NavApps - A mobile game to reinforce spatial literacy for secondary school children

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Abstract

NavApps is an educational game that aims to foster and reinforce spatial literacy in secondary school students. Indoor positioning and different wayfinding techniques are used to train spatial skills while having fun playing a mobile treasure hunting game. In the three phases of the game, students perform a set of established tasks, each designed to cover and train specific spatial skills. At the same time, gamification techniques are used to engage children in the game, and thereby maximize their learning results. In this paper, we give an overview of the game, its different phases, and point out how spatial skills are trained throughout the game.
Keywords: educational game, geo-game, mobile learning, gamification, indoor location, wayfinding, spatial skills.

1 Introduction

Nowadays, spatial literacy is indispensable in daily life. Reading, interpreting and understanding a map, spatial reasoning, or being able to spatially orient oneself are just a few examples of spatial skills we use in our day-to-day activities, e.g., when commuting, doing tourism, giving directions, searching for locations, etc. Historically, in our education trajectory, these competences are only taught as a secondary skill, bound to a principal STEM[1] subject (e.g., reading a map as part of geography; interpreting a 3D structure as part of mathematics). Schools and high schools are slowly adopting new technologies to assist in the task of teaching and training these spatial competences (Tsou, 2010), whereby ICT plays a crucial role. As such, over the last decennia we have seen a wide range of new techniques introduced under the electronic learning (e-learning) (Simpson, 2005) umbrella, and more recently, under mobile learning (m-learning) (Gikas & Grant, 2013) (Kurucu & Alan, 2011).

The European Union is committed to encourage research and development in new forms of learning, and to develop new tools and techniques for educational improvements. Within the Horizon 2020[2] framework, the thematic "Lifelong Learning Programme" funds such educational innovation projects. The educational game described in this paper was developed under this programme, as part of the "Educational Advancement of ICT-based spatial Literacy in Europe (ENAbLE)" Erasmus+ project. ENAbLE aims to enforce and supplement acquired knowledge and skills regarding spatial literacy in secondary school students, at hand of two mobile games: Origami (Bartoschek, Schwering, Li & Münzer, 2013) and NavApps (the latter described in this paper). Both games are map-based mobile applications, the former outdoors, and the latter indoors. In research, other authors explored the use of mobile applications (Boari, Fraser, Fraser & Cater, 2012), and few of mobile location-based and location-aware games (Feulner. & Kremer, 2014) to train or enhance spatial skills.

NavApps was developed by the GEOTEC research group at the University Jaime I (Spain), in close cooperation with experts in pedagogy at the University of Aveiro (Portugal). It's a mobile, indoor treasure hunting game, targeted at high school children aged between 12 and 16. It relies on our proprietary indoor-positioning system (IPS) (Torres-Sospedra et al., 2015), a WiFi fingerprint-based algorithm to locate the user, and exploits different wayfinding techniques to train various spatial skills. Gamification techniques, together with an attractive look and feel, make the app a fun way to foster and embrace spatial abilities.

In the next sections we will discuss the motivation for the game, the game itself, and formulate conclusions.

2 Motivation and preliminaries

Information and Communication Technologies (ICT's) have evolved at a dazzling pace, and radically changed the way we live, work and learn. With the release of the iPhone (2007), and the subsequent revolution in mobile technologies, mobile learning became feasible, and a plethora of educational applications have been proposed. Mobile games are of particular interest, as they are a proven way to enhance the student's learning experience, given appropriate use of gamification techniques, such as following a game story, earning points or digital objects, competing among friends, etc. Furthermore, if well designed, they entice the desire to play again, thereby enforcing the learning activity (Hwang, 2012) (Sung & Hwang, 2013).

In this spirit, NavApps is developed as a mobile geogame (Hall, 2014), specifically aimed at fostering and reinforcing spatial skills in secondary school students. NavApps specifically focuses on three spatial skills: map orientation, spatial orientation and spatial reasoning. To achieve this goal, a treasure hunting game was chosen, as there is a significant spatial component both while searching and planting

[1] Science, Technology, Engineering, Mathematics
[2] https://ec.europa.eu/programmes/horizon2020/

treasures; it is thus ideal to practice spatial skills (Perkins, Hazelton, Erickson & Allan, 2010). Considering the fact that the school's premises are a well-known place for students, to move around, to give directions, and to search for places, the game was developed to be used inside the school buildings, either during class hours or as an extra-curriculum activity (e.g., before classes start, during lunch break). To increase user involvement in the game, promote recurring use, and thereby enhance impact, Navapps employs various gamification techniques: a scoring system, progress indication, possibility to earn badges, scoreboards, etc.

