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Re-experiencing History in Archaeological Parks by Playing a Mobile Augmented Reality Game

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Abstract. This paper presents a mobile system that supports young students learning history at an archaeological site. It adopts gameplay as a novel and effective technique particularly suited for learning through mobile systems (m-learning). From a technological point of view, the main novelty of our system is its slim architecture. Minimal investments are required because the system runs on the students' own cellular phones. Experimental studies indicate that gameplay is able to trigger a desire to learn more about ancient history and to make archaeological visits more exciting and learning about the past more effective.

Keywords: Mobile technology, M-learning, Educational game.

1 Introduction

The development of mobile applications for educational purposes is beared by the continuing expansion of broadband wireless networks and the explosion of power and capacity of the new generation of cellular phones [1, 4, 20]. In particular, by exploiting the imaging and multimedia capabilities of the last generation mobile devices, it is possible to create mobile systems that can support learning (also said m-learning systems [10]). Mobile technology allows people to learn in non-formal settings (i.e. museums, archaeological sites, natural parks) different from the traditional ones (i.e. classroom, laboratory, home).

Italy is full of historical sites dating back to about the year 1000 B.C.. Among current visitors of these historical sites, families and students, especially middle school children, account for 80%. The interviews with school teachers revealed that the children are not very involved by traditional guided visits. With the aim of providing young students with a more engaging and culturally rich experience, we have developed a mobile system to support learning of ancient history during a visit to archaeological parks.

We agree with other authors that to effectively learn through mobile systems new techniques need to be defined, which can arouse the emotions of young visitors, stimulating their imagination and curiosity [1]. Our approach is to exploit gameplay

since it is a technique capable to trigger a desire to learn more about the park history and to make archaeological visits more effective and exciting.

This paper describes the m-learning system we have implemented. The system runs on cellular phones, which are very popular in Italy even among young students. A peculiarity of the system is its slim architecture, thanks to which the archaeological park does not need to provide any hardware infrastructure. Moreover, the system is capable to provide realistic 3D representations of historical monuments even in cellular phones with limited RAM memory.

The paper has the following organization. Section 2 motivates the choice of gameplay as a technique to learn history and briefly describes a paper-based game designed for visiting archaeological parks. Section 3 illustrates how this game is enhanced by using mobile technology and Section 4 describes the system architecture. Indications about user evaluation are provided in Section 5. Finally, Section 6 closes the paper.

2 A Game to Learn History

Play stimulates in young students an understanding of history that would otherwise be difficult to engender, helping players to acquire historical notions [3, 19]. There are various advantages in using play to teach/learn history [3]: 1) play is amusing and fun, and enjoyment is important when endeavouring to achieve learning goals, because what is enjoyably learned is less likely to be forgotten; 2) play requires different skills to be deployed simultaneously, and each player can practice those skills felt to be most congenial; 3) play is a relational activity, which encourages group activities, stimulates collaboration, helps with conflict management. The play phase must be followed by a reflection phase, separate from the true game, in which the acquired knowledge is revised and shared among students. This part of the activity is called debriefing and is fundamental in didactic gameplay because it fosters generalization and conceptualization of the information acquired during the game [3].

At the University of Bari, researchers in the field of Teaching History have set up an association, called Historia Ludens, that has developed the excursion-game as a technique for teaching middle school students during didactic excursions to visit historical sites. “Una giornata di Gaio ad Egnathia” (Gaius’ Day in Egnathia) is an example of excursion-game designed for visiting the archaeological park of Egnathia, an ancient city in Apulia. The city walls date back to the Messapian phase, from the end of the 5th century B.C.. Pre-Roman tombs have been found within the city walls. The city was destroyed in 545 A.D..

“Gaius’ Day” is structured like a treasure hunt to be played by a class of students: it combines the excitement of both chase and solving a case with the joy of freely exploring a place and discovering its hidden secrets. This type of game is perfectly suited to the archaeological park context, with wide spaces where students can freely move and use their intelligence and imagination to conjure up how life used to be there, by observing the park and memorizing places, names and functions. Excursion-games have been designed by Historia Ludens for several archaeological parks in Southern Italy. The experience with these excursion-games has been replicated

hundreds of times with different classes and teachers, who appreciated a lot how students were stimulated by the game to know more about the park and how they enjoyed the overall visit.

