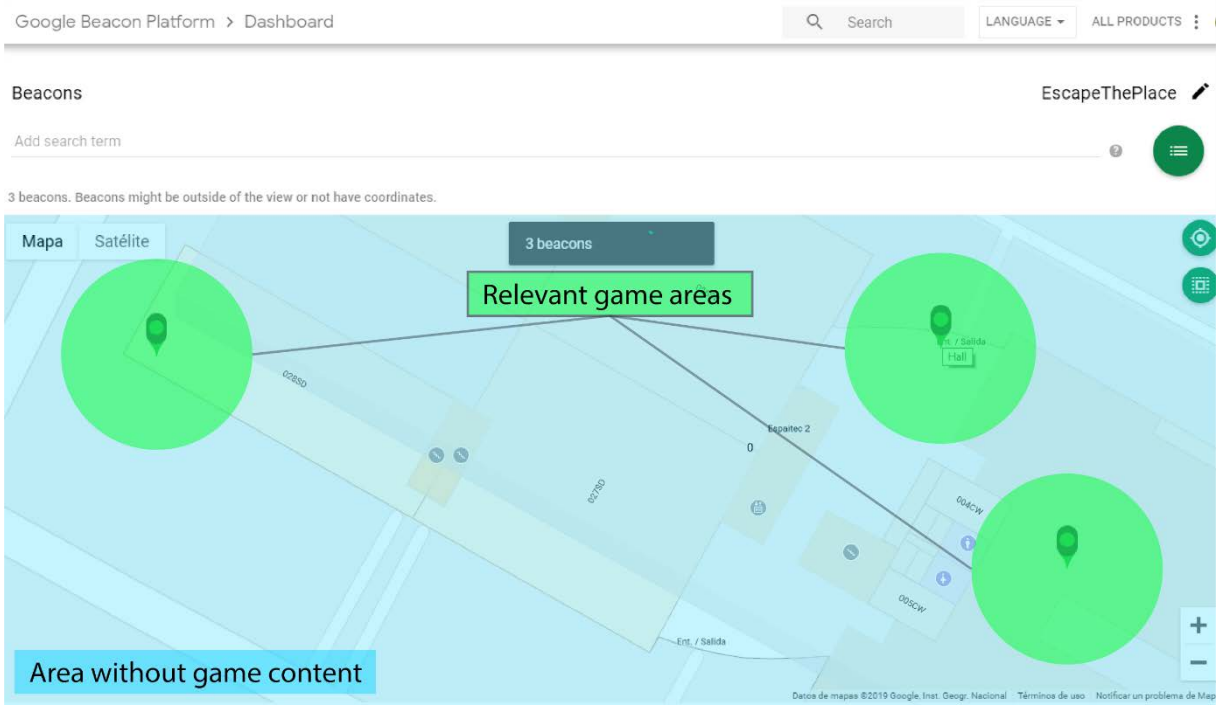

Figure 10 Example beacons deployment for the developed game.

4 CONCLUSIONS

In this work, an educational mixed reality escape room video game has been presented. It combines the physical and virtual world, and its design was inspired by the theory of constructivist learning, taking into account learning centered on the player and aware of the context. The game was built around a system of challenges that require the application of knowledge acquired by the player to get their corresponding reward. In this way, the fun and the educational aspect of the game are merged.

Regarding future work, the video game will be tested by a group of players. This experiment will be carried out to verify the effectiveness of constructivist learning theory elements to promote learning on one hand, and the acceptance of the players on the other hand. Feedback obtained will be taken into account to improve next releases of the game. We also plan to extend the game, introducing more puzzles and additional factors to maintain player motivation, such as cooperation or competition. The use of Google's Nearby Messages API allows to know if there are other devices running the game nearby. This way, the puzzles could be designed to be solved by a team or be completed with the help of another person. Finally, we want to leverage our experiences creating, extending and testing this and other similar games to develop a design methodology for mixed reality escape room video games, to facilitate other developers in creating such games.

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