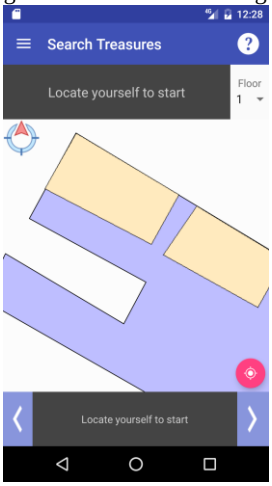
As a key component for an indoor location-based game, an indoor positioning system (IPS) is required. Traditional GPS positioning, which provides reliable and high-accuracy positioning outdoors, is not usable indoors due to poor or failing signal reception, and consequent inaccurate positioning. We therefore used our proprietary IPS, based on WiFi fingerprints. In a nutshell, the system fist requires measurements of the wireless access points' signal strengths (a so-called "fingerprint") at predetermined positions in the covered buildings (these can be captured with a standard mobile device, e.g., a smart phone). Once these measurements are obtained, any new position can be determined by comparing it with the database of pre-collected fingerprints. Full details of the algorithm can be found in (Torres-Sospedra et al., 2015).

Finally, before explaining the game, we mention that it requires some initial setup. As it is a map-based game, it requires the schools' premises (i.e., building, floors, rooms) to be available. These can be provided in any standard format (e.g., DWG files), or be created by our purposely-developed Web-based tool. The latter however is outside the scope of this paper.

3 The NavApps game

NavApps discerns three well-delineated phases, which need to be performed in sequence to successfully progress in the game narrative. As mentioned, NavApps is a map-based game; consequently, the main view of the game shows a map of the student's school – see Figure 1.

Figure 1 - Main view of the game

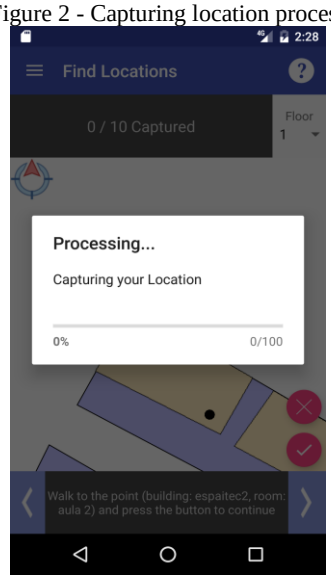


3.1 Phase one – finding locations

As previously mentioned, our proprietary indoor positioning system requires a set of WiFi fingerprints to be taken at predefined locations in the gaming area. As this task by itself requires spatial skills, we incorporated it into the game.

Therefore, the first phase of the game simply consists of finding specific locations, shown as a dot on the map of the school in the mobile game, along with a description of the location (building and room). The student is to physically walk to this position, and press the "check" button once arrived. Figure 2 shows a screenshot of the game, where a location is indicated for the student to find.

Figure 2 - Capturing location process



In the background, and oblivious to the user, the application captures the WiFi fingerprint, and stores it on the server for future reference. The locations presented to users are randomly distributed among the gamers, and collectively form an equally distributed network, which guarantees that the in-between distance will not be more than 3 meters, as required by our IPS algorithm. As such, the internals of the IPS system are completely and transparently integrated into the game, and form an integral part of it.

Each student receives a certain amount of locations to capture. Each time students capture a location, their score in the game increases, thus naturally incorporating location finding into the game using gamification. The student's score, together with their rank relative to other students, is shown in the main view of the game, so that every time a student enters the game, he sees his score and the best scores in his school. Figure 3 shows an example account with score and ranking.

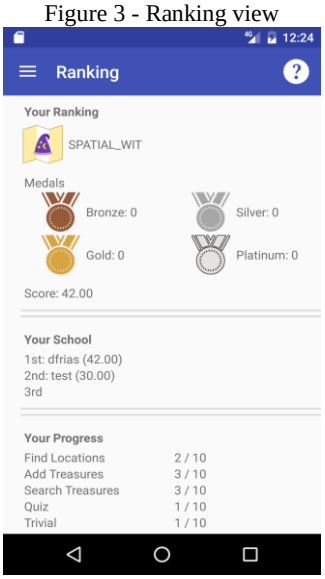
This phase helps the student to understand the relation between the map elements and the real world, training their spatial skills. In particular, it trains map orientation, and to some extent spatial reasoning.

The "find location" phase is considered finished when at least 80% of the locations of the school, distributed over all students, have been found.

3.2 Phase two – planting treasures

Once the "finding location" phase is finished, the next phase is enabled: planting treasures. Treasures can be any physical objects in the school (e.g., a specific plant, a desk, a classroom attribute such as a stuffed owl, Mendeleev's table hanging on the wall…), or students can bring their own treasures and hide them somewhere in the school for other students to find.

Figure 3 - Ranking view



For a predefined amount of treasures, the game prompts the student to hide it, and subsequently indicate on the map where it is hidden. Once hidden, the student needs to provide some basic information about the treasure, i.e., name, description, size, colour, etc. (see Figure 4), and a verification question and answer about the treasure (see Figure 5).