3 Enhancing the Game Using Mobile Technology

Edutainment is a recently coined term that merges education and entertainment in an electronic game, a television program or website [15]. Some empirical studies have shown evidence of children's effective learning from educational electronic games [9], primarily to teach mathematics [5, 12, 16], physics [19], and logic [13]. Very recently, some examples of games to learn history [11, 18] and music [6] have been proposed. Indeed, a remarkable feature of electronic games is their power to motivate, and motivation plays a central role in any learning activity [8]. The literature review of electronic games and handled devices indicates that they could be an effective tool for facilitating student learning [16, 17].

Our work aims at improving the student's whole experience of playing a game in an archaeological park as well as its learning effectiveness, by making use of several advantages provided by mobile technology. Common features of electronic games such as active participation, intrinsic and prompt feedback, challenging but achievable goals, and a mix of uncertainty and open-endedness, contribute to student's motivation. Electronic games on cellular phones, more than any other interactive technology, have become a significant part of young people contemporary culture. In Italy, use of cellular phones by middle school students is very popular. This lead us to consider using games on handled devices to achieve educational goals. The system we are developing implements the electronic version of the excursion-game proposed by Historia Ludens to support students during the visit of archaeological parks.

We made use of the contextual inquiry technique to collect data about users' own activities [2, 7]. We participated in an actual excursion-game performed at Egnathia by students (11-12 years old) of the middle school "Michelangelo" in Bari, Italy. The pictures shown in the paper were taken during that visit.

Fig. 1. Students listening to the game master at the archaeological park.

The excursion-game is as follows. After children arrive at the archaeological park, the game master (teacher or Historia Ludens associate) gives a brief introduction

about place and period being studied. Then, she explains the game, the various phases and the rules (Fig. 1).

Groups of 4/5 players are formed: each group has a navigator (group leader) and impersonates a Roman family that has just arrived in Egnathia, having received a plot of land and a house. The experience with the paper version of the game has shown that playing historical roles strongly motivate students. Each group has to explore Egnathia by collecting information, identifying places and noting them down on a map of the park (Fig. 2).

Fig. 2. The student groups carry out the game.

Each group is given a cellular phone and the map of the site, that allows the players to find their way around and follow the right pathway; it also has a teaching function, because players have to mark places in the site, it fosters conceptualization and organization of the information.

To carry out the missions, players have to formulate hypotheses, discuss them, retrace their steps when they go wrong and correct their mistakes. If students have difficulties in reaching the place that is the mission target, an item in the Menu list allows them to ask the “oracle” for help. The oracle gives them some hints that help discovering the right place. In the ancient Roman culture, the oracle ("oraculum" in latin) was a divine communication delivered in response to a petitioner's request. Hints, provided by the oracle, are formulated for supporting both gameplay and students’ learning of the underlying educational content.

When the group believes they have identified the target place of a particular mission, it marks that place on the map. In the electronic version, the group leader digits the place code on the cellular phone or photographs the place visual tag, if the phone has a camera. Place codes and visual tags are assumed to be distributed across the park. After completing the last mission, the group has the possibility to see the 3D-reconstruction of the identified place on the phone (see Fig. 3 for an example) and compare it side by side with the current traces of it. When the game is over, game master meets students for debriefing, to reflect upon their experience. This phase can be carried out in a lecture room in the museum or on return to the classroom. The electronic version of the game facilitates this phase as well, since it relies on a notebook with a digital map of the archaeological park and a complete virtual reconstruction of the entire park. This offers the possibility to play a “collective memory game” where monuments and archaeological objects (previously encountered by the students as part of the game) are to be placed in the “right” place

and the whole school class is encouraged to participate and collaborate.

Fig. 3. The remains of the temple (left) and a phone 3D reconstruction of how it probably looked two thousands years ago (right).

4 The Slim System Architecture

Striving for a simple and cheap digital infrastructure, we have based our design on standard cellular phones, complemented with compatible memory cards containing the game software. Such mobile devices are very popular in Italy among middle school students also because their limited cost, compared with PDA and other more sophisticated handset devices. We can assume that at least one student in each group carries a suitable one, thus the archaeological park does not need to provide any hardware infrastructure for game playing. To further reduce costs and architectural complexity, no data is transmitted from/to the cellular phone during the actual game. Instead, all data exchange takes place between the cellular phone and the memory card inside it. A PC or a notebook equipped with a large screen or projector is needed by the game master for the debriefing phase. For ergonomic and within-group collaboration reasons, complementary information, such as the map of the archaeological site as well as the mission description are left on paper media.

Specifically, in order to run Game Player Application each student group needs a cellular phone Java Micro Edition (J2ME) compatible, equipped with a memory card slot and (optionally) a digital camera. The memory card is handed out to each group at the start of the game session and contains (see Fig. 4):

- a gameplay engine in the shape of a Java application, which is executed at the start of the game session for each group;
- an XML file describing the structure and content of the actual game (in this case “Gaius’ Day”) for the particular archaeological site;
- a set of M3G files representing 3D reconstruction models of historical buildings, objects, and places;
- a gameplay logfile in XML format, which is continuously updated as the group visits different parts of the site and answers questions.

The game master PC is equipped with a memory card reader used for reading the gaming logfiles. The Game Master Application installed on the PC will allow for collecting gameplay logfiles from the groups as they come in with their concluded

missions. Based on that data, the application will offer the possibility for a) analysing the XML gameplay logfiles in various ways using statistics and visualisation tools, b) setting up a debriefing event for a particular gameplay session, c) altering existing games or creating completely new ones by providing an easy-to-use graphical user interface for editing the XML files that define content and structure of the games.

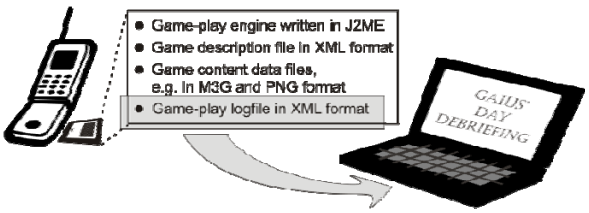

Fig. 4. The game system. The phone memory card stores the listed components.

The display of 3D graphics on mobile devices is still in its infancy although software libraries and APIs, tied to mobile 3D hardware, continuously improve and facilitate such efforts. Currently, the most popular software platforms for mobile 3D development and representation are OpenGL, OpenGL ES, VRML, Java 2D, Java 3D, Microsoft DirectX [14]. Aiming for being able to run our game on the student's own cellular phones, we chose the Java 3D/J2ME (Java Micro Edition) platform due to the fact that Microsoft DirectX capable phones at the moment are significantly more expensive and therefore less likely to appear among the students. J2ME/Java 3D uses the file format M3G for the representation and storage of 3D scenes.

The J2ME Game Player Application running on the cellular phone requires three optional J2ME packages, which however are currently provided by default in many cellular phones supporting J2ME: JSR75 (for managing XML files), JSR184 (for visualizing the M3G files containing the 3D models), and JSR234 (for reproducing multimedia). For example, the developed application can be executed on the Nokia E70 and Nokia 6630 phones although the amount of RAM memory available in the phones have forced us to reduce the detail in the 3D models originating from 3D StudioMax. While waiting for more powerful phones, we have chosen to temporarily substitute the "real" 3D M3G files with a sequence of snapshots of the 3D models taken while rotating around the object in 360 degrees in 3D Studio Max (see Fig. 5). We have evaluated one version of the game where 16 snapshots were taken with 22.5 degrees of difference between each snapshot viewpoint of each historical monument, and another version where 8 snapshots were taken with 45 degrees between the snapshots but at two different distances from the monument. The latter version allows the user of the cellular phone to perform a very basic zoom-in and zoom-out at any desirable viewing angle.

The snapshot method trades navigation flexibility for higher graphics detail by restricting navigation to left rotation, right rotation and limited zoom (in the second case described above), but providing very detailed presentation of the monuments, only restricted by the resolution of the cellular phone display which in the case of the Nokia E70 phone (pictured in the screenshots in this paper) provides a superior visual experience. The memory and CPU load is also significantly lower compared to the M3G approach. We do however expect that this method of showing 3D graphics on cellular phones to loose its attractiveness as mobile devices gain in graphics and CPU

power, enabling them to show full-scale 3D models in "native" format such as M3G.

By not depending on absolute location information systems, such as GPS, the system works indoors as well as outdoors. Furthermore, there is no need to make any alteration of the existing physical exhibition space, apart from attaching visual tags to important places and/or objects. Last but not least, hardware for the system is inexpensive. These three features of the proposed platform are important to cultural heritage institutions in Italy.

The proposed architecture is applicable to a wider set of historical sites. The way historical information is presented (time, location, modality) is determined by an XML file and can thus be authored in numerous ways and adapted to different sites. We are currently developing an authoring tool to be used for this purpose.