Figure 4 - Treasure information form

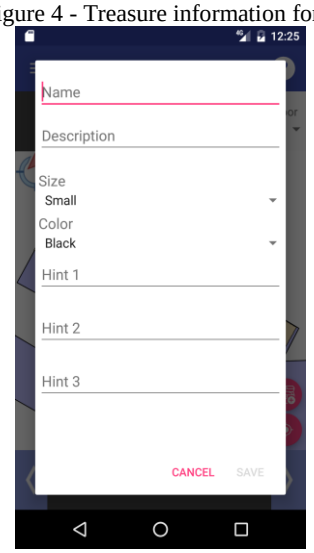
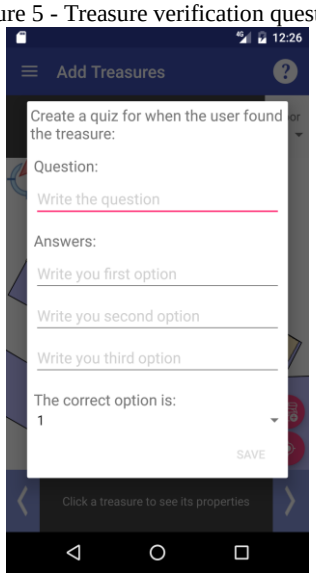


Figure 5 - Treasure verification question



This information will respectively be used in the next phase, to give hints in case the user has trouble finding the treasure (treasure information) and to verify if a treasure has indeed been found (verification question).

For every treasure they plant, students receive points, thus motivating them to plant all their treasures. At any point in the game, students can edit, move and delete treasures they added.

As the previous phase, the treasure planting phase also requires spatial abilities, namely to relate the physical location of the treasure with the real world location of it: map orientation, spatial orientation and map interpretation.

3.3 Phase three – finding treasures

The last phase, after all treasures have been planted, is finding treasures that were planted by other students.

The game provides different ways to find treasures. By touching the "Localize me" button, students start treasures' discovery: they are shown their current location on the map, and either see the closest treasure on the map within a predefined radius (see figure 6), or get cardinal directions (i.e., north, east, south, west) to guide them to a treasure (see figure 7). Both wayfinding techniques require spatial abilities – albeit in different ways - namely map orientation, spatial orientation and to a minor extent spatial reasoning, to be able to find the treasure.

When students are physically close to the treasure, i.e., they have found it, they can touch the "Found it" button in the game, indicating that they found the treasure. At this moment, the game shows the verification question related to the treasure (see Phase Two – Planting Treasures) to verify if they indeed found it. If the student answers correctly, they indeed found the treasure, and their score is increased.

Additional wayfinding techniques are planned, and currently considered future work.

Figure 6 - Treasure hunting with distances

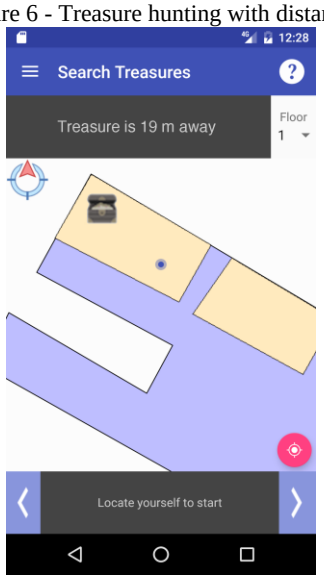
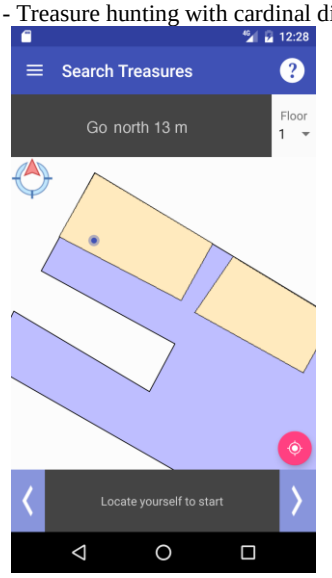


Figure 7 - Treasure hunting with cardinal directions



4 Conclusions and future work

NavApps is a mobile educational geogame that aims to reinforce spatial literacy for high school children. Specifically, it is designed to train and enforce map reasoning, spatial orientation and spatial reasoning skills. The game is a treasure hunt, to be played indoors on the high school's premises, and consists of three phases: 1/ location finding, where students have to go to specific places in the school shown on the map and described by building and room name; 2/ treasure planting, where students hide physical treasures in the school, and indicate on the map where they are hidden; and 3/ treasure finding, where students search for treasures hidden by other students. At the heart of the game, our proprietary Indoor Positioning System provides indoor positioning, based upon which different wayfinding techniques are defined to guide the student to hidden treasures. As such, during each phase, spatial skills are trained.

Finally, to engage students and promote frequent use of the game, gamification elements are used: points for actions, progress indication, possibility to earn badges, scoreboards, etc. In this way, we aim to provide a pleasant, alternative learning experience, and ultimately improve and reinforce learning itself.

The next step in this research is to put the game in practice, assess how secondary school children perceive the game, and quantify to what extend the game helps in reinforcing the targeted spatial skills.

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