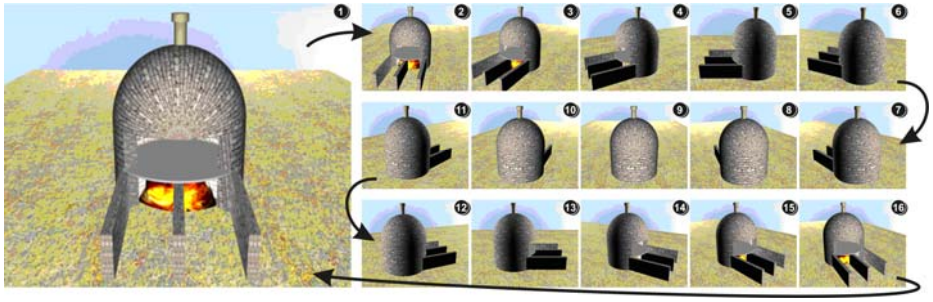

Fig. 5. The furnace as it appears on the Nokia E70 phone using the 16 snapshots.

5 Evaluating the Gaius' Day Game

Usability evaluation is fundamental in Learner-Centered design. We perform evaluation with various techniques during the whole development life cycle. In this section, we summarize the results of two evaluation sessions we have performed by involving real users. In both evaluations, the participants were four students that have already once played the traditional excursion-game during a school visit to Egnathia. The participants were divided in two groups, in which one student took the navigator role carrying the cellular phone, while the other student kept the map. Our aim was not to evaluate the overall user experience in a real setting. That would require a more accurate study, which we plan to perform later. Instead, the objective of these first studies were to receive students' feedback about the design and the usability of the overall prototype. For this reason, the studies have been performed in a university laboratory, where pictures of the real site were posted on the walls (Fig. 6). Based on photos attached to the walls, the students were able to recall the site they had visited, thus simulating their presence in the real site. During the first preliminary evaluation, the students played the game in two different ways: with and without the audio modality. In the audio modality, the system beeps to capture students' attention, then gives spoken messages to inform users about application actions, i.e. the start of a new mission or the passage from one phase to the next. In both cases, the students were very enthusiastic about the new experience. They interacted pretty easily with the system and were able to correctly perform all the missions.

Fig. 6. The participants in the pilot study during the execution of the electronic game.

The first user evaluation revealed some usability problems, such as the absence of feedback in case of system delay. This is a particularly important aspect when interacting in a mobile context. We have therefore improved the system by sending visual and sound messages that warn the user about what is happening. In addition, we introduced the possibility to undo previously performed actions.

During the second evaluation, the participants interacted with the prototype modified according to the comments given in the first one. Moreover, the second prototype was an incremented version that implemented a large number of 3D reconstructions. The participants appreciated the changes and they were pleased that the problems they encountered during the first study were solved.

The audio version stimulates a greater engagement in the game. During the first evaluation, sometimes the navigator did not tell the other member of the group about what was shown on the phone display. In the audio version, the audio messages advise the group about a new mission and also provide feedback on the actions carried out up to now, allowing the group to keep track of the system actions. We have modified the user interface so that the whole text of the mission is read out aloud for all members to hear. In the second study, the participants chose to use only the audio version of the system, confirming their preference in interacting with this system modality.

While navigating among the 3D reconstructions, the students used the joypad straight away, because they were used to it. They didn't notice that they could use the menu, which also provides zoom and automatic tour functions that can be used to navigate the virtual reconstructions. We therefore modified the screen to provide hints about menu actions, making them clearly visible on the screen. Even during the second evaluation, the participants did not interact with the 3D reconstructions using all the available functionalities. Consequently, we modified the system: an automatic tour starts when the students are in front of the target mission they have identified. Moreover, the students can individually interact by using the provided mechanisms, which are still visible on the screen.

After playing the game, the students were interviewed. They all said they greatly appreciated the electronic version of the game. At the end of the first evaluation, they asked for a map on the device. In order to satisfy the students' request, we decided to reproduce the site map on the screen of the cellular phone. Before students explore the

3D reconstruction of the mission target, the system indicates the right position of the mission target. The introduction of the map allows students to autonomously correct their performance. In the second evaluation the participants were very happy to see that their request had been satisfied and they found the map very useful.

6 Conclusions

This paper has presented a system that exploits gameplay on a cellular phone to help middle school students to acquire historical notions during the visit of archaeological sites. The game aims at stimulating in the students an understanding of history that would be otherwise difficult to engender.

Gameplay is indeed capable to engage students and to permit an effective and exciting visit of archaeological sites, thus enhancing the overall students' experience. This belief has been confirmed by the results of a more systematic on-site empirical evaluation we have performed, which will be described in a future paper.

From a technological point of view, the main novelty of our system is its slim architecture. The Game Player Application resides entirely in the phone memory card. All data exchange takes place between the cellular phone and its memory card: no data is transmitted from/or to the phone during the game, thus reducing communication cost and time. The system is also capable to visualize 3D representations overcoming the limitation of RAM in cellular phones.

Finally, the proposed architecture is applicable to a wider set of historical sites by simply modifying XML files and can thus be authored in numerous ways. An authoring tool to be used for this purpose is currently under development.

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References

1. Berri, J., Benlamri, R., Atif, Y.: Ontology-based framework for context-aware mobile learning. In: Int. Conf. on Wireless communications and mobile computing, pp. 1307--310. ACM Press (2006)
2. Beyer, H., Holtzblatt, K.: Contextual Design: Defining Customer-Centered Systems. Morgan Kaufmann, San Francisco (1998)
3. Cecchini, A., Taylor J.L.: La simulazione giocata, Franco Angeli, Milano (1987)

4. Chittaro, L.: Visualizing Information on Mobile Devices. IEEE Computer, 40--45 (March 2006).
5. Conati, C., Zhao, X.: Building and evaluating an intelligent pedagogical agent to improve the effectiveness of an educational game. In: 9th Int. Conf. on Intelligent User Interface, pp. 6--13. ACM Press, (2004)
6. Denis, G., Jouvelet, P.: Motivation-driven educational game design: applying best practices to music education. In: Int. Conf. on Advances in Computer Entertainment Technology, pp. 462--465. ACM Press (2005)
7. Druin, A. (ed.).: The design of children's technology. Morgan Kaufman, San Francisco (1999)
8. Dweck, C. S.: Motivational processes affecting learning. American Psychologist 41, 10, 1040--1048 (1986)
9. Fisch, S.M.: Making educational computer games “educational”. In: Int. Conf. on Interaction Design and Children, pp. 56--61, ACM Press (2005)
10. Holzinger, A., Nischelwitzer, A., Meisenberger, M.: Lifelong-Learning Support by M-learning: Example Scenarios. eLearn, 11, 2 (2005)
11. Kardan, K.: Computer role-playing games as a vehicle for teaching history, culture, and language. In: ACM SIGGRAPH Symposium on Videogames, pp. 91--93. ACM Press (2006)
12. Ke, F.: Classroom goal structures for educational math game application. In: 7th Int. Conf. on Learning Sciences, pp. 314--320. ACM Press (2006)
13. Lanzilotti, R., and Roselli, T.: An Experimental Evaluation of Logiocando, an Intelligent Tutoring Hypermedia System. Int. J. of Artificial Intelligence in Education, 17, 1, 41--56 (2007)
14. Malizia, A.: Mobile 3D Graphics. Springer-Verlag (2006)
15. Pan, Z.: Special issue on edutainment (E-learning and game). Computers & Graphics, 30, 1--2 (2006)
16. Rosas, R., Nussbaum, M., Cumsille, P., Marianov, V., Correa, M., Flores, P., et al.: Beyond Nintendo: design and assessment of educational video games for first and second grade students. Computers & Education, 40, 71--94 (2002)
17. Shin, N., Norris, C., Soloway, E.: Effects of handheld games on students learning in mathematics. In: 7th Int. Conf. on Learning Sciences, pp. 702--708 (2006)
18. Squire, K.: Replaying history: Learning world history through playing Civilization III. Doctoral dissertation, Indiana University School of Education. Indiana University, Bloomington, IN, 2004. http://website.education.wisc.edu/kdsquire/dissertation.html
19. Squire, K., Barnett, M., Grant, J.M., Higginbotham, T.: Electromagnetism supercharged!: Learning physics with digital simulation games. In: 6th Int. Conf. on Learning Sciences, pp. 513--520. ACM Press (2004)
20. Vavoula, G., Sharples, M.: KLeOS: A personal Mobile Knowledge and Learning Organisation System. In: 2nd IEEE Int. Workshop on Wireless and Mobile Technologies in Education, pp. 152--157 (2002)